Scilab Textbook Companion for Thermodynamics by Gaggioli and Obert[1]

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Book Description

Title: Thermodynamics

Author: Gaggioli and Obert

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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

Survey of Units and Dimensions

Scilab code Exa 1.1 Force calculation

```
clc
clear
//Initialization of variables
gc=32.1739 //lbm ft/lbf s^2
m=10 //lbm
a=10 //ft/s^2
//calculations
F=m*a/gc
//results
printf("Force to accelerate = %.3f lbf",F)
```

Scilab code Exa 1.2 Force calculation

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

```
gc=32.1739 //lbm ft/lbf s^2
m=10 //lbm
a=gc //ft/s^2
//calculations
F=m*a/gc
//results
printf("Force to accelerate = %d lbf",F)
```

Scilab code Exa 1.3 velocity calculation

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

Scilab code Exa 1.4 velocity calculation

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

Scilab code Exa 1.5 Force calculation

```
clc
clear
//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 density calculation

```
clc
clear
//Initialization of variables
rho=62.305 //lbf/ft^2
g=32.1739 //ft/s^2
//calculations
gam=rho/g
//results
printf("Density of water in this system = %.3f lbf/
   ft^2",gam)
printf("\n Specific weight = %.3f lbf/ft^2",rho)
```

Chapter 2

Fundamental Concepts

Scilab code Exa 2.1 Potential energy calculation

```
clc
clear
//Initialization of variables
z=100 //ft
m=32.1739 //lbm
//calculations
PE=m*z
//results
printf("Potential energy = %.2f ft-lbm",PE)
```

Scilab code Exa 2.2 Absolute energy calculation

```
clc
clear
//Initialization of variables
m0=18.016 //lbm
gc=32.1739 //lbm ft/lbf sec^2
c=186000*5280
```

```
dU=94.4*10^6 //ft-lbf
//calculations
U=m0/gc *c^2
dm= -dU*gc/c^2
//results
printf("Absolute energy of this mixture = %.2e ft-lbf",U)
printf("\n In case b, there is no change in mass")
printf("\n Change in mass = %.2e lbm",dm)
disp("The answers are a bit different due to rounding off error in textbook.")
```

Chapter 3

Temperature and the Ideal gas

Scilab code Exa 3.2 volume calculation

```
clc
clear
//Initialization of variables
p=14.7 //psia
R0=1545
t=460 +60 //R
//calculations
v=R0*t/(p*144)
//results
printf("Volume = %.1f ft^3/mol",v)
```

Scilab code Exa 3.3 density calculation

```
clc
clear
//Initialization of variables
p=20 //psia
R0=1545
```

```
t=460 +100 //R
M=28
//calculations
v=R0*t/(p*144*M)
rho=1/v
//results
printf("density of nitrogen = %.4f lbm/ft^3",rho)
```

Chapter 5

The first law and the dynamic open system

Scilab code Exa 5.2 work done and power calculation

```
clc
clear
//Initialization of variables
rate= 5 //lbm/sec
Q=50 //Btu/s
h2=1020 //Btu/lbm
h1=1000 //Btu/lbm
V2=50 //ft/s
V1=100 //ft/s
J=778
g=32.2 //ft/s^2
gc=g
Z2=0
Z1=100 //ft
//calculations
dw=Q/rate -(h2-h1) -(V2^2- V1^2)/(2*gc*J) -g/gc *(Z2
    -Z1)/J
power=dw*rate
//results
```

```
printf("work done by the system = %.1f Btu/lbm",dw)
printf("\n Power = %.1f Btu/s",power)
```

Scilab code Exa 5.3 Area calculation

```
clc
clear
//Initialization of variables
V=100 //ft/s
v=15 //lbm/ft^3
m=5 //lbm/s
//calculations
A=m*v/V
//results
printf("Area of inlet pipe = %.2f ft^2",A)
```

Scilab code Exa 5.4 Temperature calculation

```
clc
clear
//Initialization of variables
P=100 //psia
//calculations
disp("From table B-4")
h=1187.2 //Btu/lbm
t1=328 //F
t2=540 //F
dt=t2-t1
//results
printf("Final temperature of the steam = %d F",t2)
printf("\n Change in temperature = %d F",dt)
```

Chapter 7

The Second law

Scilab code Exa 7.2 Entropy and efficiency calculation

```
clc
clear
//Initialization of variables
cv=0.175 //Btu/lbm R
R0=1.986
M=29
T2=1040 //R
T1=520 //R
//calculations
cp=cv+R0/M
sab=cv*log(T2/T1)
sac=cp*log(T2/T1)
dqab=cv*(T2-T1)
dqca=cp*(T1-T2)
dqrev=T2*(sac-sab)
eta=(dqab+dqrev+dqca)/(dqab+dqrev)
//results
printf("Entropy in ab part = %.4f Btu/lbm R",sab)
printf("\n Entropy in ac part = %.4f Btu/lbm R",sac)
printf("\n Efficiency = %.2f percent",eta*100)
disp("The answers are a bit different due to
```

```
rounding off error in textbook")
```

Scilab code Exa 7.3 Entropy calculation

```
clc
clear
//Initialization of variables
tc=32 //F
th=80 //F
mw=5 //lbm
mi=1 //lbm
P=14.7 //psia
cp=1
//calculations
t= (-144*mi+tc*mi+th*mw)/(mw+mi)
ds1=144/(tc+460)
ds2=cp*log((460+t)/(460+tc))
dsice=ds1+ds2
dswater=mw*cp*log((t+460)/(460+th))
ds=dsice+dswater
//results
printf("Change in entropy of the process = %.4f Btu/
    R",ds)
disp("The answer is a bit different due to rounding
    off error in textbook")
```

Scilab code Exa 7.4 Energy calculations

```
clc
clear
//Initialization of variables
cp=1
T2=60 //F
```

```
T1=100 //F
ta=32 //F
//calculations
dq=cp*(T2-T1)
ds=cp*log((460+T2)/(460+T1))
dE=dq-ds*(ta+460)
dec=dq-dE
//results
printf("Change in available energy = %.1f Btu/lbm",
   dE)
printf("\n The available energy of the isolated
   system decreased in the amount of  %.1f Btu/lbm",
   dec)
disp("The answer is a bit different due to rounding
   off error in textbook")
```

Chapter 8

Second and Third law topics

Scilab code Exa 8.1 PvsS calculation

