Scilab Textbook Companion for Elements of Thermodynamics and Heat Transfer
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Book Description

Title: Elements of Thermodynamics and Heat Transfer

Author: O. N. Young

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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 calculation

```
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 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 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 5

The first law and the dynamic open system

Scilab code Exa 5.1 `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 5.2 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 5.3 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 calculations

```
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 calculations

```
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)
//results
printf("Change in available energy = %.1f Btu/lbm",
    dE)
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 dpbyds 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 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)
```

Chapter 9

Properties of 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 transferred 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 done 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 and pressure 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 9.10 `Quality calculations`

```
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
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 11

The Ideal gas and mixture relationships

Scilab code Exa 11.1 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 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 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)
```

Scilab code Exa 11.5 Mole fraction calculation

```
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
//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)
```

Scilab code Exa 11.6 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
//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)
```

Scilab code Exa 11.7 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 11.8 Entropy calculation

```
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 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)
```

Scilab code Exa 11.10 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
//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)
disp("The answer is a bit different due to rounding
   off error in the textbook")
```

Scilab code Exa 11.11 Entropy and temperature 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 11.12 Mass and volume 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 calculations

```
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 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)
```

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 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)
```

Scilab code Exa 12.3 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
//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 12.4 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
//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)
```

Chapter 13

Fluid Flow

Scilab code Exa 13.1 Velocity and area calculation

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

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 = %.5f ft^2",A2)
```

Scilab code Exa 13.3 Throat area calculation

```
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 in case 2 = %.4f ft^2",A2d)
```

Scilab code Exa 13.4 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 13.5 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 13.6 velocity and flow rate calculation

```
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 13.7 Throat area calculation

```
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 13.8 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 13.9 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 13.10 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")
```

Chapter 14

Psychrometrics

Scilab code Exa 14.1 Pressure calculation

```
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 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 14.4 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 14.5 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 14.6 Partial pressure calculation

```
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 14.7 `Enthalpy 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 14.8 Humidity calculation

```
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 14.9 Dry bulb calculation

```
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 `cooling range calculation`

```
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)
```

Chapter 15

Vapor cycles and processes

Scilab code Exa 15.1 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 15.2 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 15.3 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 15.4 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 15.5 Efficiency calculation

```
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
```

```
//calculations
O2=8.74
N2=per/2 + 3.76*O2
//results
printf("Oxygen = %.2f and Nitrogen = %.2f",O2,N2)
```

Scilab code Exa 16.4 Air fuel ratio

```
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

```
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

```
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

```
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

```
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

```
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

```
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 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)
```

Scilab code Exa 16.13 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("percentage of dissociation = %.1f percent",x
    *100)
printf("\n If pressure =10 . degree of dissociation
    = %d percent",y*100)
```

Scilab code Exa 16.14 Extent of the 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 18

Refrigeration

Scilab code Exa 18.1 cop and work 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 hp calculation`

```
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 calculation

```
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)
//The answers are a bit different due to rounding
   off error in textbook
```

Chapter 19

Fundamentals of heat transfer

Scilab code Exa 19.1 Thermal conductivity and temperature calculations

```
clc
clear
//Initialization of variables
r1=1.12 //in
r2=3.06 //in
t1=203 //F
t2=184 //F
r3=2.09 //in
pow=11.1 //watts
//calculations
km=pow*3.413*(12/r1-12/r2)/(4*%pi*(t1-t2))
dt=pow*3.413*(12/r1-12/r3)/(4*%pi*km)
t3d=t1-dt
//rewsults
printf("The experimental value of thermal
    conductivity = %.2f Btu/hr ft F",km)
printf("\n Required temperature = %.1f F",t3d)
```

