Scilab Textbook Companion for Thermodynamics Demystified by M. C. Potter[1]

Created by
Aviral Yadav
B.Tech
Mechanical Engineering
ABES Engineering college
College Teacher
None
Cross-Checked by
Harpreeth Singh

September 14, 2014

---

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

Book Description

Title: Thermodynamics Demystified

Author: M. C. Potter

Publisher: McGraw-Hill, USA

Edition: 1

Year: 2009

ISBN: 0071605991

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

Basic Principles

Scilab code Exa 1.2 kinetic energy

```
clc
// solution

// initialization of variables
m=10 // mass in Kg
V=5 // velocity in m/s

KE=m*V**2/2 // kinetic energy in N-m
printf(”The Kinetic Energy is ”+string(KE)+” N.m”)
```

Scilab code Exa 1.3 density and specific volume is asked

```
clc
// solution

// initialization of variables
V=3*5*20 // Volume of air in m^3 from dimensions
m=350 // mass in kg
```

```
g=9.81 // gavitational acceleration in m/s^2
rho=m/V // density
printf("The Density is %.3f kg/m^3 \n",rho)

v=1/rho // specific volume of air
printf(" The specific volume  is %.3f m^3/kg \n",v)

gama=rho*g // specific weight of air
printf(" The specific weight is %.2f N/m^3",gama)
```

Scilab code Exa 1.4 absolute pressure

```
clc
// solution

// initialization of variables
h=0.020 // height of mercury in m
gammawater=9810 // specific weight of water in N/m^3
Patm=0.7846*101.3 // atmospheric pressure in kPa
   from table B.1

Pgauge=13.6*gammawater*h/1000 // pressure in Pascal
   from condition gammaHg=13.6*gammawater

P=(Pgauge+Patm)// absolute pressure in KPa
printf("The Pressure is %.2f kPa",P)
```

Scilab code Exa 1.5 Compression in spring

```
clc
// solution

// initialization of variables
```

```
d=10/100 // diameter of cylinder in 'm'
P=600 // pressure in KPa
Patm=100 // atmospheric pressure in Kpa
K=4.8*1000 // spring constant in N/m

deltax=(P-Patm)*(%pi*1000*d**2)/(4*K) // by
   balancing forces on piston
printf("The Compression in spring is %.3f m",deltax)
```

Scilab code Exa 1.6 increase in kinetic energy

```
clc
// solution

// initialization of variables
ma=2200 // mass of Automobile 'a' in kg
va=25 //velocity of Automobile 'a' in m/s before
   collision
va1=13.89 // velocity of Automobile 'a' after
   collision in m/s
mb=1000 // mass of Automobile 'b' in kg
vb=24.44 //velocity of Automobile 'b' after
   collision in m/s

KE1=(ma*va**2)/2 // kinetic energy before collision
KE2=(ma*va1**2)/2+(mb*vb**2)/2 // kinetic energy
   after collision
U=(KE1-KE2)/1000 // internal energy from
   conservation of energy principle in kJ
printf("The increase in kinetic energy is of %.1f kJ
   ",U)
```

Chapter 2

Properties of Pure Substances

Scilab code Exa 2.1 saturated water is vaporized

```
clc
//solution
//    initialization of variables
m=10;  // mass of saturated water in kg
 // All the necessary values are taken from table C.2
 // part (a)

P=0.001; // Pressure in MPa
vf=0.001; // specific volume of saturated liquid at 0.001 Mpa in Kg/m^3
vg=129.2;//  specific volume of saturated vapour at 0.001 Mpa in Kg/m^3
deltaV=m*(vg-vf)//properties of pure substance
printf("The Volume change at pressure "+string(P)+" MPa is %.0f m^3 \n",deltaV)

// part (b)
P=0.26;  // Pressure in MPa
vf=0.0011; //   specific volume of saturated liquid at 0.26 MPa( it is same from at 0.2 and 0.3 MPa
```

```
upto 4 decimals)
vg=(P-0.2)*(0.6058-0.8857)/(0.3-0.2)+0.8857;  // specific volume of saturated vapour by interpolation of Values at 0.2 MPa and 0.3 MPa
deltaV=m*(vg-vf)
printf(" The Volume change at pressure "+string(P)+" MPa is %.2f m^3 \n",deltaV)

// part (c)
P=10;  // Pressure in MPa
vf=0.00145;  // specific volume of saturated liquid at 10 MPa
vg=0.01803; //specific volume of saturated vapour at 10 MPa
deltaV=m*(vg-vf)
printf(" The Volume change at pressure "+string(P)+" MPa is %.4f m^3",deltaV)
```

Scilab code Exa 2.2 volume of vapour

```
clc
//solution
//    initialization of variables
m=4// mass of water in kg
V=1 // volume in m^3
T=150 // temperature of water in degree centigrade

// TABLE C.1 is used for values in wet region
// Part (a)
P=475.8// pressure in KPa in wet region at temperature of 150 *C
printf("The pressure is %.1f kPa \n",P)

// Part (b)
// first we determine the dryness fraction
```

```
v=V/m// specific volume of water
vg=0.3928 //  specific volume of saturated vapour @150 degree celsius
vf=0.00109 // specific volume of saturated liquid @150 degree celsius
x=(v-vf)/(vg-vf); //dryness fraction
mg=m*x; // mass of vapour
printf(" The mass of vapour present is %.3f kg \n",mg)

// Part(c)
Vg=mg*vg;// volume of vapour
printf(" The volume of vapour is %.3f m^3",Vg)
```

Scilab code Exa 2.3 the final volume of mixture

```
clc
//solution
//    initialization of variables
m=2 // mass of water in kg
P=220 // pressure in KPa
x=0.8 // quality of steam
// Table C.2 is used for values
vg=(P-200)*(0.6058-0.8857)/(300-200)+0.8857 // specific volume of saturated vapour @ given pressure by interpolating
vf=0.0011 // specific volume of saturated liquid @ 220 KPa
v=vf+x*(vg-vf)// property of pure substance
V=m*v // total volume
printf("The Total volume of the mixture is "+string(V)+" m^3")
```

Scilab code Exa 2.4 constant pressure cylinder

```
clc
//solution
//    initialization of variables
m=2 // mass of water in kg
P=2.2 // pressure in Mpa
T=800 // temperature in degree centigrade
 // Table C.3 is used for values
v=0.2467+(P-2)*(0.1972-0.2467)/(2.5-2)// specific
   volue by interpolatin between 2 and 2.5 MPa
V=m*v // final volume
printf("The Final Volume is %.3f m^3",V)
```

Scilab code Exa 2.5 mass of air in the tire

```
clc
//solution
//    initialization of variables
V=0.6 // volume of tyre in m^3
Pgauge=200 // gauge pressure in KPa
T=20+273 // temperature converted to kelvin
Patm=100 // atmospheric pressure in KPa
R=287 // gas constant in Nm/kg.K
Pabs=(Pgauge+Patm)*1000 // calculating absolute
   pressue in Pa

m=Pabs*V/(R*T)// mass from ideal gas equation
printf("The Mass of air is %.2f Kg",m)
```

Scilab code Exa 2.6 the van der Waals equation

```
clc
```

```
//solution
//    initialization of variables
T=500+273 // temperature of steam in kelvin
rho=24 // density in Kg/m^3
R=0.462 // gas constant from Table B.2
v=1/rho // specific volume and density relation
// PART (a)
P=rho*R*T // from Ideal gas equation
printf("PART (a) The Pressure is "+string(P)+" KPa \n")
// answer is approximated in textbook

// PART (b)
a=1.703 //  van der Waal's constant a value from Table B.7
b=0.00169 // van der Waal's constant b value from Table B.7
P=(R*T/(v-b))-(a/v**2) // Pressure from van der Waal's equation
printf(" PART (b) The Pressure is "+string(P)+" KPa \n")
// answer is approximated in textbook

// PART (c)
a=43.9 //  van der Waal's constant a value from Table B.7
b=0.00117 // van der Waal's constant b value from Table B.7

P=(R*T/(v-b))-(a/(v*(v+b)*sqrt(T)))// Redlich-Kwong equation
printf(" PART (c) The Pressure is "+string(P)+" KPa \n")
// answer is approximated in textbook

// PART (d)
Tcr=947.4 // compressibilty temperature from table B.3
```

```
Pcr=22100 // compressibility pressure from table B.3

TR=T/Tcr // reduced temperature
PR=P/Pcr // reduced pressure
Z=0.93 // from compressiblility chart
P=Z*R*T/v // Pressure in KPa
printf(" PART (d) The Pressure is "+string(P)+" KPa \n")
// answer is approximated in textbook

// PART (e)
P=8000 // pressure from steam table @ 500*c and v= 0.0417 m^3
printf(" PART (e) The Pressure is "+string(P)+" KPa \n")
// answer is approximated in textbook
```

Chapter 3

Heat and Work

Scilab code Exa 3.1 constant pressure work done

```
clc
//solution
//initialization of variables
m=1                     // mass in kg
x=20/100               //quality of steam
P=200             //constant pressure in kPa
T1=100             //temperature intitial in degree centigrade
T2=400             //temperature final in degree centigrade

// first we find initial volume v1 and final volume v2

// using table C.2
vf=0.001061 // specific volume of saturated liquid in m^3 per kg
vg=0.8857  //specific volume of saturated vapour in m^3 per kg

v1=vf+x*(vg-vf);
```

```

v2=1.549   //specific volume of steam in m^3 per kg at T2=400*C and P2=0.2MPa
// now calculate work
W=m*P*(v2-v1);   //work done in constant pressure process
printf(”Work done is %.1f kJ”,W) // work is in kJ as pressure was in kPa
```

Scilab code Exa 3.2 110mm diameter cylinder work done

```
clc
//initialization of variables
D=110/1000 // diameter of cylinder in m
V1=100e-6 // initial volume@ state 1 in m^3
T1=60 // initial temp @ state 1 in *C
T2=200 // final temo @ state 2 in *C
M=50 // weight of piston in kg
g=9.81 // gravitational accleration in m/sec^2
Patm=100000 // atmospheric pressure in Pa
A=%pi*(D^2)/4 // area of piston in m^2

// BALANCING THE FORCES To GET PRESSURE P
// M.g=P.A-Patm
P=Patm+(M*g/A) // atm pressure is added to get absolute pressure

v1=0.001017 // specific volume at 60*C and 0.15Mpa pressure
m=V1/v1; // mass of water in kg

// find volume at state 2
v2=1.444 // specific volume of steam at 200*C and 0.15 MPa
V2=m*v2// final volume in m^3
```

```

W=P*(V2-V1)/1000; // work done divided by 1000 to get in kJ
printf("The work done is %.1f kJ",W)
```

Scilab code Exa 3.3 isothermal work by the ideal gas

```
clc
//initialization of variables
P1=200      // initial pressure in kPa
V1=2        //initial volume in m^3
P2=100      //final pressure in kPa
C=P1*V1// isothermal process i.e P.V=constant
//  find final volume
V2=P1*V1/P2 // final volume by P1.V1=P2.V2

function[p]=pressure(v) // expressing pressure as function of volume
    p=C/v;
endfunction

W=integrate('C/v','v',V1,V2) //itegrating over volume to get work
printf("The Work done by gas is %.0f kJ",W) // answer is approximated in textbook
```

Scilab code Exa 3.4 A 100 kg mass drops 3 m

```
clc//
//initialization of variables
M=100 // mass in kg
d=3 // depth by which mass drops in m
V=0.002 // increased volume in m^3
```

```
g=9.81 // gravitational accleration in m/sec^2
Pgauge=100*1000// gauge pressure in N/m
Patm =100*1000 // atmospheric pressure in N/m
P=Pgauge+Patm // to get absolute pressure

//calculate work done by paddle wheel
Wpaddlewheel=(-M*g*d) // work is negative as it is done on the system

//calculate work done on piston it
Wboundary=P*V // area mulitiplied by height is volume thus W=P.V
//net work
Wnet=Wpaddlewheel+Wboundary; // Work in joule as SI units are used
printf("The Net Work done is "+string(Wnet)+" J")
// in textbook answer is 2450 J which is when we assume g=9.80
```