```
clc
clear
//Initialization of variables
P=500 //psia
T=700 //F
J=778
//calculations
dpds=1490 *144/J
//results
printf("dp by ds at constant volume = %d F/ft^3/lbm"
   ,dpds)
disp("The answer is a bit different due to rounding
   off error in textbook")
```

Scilab code Exa 8.2 Thermal efficiency calculation

```
clc
clear
```

```
//Initialization of variables
cp=0.25 //Btu/lbm R
T0=520 //R
T1=3460 //R
//calculations
dq=cp*(T0-T1)
ds=cp*log(T0/T1)
dE=dq-T0*ds
eta=dE/dq
//results
printf("Thermal efficiency = %.1f percent",eta*100)
```

Scilab code Exa 8.3 Loss of available energy calculation

```
clc
clear
//Initialization of variables
cp=0.25 //Btu/lbm R
T0=520 //R
T1=3460 //R
dG=21069 //Btu/lbm
dH=21502 //Btu/lbm
//calculations
dq=cp*(T0-T1)
ds=cp*log(T0/T1)
dE=dq-T0*ds
eta=dE/dq
dw=eta*dH
de=-dG+dw
//results
printf("Loss of available energy = %d Btu/lbm",de)
disp("The answer is a bit different due to rounding
    off error in textbook")
```

Chapter 9

Properties of the pure substance

Scilab code Exa 9.1 Internal energy calculation

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

Scilab code Exa 9.2 Entropy calculation

```
clc
clear
//Initialization of variables
P=40 //psia
//calculations
disp("from steam tables,")
hf=200.8 //Btu/lbm
hg=27 //Btu/lbm
T=495  //R
ds=(hf-hg)/T
//results
printf("Change in entropy = %.3f Btu/lbm R",ds)
```

Scilab code Exa 9.3 Enthalpy calculation

```
clc
clear
//Initialization of variables
x=0.35
T=18 //F
//calculations
disp("From table B-14,")
hf=12.12 //Btu/lbm
hg=80.27 //Btu.lbm
hfg=-hf+hg
h=hf+x*hfg
//results
printf("specific enthalpy = %.1f Btu/lbm",h)
```

Scilab code Exa 9.4 Heat calculation

```
clc
clear
```

```
//Initialization of variables
x=0.35
T=18 //F
T2=55.5 //F
//calculations
disp("From table B-14,")
hf=12.12 //Btu/lbm
hg=80.27 //Btu.lbm
hfg=-hf+hg
h=hf+x*hfg
h2=85.68 //Btu/lbm
dh=h2-h
//results
printf("Heat required = %.2f Btu/lbm",dh)
```

Scilab code Exa 9.5 Enthalpy and Quality calculation

```
clc
clear
//Initialization of variables
P=1460 //psia
T=135 //F
P2=700 //psia
//calculations
disp("From mollier chart,")
h=120 //Btu/lbm
x=0.83
//results
printf("enthalpy = %d Btu/lbm",h)
printf("\n Qulaity = %.2f",x)
```

Scilab code Exa 9.6 Heat calculation

```
clc
clear
//Initialization of variables
m=1 //lbm
P1=144 //psia
P2=150 //psia
T1=360 //F
J=778.16
//calculations
disp("From table 3,")
v1=3.160 //ft^3/lbm
h1=1196.5 //Btu/lbm
u1=h1-P1*144*v1/J
h2=1211.4 //Btu/lbm
u2=h2-P2*144*v1/J
dq=u2-u1
//results
printf("Heat transferred = %.1f Btu/lbm",dq)
```

Scilab code Exa 9.7 Work calculation

```
clc
clear
//Initialization of variables
T1=100 //F
P2=1000 //psia
x=0.6
J=778.16
//calculations
disp("From table 3,")
v=0.01613 //ft^3/lbm
P1=0.9 //psia
wrev=-v*(P2-P1)*144/J
dv=0.000051 //ft^3/lbm
wcomp=(P2+P1)/2 *dv*144/J
```

```
wact=wrev/x
//results
printf("Work done = %.1f Btu/lbm",wrev)
printf("\n In case 2, work required = %.1f Btu/lbm",
   wact)
```

Scilab code Exa 9.8 Heat calculation

```
clc
clear
//Initialization of variables
pa=1000 //atm
ta=100 //F
//calculations
hf=67.97 //Btu/lbm
w=3 //Btu/lbm
ha=hf+w
disp("from steam table 2,")
hc=1191.8 //Btu/lbm
qrev=hc-ha
//results
printf("Heat transferred = %.1f Btu/lbm",qrev)
```

Scilab code Exa 9.9 Work done calculation

```
clc
clear
//Initialization of variables
P1=144 //psia
T1=400 //F
y=0.7
//calculations
disp("From steam tables,")
```

```
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
sfg=1.6855 //Btu/lbm R
x=(s1-sf)/sfg
hf=109.37 //Btu/lbm
hfg=1013.2 //Btu/;bm
h2=hf+x*hfg
work=h1-h2
dw=y*work
h2d=h1-dw
//results
printf("Work done = %d Btu/lbm",work)
printf("\n work done in case 2 = %.1f Btu/lbm",dw)
printf("\n Final state pressure = %d psia",P2)
disp("The answer is a bit different due to rounding
    off error in textbook")
```

Scilab code Exa 9.10 Quality calculation

```
clc
clear
//Initialization of variables
pb=14.696 //psia
pa=150 //psia
tb=300 //F
//calculations
disp("From steam tables,")
hb=1192.8 //Btu/lbm
ha=hb
hf=330.51 //Btu/lbm
hfg=863.6 //Btu/lbm
x=(ha-hf)/hfg
```

```
//results
printf("Quality of wet steam = %.1f percent",x*100)
```

Chapter 10

The Pvt relationships

Scilab code Exa 10.1 Pressure calculations

```

clc
clear
//Initialization of variables
m=1 //lbm
T1=212+460 //R
sv=0.193 //ft^3/lbm
M=44
a=924.2 //atm ft^2 /mole^2
b=0.685 //ft^3/mol
R=0.73 //atm ft^3/R mol
//calculations
v=sv*M
p=R*T1/v
p2=R*T1/(v-b) -a/v^2
//results
disp("For ideal gas case, Table B-6 and for
   vanderwaals case, Table B-8 have been used")
printf("\n In vanderwaals equation, pressure = %.1f
   atm",p2)
printf("\n In ideal gas case, pressure = %.1f atm",p
```