Scilab code Exa 19.2 Heat loss calculations

```
clc
clear
//Initialization of variables
r1=4.035 //in
r2=4.312 //in
r3=5.312 //in
r4=6.812 //in
k12=25 //Btu/hr ft F
k23=0.05 //Btu/hr ft F
k34=0.04 //Btu/hr ft F
t1=625 //F
t4=125 //F
l=100 //ft
hr=1.7 //Btu/hr ft^2 F
//calculations
Rs=1/(2*%pi*l) *(log(r2/r1) /k12+log(r3/r2) /k23 +
   log(r4/r3) /k34)
Qd=(t1-t4)/Rs
dt=Qd*12/(hr*%pi*2*l*6.812)
t0=t4-dt
//results
printf("Heat loss = %d Btu/hr",Qd)
printf("\n Temperature required = %d F",t0)
disp("The answers given in the textbook are a bit
   different due to rounding off error")
```

Scilab code Exa 19.3 coefficient of heat transfer

```
clc
clear
//Initialization of variables
dout=1 //in
d1=0.049 //in
t1=70 //F
t2=80 //F
```

```
rho=62.2 //lbm/ft^3
mum=2.22 //lbm/ft hr
k=0.352 //Btu/hr ft F
cp=1 //Btu/lbm F
vel=500000 //lbm/hr
n=100 //tubes
//calculations
D=dout-2*d1
t=(t1+t2)/2
V=vel/n *4*144/(%pi*D^2 *rho)
Re=rho*V*D/(mum*12)
Pr=cp*mum/k
Nu=0.023*Re^0.8 *Pr^0.4
hc=Nu*k*12/D
//results
printf("Coefficient of heat transfer = %d Btu/hr ft
    ^2 F",hc)
```

Scilab code Exa 19.4 coefficient of heat transfer

```
clc
clear
//Initialization of variables
d1=0.5 //ft
t1=200 //F
t2=80 //F
ta=400 //F
rho=0.0662 //lbm/ft^3
mum=0.0483 //lbm/ft hr
k=0.0167 //Btu/hr ft F
cp=0.2408 //Btu/lbm F
rho2=0.0567 //lbm/ft^3
mum2=0.0542 //lbm/ft hr
k2=0.0190 //Btu/hr ft F
cp2=0.2419 //Btu/lbm F
```

```
g=32.17
//calculations
ti=(t1+t2)/2
bet=1/(460+ti)
Pr1=cp*mum/k
Gr1=d1^3 *rho^2 *3600^2 *g*bet*(t1-t2)/mum^2
Gr1pr1=Gr1*Pr1
hc1=k/d1 *0.53*(Gr1pr1)^0.25
Q1=hc1*(t1-t2)
tf=(ta+t2)/2
bet2=1/(460+tf)
Pr2=cp2*mum2/k2
Gr2=d1^3 *rho2^2 *3600^2 *g*bet2*(ta-t2)/mum2^2
Gr2pr2=Gr2*Pr2
hc2=k2/d1 *0.53*(Gr2pr2)^0.25
Q2=hc2*(ta-t2)
per=100*(Q2-Q1)/Q1
//results
printf("Coefficient of heat transfer in case 1= %.3f Btu/hr ft^2 F",hc1)
printf("\n Coefficient of heat transfer in case 2 = %.3f Btu/hr ft^2 F",hc2)
printf("\n Percentage change = %d percent",per)
```

Scilab code Exa 19.5 Temperature and heat calculations

```
clc
clear
//Initialization of variables
chord=40 //ft
v=1200 //mph
t1=80 //F
t2=200 //F
mu=0.0447 //lbm/ft hr
rho=5280 //lbm/ft^3
```

```
cp=0.2404 //Btu/lbm F
k=0.0152 //Btu/hr ft F
J=778
gc=32.17 //ft/s^2
mu2=0.0514 //lbm/ft hr
k2=0.0179 //Btu/hr ft F
cp2=0.2414 //Btu/lbm F
//calculations
Re=rho*v*chord*0.0735/mu
r=(mu*cp/k)^(1/3)
tav=t1+ r*v^2 *rho^2 /(2*gc*J*cp*3600^2)
ts=t1+ 0.5*(t2-t1)+ 0.22*(tav-t1)
Re2=v*rho*chord*0.0610/mu2
Pr2=cp2*mu2/k2
hc=cp2*v*rho*0.0610 *0.037*Re2^(-0.2) *Pr2^(-0.667)
Q2=hc*(t2-tav)
//results
printf("Temperature of wing surface = %.1f F",tav)
printf("\n Heat transfer convective = %d Btu/hr ft^2
   ",Q2)
disp("The answers are a bit different due to
   rounding off error in textbook")
```