Scilab code Exa 3.5 drive shaft in an automobile delivers

```
clc
// initialization of variables
T=100 // torque of shaft in N.m
N=3000 // rotation speed in rpm
omega=(N*2*%pi/60) // angular velocity in rad/sec
// calculation of power
Wdot=(T*omega); // power is work done per unit time
printf("Power transmitted is %.1f hp",Wdot/746)  // divided by 746 to convert W into hp
//answer is approximated in textbook
```

Scilab code Exa 3.6 Heat supplied at constant pressure

```
clc
// initialization of variables
D=10/100  //diameter of cylinder in m
d=50/1000  //compression in spring in m
Patm=100000    // atmospheric pressure in Pa
K=10*1000   // spring constant converted in  N/m
w=50*9.81  // weight of piston in Newton =mass*
   gravitational acceleration

// find the initial pressure in cylinder by force
   balance
A=(%pi*D^2)/4; // area of piston
P1=((Patm*A)+w)/A;      // balancing forces on
   piston P1.A=Patm.A+W

// work done by air to raise the piston for 50mm if
   spring not present
Wgas=P1*A*d; // pressure*area= force and Work =
   Force* displacement

// work done on spring to compress
Wspring=(K*d^2)/2; // Work in j

// now total work done by air is sum of two works
Wnet=Wgas+Wspring; // Work in j

printf("The net work done by air is %.2f J",Wnet)
//The answer is approximated in textbook but here it
    is precise
```

Scilab code Exa 3.7 non quasiequilibrium process

```
clc
// variable initialization

```

```
d=2   //distance travelled by weight in m
m=50  // mass of weight in kg
g=9.8  // gravitaional acceleration in m/sec^2

// calculation of work in non-quasiequilibrium process
W=m*g*d;// work in joules

// the work done must be transferred as heat
Q=W;

printf("The heat that must transfer is "+string(Q)+" Joules")
```

Chapter 4

The First Law of Thermodynamics

Scilab code Exa 4.1 paddle wheel heat transfer

```
clc
//initialization of variables
K=100 // spring constant in kN/m
d=0.8 // dispacement of spring in m
 // to get total work we integrate from 0 to 0.8 displacement
x1=0; // lower limit of integration
x2=0.8;  // upper limit of integration
W12=integrate('K*x','x',x1,x2);
Q12=W12; // by first law of thermodynamics
printf("The Heat transfer is "+string(Q12)+" J")
```

Scilab code Exa 4.2 internal energy increase

```
clc
//initialization of variables
```

```
P= 5*746 // power of fan converted in watt
t=1*60*60 // time converted to seconds

// by first law of thermodynamics Q=delU + W
// Q=0 hence -W=delU
// first we find work input
W=-P*t // work in J
delU=-W // from 1st law
printf("The internal energy increase is "+string(delU)+" J")
// The answer is approximated in textbook
// our answer is precise
```

Scilab code Exa 4.3 frictionless piston

```
clc
//initialization of variables
P=400 // pressure in kPa
T1=200 // initial temperature in degree celsius
V1= 2 // initial volume in m^3
Q=3500 // heat added in kJ
v1=0.5342 // specific volume of steam at 200 degree celcius and 0.4 Mpa pressure from table C.3
u1=2647 // specific internal energy in kJ/kg @ pressure = 0.4 MPa
m=V1/v1 // mass in kg
// we have a relation Between u2 and v2 from 1st law of thermodynamics
v2=1.06 // specific volume at state 2 by trial and error and interpolation
V2=m*v2
u2=((3500-400*(V2-V1))/m)+2647 // specific internal energy for v2=1.06 by trial and error

// on interpolation from steam table at 0.4 MPa we
```

```
get temperature
T2=644 // temperature in degree celsius
printf("The temperature for u2= "+string(u2)+" kJ and\n v2 ="+string(v2)+" kg/m^3 is \n"+string(T2)+" degree celsius")
// this numerical is solved by trial and error thus refer to Appendix C
```

Scilab code Exa 4.4 concept of enthalpy

```
clc
// initialization of variables
P=400 //  pressure in kPa
T1=200 // initial tmperature in degree celsius
V=2 // initial volume in m^3
Q=3500 // heat added in kJ

//solution
h1=2860 // initial enthalpy @ 200*C and 400 kPa from steam table
v=0.5342 // specific volume from steam table C.3
m=V/v;
h2=(Q/m)+h1; // final enthalpy in kJ/kg from energy equation

// NOW USING THIS ENTHLAPY AND INTERPOlATING FROM STEAM TABLE
T2=600+(92.6/224)*100
printf("The Final temperature is  "+string(T2)+" degree Celsius")
// result is obtained from interpolation on steam table
```

Scilab code Exa 4.5 specific heat of superheated steam

```
clc
// initialization of variables
T1=300 // initial temperature in degree celsius
T2=700 // final temperature in degree celsius
P=150// pressure in kPa
m=3 // mass of steam in kg

// solution
// part (a)

delH=m*integrate('2.07+(T-400)/1480','T',T1,T2) // expressing as function of temperature and integrating
printf(" The change in Enthalpy is "+string(delH)+" kJ \n")

// part(b)
CPavg=delH/(m*(T2-T1)) // avg value of specific heat at constant pressure
printf(" The average value of Cp is "+string(CPavg)+" kJ/kg.*C")
```

Scilab code Exa 4.6 enthalpy change for 1 kg of nitrogen

```
clc
// initialization of variables
m=1 // mass of nitrogen in kg
T1=300 // initial temperature in Kelvin
T2=1200 // final temperature in Kelvin
M=28 // in kg/kmol
// part(a)
// the enthalpy change is found from gas table in App.E
```

```
delh=36777-8723 // from gas table
delH=delh/M
printf(”The entalpy change from gas table is ”+string(delH)+” kJ/kg \n”)

// part (b)
Cp=1.042 // from table B.2
delH=Cp*(T2-T1)
printf(” The entalpy change  by assuming constant specific heat is ”+string(delH)+” kJ/kg”)
```

Scilab code Exa 4.7 quasiequilibrium process

```
clc
// initialization of variables
x=0.7 // quality of steam
P1=200 // initial pressure in kPa
P2=800 // final pressure in kPa
V=2 // volume in m^3
//The values are taken from TABLE C.2
vf1=0.0010 //specific volume of saturated liquid at 200 kPa
vg1=0.8857 //specific volume of saturated gas at 200 kPa
uf1=504.5 // specific internal energy of saturated liquid @ state 1
ug1=2529.5 // speciific internal energy of saturated gas @ state 1

v1=vf1+x*(vg1-vf1); //specific volume of vapour
m=V/v1

u1=uf1+x*(ug1-uf1) // specific internal energy of vapour @ state 1
v2=v1 // constant volume process
```

```
u2=((0.6761-0.6203)*(3661-3853)/(0.6761-0.6181))
   +3853// from steam table @ 800kPa by
   interpolating
Q=m*(u2-u1)// heat transfer
printf("The heat transfer is "+string(Q)+" kJ")
```

Scilab code Exa 4.8 piston cylinder arrangement

```
clc
// initialization of variables
V=0.02 // volume in m^3
P=400 // pressure in kPa
T1=50+273 // initial temperature in kelvin
T2=700+273 // final temperature in kelvin
Q=50 // heat added in kJ
R=287 // constant for air
Cp=1 // constant for specific heat of air

//using the ideal gas equation

m=P*1000*V/(R*T1) // mass of air in kg
W=Q-(m*Cp*(T2-T1)) // work done from first law
printf("The Paddle work is "+string(W)+" kJ")
```

Scilab code Exa 4.9 air in an insulated cylinder

```
clc
// initialization of variables
V1=2 // initial volume in m^3
V2=0.2 // final volume in m^3
T1=20+273// temperature in kelvin
P=200 // pressure in kPa
R=0.287 // constant for air
```

```
gama=1.4 // polytropic index for air
Cv=0.717// specific heat at constant volume for air
//solution

//using the ideal gas equation
m=(P*V1)/(R*T1) // mass in kg
// process is adiabatic thus
T2=T1*((V1/V2)**(gama-1))// final temperature

W=-m*Cv*(T2-T1)// work from first law
printf("The Work is "+string(W)+" kJ")
// solution is approximated in textbook
```

Scilab code Exa 4.10 Steam at 2000 kPa and 600 degree celsius

```
clc
// initialization of variables
P1=2000 // initial pressure in kPa
T1=600 // initial temperature in degree celsius
p2=600 // final pressure in kPa
T2=200 //   final temperature in degree celsius
d1=0.06 // diameter of inlet pipe in metre
d2=0.120 // diameter of outlet pipe in metre
V1=20 // velocity at inlet in m/s

//solution
// from superheat table C.3 values are noted
v1=0.1996 // specific volume of superheated steam @
    600*C and 2000 kPa
v2=0.3520 // specific volume of superheated steam @
    200*C and 2000 kPa
rho1=1/v1 //  initial density
rho2=1/v2 // final density
A1=(%pi*d1**2)/4 // inlet area
A2=(%pi*d2**2)/4 // exit area
```

```

V2=(rho1*A1*V1)/(rho2*A2) // from continuity
   equation
printf("The Exit velocity is "+string(V2)+" m/s \n")

mdot=rho1*A1*V1 // mass flow rate
printf(" The mass flow rate is "+string(mdot)+" kg/s
   ")
```

Scilab code Exa 4.11 throttling valve

```
clc
// initialization of variables
P1=8000 // initial pressure in kPa
T1=300 // temperature in degree celsius
P2=2000 // final pressure in kPa

//solution
h1=2785 // specific enthalpy of steam in kJ/kg @
   8000 kPa and 300 degree celsius from  steam table
h2=h1 // throttling process thus enthalpy is
   constant
T2=212.4 // from steam table as we know enthalpy and
    pressure
hf2=909 // specific enthalpy of saturated liquid @
   2000 kPa and 300 degree celsius
hg2=2799.5 // specific enthalpy of saturated gas @
   2000 kPa and 300 degree celsius
x2=(h2-hf2)/(hg2-hf2) // quality of steam

vg2=0.0992 //specific    volume of saturated gas @
   2000 kPa and 212.4*c
vf2=0.0012 //specific volume of saturated liquid @
   2000 kPa and 212.4*c
v2=vf2+x2*(vg2-vf2) // from properties of pure
```

```
substance

printf("The Final Temperature and Specific volume is "+string(T2)+" *C and "+string(v2)+" m^3/kg")
```

Scilab code Exa 4.12 turbine power output

```
clc
// initialization of variables
P1=4000 // inlet pressure in kPa
T1=500 // inlet temperature in degree celsius
V1=200 // inlet steam velocity in m/s
d1=0.05 // inlet diameter in 'm'
P2=80 // exit pressure in kPa
d2=0.250 // exit diameter in 'm'

// solution
v1=0.08643 // specific volume from steam table @ 4000 kPa and 500*C
v2=2.087 // specific volume from steam table @ 80 kPa and 500*C
rho1=1/v1 // density at inlet
rho2=1/v2 // density at outlet
A1=(%pi*d1**2)/4 // inlet area
A2=(%pi*d2**2)/4
mdot=rho1*A1*V1 // mass flow rate

//now using table C.3
h1=3445 // initial specific enthalpy @ 4000 kPa and 500 *C
h2=2666 // final specific enthalpy @ 80 kPa and 500 *C
WT=-mdot*(h2-h1) // maximum power from first law
printf("The power output is "+string(WT)+" kJ/s \n ")
```

```

V2=(A1*V1*rho1)/(A2*rho2)
delKE=mdot*((V2**2)-(V1**2))/2
printf(" The change in K.E is "+string(delKE)+" J/s"
    )
// the amswer is different as the solution in scilab
     is highly precise while the solution in textbook
     is wrong due to approximation of exit velocity
```