```
)
```

Scilab code Exa 10.2 volume calculation

```
clc
clear
//Initialization of variables
m=1 //lbm
p=50.9 //atm
t=212+460 //R
R=0.73
//calculations
pc=72.9 //atm
tc=87.9 +460 //R
pr=p/pc
Tr=t/tc
z=0.88
v=z*R*t/p
//results
printf("volume = %.3f ft^3/mole",v)
```

Scilab code Exa 10.3 Pressure calculations

```
clc
clear
//Initialization of variables
t=212+460 //R
v=0.193 //ft^3/lbm
M=44
R=0.73
//calculations
tc=87.9+460 //F
zc=0.275
```

```
vc=1.51 //ft^3/mol
tr=t/tc
vr=v*M/vc
vrd=vr*zc
z=0.88
p=z*R*t/(M*v)
//results
printf("Pressure = %.1f atm",p)
```

Chapter 11

The Ideal gas and mixture relationships

Scilab code Exa 11.1 Work calculation

```
clc
clear
//Initialization of variables
n=1.3
T1=460+60 //R
P1=14.7 //psia
P2=125 //psia
R=1545
M=29
//calculations
T2=T1*(P2/P1)^((n-1)/n)
wrev=R/M *(T2-T1)/(1-n)
//results
printf("Work done = %d ft-lbf/lbm",wrev)
disp("The answer is a bit different due to rounding
   off error in textbook")
```

Scilab code Exa 11.2 Kinetic energy calculation

```
clc
clear
//Initialization of variables
P2=10 //psia
P1=100 //psia
T1=900 //R
w=50 //Btu/lbm
k=1.39
cp=0.2418
//calculations
T2=T1*(P2/P1)^((k-1)/k)
T2=477
KE=-w-cp*(T2-T1)
//results
printf("Change in kinetic energy = %.1f Btu/lbm",KE)
```

Scilab code Exa 11.3 Temperature calculation

```
clc
clear
//Initialization of variables
T1=900 //R
P1=100 //psia
P2=10 //psia
//calculations
disp("From table B-9")
pr1=8.411
pr2=pr1*P2/P1
T2=468 //R
//results
printf("Final temperature = %d R ",T2)
```

Scilab code Exa 11.4 Temperature work and Enthalpy calculations

```
clc
clear
//Initialization of variables
cr=6
p1=14.7 //psia
t1=60.3 //F
M=29
R=1.986
//calculations
disp("from table b-9")
vr1=158.58
u1=88.62 //Btu/lbm
pr1=1.2147
vr2=vr1/cr
T2=1050 //R
u2=181.47 //Btu/lbm
pr2=14.686
p2=p1*(pr2/pr1)
dw=u1-u2
h2=u2+T2*R/M
//results
printf("final temperature = %d R",T2)
printf("\n final pressure = %.1f psia",p2)
printf("\n work done = %.2f Btu/lbm",dw)
printf("\n final enthalpy = %.1f Btu/lbm",h2)
```

Scilab code Exa 11.5 Weight calculations

```
clc
clear
```

```
//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)
```

```
clc
clear
//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=1545/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
pt=p1+p2
vt=v1+v2
//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 lbf ft/lbm R",R)
disp("part d")
printf("volume of mixture = %.1f ft^3",V)
printf("\n density of mixture is %.5f mole/ft^3 and
```

```
    %.3f 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)
printf("\n Net partial pressure in case of oxygen =
    %.2f psia",pt)
printf("\n Net partial volume =%.2f ft^3",vt)
```

Scilab code Exa 11.6 Analysis calculations

```

clc
clear
//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
sum1=(x1+x2+x3)*100
sum2=(C+N+O)*100
//results
printf("From gravimetric analysis , co2 = %.1f
    percent , o2 = %.1f percent and n2 = %.1f percent
    ",x1*100,x2*100,x3*100)
printf("\n From ultimate analysis , co2 = %.2f
    percent , o2 = %.2f percent and n2 = %.2f percent
```

```
    ",C*100,O*100,N*100)
printf("\n Sum in case 1 = %.1f percent",sum1)
printf("\n Sum in case 2 = %.1f percent",sum2)
```

Scilab code Exa 11.7 Entropy calculations

```
clc
clear
//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 = %.2f Btu/R",S)
printf("\n the answer given in textbook is wrong.
    please check using a calculator")
```

Scilab code Exa 11.8 Internal energy and entropy calculations

```
clc
clear
//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 11.9 Pressure and temperature calculations

```
clc
clear
//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)
printf("\n Mixing temperature = %.1f F",t)
```

Scilab code Exa 11.10 Entropy calculations

```
clc
clear
//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
ds3=n1*c1*log(T2/T1)+n2*c2*log(T2/T3)
ds4=n2*R0*log(v2/v3)+ n1*R0*log(v2/v1)
dss=ds3+ds4
//results
printf("Change in  entropy for gas 1 = %.3f Btu/R",
    ds1)
printf("\n Change in  entropy for gas 1 = %.3f Btu/R
    ",ds2)
printf("\n Net change in entropy = %.3f Btu/R",ds)
printf("\n In case 2, change in entropy = %.3f Btu/R
```

```
    ",dss)
disp("The answer is a bit different due to rounding
    off error in the textbook")
```

Scilab code Exa 11.11 Entropy calculations

```
clc
clear
//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)
```

```
disp("The answers are a bit different due to
    rounding off error in textbook")
```

Scilab code Exa 11.12 Volume and mass calculations

```
clc
clear
//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 11.13 Percentage calculation

```
clc
clear
//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 = %.1f percent",mb*100)
```

Scilab code Exa 11.14 Partial Pressure calculations

```
clc
clear
//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)
```

Chapter 12

Non steady flow friction and availability

Scilab code Exa 12.1 Work done calculation

```
clc
clear
//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)
m1=p1*V/(R*T1)
m2=p2*V/(R*T2)
Wrev= cv*(m1*T1 - m2*T2) - (m1-m2)*(T2)*cp
//results
printf("Work done in case 1 = %d Btu",Wrev)
```

Scilab code Exa 12.2 Friction calculations