Scilab code Exa 19.6 Radiation calculation

```
clc
clear
//Initialization of variables
r1=1 //in
r2=5 //in
F12=1
//calculations
F21=4*%pi*r1^2 *F12/(4*%pi*r2^2)
F22=1-F21
//results
```

```
printf("Percent of radiation emitted by surface 2 on
    small sphere = %d percent",F21*100)
printf("\n Remaining %d percent is absorbed by inner
    surface of larger sphere",F22*100)
```

Scilab code Exa 19.7 Radiation exchange calculation

```
clc
clear
//Initialization of variables
short=2 //ft
apart=3 //ft
long=4 //ft
T1=2260 //R
T2=530 //R
sigma=0.1714
//calculations
A1=short*long
ratio=short/apart
disp("from curve 3")
F=0.165
Q12=A1*F*sigma*((T1/100)^4 -(T2/100)^4)
//results
printf("Net exchange of radiation = %d Btu/hr",Q12)
disp("The answer in the textbook is a bit different
   due to rounding off error in textbook.")
```

Scilab code Exa 19.8 Radiation exchange calculation

```
clc
clear
//Initialization of variables
F=0.51
```

```
A1=8 //ft^2
sigma=0.1714
T1=2260 //R
T2=530 //R
//calculations
Q12=A1*F*sigma*((T1/100)^4 -(T2/100)^4)
//results
printf("Net exchange of radiation = %d Btu/hr",Q12)
disp("The answer in the textbook is a bit different
    due to rounding off error in textbook.")
```

Scilab code Exa 19.9 Radiation exchange calculation

```
clc
clear
//Initialization of variables
F=0.51
A1=8 //ft^2
sigma=0.1714
T1=2260 //R
T2=530 //R
//calculations
F12=1/(1/0.51 +(1/0.9 -1) +(1/0.6 -1))
Q12=A1*F12*sigma*((T1/100)^4 -(T2/100)^4)
//results
printf("Net exchange of radiation = %d Btu/hr",Q12)
disp("The answer in the textbook is a bit different
    due to rounding off error in textbook.")
```

Scilab code Exa 19.10 Percentage change calculation

```
clc
clear
```

```
//Initialization of variables
em=0.79
sigma=0.1714
T1=660 //R
T2=540 //R
T3=860 //R
//calculations
Q1=em*sigma*((T1/100)^4 -(T2/100)^4)
Q2=em*sigma*((T3/100)^4 -(T2/100)^4)
Qh1=129+Q1
Qh2=419+Q2
per=100*(Qh2-Qh1)/Qh1
//results
printf("Percentage change in total heat trasnfer = %
    .1f percent",per)
disp("The answer in the textbook is a bit different
    due to rounding off error in textbook.")
```

Scilab code Exa 19.11 Error in probe reading

```
clc
clear
//Initialization of variables
Tp=12.57
Tw=10.73
ep=0.8
sig=0.1714
hc=7
//calculations
dt=ep*sig*(Tp^4-Tw^4)/hc
//results
printf("Error in probe reading = %d F",dt)
```