Scilab code Exa 4.13 maximum pressure increase by pump

```
clc
// initialization of variables
Wdot=10 // pump power in hp
g=9.81 // acceleration due to gravity
rho=1000 // density of water in kg/m^3
d1=0.06 // inlet dimeter in 'm'
d2=0.10 // oulet diamter in 'm'
V1=10 // velocity of water at inlet in m/s

//solution
A1=%pi*(d1**2)/4 // area of inlet
A2=%pi*(d2**2)/4 // area of outlet
V2=A1*V1/A2 // oulet velocity from continuity
    equation

mdot=rho*A1*V1 // mass flow rate
delP=((((Wdot*746)/mdot)-((V2**2)-V1**2)/(2*g))*rho)
    /1000 // change in pressure in kPa
printf("The rise in pressure is "+string(delP)+" kPa
    ")
// The answer is approximated in textbook , our
    answer is precise
```

Scilab code Exa 4.14 the supersonic nozzle

```
clc
// initialization of variables
P1=7000 // inlet pressure in Pa
T1=420 // inlet temperature in degree celsius
V1=400// inlet velocity in m/s
d1=0.200 // inlet diameter in 'm'
V2=700 // exit velocity in m/s
k=1.4 // polytopic index for air
Cp=1000 // specific heat at constant pressure for
   air in j/kg.K
R=287 // specific gas constant for air
//solution

//part (a)
T2=(((V1**2)-V2**2)/(2*Cp))+T1 // outlet temperature
    in degree celsius
printf("The exit temperature is "+string(T2)+" *C \n
   ")

//part (b)

rho1=P1/(R*(T1+273)) // density at entrance
A1=(%pi*d1**2)/4
mdot=rho1*A1*V1 //
printf(" The mass flow rate is "+string(mdot)+" kg/s
    \n")

// part (c)

rho2=rho1*(((T2+273)/(T1+273))**(1/(k-1))) //
   density at exit
// now we find the exit diameter
```

```
d2=sqrt((rho1*V1*(d1)**2)/(rho2*V2))
printf(" The outlet diameter is "+string(d2)+" m")
```

Scilab code Exa 4.15 heat exchanger

```
clc
// initialization of variables
mdots=100 // mass flow rate of sodium in kg/s
Ts1=450 // inlet temperature of sodium in degree celsius
Ts2=350 // exit temperature of sodium in degree celsius
Cp=1.25 // specific heat of sodium in KJ/kg.*C
Tw1=20 // inlet temperature of water in degree celsius
Pw=5000 // inlet pressure of water in kPa

// solution
hw1=88.65 // enthalpy from table C.4
hw2=2794 // enthalpy from table C.3
mdotw=(mdots*Cp*(Ts1-Ts2))/(hw2-hw1) // mass flow rate of water
printf("The mass flow rate of water is "+string(mdotw)+" kg/s \n")
Qdot=mdotw*(hw2-hw1) // heat transfer in kW using energy equation
printf(" The rate of heat transfer is "+string(Qdot)+" kW")
```

Chapter 5

The Second Law of Thermodynamics

Scilab code Exa 5.4 Carnot engine

```
clc
// initialization of variables
Th=200+273 // higher temperture in kelvin
Tl=20+273 // lower temperture in kelvin
Wdot=15 // output of engine in kW

ef=1-(Tl/Th) // carnot efficiency

Qhdot=Wdot/ef // heat supplied by reservoir
printf(" The heat suppled by higher temperature
   reservoir is %.2f kW \n ",Qhdot)
// using forst law
Qldot=Qhdot-Wdot // heat rejected to reservoir
printf(" The heat suppled by lower temperature
   reservoir is %.2f kW",Qldot)
```

Scilab code Exa 5.5 percentage increase in work

```
clc
// initialization of variables
TL1=-5+273 // lower temperature in kelvin for first situation
TH=20+273 // higher temperature in kelvin
TL2=-25+273 //lower temperature in kelvin for second situation

//solution

COP1=TL1/(TH-TL1) // carnot refrigerator COP for first situation
// Let Heat be 100 kJ
QL=100 // assumption
W1=QL/COP1 // work done for situation 1

// for situation 2
COP2=TL2/(TH-TL2) // COP carnot for second situation
W2=QL/COP2 // work done

Per=(W2-W1)*100/W1 // percentage increase in work done
printf(" The perccentage increase in work is %.1f%%",Per)
```

Scilab code Exa 5.6 paddle wheel work

```
clc
// initialization of variables
T1=20+273 // initial temperature in kelvin
P=200 // pressure in kPa
V=2 //volume in m^3
R=0.287 // gas constant for air
```

```
W=720 // work done on air in kJ
Cv=0.717 // specific heat at constant volume for air

//solution
m=(P*V)/(R*T1)// mass of air

T2=T1+(W/(m*Cv))// final temperature in kelvin

delS=m*Cv*log(T2/T1) // ENROPY CHANGE FOR CONSTANT
   VOLUME PROCESS
printf(" The Entropy increase is %.3f kJ/K ",delS)
```

Scilab code Exa 5.7 a combustion process in a cylinder

```
clc
// initialization of variables
T1=350+273 // initial temperature in kelvin
P1=1200 // initial pressure in kPa
P2=140 // final pressure in kPa
k=1.4 // polytopic index for air
Cv=0.717 // specific heat at  constant volume for
   air
//solution
T2=T1*((P2/P1)**((k-1)/k))  // reversible adiabatic
   process relation

w=-Cv*(T2-T1) // work done by gases in reversible
   adiabatic process
printf(" The work done by gases is %.0f kJ/kg",w)
```

Scilab code Exa 5.8 with variable specific heats

```
clc
```

```
// initialization of variables
T1=20+273 // initial temperature in kelvin
P1=200 // pressure in kPa
V=2 //volume in m^3
R=0.287 // gas constant for air
W=-720 // negative as work is done on air in kJ

//solution

m=(P1*V)/(R*T1)// mass of air

u1=209.1 //specific internal energy of air at 293K
    and 200 kPa from table E.1
s1=1.678 // by interpolation from table E.1
// change  in internal energy= work done
u2=-(W/m)+u1 // final internal energy
T2=501.2// final temperature interpolated from table
     E.1 corresponding to value of u2
s2=2.222 // value of s from table E.3 by
    interpolating from corresponding to value of u2

P2=P1*(T2/T1) // final pressure in kPa

delS=m*(s2-s1-R*log(P2/P1))// entropy change
printf(" The Entropy increase is %.3f kJ/K ",delS)
```

Scilab code Exa 5.9 a reversible adiabatic process

```
clc
// initialization of variables
T1=350+273 // initial temperature in kelvin
P1=1200 // initial pressure in kPa
P2=140 // final pressure in kPa
k=1.4 // polytopic index for air

```

```
//solution
// The values are taken from table E.1
Pr660=23.13// relative pressure @ 660K
Pr620=18.36// relative pressure @ 620K
Pr1=((Pr660-Pr620)*3/40)+Pr620 // relative pressure
    by interpolation
Pr2=Pr1*(P2/P1) // relative pressure at state 2

Pr340=2.149 // relative pressure @ 340K
Pr380=3.176 // relative pressure @ 380K
T2=((Pr2-Pr340)/(Pr380-Pr340))*40+340 //
    interpolating final temperature from table E.1

// now interpolating u1 AND u2 from table E.1
u620=451.0// specific internal energy @ 620k
u660=481.0// specific internal energy @ 660k
u1=(u660-u620)*(3/40)+u620 // initial internal
    energy

u380=271.7 //specific internal energy @ 380k
u340=242.8 //specific internal energy @ 340k
u2=((Pr2-Pr340)/(Pr380-Pr340))*(u380-u340)+u340 //
    final internal energy

w=u2-u1 // work= change in internal energy
printf(" The work done by gas is %.0f kJ/kg",w)
// The answer is slightly different as values are
    approximated in textbook
```

Scilab code Exa 5.10 Steam in a rigid container

```
clc
// initialization of variables
T1=300+273 // initial temperature in kelvin
P1=600 // initial pressure in kPa
```

```
P2=40 // final pressure in kPa

//solution
//please refer to steam table for values
v1=0.4344 // specific volume from steam table @ 573k and 600 kPa
v2=v1 // rigid container
u1=2801 // specific internal energy from steam table @ 573k and 600 kPa
s1=7.372 // specific entropy @ 600 kPa and 573 K

vg2=0.4625 // specific volume of saturated vapour @ 40 kPa and 573 K
vf2=0.0011 // specific volume of saturated liquid @ 40 kPa and 573 K
sf2=1.777 // specific entropy of saturated liquid @ 40 kPa and 573 K
sg2=5.1197 // specific entropy of saturated vapour @ 40 kPa and 573 K
x=(v2-vf2)/(vg2-vf2)// quality of steam using pure substance relation

s2=sf2+x*sg2 // overall specific enthalpy at quality 'x'
delS=s2-s1 // entropy change
printf(" The entropy change  is %0.3f kJ/kg.K \n ",delS)

//heat transfer
uf2=604.3 //specific internal energy of saturated liquid @ 40 kPa and 573 K
ug2=1949.3 //specific internal energy of saturated vapour @ 40 kPa and 573 K
u2=uf2+x*ug2 //specific internal energy @ quality x
q=u2-u1 // heat transfer in kJ/kg from first law as W=0
printf(" The heat transfer is %.0f kJ/kg",q)
// the answers are approximated in textbook but here
```

```
    they are precise thus minute difference is there
```

Scilab code Exa 5.11 Air in one half of an insulated tank

```
clc
// initialization of variables
v1=0.5 // assumed as air is filled in half of the
   tank
v2=1 // final volume when partition is removed
R=0.287 // gas contant for air
//solution
q=0 // heat transfer is zero
w=0 // work done is zero
// temperatue is constant as no change in internal
   energy by first law
dels=R*log(v2/v1)// change in entropy when
   temperature is constant
printf("The change in specific entropy is %.3f kJ/kg
   .K",dels)
```

Scilab code Exa 5.12 Two kilograms of steam

```
clc
// initialization of variables
T1=400+273 // initial temperature in kelvin
P=600 // pressure in kPa
Tsurr=25+273 // surrounding temperature in K
m=2 // mass of steam in kg

//solution
//please refer to steam table for values
s1=7.708 // specific entropy of steam @ 400 degree
   celsius and 0.6 MPa
```

```
s2=1.9316// specific enropy of condensed water @ 25
   degree celsius and 0.6 MPa
delSsys=m*(s2-s1) // entropy change in system i.e of
    steam

h1=3270 // specific enthalpy of steam @ 400 degree
   celsius and 0.6 MPa
h2=670.6//specific enropy of condensed water @ 25
   degree celsius and 0.6 MPa

Q=m*(h1-h2)// heat transfer at constant pressure
delSsurr=Q/Tsurr // entropy change in surroundings

sigma=delSsys+delSsurr // net entropy change

printf("The net entropy production is %.1f kJ/K",
   sigma)
```

