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

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# Book Description

**Title:** Concepts of Thermodynamics

**Author:** F. Obert

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**Edition:** 2

**Year:** 1994

**ISBN:** 0521850428

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 %.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 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)
```