Scilab Textbook Companion for Concepts of Thermodynamics by F. Obert[1]

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Book Description

Title: Concepts of Thermodynamics

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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 Force required

```
clc
clear
//Initialization of variables
gc=32.1739 //lbm ft/lbf s^2
F=5.00e-9 //lbf hr/ft^2
//calculations
F2=F*3600*gc
//results
printf("Force required = %.2e lbm/ft sec",F2)
```

Scilab code Exa 1.4 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 1.5 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 1.6 density and specific weight

```
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

```
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 2.3 Energy and mass 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)
```

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 Change in 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 Thermal efficiency calculation

```
clc
clear
//Initialization of variables
cp=0.25 //Btu/lbm R
T2=520 //R
```

```
T1=3460 //R
//calculations
dq=cp*(T2-T1)
ds=cp*log(T2/T1)
dG=dq-T2*ds
eff=dG/dq
//results
printf("Thermal efficiency = %.1f percent",eff*100)
```

Scilab code Exa 7.5 Energy change calculation

```
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 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 Change in 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 `Specific 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 required`

```
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

```
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 transferred

```
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 done calculation`

```
clc
clear
//Initialization of variables
T1=100 //F
P2=1000 //psia
x=0.6
J=778.16
tir=2
P1=0.9 //psia
//calculations
disp("From table 3,")
hf=67.97
htc=2.7
hpc=0.32
```

```
h1=67.97
dv=0.000051
v=0.01613
h2=hf+htc+hpc
wrev=h1-h2
wact=wrev/x
dt=hpc+tir
t2act=T1+dt
wrev2=-v*144*(P2-P1)/J
dw=(P1+P2)/2 *dv *144/J
//results
printf("Work required = %.2f Btu/lbm",wact)
printf("\n reversible work done = %.2f Btu/lbm",wrev2)
printf("\n Work done in compression = %.4f Btu/lbm",dw)
```

Scilab code Exa 9.8 Heat transferred

```
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 9.10 `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)
```

Scilab code Exa 9.11 `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)
```

Scilab code Exa 9.12 Efficiency calculation

```
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 9.13 Efficiency calculation

```
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 9.14 Efficiency calculation

```
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 9.15 Efficiency calculation

```
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 9.16 cop and work calculation

```
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 9.17 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)
```

Chapter 10

The pvT relationships

Scilab code Exa 10.1 Pressure calculation

```
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
printf("In ideal gas case, pressure = %.1f atm",p)
printf("\n In vanderwaals equation, pressure = %.1f
   atm",p2)
```

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 calculation

```
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 12

The Ideal gas and derivations of real gases

Scilab code Exa 12.1 `Work done`

```
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 12.2 `kinetic energy change`

```
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 12.3 `Final 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 12.4 temperature pressure and work done calculation

```
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)
```

Chapter 13

Mixtures

Scilab code Exa 13.1 Pressure volume 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 %.2f 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 13.2 Volumetric and gravimetric analysis

```

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 13.3 Entropy calculation

```
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 13.4 Internal energy and entropy change 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 13.5 Pressure and mixing temperature calculation

```
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 13.6 Change in Entropy calculation

```
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 13.7 Change in Entropy calculation

```
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 13.8 volume and mass calculation

```
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 13.9 `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 13.10 `Partial pressure calculation`

```
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)
```

Scilab code Exa 13.11 Partial pressure and saturation 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 13.12 Change in 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 13.13 Humidity calculation

```
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
//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 13.14 Enthalpy and sigma function calculation

```
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 13.15 Enthalpy calculation

```
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 13.16 Partial pressure and 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 steam/lbm air"
   ,w)
```

Scilab code Exa 13.17 Enthalpy change calculation

```
clc
clear
//Initialization of variables
W1=0.00206 //lbm/lbm dry air
W2=0.01090 //lbm/lbm dry air
t=60 //F
//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 13.18 Humidity calculations

```
clc
```

```
clear
//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=62.5// F
phi=0.83 //percent
//results
printf("humidity = %.2f ",phi)
printf("\n Temperature = %.1f F",t)
```