Scilab code Exa 5.13 Superheated steam enters a turbine

```
clc
// initialization of variables
T1=600+273 // initial temperature in kelvin
P1=2 // initial pressure in MPa
P2=10 // final pressure in kPa
mdot=2 // mass flow rate in kg/s

//solution
//please refer to steam table for values
h1=3690 // specific enthalpy in kJ/kg @ 2MPa and 600
    degree celsius
s1=7.702 //specific entropy in kJ/kg.K @ 2MPa and
   600 degree celsius
s2=s1 // Reversible adiabatic process thus entropy
   is constant
```

```
sf2=0.6491 //specific entropy of saturated liquid from steam table @ 10 kPa
sg2=8.151 //specific entropy of saturated vapour from steam table @ 10 kPa

x2=(s2-sf2)/(sg2-sf2) // quality of steam at turbine exit

h2f=191.8 //specific enthalpy of saturated liquid from steam table @ 10 kPa
h2g=2584.8 //specific enthalpy of saturated vapour from steam table @ 10 kPa
h2=h2f+x2*(h2g-h2f) // specific enthalpy @ quality 'x'

WdotT=mdot*(h1-h2)// from work done in adiabatic process
printf(" The maximum power output is %.0f kJ/s",WdotT)
// the answers are approximated in textbook but here they are precise thus minute difference is there
```

Scilab code Exa 5.14 turbine is assumed to be 80 percent efficient

```
clc
// initialization of variables

T1=600+273 // initial temperature in kelvin
P1=2 // initial pressure in MPa
P2=10 // final pressure in kPa
mdot=2 // mass flow rate in kg/s
EffT=0.8 // efficiency of turbine
WdotT=2496 // theoritical power of turbine in kW

//solution
```

```
Wdota=EffT*WdotT // actual power output of turbine
h1=3690 // specific enthalpy @ 2MPa and 600 degree celsius
h2=h1-(Wdota/mdot) // final enthalpy from first law of thermodynamics

T2=((h2-2688)/(2783-2688))*(150-100)+100 // by interpolating from steam table @ P2= 10 kPa, h2=2770
s2=8.46 // final specific entropy by interpolation from steam table

printf("The temperature by interpolation is %.0f degree celsius \n",T2)
printf("The final entropy by interpolation is %.2f kJ/kg.K",s2)
// The temperature and entropy are found by interpolation from steam table and cannot be shown here.
```

Scilab code Exa 5.15 preheater is used in a power plant cycle

```
clc
// initialization of variables

T2=250 // temperature of steam in degree celsius
mdot2=0.5 // mass flow rate of steam in kg/s
T1=45 // temperature of water in degree celsius
mdot1=4 // mass flow rate of water in kg/s
P=600 // pressure in kPa


mdot3=mdot1+mdot2 // by mass balance

h2=2957 // specific enthalpy in kJ/kg of steam @ 600
```

```
Kpa from steam table
h1=188.4 // specific enthalpy in kJ/kg  of water @ 600 Kpa from steam table

h3=(mdot1*h1+mdot2*h2)/mdot3 // specific enthalpy in kJ/kg at exit

// by interpolation from saturated steam table
T3=(h3-461.3)*10/(503.7-461.3)+110 // temperature of mixture

sf3=1.508 // entropy of saturated liquid in kJ/kg.K at 600Kpa and T3 temperature from steam table
s3=sf3
s2=7.182 // entropy of superheated steam in kJ/kg.K @ 600Kpa from steam table
s1=0.639 // entropy of entering water in kJ/kg.K at T= 45 degree celsius

sigmaprod=mdot3*s3-mdot2*s2-mdot1*s1
printf("The rate of entropy production is %0.3f kW/K ",sigmaprod)
```

Chapter 6

Power Vapor Cycles

Scilab code Exa 6.1 power plant operate at the pressures of 10 kPa

```
clc
// solution
//initialization of variables
// Please refer to the given figure in question for
   quantities
P2=2*1000 //higher pressure converted in in kPa
P1=10 // lower pressure in kPa
rho=1000 // density of water in Kg/m^3
h1=192 // enthalpy at state 1 in kJ/kg
h3=3248 // enthalpy at state 3 in kJ/kg
s3=7.1279// entropy at state 3 in kJ/kg.K

//calculation of pump work
wp=(P2-P1)/rho // pump work given by equation 4.56
   in textbook
h2=h1+wp // by enrgy balance b/w state 1 and 2
q=h3-h2 // Heat input from 2 to 3

s4=s3 // isentropic process
sf=0.6491 // entropy of saturated liquid @10 kPa
   from steam table
```

```
sg=8.151 // entropy of saturated vapour @10 kPa from
    steam table
x=(s4-sf)/(sg-sf)// from property of pure substance
hf=191.8 //enthalpy of saturated liquid @10 kPa from
    steam table
hg=2584 // enthalpy of saturated vapour @10 kPa from
    steam table
h4=hf+x*(hg-hf)// enthalpy @ state 4

wt=h3-h4 // turbine work

efficiency=(wt-wp)/q // efficiency of power cycle
printf(" The Efficiency is %.3f or %.1f %% \n",
   efficiency,efficiency*100)
// the answer is correct within limits
```

Scilab code Exa 6.2 Increase the boiler pressure

```
clc
// solution
//initialization of variables
// Please refer to the given figure of question 6.1
   for quantities
effi1=0.323 //old efficiency
P2=4*1000 //higher pressure converted in in kPa
P1=10 // lower pressure in kPa
rho=1000 // density of water in Kg/m^3
h1=192 // enthalpy at state 1 in kJ/kg
h3=3214 // enthalpy at state 3 i.e @400 degree
   celsius and 4MPa in kJ/kg
s3=6.769// entropy at state 3 i.e @400 degree
   celsius and 4MPa in kJ/kg.K

s4=s3 // insentropic process
sf=0.6491 // entropy of saturated liquid @10 kPa
```

```
from steam table
sg=8.151 // entropy of saturated vapour @10 kPa from steam table

x=(s4-sf)/(sg-sf)// quality of steam

hf=192 //enthalpy of saturated liquid @10 kPa from steam table
hg=2584 // enthalpy of saturated vapour @10 kPa from steam table
h4=hf+x*(hg-hf)// enthalpy @ state 4
h2=h1 // isenthalpic process
qb=h3-h2 // heat addition

wt=h3-h4 // turbine work

effi2=(wt)/qb // efficiency of power cycle
printf(” The Efficiency is %.3f or %.1f %% \n”,effi2,effi2*100)
%increase=((effi2-effi1)/effi1)*100
printf(” The %% increase in Efficiency is %.2f \n”,%increase)
```

Scilab code Exa 6.3 Increase the maximum temperature

```
clc
// solution
//initialization of variables
// Please refer to fig of question 6.1 for quantities
effi1=0.323 //old efficiency
P2=2*1000 //higher pressure converted in in kPa
P1=10 // lower pressure in kPa
rho=1000 // density of water in Kg/m^3
T2=600// max temperature of cycle in degree celsius
```

```
h1=192 // enthalpy at state 1 in kJ/kg
h3=3690 // enthalpy at state 3 in kJ/kg, 600*C and 2 MPa pressure
s3=7.702// entropy at state 3 in kJ/kg.K, 600*C and 2MPa pressure

s4=s3// isentropic process
sf=0.6491 // entropy of saturated liquid @10 kPa from steam table
sg=8.151 // entropy of saturated vapour @10 kPa from steam table

x=(s4-sf)/(sg-sf)// quality of steam

hf=192 //enthalpy of saturated liquid @10 kPa from steam table
hg=2584 // enthalpy of saturated vapour @10 kPa from steam table
h4=hf+x*(hg-hf)// enthalpy @ state 4

h2=h1 // isenthalpic process
qb=h3-h2 // heat addition

wt=h3-h4 // turbine work

effi2=(wt)/qb // efficiency of power cycle
printf(" The Efficiency is %.3f or %.1f %% \n",effi2,effi2*100)
%increase=((effi2-effi1)/effi1)*100
printf(" The %% increase in Efficiency is %.2f \n", %increase)
```

Scilab code Exa 6.4 Decrease the condenser pressure

```
clc
```

```
// solution
//initialization of variables
// Please refer to fig of question 6.1 for
   quantities
effi1=0.323 //old efficiency
P2=2*1000 //higher pressure converted in in kPa
P1=4 // condenser pressure in kPa
rho=1000 // density of water in Kg/m^3
h1=192 // enthalpy at state 1 in kJ/kg
h3=3248 // enthalpy at state 3 in kJ/kg
s3=7.1279// entropy at state 3 in kJ/kg.K

s4=s3 // isentropic process

sf=0.4225 // entropy of saturated liquid @10 kPa
   from steam table
sg=8.4754 // entropy of saturated vapour @10 kPa
   from steam table

x=(s4-sf)/(sg-sf)// from property of pure substance

hf=121 //enthalpy of saturated liquid @4 kPa from
   steam table
hg=2554 // enthalpy of saturated vapour @4 kPa from
   steam table
h4=hf+x*(hg-hf)// enthalpy @ state 4h1=h2 //
   isenthalpic process
h2=h1 // isenthalpic process
qb=h3-h2 // heat addition

wt=h3-h4 // turbine work

effi2=(wt)/qb // efficiency of power cycle
printf(" The Efficiency is %.3f or %.1f %% \n",effi2
   ,effi2*100)
%increase=((effi2-effi1)/effi1)*100
printf(" The %% increase in Efficiency is %.2f \n",
   %increase)
```

```
// the answer in the textbook is different due to approximations
```

Scilab code Exa 6.5 High pressure steam enters a turbine at 2 MPa

```
clc
clear
// solution
//initialization of variables
P2=2*1000 //higher pressure converted in in kPa
P1=10 // lower pressure in kPa
h1=192 // enthalpy at 10 kPa  in kJ/kg
h3=3248 // enthalpy @ state 3 in kJ/kg from table C.3
s3=7.128 // entropy @ state 3 in kJ/kg.K from table C.3
s4=s3 // isentropic process

h2=h1 //isenthalpic process
h4=((s4-7.038)/(7.233-7.038))*(3056-2950)+2950 // using adjacent values for
//interpolation from table C.3
h5=3267 // enthalpy at 800 kPa and $00 degree celsius
s5=7.572 // entropy at 800 kPa and $00 degree celsius

s6=s5 // isentropic process
sf=0.6491//  entropy of saturated liquid @10 kPa from steam table
sg=8.151 // entropy of saturated vapour @10 kPa from steam table

x=(s6-sf)/(sg-sf)// quality of steam

```

```
hf=192 //enthalpy of saturated liquid @10 kPa from steam table
hg=2585 // enthalpy of saturated vapour @10 kPa from steam table

h6=hf+x*(hg-hf)// enthalpy @ state 6

// we now calculate energy input
qb=(h5-h4)+(h3-h2)// heat interaction

// we now calculate work output
wt=(h5-h6)+(h3-h4)// turbine work

eff=(wt)/qb // efficiency of power cycle
printf(" The Efficiency is %.4f9 or %.2f %% \n",eff,eff*100)
```

Scilab code Exa 6.6 inserted an open feedwater heater

```
clc
clear
// solution
// initialization of variables
// Please refer to fig of question 6.1 for quantities
effi1=0.357//efficiency from example 6.3
P2=2*1000 //higher pressure converted in in kPa
P1=10 // lower pressure in kPa
rho=1000 // density of water in Kg/m^3
T2=600// max temperature of cycle in degree celsius
h1=192 // enthalpy at state 1 in kJ/kg
h3=3690 // enthalpy at state 3 in kJ/kg, 600*C and 2 MPa pressure
h4=2442 // enthalpy from example 6.3
h6=505 // specific enthalpy @ 200 kPa from steam
```

```
    table
h7=h6 // isenthalpic process
s3=7.702// entropy at state 3 in kJ/kg.K, 600*C and 2MPa pressure

h2=h1 // isenthalpic process
s5=s3 // isentropic process
h5=(s3-7.509)*(2971-2870)/(7.709-7.509)+2870 // interpolationg from steam table 2 200 kPa using s5=s3= 7.702 kJ/kg.

m6=1 // let mass of steam =1 Kg
m5=(h6-h2)*(m6)/(h5-h2)
m2=m6-m5 // conservation of mass

wt=h3-h5+(h5-h4)*m2 // work done by turbine
qb=h3-h7 // heat given to bolier
effi2=(wt)/qb // efficiency of power cycle
printf(" The Efficiency is %.3f or %.1f %% \n",effi2,effi2*100)
%increase=((effi2-effi1)/effi1)*100
printf(" The %% increase in Efficiency is %.2f \n",%increase)
// The anwer is different in textbook as there the intermediate values are approximated while in scilab the calculations are precise
```