```
clc
clear
//Initialization of variables
p1=100 //psia
p2=10 //psia
n=1.3
T1=800 //R
cv=0.172
R=1.986/29
T0=537 //R
cp=0.24
//calculations
T2=T1*(p2/p1)^((n-1)/n)
dwir=cv*(T1-T2)
dwr=R*(T2-T1)/(1-n)
dq=dwr-dwir
dI=-T0*(cp*log(T2/T1) - R*log(p2/p1))
//results
printf("The friction of the process per pound of air
    = %.1f Btu/lbm",dq)
printf("\n Loss of available energy = %.2f Btu/lbm",
    dI)
```

Scilab code Exa 12.3 Energy loss calculations

```
clc
clear
//Initialization of variables
ms=10 //lbm
```

```
den=62.3 //lbm/ft^3
A1=0.0218 //ft^2
A2=0.00545 //ft^2
p2=50 //psia
p1=100 //psia
gc=32.2 //ft/s^2
dz=30 //ft
T0=537 //R
T1=620 //R
T2=420 //R
//calculations
V1=ms/(A1*den)
V2=ms/(A2*den)
df=-144/den*(p2-p1) - (V2^2 -V1^2)/(2*gc) - dz
dI=-T0/T1 *df
dI2= -T0/T2 *df
//results
printf("Friction = %.1f ft-lbf/lbm",df)
printf("\n Available energy loss in case a = %.1f ft
    -lbf/lbm",dI)
printf("\n Available energy loss in case b = %.1f ft
    -lbf/lbm",dI2)
```

Scilab code Exa 12.4 Pressure drop calculation

```
clc
clear
//Initialization of variables
r=2.5 //in
mf=160 //cfm
rho=1/14
mu=0.0000121
v=14 //ft^3/lbm
g=32.2 //ft/s^2
z=100 //ft
```

```
//calculations
A=3.14*(r/12)^2
V=mf/A /60
Re=(2*r/12)*V*rho/mu
disp("From fig 12.4,")
f=0.0225/4
dp=4*f*(rho)*(V/v)^2 /(2*g*(2*r/12)) *z
//dp=2.32
//results
printf("Pressure drop = %.2f lbf/ft^2 100 ft",dp)
disp("The answer in the textbook is wrong. Please
    use a calculator to verify it.")
```

Scilab code Exa 12.5 Mass rate calculation

```
clc
clear
//Initialization of variables
D=0.0724 //ft
gc=32.2 //ft/s^2
rho=1/14
L=100 //ft
mu2=1.46*10^(-10)
dp=2.32
dia=5 //in
rho2=48500
vol=14 //ft^3/lbm
//calculations
ref=D^3 *2*dp*gc*rho/(mu2*L)
mf=rho2*%pi/4 *(dia/12) *sqrt(mu2)
mfr=mf*vol*60
//results
printf("Mass rate of air flow = %d cfm",mfr)
disp("The answer is a bit different due to rounding
    off error in textbook")
```

Scilab code Exa 12.6 Loss and effectiveness calculations

```
clc
clear
//Initialization of variables
cp=0.25
T=3460 //R
T0=520 //R
dG=1228 //Btu/lbm
//calculations
hf=cp*(T-T0)-T0*cp*log(T/T0)
dC=hf-dG
Ec=hf/dG
//results
printf("Loss of available energy = %d Btu/lbm
   mixture ",dC)
printf("\n Effectiveness of combustion = %.3f ",Ec)
```

Scilab code Exa 12.7 Loss and effectiveness calculations

```
clc
clear
//Initialization of variables
cp1=0.25
T=3460 //R
T0=946.2 //R
T00=520 //R
dG=1228 //Btu/lbm
cp=0.45
//calculations
dqa=cp1*(T-T0)
```

```
w=cp*dqa
hf=cp1*(T-T00)-T00*cp1*log(T/T00)
heat=w-hf
eff=w/hf
epower=w/dG
//results
printf("Loss of available energy = %.1f Btu/lbm
   mixture ",heat)
printf("\n Efficiency of cycle = %.3f ",eff)
printf("\n Effectiveness of overall cycle = %.2f",
   epower)
disp("The answer is a bit different due to rounding
   off error in textbook")
```

Scilab code Exa 12.8 Loss and effectiveness calculations

```
clc
clear
//Initialization of variables
p1=400 //psia
t1=600 //F
h1=1306.9 //Btu/lbm
b1=480.9 //Btu/lbm
p2=50 //psia
h2=1122 //Btu/lbm
h3=1169.5 //Btu/lbm
b3=310.9 //Btu/lbm
//calculations
disp("All the values are obtained from Mollier chart
   ,")
dw13=h1-h3
dw12=h1-h2
dasf=b3-b1
etae=dw13/dw12
eta=abs(dw13/dasf)
```

```
dq=dw13+dasf
//results
printf("Engine efficiency = %.1f percent",etae*100)
printf("\n Effectiveness = %.1f percent",eta*100)
printf("\n Loss of available energy  = %.1f Btu/lbm"
   ,dq)
```

Chapter 13

Fluid Flow

Scilab code Exa 13.1 Velocity and area calculations

```
clc
clear
//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 (ft/s)= ')
disp(V2 )
disp('Area (ft^2)= ')
```

```
disp(A)
disp('The initial values of velocity and area are 0
   and infinity respectively. Since, Infinity in
   calculations stops the code to display an error.
   It has been mentioned separately.')
```

Scilab code Exa 13.2 Area calculations

```
clc
clear
//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 at the exit= %.5f ft^2",A2
   )
```

Scilab code Exa 13.3 Area calculations

```
clc
clear
//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
//results
printf("Throat area= %.4f ft^2",A2d)
```

Scilab code Exa 13.4 velocity and flow rate calculations

```
clc
clear
//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 13.5 Area calculations

```
clc
clear
//Initialization of variables
p0=50 //psia
T0=520 //R
rho0=0.259 //lbm/ft^3
p2=10 //psia
mf=1 //lbm
//calculations
disp("From table B-17,")
pr=0.528
Tr=0.833
rhor=0.634
ps=pr*p0
Ts=Tr*T0
rhos=rho0*rhor
Vs=49.1*sqrt(Ts)
As=mf/(Vs*rhos)
p2r=p2/p0
M2=1.71
V2=1.487*Vs
T2=0.632*Ts
A2=As*1.35
rho2=rhos*0.317
```

```
//results
printf("Area of throat = %.5f ft^2",As)
printf("\n Area of exit = %.5f ft^2",A2)
```