Scilab code Exa 13.19 Humidity 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 13.20 cooling range 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 13.21 Pressure calculations

```
clc
clear
//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 Pressure in case 2 = %.1f atm",pb)
printf("\n error in ideal case = %.1f percent",err
    *100)
printf("\n error in  case 2 = %.1f percent",err2
    *100)
disp('The answer is a bit different due to rounding
    off error in textbook')
```

Scilab code Exa 13.22 `Pressure calculations`

```
clc
clear
//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)
printf("\n Error = %d percent",err*100)
```

Scilab code Exa 13.23 `Pressure calculation`

```
clc
```

```
clear
//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 14

Equilibrium and the third law

Scilab code Exa 14.1 `Equilibrium constant 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 14.2 Degree of dissociation

```
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("degree of dissociation = %.2f",x)
printf("\n If pressure =10 . degree of dissociation
    = %.2f",y)
```

Scilab code Exa 14.3 Degree of dissociation calculation

```
clc
clear
//Initialization of variables
k=5
//calculations
x=poly(0,"x")
p=x^2 *(k-x) -k^2 *(1-x)^2 *(3-x)
vec=roots(p)
x=vec(3)
//results
printf("degree of dissociation = %.2f",x)
```

Scilab code Exa 14.4 Work done calculations

```
clc
clear
//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)
```

Chapter 15

Basic flow equations

Scilab code Exa 15.1 `Temperature and pressure calculations`

```
clc
clear
//Initialization of variables
disp("From Table B-4,")
h=1187.2 //Btu/lbm
t=328 //F
//calculations
p2=100 //psia
u2=1187.2 //Btu/lbm
t2=540 //F
dt=t2-t
//results
printf("Final temperature of steam = %d F",t2)
printf("\n Final pressure = %d psia",p2)
printf("\n Change in temperature = %d F",dt)
```

Scilab code Exa 15.3 `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 15.4 Friction calculation

```
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
//results
printf("The friction of the process per pound of air
    = %.1f Btu/lbm",dq)
```

Scilab code Exa 15.5 Friction calculation

```
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
//results
printf("Friction = %.1f ft-lbf/lbm",df)
```

Scilab code Exa 15.6 Efficiency calculation

```
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
dg=489
eff=w/dg
dI=-dg+w
//results
printf("\n Efficiency of cycle = %.1f percent",eff
    *100)
printf("\n Loss of available energy = %.1f Btu/lbm",
    dI)
```

Scilab code Exa 15.7 `Efficiency calculation`

```
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 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 Equation calculation

```
clc
clear
//Initialization of variables
per=0.071
```

```
//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 16.4 `Air fuel ratio calculation`

```
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 16.5 `Air fuel ratio calculation`

```
clc
clear
//Initialization of variables
N2=78.1
M=29
ba=2.12
x4=0.3
x5=3.7
x6=14.7
//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 16.6 Air fuel ratio calculation

```
clc
clear
//Initialization of variables
N2=78.1
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 16.7 Air fuel ratio calculation

```
clc
clear
//Initialization of variables
N2=78.1
M=29
ba=2.12
co2=8.7
co=8.9
x4=0.3
x5=3.7
x6=14.7
//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 16.8 Air fuel ratio calculation

```
clc
clear
//Initialization of variables
x1=8.7
x2=8.9
```

```
x3=0.3
N=78.1
z=113
M=29
//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 16.9 Higher heating value calculation

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

Scilab code Exa 16.10 Lower heating value calculation

```
clc
clear
//Initialization of variables
y=13
x=12
M2=18
```

```
M=170
p=0.4593
vfg=694.9
J=778.2
m=9*18
u1=-2363996 //Btu
//calculations
z=y*M2/M
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)
```

Scilab code Exa 16.11 Heat of reaction calculation

```
clc
clear
//Initialization of variables
n1=8
n2=9
n3=1
n4=12.5
U11=3852
U12=115
U21=3009
U22=101
U31=24773
U32=640
U41=2539
U42=83
H=-2203389
//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)
```

Scilab code Exa 16.12 Temperature calculation

```
clc
clear
//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)
```