Scilab code Exa 6.7 efficiency of this reheat regeneration cycle

```
clc
// solution
//initialization of variables
P2=2*1000 //higher pressure converted in  kPa
P1=10 // lower pressure in kPa
h1=192 // enthalpy at 10 kPa  in kJ/kg
```

```
h3=3248 // enthalpy @ state 3 in kJ/kg from table C.3
s3=7.128 // entropy @ state 3 in kJ/kg.K from table C.3

s4=s3 // isentropic process

h4=((s4-7.038)/(7.233-7.038))*(3056-2950)+2950 // using adjacent values for
//interpolation from table C.3
h5=3267 // enthalpy at 800 kPa and $00 degree celsius
s5=7.572 // entropy at 800 kPa and $00 degree celsius

s6=s5 // isentropic process
sf=0.6491// entropy of saturated liquid @10 kPa from steam table
sg=8.151 // entropy of saturated vapour @10 kPa from steam table

x=(s6-sf)/(sg-sf)// quality of steam

hf=192 //enthalpy of saturated liquid @10 kPa from steam table
hg=2585 // enthalpy of saturated vapour @10 kPa from steam table

h6=hf+x*(hg-hf)// enthalpy @ state 6
h7=721 // enthalpy of saturated liquid @800 kPa from steam table
h8=h7 // isenthalpic process
h2=h1 // isenthalpic process

m8=1 // let mass of steam =1 Kg
m4=(h8-h2)*(m8)/(h4-h2)
m2=m8-m4 // conservation of mass

```

```
wt=h3-h4+(h5-h6)*m2 // work done by turbine
qb=h3-h8+(h5-h4)*m2 // heat given to bolier

effi=(wt)/qb // efficiency of power cycle
printf(" The Efficiency is %.3f or %.1f %% \n",effi,
   effi*100)
```

Scilab code Exa 6.8 A Rankine cycle operates between 2 MPa and 10 kPa

```
clc
clear
// solution
//initialization of variables

// for rankine cycle refer to fig 6.9

effiT=0.8 // turbine efficiency
P2=2*1000 // higher pressure converted in  kPa
P1=10 // lower pressure in kPa
h1=192 // enthalpy at 10 kPa  in kJ/kg
h3=3690 // enthalpy of superheated steam @ 2 MPa
   from steam table in kJ/kg
s3=7.702 //entropy of superheated steam @ 2 MPa from
    steam table in kJ/kg.K
// state 4' is repsresented by '41'
h2=h1 //isenthalpic process
s41=s3 // entropy is constant
sf=0.6491 // entropy of saturated liquid @10 kPa
   from steam table
sg=8.151 // entropy of saturated vapour @10 kPa from
    steam table
x=(s41-sf)/(sg-sf)// from property of pure substance

hf=191.8 //enthalpy of saturated liquid @10 kPa from
    steam table
```

```
hg=2584 // enthalpy of saturated vapour @10 kPa from
    steam table
h41=hf+x*(hg-hf)// enthalpy @ state 41

wa=effiT*(h3-h41)// turbine efficiency =(actual work
   )/(isentropic work)

qb=h3-h2 // heat supplied

effi=(wa)/qb // efficiency of power cycle
printf(" The Efficiency is %.3f or %.1f %% \n",effi,
   effi*100)

h4=h3-wa // adiabatic process

// now using interpolation for superheated steam @
   10 kPa
T4=(h4-2688)*(150-100)/(2783-2688)+100

printf("\n The Temperature from interpolation comes
   out to be %i degree celsius",T4)
```

Scilab code Exa 6.9 ideal vapor refrigeration cycle

```
clc
// solution
//initialization of variables
// refer to fig 6.10c

mdot=0.6 // mass flow rate of refrigerant in kg/sec
T1=-24 // evaporator temperature in degree celsius
T2=39.39 // condenser temperature in degree celsius
h1=232.8 // enthalpy of saturated R134a vapour @ −24
    degree celsius from table D.1
s1=0.9370 // entropy of saturated R134a vapour @ −24
```

```
    degree celsius from table D.1
h3=105.3 // enthalpy of saturated R134a liquid @ −24
    degree celsius from table D.2
h4=h3 // isenthalpic process

// interpolating enthalpy from table D.3 @ 39.39
   degree celsius
h2=(s1-0.9066)*(280.19-268.68)/(0.9428-0.9066)
   +268.68
QdotE=mdot*(h1-h4) // heat transfer rate
WdotC=mdot*(h2-h1)// power given to compressor

COP=QdotE/WdotC // coefficient of performance

Hp=(WdotC/0.746)/(QdotE/3.52) //calculating
   Horsepower required per Ton

printf(”The rate of refrigeration is %0.1f kJ/s \n ”
   ,QdotE)
printf(”The coefficient of performance is %0.2f \n ”
   ,COP)
printf(”The rating in horsepower per ton is %0.3f \n
    ”,Hp)
```

Scilab code Exa 6.10 compressor is 80 percent efficient

```
clc

// solution
//initialization of variables
// refer to fig 6.10c
effi=0.8 // compressor efficiency
mdot=0.6 // mass flow rate of refrigerant in Kg/sec
T4=-24 // temperature of evaporator
T2=39.39 // temperature of condensor
```

```
T1=-20 // supeheating temperature
T3=40 // subcooling temperature
h3=106.2 // enthalpy of liquid R-134a @ 40 degree celsius from table D.1
h4=h3 // isenthalpic process
h1=236.5 // enthalpy of superheated R-134a @ 0.10 MPa and -20 degree celsius from table D.3
s1=0.960 //entropy of superheated R-134a @ 0.10 MPa and -20 degree celsius from table D.3

s2dash=s1 // isentropic process

// using interpolation from table D.3 @ 1.0 MPa for s2dash=0.960
h2dash=(s2dash-0.9428)*(291.36-280.19)/(0.9768-0.9428)+280.19

h2=(h2dash-h1)/(effi)+h1 // by definition of compressor efficiency

QdotE=mdot*(h1-h4)//heat transfer rate power given to compressor

wdotc=mdot*(h2-h1)// power given to compressor

COP=QdotE/wdotc // coefficient of performance

printf("The rate of refrigeration is %0.1f kJ/s \n",QdotE)

printf("The coefficient of performance is %0.2f \n",COP)
// The value of Wdotc is shown wrong in the textbook. It should be multiplied by mass flow rate
```

Scilab code Exa 6.11 A heat pump using R134a

```
clc
// solution
//initialization of variables
// refer to fig 6.10c

QdotC=300 //heating Load in KWh or heat rejected by condensor
T1=-12 // evaporator temperature in degree celsius
P2=800 // condensor pressure in kPa
h1=240 // specific enthalpy of saturated R-134a vapour @ -12 degree celsius from table D.1
s1=0.927 // specific entropy of saturated R-134a vapour @ -12 degree celsius from table D.1
s2=s1 // isentropic process
h3=93.4 //specific enthalpy of saturated R-134a liquid @ 800 kPa from tableD.2

// extrapolating enthalpy from table D.2 @ 0.8 MPa for s=0.927
h2=273.7-(0.9374-s2)*(284.4-273.7)/(0.9711-0.9374)

// QdotE=mdot*(h1-h4) is heat transfer rate
mdot=QdotC/(h2-h3)// mass flow rate

WdotC=mdot*(h2-h1)// power given to compressor

//part(a)
COP=QdotC/WdotC // coefficient of performance
printf("The coefficient of performance is %0.2f \n ",COP)

//part(b)
cost=WdotC*0.07 // cost of electricity
printf("The cost of electricity is $ %0.3f /hr \n",cost)

```

```
//part(c)
costgas=(300*3600*0.50)/100000 // cost of gas
printf("The cost of gas is $ %0.2f /hr \n Thus heat pump is better ",costgas)
```

Chapter 7

Power Gas Cycles

Scilab code Exa 7.1 the percent clearance and the MEP

```
clc
//solution
// initialization of variables

r=12 // compression ratio
k=1.4 // polytropic index for air
p1=200 // pressure at state 1 in kPa
p3=10000 // pressure at state 3 in kPa

c=100/(r-1) // clearance in percentage
printf("The percent clearance is %0.2f %% \n",c)
v3=100 // let us assume v3=100 m^3 for calculations
p2=p1*(r**k) // polytopic process pressure relation
p4=p3*(1/(r**k))// polytropic process pressure
   relation
w34=v3*(r*p4-p3)/(1-k) // polytropic work done in
   process 3 to 4
v2=v3 // constant volume process
w12=v2*(p2-r*p1)/(1-k)
wcycle=w12+w34 // total work in cycle
 // now equating the polytropic work calculated to
```

```
work by MEP
MEP=wcycle/(r*v2-v2) // as work = pressure*change in volume
printf("The MEP is %i kPa",MEP)
// The solution is wrong in textbook as calculation for P2 is wrong
```

Scilab code Exa 7.2 Otto cycle with compression ratio of 10

```
clc
//solution
// initialization of variables

r=10 // compression ratio
k=1.4 // polytropic index for air
R=0.287 // specific gas constant for air
Cv=0.717 // specific heat at constant volume
Wnet=1000 // net work output in kJ/kg
T1=227+273 // low air temperaure in kelvin
p1=200 // low pressure in kPa

effi=1-(1/r^(k-1)) // thermal efficeiency
printf("The maximum possible thermal efficiency is %0.1f %% \n",effi*100)

T2=T1*(r)^(k-1) // isentropic process temperature relation

T4=((Wnet/Cv)+T2-T1)/((r^(k-1))-1) // using expression for work

T3=T4*(r)^(k-1)

efficarnot=1-T1/T3
printf("The carnot efficiency is %0.1f %%",
```

```
   efficarnot*100)

v1=R*T1/p1 // initial volume
v2=v1/r // from compression ratio

MEP=Wnet/(v1-v2) // mean effective pressure equation

printf("The MEP is %0.0f kPa",MEP)
```

Scilab code Exa 7.3 A diesel cycle with a compression ratio 18

```
clc
//solution
// initialization of variables


r=18 // compression ratio
k=1.4 // polytropic index for air
R=0.287 // specific gas constant for air
Cv=0.717 // specific heat at constant volume
Cp=1.0 // specific heat at constant pressure
T1=200+273 // lower temperaure in kelvin
P1=200 // low pressure in kPa
T3=2000 // higher temperature of cycle in kelvin

v1=R*T1/P1 // specific volume at state 1 in m^3
v2=v1/r // specific volume after compression in m^3

T2=T1*(v1/v2)^(k-1) // temperature after compression
P2=P1*(v1/v2)^k // pressure after compression
P3=P2 // diesel cycle
v3=R*T3/P3 // volume at state 3

rc=v3/v2 // cutoff ratio

```

```
effi=1-((rc^k)-1)/(r^(k-1)*k*(rc-1))


printf("The thermal efficiency is %0.2f %% \n",effi
   *100)

v4=v1 // diesel cycle
T4=T3*(v3/v4)^(k-1) // adiabatic process

qin=Cp*(T3-T2) // using first law
qout=Cv*(T4-T1) // heat rejected

Wnet=qin-qout // net work
MEP=Wnet/(v1-v2) // expression of mean effective
   pressure in terms of work

printf(" The MEP is %i kPa",MEP)
```