Scilab code Exa 13.6 Length calculation

```
clc
clear
//Initialization of variables
M1=0.2
M2=0.4
D=0.5  //ft
f=0.015
//calculations
f1=14.5
f2=2.31
dl=(f1-f2)*D/f
//results
printf("Length of pipe = %.1f ft",dl)
```

Scilab code Exa 13.7 Change in entropy calculation

```
clc
clear
//Initialization of variables
py=20 //psia
px=3.55 //psia
R=1.986/29
//calculations
pr=py/px
disp("from table B-19")
Mx=2
My=0.577
```

```
pr2=0.721
ds=R*log(1/pr2)
//results
printf("Change in entropy = %.4f Btu/lbm R",ds)
```

Scilab code Exa 13.8 Pressure calculation

```
clc
clear
//Initialization of variables
pi=50 //psia
pe=34.6 //psia
//calculations
disp("From table B-18 and B-17,")
pr1=1.35
p0f=pi/pr1
pfs=0.528*p0f
per=pe/pfs
Me=0.6
p0e=1.19
pyx=p0e/pr1
Mx=1.64
My=0.658
px=0.22*pi
py=32.9 //psia
p2yx=0.852
pe2=1.65*pfs
//results
printf("Mach numbers before and after are %.2f and %
    .3f respectively",Mx,My)
printf("\n Pressure before and after are %.1f psia
    and %.1f psia",px,py)
printf("\n Exhaust pressure = %.1f psia",pe2)
```

Scilab code Exa 13.9 Heat calculation

```
clc
clear
//Initialization of variables
T1=550 //R
T2=2660 //R
ts1=0.207
ts2=0.833
cp=0.24
//calculations
Ts=T1/ts1
Ts0=T2/ts2
disp("From table B-20")
tr1=0.529
tr2=0.174
dq=cp*Ts0*(tr1-tr2)
//results
printf("Heat required = %d Btu/lbm",dq)
```

Scilab code Exa 13.10 Thrust calculation

```
clc
clear
//Initialization of variables
M1=0.5
M2=1
A1=0.5 //ft^2
A2=1 //ft^2
p1=14.7 //psia
p2=14.7 //psia
k=1.4
```

```
//calculations
thru=p2*144*A2*(1+k*M2^2)-p1*144*A1*(1+k*M1^2)
net=thru-p1*144*(A2-A1)
//results
printf("Internal thrust = %d lbf",thru)
printf("\n Net thrust = %d lbf",net)
disp("The answers are a bit different due to
    rounding off error in textbook")
```

Scilab code Exa 13.11 Mass flow rate calculation

```
clc
clear
//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 13.12 Mass flow rate calculation

```
clc
clear
//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 13.13 Area calculations

```
clc
clear
//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 13.14 Area calculations

```
clc
clear
//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 13.15 Area of discharge calculation

```
clc
clear
//Initialization of variables
dFf=110.5 //ft-lbf/lbm
Vd=1028 //ft/s
```

```
gc=32.2 //ft/s^2
p0=100 //psia
k=1.4
v0=2.08
p1=55 //psia
p2=99.2 //psia
//calculations
dFe=0.01*Vd^2 /(2*gc)
dF=dFf+dFe
V2ig=(p0*144)^(1/k) *v0/(1-1/k) *((p1*144)^(1-1/k)
    -(p2*144)^(1-1/k))
C2=(V2ig+dF)/V2ig
C=sqrt(C2)
//results
printf("Coefficient of discharge = %.3f ",C)
```

Scilab code Exa 13.16 Pressure drop calculation

```
clc
clear
//Initialization of variables
dL=1/6 //ft
mf=0.430 //lbm/sec
rho=62.4
gc=32.2 //ft/s^2
d=0.81/12 //ft
//calculations
V=mf*4/(rho*%pi)
VD=V/dL^2
Vd=1.92 //ft/s
dFf=0.031/(2*gc) *2.31
dFe=0.04*Vd^2 /(2*gc)
dF=dFf+dFe
dp=rho*(3.5/(2*gc) +dF)
vd22=(2*gc)/rho *dp /(1-(d/dL)^4)
```

```
vd2=sqrt(vd22)
C=Vd/vd2
//results
printf("Pressure drop in the nozzle = %.2f lbf/ft^2"
    ,dp)
printf("\n Coefficient of discharge = %.3f ",C)
```

Scilab code Exa 13.17 Mass flow rate calculation

```
clc
clear
//Initialization of variables
K=0.6003
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 *D2^2 *sqrt(rho1*(p1-p2))
C=K*sqrt(1-bet^4)
//results
printf("mass flow rate = %.3f lbm/sec",m)
printf("\n Coefficient of discharge = %.3f",C)
```

Chapter 14

Psychrometrics

Scilab code Exa 14.1 Pressure and density calculations

```
clc
clear
//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
mu=phi*(p-ps)/(p-pw)
```

```
Ws=0.622*(ps/(p-ps))
mu2=w/Ws
//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)
disp("part d")
printf("In method 1, Degree of saturation = %.3f",mu
    )
printf("\n In method 2, Degree of saturation = %.3f"
    ,mu2)
```

Scilab code Exa 14.2 Moisture content calculation

```
clc
clear
//Initialization of variables
p=14.696 //psia
ps=0.0808  //psia
ps2=0.5069 //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 = %.2f grains water/lbm
    dry air",dwg)
disp("The answers are a bit different due to
   rounding off error in textbook")
```

Scilab code Exa 14.3 Humidity calculations

```
clc
clear
//Initialization of variables
t1=80 //F
t2=60 //F
p=14.696 //psia
ps=0.507 //psia
pss=0.256 //psia
cp=0.24
disp("From steam tables,")
//calculations
ws=0.622*pss/(p-pss)
w=(cp*(t2-t1) + ws*1060)/(1060+ 0.45*(t1-t2))
pw=w*p/(0.622+w)
phi=pw/ps
td=46 //F
//results
printf("\n humidity ratio = %.4f lbm/lbm dry air",w)
printf("\n relative humidity  = %.1f percent",phi
   *100)
printf("\n Dew point = %d F",td)
```