Scilab code Exa 19.12 Heat transfer

```
clc
clear
//Initialization of variables
l=6 //ft
d1=0.55 //in
d2=0.75 //in
h1=280 //Btu/hr ft^2 F
h2=2000 //Btu/fr ft^2 F
k=220 //Btu/hr ft F
t2=212 //F
t1=60 //F
f=500 //Btu/hr ft^2 F
//calculations
A2=%pi*d1*l/12
A3=%pi*d2*l/12
Rt=1/(h1*A2) + 1/(h2*A3) +log(d2/d1) /(2*%pi*k*l)
Q=(t2-t1)/Rt
Rt2=Rt+ 1/(f*A2)
Q2=(t2-t1)/Rt2
//results
printf("Heat transfer = %d Btu/hr",Q)
printf("\n Heat transfer in case 2= %d Btu/hr",Q2)
disp("The answer in the textbook is a bit different
   due to rounding off error in textbook.")
```

Scilab code Exa 19.13 Overall heat transfer calculation

```
clc
clear
//Initialization of variables
l=6 //ft
d1=0.55 //in
d2=0.75 //in
```

```
h1=280 //Btu/hr ft^2 F
h2=2000 //Btu/fr ft^2 F
k=220 //Btu/hr ft F
t2=212 //F
t1=60 //F
//calculations
A2=%pi*d1*l/12
A3=%pi*d2*l/12
Rt=1/(h1*A2) + 1/(h2*A3) +log(d2/d1) /(2*%pi*k*l)
U3=1/(A3*Rt)
//results
printf("Overall Heat transfer coefficient = %.1f Btu/hr ft^2 F",U3)
disp("The answer in the textbook is a bit different due to rounding off error in textbook.")
```

Scilab code Exa 19.14 X and Y calculation

```
clc
clear
//Initialization of variables
t1=300 //F
t2=260 //F
t3=200 //F
t4=160 //F
//calculations
X=(t2-t4)/(t1-t4)
Z=(t1-t3)/(t2-t4)
//results
printf("Parameters X and Z are %.3f and %.1f respectively",X,Z)
```

Chapter 20

Advanced topics in heat transfer

Scilab code Exa 20.1 Temperature and heat calculation

```
clc
clear
//Initialization of variables
heat=54.5 //Btu/hr ft
d=0.811 //in
h=2.5 //Btu/hr ft^2 F
ts=100 //F
km=220 //Btu/hr ft F
//calculations
t2=heat*12/(h*%pi*d) +ts
w=heat*4*144/(%pi*d^2)
t1=w*(d/2)^2 /(4*144*km) + t2
//results
printf("Surface temperature of transmission line = %
   .1f F",t2)
printf("\n Rate of heat generaton per unit volume of
    wire = %d Btu/hr ft^2",w)
printf("\n Max. temperature in the line = %.2f F",t1
   )
```

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

Scilab code Exa 20.2 Heat rate calculation

```
clc
clear
//Initialization of variables
d1=1 //in
l=1 //ft
r=0.5 //ft
L=0.5 //in
Ts=430 //F
Ta=170 //F
del=0.0125 //ft
h=10 //Btu/hr ft^2 F
eta=0.77
eta2=0.94
n=60 //fins
thick=0.025 //in
k2=132 //Btu/hr ft F
//calculations
Q=h*%pi*d1^2 *(Ts-Ta)/12
rate=(r+L)/r
k=26 //Btu/hr ft F
Lt=L/12 *(h*12/(k*del))^(1/2)
dtm=eta*(Ts-Ta)
As=2*%pi*((2*d1)^2 -d1^2)/4
Q1=h*n*As*dtm/144
Q2=h*%pi*d1*(12-60*thick)*(Ts-Ta)/144
Qt=Q1+Q2
al=0.8
tl=Ta+(Ts-Ta)/cosh(al)
al2=r/12 *(h*12*2/(k2*thick))
dtm2=eta2*(Ts-Ta)
```

```
Q12=h*n*As*dtm2/144
Qt2=Q12+Q2
//results
printf("Heat rate per foot of bare tube = %.1f Btu/
   hr",Q)
printf("\n Total hourly heat loss per foot of finned
    tube = %.1f Btu/hr",Qt)
printf("\n Approx. temp for tip of the fin = %d F",
   tl)
printf("\n In case of Al, Total beat loss = %.1f Btu
   /hr",Qt2)
disp("The answers in the textbook are a bit
   different due to rounding off errors")
```