Scilab code Exa 7.4 without constant specific heats

```
clc
//solution
// initialization of variables

r=18 // compression ratio
k=1.4 // polytropic index for air
R=0.287 // specific gas constant for air
T1=200+273 // lower temperaure in kelvin
P1=200 // low pressure in kPa
T3=2000 // higher temperature of cycle in kelvin

v1=R*T1/P1 // specific volume at state 1 in m^3
//using table E.1
u1=340 // specific internal energy in kJ/kg
vr1=198.1 // in m^3/kg
```

```

vr2=vr1*(1/r) // as r=v1/v2

// now finding corresponding values from table E.1
T2=1310 // temperature in kelvin
Pr2=34 // pressure in kPa
h2=1408 // specific entropy in kJ/kg
v2=v1/18 // volume at state 2
P2=R*T2/v2 // pressure at state 2

h3=2252.1 // specific enthalpy in kJ/kg from table E.1
vr3=2.776
P3=P2 // diesel cycle
v3=R*T3/P3 // after compression volume
v4=v1 // isochoric process
vr4=vr3*v4/v3 // isentropic process
// now using Vr4 we read corresponding value from table E.1
T4=915 // final temperature in kelvin
u4=687.5 // specific internal energy at state 4

qin=h3-h2 // using first law
qout=u4-u1 // heat rejected

Wnet=qin-qout // net work
effi=100*Wnet/qin // thermal efficiency
printf(”The thermal efficiency is %0.2f %% \n”,effi)

MEP=Wnet/(v1-v2) // expression of mean effective pressure in terms of work

printf(” The MEP is %0.2f kPa \n”,MEP)

erroreffi=(66.6-effi)*100/effi // error in efficiency
errorMEP=(515-MEP)*100/MEP // error in MEP

```

```
printf(" The %% error in efficiency is %0.1f %% \n",
   erroreffi)
printf(" The %% error in MEP is %0.1f %% \n",
   errorMEP)

// the answers are slight different due to
   approximation in textbook ... here answers are
   precise
```

Scilab code Exa 7.5 thermal efficiency for this Brayton cycle

```
clc
//solution
// initialization of variables
Cp=1.0 // specific heat at constant pressure
k=1.4 // polytropic index for air
T1=25+273 // temperature at compressor inlet
T3=850+273 // maximum temperature in kelvin

r=5 // pressure ratio=P2/P1 & P4/P3

T2=T1*(r)^((k-1)/k) // temperature after compression

T4=T3*(1/r)^((k-1)/k) // final temperature

Wcomp=Cp*(T2-T1) // compressor work
Wturb=Cp*(T3-T4) // turbine work

BWR=Wcomp/Wturb // back work ratio

printf("The BWR is %0.1f %%\n",BWR*100)

Effi=1-r^((1-k)/k) // thermal efficiency

printf(" The thermal efficiency is %0.1f %% \n",Effi
```

```
*100)
```

Scilab code Exa 7.6 compressor and gas turbine have efficiency of 75 percent

```
clc
//solution
// initialization of variables

Cp=1.0 // specific heat at constant pressure
k=1.4 // polytropic index for air
T1=25+273 // temperature at compressor inlet
T3=850+273 // maximum temperature in kelvin

r=5 // pressure ratio=P2/P1 & P4/P3
efficomp=0.75 // efficiency of compressor
effiturb=0.75 // efficiency of turbine

T2dash=T1*(r)^((k-1)/k) // temperature after compression
Wcomp=Cp*(T2dash-T1)/efficomp // compressor work

T4dash=T3*(1/r)^((k-1)/k) // final temperature
Wturb=Cp*(T3-T4dash)*effiturb // turbine work

BWR=100*Wcomp/Wturb // back work ratio

printf("The BWR is %0.1f %%\n",BWR)

T2=(Wcomp/Cp)+T1 // actual temperature of state 2

qin=Cp*(T3-T2) // using first law

Wnet=(Wturb-Wcomp) // net work

```

```
effi=100*Wnet/qin // thermal efficiency
printf(”The thermal efficiency is %0.2f %% \n”,effi)
```

Scilab code Exa 7.7 ideal regenerator to the gas turbine cycle

```
clc
//solution
// initialization of variables

Cp=1.0 // specific heat at constant pressure
k=1.4 // polytropic index for air
T1=25+273 // temperature at compressor inlet
T3=850+273 // maximum temperature in kelvin

r=5 // pressure ratio=P2/P1 & P4/P3

T2=T1*(r)^((k-1)/k) // temperature after compression

T4=T3*(1/r)^((k-1)/k) // final temperature

Wcomp=Cp*(T2-T1) // compressor work
Wturb=Cp*(T3-T4) // turbine work

BWR=Wcomp/Wturb // back work ratio

printf(”The BWR is %0.1f %%\n”,BWR*100)

effi=(1-((T1/T4)*(r^((k-1)/k))))// efficiency
printf(” The thermal efficiency is %0.1f %% \n”,effi*100)
// The solution in textbook is incorrect dur to wrong value of T4 (temperature at state 4)
```

Scilab code Exa 7.8 gas turbine provides the energy to the boiler

```
clc
clear
//solution
// initialization of variables

//REFER TO FIG.:7.8

Cp=1 // specific constant at constant pressure
k=1.4 // polytropic constant for air
T5=25+273 // temperature at state 5 in kelvin
T7=850+273 // temperature at state 4 in kelvin
T9=350 // exit temperature of water from bolier in
    kelvin
WdotST=100000 // power from steam turbine in Watt
r=5 // pressure ratio=P2/P1 & P4/P3

h1=192 // specific enthalpy at 10 Kpa from steam
    table
h2=h1 // isenthalpic process
h3=3214 // specific enthalpy at 4 Mpa and 400 degree
     celsius from steam table
s3=6.769 // specific entropy at 4 Mpa and 400 degree
     celsius from steam table

s4=s3 // isentropic process
sf=0.6491 // specific entropy of saturated liquid at
     10 kPa and 45 degree celsiusfrom table C.2
sg=8.1510 // specific entropy of saturated liquid at
     10 kPa and 45 degree celsiusfrom table C.2
x4=(s4-sf)/(sg-sf) // quality of steam

hf=h1 // specific enthalpy of saturated liquid @ 10
    Kpa
hg=2584.6
h4=hf+x4*(hg-hf) // specific entropy at state 4

```

```
mdots=WdotST/(h3-h4) // steam mass flow rate from turbine output

T6=T5*(r^((k-1)/k)) // adiabatic process relation
T8=T7*(1/r^((k-1)/k)) // adiabatic process relation

// Now using energy balance in boiler
mdota=mdots*(h3-h2)/(Cp*(T8-T9)) // mass flow rate of water
Wdotturb=mdota*Cp*(T7-T8) //  power produced by turbine

Wdotcomp=mdota*Cp*(T6-T5) // energy needed by compressor

WdotGT=Wdotturb-Wdotcomp // net turbine work

Qdotin=mdota*Cp*(T7-T6) // energy input by combustor

effi=100*(WdotST+WdotGT)/Qdotin // combined efficiency

printf("The thermal efficiency of the combined cycle is %0.1f %% ",effi)
```

Scilab code Exa 7.9 compressor with compression ratio of 10

```
clc
clear
//solution
// initialization of variables

Cp=1 // specific constant at constant pressure
k=1.4 // polytropic constant for air
r=10
```

```
T2=-10+273 // temperature at entry  of compressor
T4=30+273 // temperature at entry of turbine

T3=T2*(r^((k-1)/k)) // temperature at state 3 in
    kelvin
T1=T4*(1/r^((k-1)/k)) // temperature at state 1 in
    degree celsius
printf("The minimum temperature is %0.1f degree
    celsius \n",T1-273)

qin=Cp*(T2-T1) // heat input
Wcomp=Cp*(T3-T2)// compressor work
Wturb=Cp*(T4-T1) // turbine work

COP=qin/(Wcomp-Wturb) // COP of refrigeration
printf(" The COP is %0.2f ",COP)
```

Scilab code Exa 7.10 adding ideal internal heat exchanger and regenerator

```
clc
clear
//solution
// initialization of variables

Cp=1 // specific constant at constant pressure
k=1.4 // polytropic constant for air
r=10
T3=-10+273 // temperature at entry  of compressor
T6=-40+273 // temperature at entry of turbine

T5=T3 // heat exchanger
T2=T6 // heat exchanger

T4=T3*(r^((k-1)/k)) // temperature after compression
```

```
T1=T6*(1/r^((k-1)/k)) // temperature after exit from
    turbine

printf("The minimum temperature is %0.i degree
   celsius \n",T1-273)

qin=Cp*(T2-T1) // heat input
Wcomp=Cp*(T4-T3)// compressor work
Wturb=Cp*(T6-T1) // turbine work

COP=qin/(Wcomp-Wturb) // COP of refrigeration
printf(" The COP is %0.3f ",COP)

// the answer is correct within given limits
```

Chapter 8

Psychrometrics

Scilab code Exa 8.1 air at 25 degree Celsius and 100 kPa in 150 metre cube

```
clc
// solution
//initialization of variables
Ra=0.287 // specific gas constant for air
P=100 // pressure of room in kPa
V=150 // volume of room in m^3
T=25+273 // temperature of air in kelvin
phi=0.6 // relative humidity
Pg=3.29 // saturation vapour pressure in kPa at 25 *
   C from table C.1
Mv= 18 // molecular mass of water vapor
Ma=28.97 // molecular mass of air

Pv=Pg*phi // partial pressure of water vapour

Pa=P-Pv // partial pressure of air

w=0.622*(Pv/Pa) // humidity ratio in Kg of water/ Kg
    of dry air
Tdp=17.4 // dew point temperature from interpolation
```

```
in table C.2 corresponding to partial pressure Pv=1.98 kPa

ma=Pa*V/(Ra*T) // mass of air
mv=w*ma // mass of water vapour in  kg

// now we find volume percentage
Nv=mv/Mv // moles of vapour
Na=ma/Ma // moles of air

Vw= Nv/(Na+Nv) // fraction of volume occupied by water vapour

printf(" The humidity ratio is %0.3f Kg water/ kg of dry air \n",w)
printf("The dew point is %0.1f degree celsius \n ",Tdp)
printf("The mass of water vapour in the air is %0.2f kg \n",mv)
printf("The volume percentage of the room that is water vapor is %0.2f %%",Vw*100)
// The answers are correct within given limits
// The variation in answers is due to approximations made by
// textbook while scilab is precise
```

Scilab code Exa 8.2 air is cooled below the dew point to 10 degree Celsius

```
clc
clear
// solution
//initialization of variables
Ra=0.287 // specific gas constant for air
P=100 // pressure of room in kPa
w1=0.0126 // old humidity ratio of example 8.1-
```

```
Pg=3.29 // saturation vapour pressure in kPa at 25 *
    C from table C.1
mv=2.17 // initial mass of water vapour in example
    8.1
T=25+273 // temperature after reheat
V=150 // volume of room in m^3
Pv=1.228 // saturation vapour pressure in kPa @ 10
    degree celsius from table C.1
Pa=P-Pv // partial pressure of air
w2=0.622*(Pv/Pa) // new humidity ratio in Kg of
    water/ Kg of dry air
deltaw=w1-w2 // difference in humidity ratio
ma=Pa*V/(Ra*T) // mass of air
deltamv=deltaw*ma // mass of water vapour condensed
X=deltamv*100/mv // percentage of water vapour
    condensed
printf("The percentage that condenses is %0.1f %% \n
    ",X)
// AFTER REHEATING
phi=1.608*w2*Pa/Pg
printf("The relative humidity is %0.1f %%",phi*100)
```