Scilab code Exa 14.4 Enthalpy and sigma function calculations

```
clc
clear
//Initialization of variables
W=0.0065  //lbm/lbm of dry air
t=80 //F
td=60 //F
//calculations
H=0.24*t+W*(1060+0.45*t)
sig=H-W*(td-32)
Ws=0.0111
H2=0.24*td+Ws*(1060+0.45*td)
sig2=H2-Ws*(td-32)
//results
printf("In case 1, enthalpy = %.2f Btu/lbm dry air",
    H)
printf("\n In case 1, sigma function = %.2f Btu/lbm
    dry air",sig)
printf("\n In case 2, enthalpy = %.2f Btu/lbm dry
    air",H2)
printf("\n In case 2, sigma function = %.2f Btu/lbm
    dry air",sig2)
```

Scilab code Exa 14.5 Enthalpy calculations

```
clc
clear
//Initialization of variables
t1=30 //F
t2=60 //F
t3=80 //F
```

```
W1=0.00206
W2=0.01090
//calculations
cm1=0.24+0.45*W1
H1=cm1*t1+W1*1060
cm2=0.24+0.45*W2
H2=cm2*t3+W2*1060
hf=t2-32
dq=H2-H1-(W2-W1)*hf
//results
printf("In case 1, Enthalpy = %.2f Btu/lbm dry air",
    H1)
printf("\n In case 2, Enthalpy = %.2f Btu/lbm dry
    air",H2)
printf("\n Heat added = %.2f Btu/lbm dry air",dq)
```

Scilab code Exa 14.6 Humidity calculations

```
clc
clear
//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=46/7000
rhow=mw/V
w=0.00657
//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 water/lbm air"
    ,w)
```

Scilab code Exa 14.7 Enthalpy change calculations

```
clc
clear
//Initialization of variables
W1=0.00206 //lbm/lbm dry air
W2=0.01090 //lbm/lbm dry air
t=60 //F
disp("From humidity charts,")
//calculations
dw=W1-W2
hs=144.4
hs2=66.8-32
w1=14.4 //Btu/lbm
ws1=20 //Btu/lbm
w2=76.3 //Btu/lbm
ws2=98.5 //Btu/lbm
dwh1=-(w1-ws1)/7000 *hs
H1=9.3+dwh1
dwh2=(w2-ws2)/7000 *hs2
H2=31.3+dwh2
dwc=dw*(t-32)
dq=H2-H1+dwc
//results
printf("Enthalpy change = %.2f Btu/lbm dry air",dq)
```

Scilab code Exa 14.8 Enthalpy and temperature calculations

```
clc
clear
//Initialization of variables
disp("From psychrometric charts at 50 F and 80 F,")
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
disp("The two initial states have been multiplied by
    108/262 and distance 2-3 is located")
t=62.5// F
phi=0.83 //percent
//results
printf("humidity = %.2f ",phi)
printf("\n Temperature = %.1f F",t)
```

Scilab code Exa 14.9 Dry bulb calculations

```
clc
clear
//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 14.10 Approach calculations

```
clc
clear
//Initialization of variables
m=1 //lbm
t1=100 //F
t2=75 //F
db=65 //F
disp("From psychrometric charts,")
t11=82 //F
phi1=0.4
H1=30 //Btu/lbm dry air
w1=65 //grains/lbm dry air
w2=250 //grains/lbm dry air
//calculations
cr=t1-t2
appr=t2-db
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("cooling range = %d F",cr)
printf("\n Approach = %d F",appr)
printf("\n 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 14.11 Heat calculations

```
clc
clear
//Initialization of variables
mfr=1
water=900 //gallons
t2=110 //F
t1=80 //F
cp1=1
//calculations
mfa=mfr*water*8.33*60
mfc=mfa/(60*0.075)
qa=mfa*(t2-t1)
dH=qa/(mfc*4.5)
dH2=mfr*cp1*(t2-t1)
H1=23.73
H2=5.08
f=3.309
lnmean=(H1-H2)/log(H1/H2)
dtt=(t2-t1)/lnmean
per=25
//results
printf("flow rate of air = %d lbm/hr.It is equal to %d cfm",mfa,mfc)
printf("\n Total heat transferred = %d Btu/hr",qa)
printf("\n Enthalpy = %.1f Btu/lbm dry air",dH)
printf("\n Using second method, Enthalpy = %.1f Btu/lbm",dH2)
printf("\n Performance factor = %.3f ",f)
printf("\n logrithamic mean enthalpy difference = %.2f . Estimated low percentage = %d low",dtt,per)
disp("The answers are a bit different due to
```

rounding off error in textbook.")

Chapter 15

Vapor cycles and processes

Scilab code Exa 15.1 Efficiency calculations

```
clc
clear
//Initialization of variables
p1=600 //psia
p2=0.2563 //psia
t1=486.21 //F
t2=60 //F
fur=0.75
//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)
eta=fur*etat
//results
printf("Thermal efficiency = %d percent",etat*100)
printf("\n Furnace efficiency = %.1f percent",eta
    *100)
```

Scilab code Exa 15.2 Efficiency calculations

```
clc
clear
//Initialization of variables
dhab=-123.1
etac=0.5
ha=348.5
etaf=0.75
eta=0.85
hf=471.6
hfg=731.6
hc=1203.2
dhcd=452.7
//calculations
dwabs=dhab/etac
hbd=ha-dwabs
```

```
dwcds=dhcd*eta
dqa=hc-hbd
etat=(dwcds+dwabs)/dqa
eta=etat*etaf
//results
printf("Thermal efficiency = %.1f percent",etat*100)
printf("\n Overall efficiency = %.1f percent",eta
    *100)
```

Scilab code Exa 15.3 Efficiency calculations

```
clc
clear
//Initialization of variables
t=60 //F
J=778.16
p1=600 //psia
p2=0.2563 //psia
etaf=0.85
//calculations
disp("From steam tables,")
vf=0.01604 //ft^3/lbm
dw=-vf*(p1-p2)*144/J
ha=28.06 //Btu/lbm
hb=29.84 //Btu/lbm
hd=1203.2 //Btu/lbm
he=750.5 //Btu/lbm
dqa=hd-hb
dqr=ha-he
dw=dqa+dqr
dwturb=hd-he
dwpump=ha-hb
etat=dw/dqa
eta=etat*etaf
//results
```

```
printf("Thermal efficiency = %.1f percent",etat*100)
printf("\n Overall efficiency = %.1f percent",eta
   *100)
```