Scilab code Exa 20.3 Length calculation

```
clc
clear
//Initialization of variables
tl=125 //F
t0=80 //F
t1=1000 //F
d=1 //in
k=25 //Btu/hr ft F
k2=0.0208
Nu=18
//calculations
byal=(tl-t0)/(t1-t0)
al=acosh(1/byal)
b=%pi*d/12
A=%pi*d^2 /(4*144)
tm=(tl+t1)/2 +460
hr=0.79*0.1714*((tm/100)^4 - ((t0+460)/100)^4)/(tm
   -460-t0)
hc=Nu*k2*12/d
```

```
a=((hc+hr)*b/(k*A))^(0.5)
L=al/a
//results
printf("Length required = %.2f ft",L)
```

Scilab code Exa 20.5 Time required

```
clc
clear
//Initialization of variables
c=0.0947 //Btu/lbm F
rho=0.0551 //lbm/ft^3
mu=0.0553 //lbm/hr ft
t1=440 //F
ts=400 //F
t2=80 //F
d=0.1 //in
k=0.0194 //Btu/hr ft^2 F
rho2=558 //lbm/ft^3
v=10 //ft/s
//calculations
Re=d*3600*v*rho/(12*mu)
Nu=0.37*Re^0.6
hc=k*Nu*12/d
ex=log((t1-ts)/(t1-t2))
tau=-ex*d*rho2*c/(12*6*hc)
time=tau*3600
//results
printf("Time required = %d sec",time)
```

Scilab code Exa 20.6 cooling rate

```
clc
```

```
clear
//Initialization of variables
h=2 //Btu/hr ft^2 F
delta=1/6
t=125 //F
t0=100 //F
ti=350 //F
k=0.167 //Btu/hr ft F
rho=80 //lbm/ft^3
c=0.4 //Btu/lbm F
//calculations
Bi=h*delta/k
tr=(t-t0)/(ti-t0)
tau=1.5*delta^2 *rho*c/k
tr2=0.21
tc=tr2*(ti-t0) + t0
//results
printf("Cooling time = %.2f hr",tau)
printf("\n Center temperature = %d F",tc)
```

Scilab code Exa 20.7 Heat dissipation

```
clc
clear
//Initialization of variables
h=2.5 //Btu/hr ft^2 F
kc=0.1 //Btu/hr ft F
r1=0.811/2
//calculations
r2c=kc/h *12
//results
if r2c>=r1 then
    printf("Thin layer of insulation would increase
       the heat dissipation from wire, r2c = %.2f in
       ",r2c)
```

```
else
        printf("Thin layer of insulation would
           decrease the heat dissipation from wire.
           r2c=%.2f in",r2c)
end
```

Scilab code Exa 20.8 Heat transfer rate

```
clc
clear
//Initialization of variables
F12=0.19
F13=F12
FR3=F13
F2R=0.38
J1=1714
Wb2=0.1714
//calculations
disp("Upon solving the simultaneous equations")
Q1=1774 //Btu/hr ft
Q2=-547 //Btu/r ft
Q3=-1227 //Btu/hr ft
J2=548 //Btu/hr ft^2
Tr=909 //R
//results
printf("Heat transfer rate from surface 1 = %d Btu/
   hr ft",Q1)
printf("\n Heat transfer rate from surface 2 = %d
   Btu/hr ft",Q2)
printf("\n Heat transfer rate from surface 3 = %d
   Btu/hr ft",Q3)
printf("\n Temperature of surface R = %d R",Tr)
```