Scilab code Exa 8.3 100 kPa air stream

```
clc
// solution
//initialization of variables
T1=40 // dry bulb temperature in degree celsius
T2=20 // wet bulb temperature in degree celsius
Cp=1.0 // specific heat
P=100 // pressure of air stream in kPa
pg1=7.383 //saturation pressure @ 40 degree celsius
hfg2=2454 // latent heat for 20 degree celsius
Pg2=2.338 // saturation pressure @ 20 degree celsius
w2=0.622*Pg2/(P-Pg2) // specific humidity for wet
```

```
bulb condition
hg1=2574 // specific enthalpy of saturated vapour @ 40 degree celsius
hf2=83.9 //spedific enthalpy of saturated liquid @ 20 degree celsius
w1=((w2*hfg2)+Cp*(T2-T1))/(hg1-hf2)// specific humidity for 40 degree celsius
printf("The humidity ratio is %0.5f kg water/ Kg dry air \n",w1)
pv1=100*w1/(0.622+w1) // partial pressure of vapour
phi=pv1/pg1 // relative humidity
printf("The relative humidity is %0.1f %% \n",phi*100)

hv=hg1 // temperature is at DBT=40 degree celsius
h=Cp*T1+w1*hv // specific enthalpy  of air
printf("The specific enthalpy is %0.1f kJ/kg dry air",h)
```

Scilab code Exa 8.5 Hot dry air passes through an evaporative cooler

```
clc
//solution
// initialization of variables

T1=40 // inlet temperature in degree celsius
T2=27 // outlet temperature in degree celsius
phi1= 10 // relative humidity at inlet
// as no heat transfer takes place thus isenthalpic process
//Thus following the enthalpy line at DBT=40 and Relative humidity=10
phi2=45 // by interpolation of constant enthalpy line
w1=0.0046// specific humidity @ T=40 and phi1=10
```

```
w2=0.010 // specific humidity at outlet
W=w2-w1 // amount of water added
Tmin=18.5 // minimum temperature at 100% relative humidity
printf("The relative humidity is %i %% \n ",phi2)
printf("The added water is %0.04f kg water/kg dry air \n",W)
printf("The lowest possible temperature is %0.1f *C ",Tmin)
```

Scilab code Exa 8.6 incoming volume flow rate is 50 metre cube per min

```
clc
//solution
// initialization of variables
T1=5+273 // outside air temperature in kelvin
P=100 // pressure in kPa
Ra=0.287 // specific gas constant for air
phi=0.7 // relative humidity outside
Qf=50/60 // volume flow rate in m^3/sec
Pg1=0.872 // saturation pressure at 278 K
Pv1=phi*Pg1 // partial pressure of water vapour
Pa1=P-Pv1 // partial pressure of air

rhoa=Pa1/(Ra*T1) // density of dry air

mdota= Qf*rhoa // mass flow rate of dry air

// using psychrometric chart at T1=5*C and phi1=70%
h1=14 // inlet enthalpy in kJ/kg
h2=35 // enthalpy after heating in kJ/kg

Qdot=mdota*(h2-h1) // heat transfer rate
// from psychrometric chart for T=25 *C and 35 kJ/kg enthalpy
```

```
phi2=19 // realtive humidity
printf("The heat transfer rate is %0.1f kJ/s \n",Qdot)
printf("The final relative humidity is %i %% ",phi2)
```

Scilab code Exa 8.7 heat transfer if the incoming volume flow rate of air is 60 metre cube per min

```
clc
//solution
// initialization of variables
//DATA TAKEN FROM PSYCHROMETRIC CHART
T1=5+273 // outside temperature in kelvin
h1=10// enthalpy in kJ/kg @ T=5 *C and 40 % relative humidity
Pg1=0.872 // saturaion pressure in kPa for 5 degree celsius DBT
phi1=0.4
h2=33 // specific enthalpy at 25 *C and 40 % relatuve humidity
h3=45 // specific enthalpy at state 3
P=100 // atmospheric pressure in kPa
Ra=0.287 // specific gas constant for air
Qf=60/60 // volume flow rate in m^3/s
Pv1=phi1*Pg1 // partial presure of water vapour
Pa1=P-Pv1 // partial pressure of air
w2=0.0021 // specific humidity @ 40 % relative humidity and 25*C temperature
w3=0.008 // final specific humidity
rhoa1=Pa1/(Ra*T1) // air density
mdota=Qf*rhoa1 // mass flow rate of dry air

Qdot=mdota*(h2-h1) // heat transfer rate

// as the process is isothermal thus
```

```
mdots=mdota*(w3-w2)// mass flow rate of steam by conservation of mass
printf("the rate of steam supplied is %0.4f kg/s \n",mdots)
// also using energy balance
hs=(mdota*(h3-h2))/mdots // enthalpy of steam
hf=604.7 // enthalpy of saturated liquid @ 400 kPa
hg=2738.5 // enthalpy of saturated vapour @ 400 kPa
xs=(hs-hf)/(hg-hf)
printf("The quality of steam is %0.2f ",xs)
```

Scilab code Exa 8.8 Outside air at 30 degree C and 90 percent relative humidity

```
clc
//solution
// initialization of variables
// REFER TO FIG. 8.4
T1=30 // outside temperature in degree celsius
phi1=0.9 // outside relative humidity
T2=23 // room temperature in degree celsius
phi2=0.4 // relative humidity in room

// using psychrometric chart
w1=0.0245 // specific humidity @ 30 *C and relative humidity 0.9
h1=93 // specific enthalpy @ 30 *C and relative humidity 0.9
w2=w1 // during cooling humidity remains constant
w3=0.007 // specific humidity @ 23 *C and relative humidity 0.4
h4=41 // final specific enthalpy
h3=26 // specific enthalpy @ 23 *C and relative humidity 0.4
deltaw=w3-w2 // moisture removed
```

```
printf("the amount of moisture removed is %0.4f kg \n",deltaw)


qout=h3-h1 // heat removed F–G–H process

printf(" the heat removed is %i kJ/kg \n ",qout)

qin=h4-h3 // heat added to bring to desired state

printf(" the heat added is %i kJ/kg ",qin)
```

Scilab code Exa 8.9 Outside cool air is mixed with inside air

```
clc
//solution
// initialization of variables
P=100 // atospheric pressure in kPa
R=0.287 // specific gas constant for air
T1=15+273 // outside temperature in kelvin
phi1=0.4// outside air relative humidity
Qf1=40 // outside air flow rate in m^3/min
T2=32+273 // inside temperature in kelvin
phi2=0.7 // inside air relative humidity
Qf2=20 // outside air flow rate in m^3/min
Ps1=1.7 // saturation pressure @ 15 degree celsius and 40% humidity
Ps2=4.9 // saturation pressure @ 32 degree celsius and 70% humidity

Pv1=Ps1*phi1 // partial pressure of water vapour outside

Pv2=Ps2*phi2 // partial pressure of water vapour inside
```

```

Pa1=P-Pv1 //partial pressure of dry air outside
Pa2=P-Pv2 //partial pressure of dry air inside

rhoa1=Pa1/(R*T1) // density of outside air
mdota1=Qf1*rhoa1 // mass flow rate of air outside

rhoa2=Pa2/(R*T2) // density of inside air
mdota2=Qf2*rhoa2 // mass flow rate of inside air
 // using psychrometric chart locating state 1 and 2
h1=37 // specific enthalpy @ DBT 15*C and 40 % humidity
w1=0.0073 // specific humidity @ DBT 15*C and 40 % humidity
h2=110 // specific enthalpy @ DBT 32*C and 70 % humidity
w2=0.0302 // specific humidity @ DBT 32*C and 70 % humidity
ratio=mdota1/mdota2 // ratio of distance between states
//  using this ratio state 3 is located on psychrometric chart
T3=(mdota1*T1+mdota2*T2)/(mdota1+mdota2)-273 // final temparature in celsius

phi3=65// final relative humidity at T3 from psychrometric chart

printf("The relative humidity is %i %% \n",phi3)
printf(" The resultant temperature is %i degree celsius",T3)
```

Scilab code Exa 8.10 cooling tower of power plant

```
clc
```

```
//solution
// initialization of variables
mdotw3=10000 // mass flow rate of water entering in cooling tower in kg/min
Tw1=40+273 // temperature of water entering cooling tower in kelvin
Ta1=20+273 // temperature of air entering cooling tower in kelvin
phi1=0.5// relative humidity of entering air
Tw2=25+273 // temperature of water leaving cooling tower in kelvin
Ta2=32+273 // temperature of air leaving cooling tower in kelvin
phi2=0.98 // relative humidity of leaving air
// from psychrometric chart
h1=37// specific enthalpy of air @ 20*C DBT and 50% humidity
w1=0.0073 // specific humidity of air @ 20*C DBT and 50% humidity
h2=110// specific enthalpy of air @ 32*C DBT and 98% humidity
w2=0.030 // specific humidity of air @ 32*C DBT and 98% humidity

h3=167.5 // specific enthalpy of water from steam table at 40 degree celsius
h4=104.9 // specific enthalpy of water from steam table at 25 degree celsius

mdota=(mdotw3*(h4-h3))/(h1-h2+(w2-w1)*h4) // by energy balance


v1=0.84 // specific volume of air entering tower from psychrometric chart

Qf=mdota*v1 // volume flow rate in m^3/min
printf("The volume flow rate of air into the cooling
```

```
tower is %i m^3/min \n",Qf)

mdot4=mdotw3-(w2-w1)*mdota // by mass balance
printf("The mass flow rate of water that leaves the cooling tower is %i kg/min",mdot4)
// The answers is slightly different in textbook due to approximations in calculations while in scilab solution is precise
```

Chapter 9

Combustion

Scilab code Exa 9.1 air fuel ratio of 20

```
clc
clear
// initialization of variables

AFactual=20 // air fuel ratio actual
// The energy balance is done from equation

// C4H10 + 6.5(O2+3.76N2)-----> 4CO2 + 5H2O + 24.44
   N2

P=100 // atmospheic preesure in kPa
mair=6.5*(1+3.76)*29 // mass of air
mfuel=1*58 // mass of fuel
AFth=mair/mfuel // theoritical air-fuel ratio
%excessair=(AFactual-AFth)*100/AFth

printf("The %% excess air is %0.2f %% \n",%excessair
   )

// NOW THE REACTION IS
// C4H10+ (1+%excessair/100)*6.5*(O2+3.76N2) ----->
```

```
4CO2 + 5H2O + 1.903O2 + 31.6N2

%CO2=4/42.5*100 // VOLUME % OF CO2

printf(”The volume %% of CO2 is %0.2f %% \n”,%CO2)

// NOW WE FIND DEW POINT
Nv=5 // moles of water
N=42.5 // moles of air
Pv=P*(Nv/N) // partial pressure of vapour
Tdp=49// dew point temperature in degree celsius from table C.2

printf(”The Dew point temperature is %i degree celsius”,Tdp)
```

Scilab code Exa 9.2 Butane with 90 percent theoretical air

```
clc
// initialization of variables

%air=0.9 // 90% air is used for combustion

// THE REACTION IS
// C4H10 + 0.9*6.5*(O2+3.76N2)----> aCO2 + 5H20 + bCO
// a and b are calculated by atomic balance
a=2.7
b=1.3
%CO=b*100/31 // volume % of CO

printf(”The volume %% of CO is %0.2f %% \n”,%CO)

mair=6.5*%air*4.76*29 // mass of air in kg
mfuel=1*58 // mass of fuel butane in kg
```

```
AF=mair/mfuel // air-fuel ratio

printf("The air to fuel ratio is %0.2f kg air/ kg fuel ",AF)
// THE SOLUTION IS CORRECT BUT  THERE ARE SOME PRINTING MISTAKES IN TEXTBOOK
```