Scilab code Exa 15.4 Efficiency calculations

```
clc
clear
//Initialization of variables
dhab=-1.78
etac=0.5
ha=28.06
eta=0.85
hf=471.6
hfg=731.6
hd=1203.2
dhcd=452.7
//calculations
dwabs=dhab/etac
hbd=ha-dwabs
dwcds=dhcd*eta
dqa=hd-hbd
etat=(dwcds+dwabs)/dqa
eta=etat*eta
//results
printf("Thermal efficiency = %.1f percent",etat*100)
printf("\n Overall efficiency = %.1f percent",eta
   *100)
```

Scilab code Exa 15.5 Efficiency and pressure calculations

```
clc
clear
```

```
//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
Wnet=Whp+Wlp
//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)
printf("\n Net work = %.1f Btu/lbm",Wnet)
```

Scilab code Exa 15.6 Efficiency calculations

```
clc
clear
```

```
//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)
```

Chapter 16

Combustion

Scilab code Exa 16.1 Molecule formulation

```
clc
clear
//Initialization of variables
per=85
//calculations
a=per/12
b=100-per
ad=1.13*a
bd=1.13*b
//results
printf("Molecule is C %d H %d",ad,bd+1)
```

Scilab code Exa 16.2 Molecule formulation

```
clc
clear
//Initialization of variables
per=0.071 //mass fraction of nitrogen
```

```
//calculations
O2=8.74
N2=per/2 + 3.76*O2
Nin=32.85
CO2=7.333
H2o=3
So2=0.0312
//results
printf("Oxygen = %.2f and Nitrogen = %.2f",O2,N2)
printf("\n Equation is C %.3f H %d + %.2f O2 + %.2f
    N2 = %.3f CO2 + %d H2O + %.5f SO2 + %.2f N2",CO2
    ,2*H2o,O2,Nin,CO2,H2o,So2,N2)
```

Scilab code Exa 16.3 Air fuel ratio calculations

```
clc
clear
//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 16.4 Mass and energy calculations

```
clc
clear
//Initialization of variables
m1=322.3 //Mass of Co2
m2=2 //Mass of SO2
m3=926 //Mass of N2
basis=121.94 //Basis taken
//calculations
m=m1+m2+m3
ratio=m/basis
dh=5777 //Btu/mol
h1=dh*7.364
h2=14037
h3=130501
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",m/100)
printf("\n Mass of dry flue gases = %.2f lbm dry
   flue gas/lbm fuel as fired ",ratio)
printf("\n Energy carried away = %.1f btu/mol coal
   as fired which is same as  = %.1f Btu/lbm mol
   coal ",H, hrat)
disp("The answers are a bit different due to
   rounding off errors in textbook")
```

Scilab code Exa 16.6 Percentage calculations

```
clc
clear
//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("Final orsat composition is %d CO2 + %.2f H20
    + %.2f N2",n1, x, n2)
printf("\n 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 16.7 Air fuel ratio calculations

```
clc
clear
//Initialization of variables
N2=78.1
M=29
co2=8.7
co=8.9
x4=0.3
x5=3.7
x6=14.7
//calculations
O2=N2/3.76
Z=(co2+co+x4)/8
AF=(O2+N2)*M/(Z*113)
//results
printf("Air fuel ratio = %.1f lbm air/lbm fuel",AF)
```

Scilab code Exa 16.8 Air fuel ratio calculations

```
clc
clear
//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)/(5.83-0.66)
AF=(O2+N2)*M/(a*100)
//results
printf("Air fuel ratio = %.1f lbm air/lbm fuel as
   fired",AF)
```

Scilab code Exa 16.9 Air fuel ratio calculations

```
clc
clear
//Initialization of variables
N2=78.1 //Moles of Nitrogen
M=29 //Molar mass of Air
ba=2.12 //Basis
x4=0.3 //Moles of Ch4
x5=3.7 //Moles of H2
x6=14.7 //moles of H2o
//calculations
```

```
O2=N2/3.76
O2=N2/3.76
Z=(x4*4+x5*2+x6*2)/17
AF=(O2+N2)*M/(Z*113)
//results
printf("Air fuel ratio = %.1f lbm air/lbm fuel",AF)
```

Scilab code Exa 16.10 Air fuel ratio calculations

```
clc
clear
//Initialization of variables
N2=78.1 //Moles of Nitrogen
M=29 //Molar mass of Air
ba=2.12 //Basis
x4=0.3 //Moles of Ch4
x5=3.7 //Moles of H2
x6=14.7 //moles of H2o
//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 16.11 Air fuel ratio calculations

```
clc
clear
//Initialization of variables
co2=8.7 //Moles of CO2
```

```
co=8.9 //Moles of CO
N2=78.1 //Moles of Nitrogen
M=29 //Molar mass of Air
ba=2.12 //Basis
x4=0.3 //Moles of Ch4
x5=3.7 //Moles of H2
x6=14.7 //moles of H2o
//calculations
O2=N2/3.76
c=14.7
Z=2.238
X=(Z*17-x4*4-x5*2)/2
a=co2+co/2+x4+x6/2
b=3.764*a
AF=(O2+N2)*M/(Z*113)
//results
printf("Air fuel ratio = %.1f lbm air/lbm fuel",AF)
```

Scilab code Exa 16.12 Air fuel ratio calculations

```
clc
clear
//Initialization of variables
x1=8.7 //Moles of Co2
x2=8.9 //Moles of CO
x3=0.3 //Moles of O2
N=78.1 //Moles of N2
z=113 //Af factor
M=29 //Molar mass of air
//calculations
co2=(x1+x2+x3)*100/(N+x1+x2+x3)
a=2.325
AF=103*M/(a*z)
//results
printf("Air fuel ratio = %.2f",AF)
```

Scilab code Exa 16.13 Equation formulation

```
clc
clear
//Initialization of variables
co=1.2 //Moles of CO
co2=10.8 //Moles of CO2
//calculations
H2=co/2
ch4=0.3
N2=88-H2-ch4
//results
printf("Nitrogen = %.1f percent",N2)
printf("\n Equation is a(96 CH4 + 3 H2+ 1 CO) + %.1f
    /3.76 O2 + %.1f N2 = %.1f CO2 + %.1f CO + %.1f H2
    + %.1f CH4 + %.1f N2",N2,N2,co2,co,H2,ch4,N2)
```

Scilab code Exa 16.14 Higher heating value

```
clc
clear
//Initialization of variables
dH=-2369859 //Btu
r=1.986 //Gas constant
dn=5.5 //Change in number of moles
T=536.7 //R
//calculations
dQ=dH+dn*r*T
//results
printf("Higher heating value = %d Btu",dQ)
```

Scilab code Exa 16.15 Lower heating value

```
clc
clear
//Initialization of variables
M2=18 //Molar mass of water
M=170 //Molar mass of octane
p=0.4593 //Pressure of octane //psia
disp("from steam tables,")
vfg=694.9
J=778.2
m=9*18 //Mass of water
u1=-2363996 //Btu
//calculations
hfg=1050.4 //Btu/lbm
ufg= hfg- p*vfg*144/J
dU=ufg*m
Lhv=u1+dU
//results
printf("Lower heating value = %d Btu/lbm",Lhv)
disp("The answers are a bit different due to
    rounding off error in textbook.")
```

Scilab code Exa 16.16 Heat of reaction

```
clc
clear
//Initialization of variables
n1=8 //Moles of CO2
n2=9 //Moles of H2O
n3=1 //Moles of Octane
n4=12.5 //Moles of Oxygen
```

```
disp("From Table B-10,")
U11=3852 //Internal energy at 1000 R of CO2
U12=115 //Internal energy at 537 R of CO2
U21=3009 //Internal energy at 1000 R of H2O
U22=101 //Internal energy at  537 R of H2O
U31=24773 //Internal energy at 1000 R of Octane
U32=640 //Internal energy at 537 R of Octane
U41=2539 //Internal energy at 1000 R of Oxygen
U42=83 //Internal energy at 537 R of Oxygen
H=-2203389 //heat Btu
//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",Q)
disp("The answers are a bit different due to
   rounding off error in textbook.")
```

Scilab code Exa 16.17 Temperature calculations

```
clc
clear
//Initialization of variables
n1=8 //Moles of CO2
n2=9 //Moles of H2O
n3=47 //Moles of N2
disp("from table B-10,")
h1=118 //Enthalpy of CO2
h2=104 //Enthalpy of H2O
h3=82.5 //Enthalpy of N2
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 16.18 Equilibrium calculations

```
clc
clear
//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 16.19 Dissociation calculations

```
clc
clear
//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("percentage of dissociation = %.1f percent",x
   *100)
printf("\n If pressure =10 . degree of dissociation
   = %d percent",y*100)
```

Scilab code Exa 16.20 Extent of reaction

```
clc
clear
//Initialization of variables
x=poly(0,"x")
vec=roots(24*x^3 +48*x^2 + 7*x -4)
x=vec(3) *100
//results
printf("Extent of reaction= %d percent",100-x)
```

Chapter 17

Gas cycles and processes

Scilab code Exa 17.1 Efficiency and air fuel ratio Equilibrium calculations

```
clc
clear
//Initialization of variables
ha=1033 //Btu/mol air
hbd=2992 //Btu/mol air
hc=7823 //Btu/mol air
hdd=5142 //Btu/mol air
Hv=2733000 //Btu/mol
M=29
//calculations
Wt=hc-hdd
Wc=ha-hbd
Net=Wt+Wc
Heat=hc-hbd
etat=Net*100/Heat
molair=Heat/Hv
mr=molair*142/M
Af=1/mr
//results
printf("\n Thermal efficiency = %.1f percent",etat)
printf("\n Moles of fuel burned per mol of air = %.5
```

```
    f mol fuel/mol air",molair)
printf("\n Mass ratio in pounds = %.5f lbm fuel/lbm
    air",mr)
printf("\n Air fuel ratio = %d lbm air/lbm fuel",Af)
```

Chapter 18

Refrigeration

Scilab code Exa 18.1 Work and cop calculations

```
clc
clear
//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 18.2 cop calculation

```
clc
clear
//Initialization of variables
x=0.8
he=26.28 //Btu/lbm
hb=26.28 //Btu/lbm
pe=98.76 //psia
pc=51.68 //psia
hc=82.71 //Btu/lbm
hf=86.80+0.95
//calculations
dwisen=-(hf-hc)
dwact=dwisen/x
hd=hc-dwact
cop=(hc-hb)/(hd-hc)
//results
printf("Coefficient of performance = %.2f",cop)
```

Scilab code Exa 18.3 work done and cop calculations

```
clc
clear
//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 18.4 Pressure ratio calculations

```
clc
clear
//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 cfm
    ",C)
disp("The answers are a bit different due to
    rounding off error in textbook")
```

Scilab code Exa 18.5 Work done and heat calculations

```
clc
clear
//Initialization of variables
disp("From fig B-4,")
disp("Appropraite notation from textbook has been
    used")
disp("All are enthalpy values at different stages")
hc=73.5 //Btu/lbm
hb=26.28 //Btu/lbm
hd=91.58 //Btu/lbm
hc2=190.7 //Btu/lbm
hd2=244.3 //Btu/lbm
hb2=44.4 //Btu/lbm
m1=1 //lbm
```

```
m2=0.461 //lbm
hc1=73.5 //Btu/lbm
hd1=83.35 //Btu/lbm
hc2=190.7 //Btu/lbm
hd2=244.3 //Btu/lbm
hb1=12.55 //Btu/lbm
hc22=197.58 //Btu/lbm
hd22=224 //Btu/lbm
//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*(hc22-hd22)
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)
disp("case 2")
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 18.6 hp and cop calculations

```
clc
clear
//Initialization of variables
disp("From fig B-4,")
disp("Appropraite notation from textbook has been
    used")
disp("All are enthalpy values at different stages")
ha=44.36 //Btu/lbm
hc=18.04 //Btu/lbm
hj=197.58 //Btu/lbm
hh=213.5 //Btu/lbm
hd=hc //Btu/lbm
he=190.66 //Btu/lbm
hk=241.25 //Btu/lbm
//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)
```