Scilab code Exa 9.3 Butane is burned with dry air

```
clc
// initialization of variables

// THE REACTION IS
// aC4H10 + b(O2+3.76N2)----> CO2 + 1CO + 3.5H20 + 84.6N2 + cH2O
// a, b and c are calculated by atomic balance
// C: 4a=11+1
// H:10a=2c
// O:2b=22+1+7+c
// solving these equations using matrix
A=[4 0 0;10 0 -2;0 2 -1]
B=[12;0;30]
x=A\B
a=x(1)
b=x(2)
c=x(3)

// Now equation becomes
//C4H10 + 7.5(O2+3.76N2)----> 3.67CO2 + 0.33CO + 1.17H20 + 28.17N2 + 5H2O
//MOLES OF AIR in this equation is 7.5 moles
mairactual=7.5 // in moles
//MOLES OF AIR in standard equation of Ex.9 is 6.5
mairtheoritical=6.5
%theoriticalair=100*(mairactual/mairtheoritical)
```

```
printf("The %% theoritical air is %0.1f %% ",
   %theoriticalair)
```

Scilab code Exa 9.4 Volumetric analysis of the products of combustion

```
clc
// initialization of variables
// The reaction equation is
//CaHb + c(O2+3.76N2)---> 10.4CO2 + 1.2CO + 2.8O2 +
   85.6N2 + dH2O

// using atomic balancing
// C:a=10.4+12
//N:3.76c=85.6
//O:2c=20.8+1.2+5.6+d
//H:b=2d

// Solving these equations using matrix
A=[1 0 0 0;0 0 3.76 0;0 0 2 -1;0 1 0 -2]
B=[11.6;85.6;27.6;0]
x=A\B
a=x(1)
b=x(2)
c=x(3)
d=x(4)

// substituing these values in reaction equation
//C11.6H37.9 + 21.08(O2+3.76N2)---> 11.6CO2 + 18.95
   H2O + 79.26N2
%theoriticalair=22.8*100/21.08 // theoritical air
excessair=%theoriticalair-100

printf("The excess air is %i %%",excessair)
```

Scilab code Exa 9.5 enthalpy of combustion of gaseous and liquid propane

```
clc
// initialization of variables
// The reaction equation is
//C3H8 + 5(O2+3.76N2)---> 3CO2 + 18.8N2 + 4H2O

// All the enthalpy of formation values are taken
   from Table B.5 with units in kJ/mol
hfCO2=-393520 // enthalpy associated with CO2
hfH2O=-285830 // enthalpy associated with H2O(l)
hfC3H8=-103850// ehthalpy associated with C3H8

// by first law Q= Hproducts - Hreactants

Qg=3*(hfCO2)+4*(hfH2O)-(hfC3H8) // enthalpy of
   combustion for gaseous propane

printf("The enthalpy of combustion for gaseous
   propane is %i kJ\n",Qg)

hv=15060 // enthalpy of vaporization for propane

Ql=3*(hfCO2)+4*(hfH2O)-(hfC3H8-hv) // enthalpy of
   combustion for liquid propane

printf(" The enthalpy of combustion for liquid
   propane is %i kJ\n",Ql)

//The answers are slightly different in textbook as
   they have approximated the result while in SCILAB
    results are precise
```

Scilab code Exa 9.6 propane and air enter a steady flow combustion chamber

```
clc
// initialization of variables
// The reaction equation is
//C3H8 + 5(O2+3.76N2)--—> 3CO2 + 18.8N2 + 4H2O

// All the enthalpy of formation values are taken
   from Table B.5 with units in kJ/mol
hfCO2=-393520 // enthalpy of formation associated
   with CO2
hbarCO2=22280 //enthalpy associated with CO2 at 600K
    from table E.4
hdotbarCO2=9364//enthalpy associated with CO2 at 298
   K from table E.4

hfH2O=-241820 // enthalpy of formation associated
   with gaseous H2O
hbarH2O=20402 //enthalpy associated with H20 at 600K
    from table E.6
hdotbarH2O=9904//enthalpy associated with H20 at 298
   K from table E.6

hfC3H8=-103850// ehthalpy of formation associated
   with C3H8

hbarN2=17563 //enthalpy associated with N2 at 600K
   from table E.2
hdotbarN2=8669//enthalpy associated with N2 at 298K
   from table E.2
// by first law Q= Hproducts - Hreactants

Qg=3*(hfCO2+hbarCO2-hdotbarCO2)+4*(hfH2O+hbarH2O-
```

```
hdotbarH2O)+18.8*(hbarN2-hdotbarN2)-(hfC3H8) // enthalpy of combustion

printf(”The heat transfer required is %i kJ\n”,Qg)

//The answer is WRONG textbook as they have made an error in calculating Qg
```

Scilab code Exa 9.7 Liquid octane fuels a jet engine

```
clc
// initialization of variables
// The reaction equation is

//C8H18 + 12.5(O2+3.76N2)--->  8CO2 + 47N2 + 9H2O

// All the enthalpy of formation values are taken from Table B.5 with units in kJ/mol
hfCO2=-393520 // enthalpy of formation associated with CO2
hbarCO2=42769 //enthalpy associated with CO2 at 1000 K from table E.4
hdotbarCO2=9364//enthalpy associated with CO2 at 298 K from table E.4

hfH2O=-241820 // enthalpy of formation associated with gaseous H2O
hbarH2O=35882 //enthalpy associated with H20 at 1000 K from table E.6
hdotbarH2O=9904//enthalpy associated with H20 at 298 K from table E.6
hfC3H8=-103850// ehthalpy of formation associated with C3H8

hbarN2p=(30784+29476)/2 //enthalpy associated with
```

```
N2 at 1000K from table E.2 by averaging enthalpy at 1020K and 980K for product
hbarN2r=17563 //enthalpy associated with N2 at 600K from table E.2 for reactant
hdotbarN2=8669//enthalpy associated with N2 at 298K from table E.2

hfC8H18=-249910 // enthalpy of formation associated with octane taken from internet as not provided in textbook

hbarO2=17929 // enthalpy associated with O2 at 600K table E.3
hdotbarO2=8682//enthalpy associated with O2 at 298K table E.3

// using first law and including kinetic energy change
// 0=Hp-Hr+Mp*(V^2)/2

Hp=8*(hfCO2+hbarCO2-hdotbarCO2)+9*(hfH2O+hbarH2O-hdotbarH2O)+47*(hbarN2p-hdotbarN2)
// enthalpy of products

Hr=(hfC8H18)+12.5*(hbarO2-hdotbarO2)+47*(hbarN2r-hdotbarN2)
// enthalpy of reactants

Mp=8*44+9*18+47*28 //(mass of products by multiplying molecular mass to number of moles)

V=sqrt(2*1000*(Hr-Hp)/Mp)// exit velocity using energy balance

printf(”The exit velocity is %i m/s”,V)

//The answers are slightly different in textbook as they have approximated the values while in SCILAB
```

```
results are precise
```

Scilab code Exa 9.8 octane with 300 percent excess air

```
clc
// initialization of variables

// The reaction equation with theoritical air is
// C8H18 + 12.5(O2+3.76N2)--->  8CO2 + 47N2 + 9H2O

// for 400% theoritical air reaction is

// C8H18 + 50(O2+3.76N2)---> 8CO2 + 188N2 + 9H2O + 37.5O2

// All the enthalpy of formation values are taken from Table B.5 with units in kJ/mol
hfCO2=-393520 // enthalpy of formation associated with CO2
hbarCO2=42769 //enthalpy associated with CO2 at 1000 K from table E.4
hdotbarCO2=9364//enthalpy associated with CO2 at 298 K from table E.4
hfH2O=-241820 // enthalpy of formation associated with gaseous H2O
hbarH2O=35882 //enthalpy associated with H20 at 1000 K from table E.6
hdotbarH2O=9904//enthalpy associated with H20 at 298 K from table E.6
hbarN2p=(30784+29476)/2 //enthalpy associated with N2 at 1000K from table E.2 by averaging enthalpy at 1020K and 980K
hdotbarN2=8669//enthalpy associated with N2 at 298K from table E.2

```

```
hfC8H18=-249910 // enthalpy associated with octane taken from internet as not provided in textbook
hbarO2=31389 // enthalpy associated with O2 at 1000K table E.3
hdotbarO2=8682//enthalpy associated with O2 at 298K table E.3

Hp=8*(hfCO2+hbarCO2-hdotbarCO2)+9*(hfH2O+hbarH2O-hdotbarH2O)+37.5*(hbarO2-hdotbarO2)+188*(hbarN2p-hdotbarN2)// enthalpy of products

Hr=(hfC8H18)
// enthalpy of reactants

Q=Hp-Hr // using first law2

printf(" The heat transfer is %i kJ",Q)

//The answers are slightly different in textbook as they have approximated the values while in SCILAB results are precise
```

Scilab code Exa 9.9 constant volume bomb calorimeter

```
clc
// initialization of variables

// The reaction equation is
//C3H8 + 5O2---> 8CO2 + 4H2O

// All the enthalpy of formation values are taken from Table B.5 with units in kJ/mol
hfCO2=-393520 // enthalpy associated with CO2
hfH2O=-241820 // enthalpy associated with gaseous H2O
```

```
hfC3H8=103850// enthalpy of formation associated with C3H8
hfgC3H8=15060// enthalpy of vapourization associated with C3H8
T=20+273 // temperature in kelvin
Rbar=8.314 // universal gas constant
Nr=6 // number of moles of reactants
Np=7 // number of moles of products
Hp=3*(hfCO2)+4*(hfH2O) // enthalpy of products

Hr=hfC3H8+hfgC3H8 // enthalpy of reactants

Q=(Hp-Hr-(Nr-Np)*Rbar*T)*10^(-3) // heat transfer from first law

printf(" The heat transfer is %i MJ",Q)

//The answers are slightly different in textbook as they have approximated the values while in SCILAB results are precise
```

Scilab code Exa 9.10 propane with 250 percent theoretical air

```
clc
// initialization of variables

// The reaction equation for theoritical air is
//C3H8 + 5(O2 + 3.76N2) ---> 3CO2 + 4H2O + 18.8N2

// for 250% theoritical air reaction becomes
//C3H8 + 12.5(O2 + 3.76N2) ---> 3CO2 + 4H2O + 47N2 + 7.5O2

// All the enthalpy of formation values are taken from Table B.5 with units in kJ/mol
```

```

Np=47+7.5+4+3 // number of moles of product
hfCO2=-393520 // enthalpy of formation associated with CO2
hbarCO2=(62963+65271)/2 //enthalpy associated with CO2 at 1380 K from table E.4
hbarCO2dash=(58381+60666)/2 //enthalpy associated with CO2 at 1300 K by average from table E.4
hdotbarCO2=9364//enthalpy associated with CO2 at 298 K from table E.4

hfC3H8=-103850// ehthalpy of formation associated with C3H8

hfH2O=-241820 // enthalpy of formation associated with gaseous H2O
hbarH2O=(51521+53351)/2 //enthalpy associated with H20 at 1380 K by taking average from table E.6
hbarH2Odash=48807 //enthalpy associated with H20 at 1300 K  from table E.6
hdotbarH2O=9904//enthalpy associated with H20 at 298 K from table E.6

hbarN2=42920 //enthalpy associated with N2 at 1380K from table E.2 by interpolating enthalpy between 1020K and 980K
hbarN2dash=40170 //enthalpy associated with N2 at 1300 K from table E.2
hdotbarN2=8669//enthalpy associated with N2 at 298K from table E.2

hfO2=(44198+45648)/2 // enthalpy associated with O2 at 1380 Kby taking average from table E.3
hfO2dash=48807 // enthalpy associated with O2 at 1380 Kby taking average from table E.3
hdotbarO2=8682//enthalpy associated with O2 at 298K table E.3

```

```
// for adiabatic flame temperature first assume products composed only of nitrogen and Q=0 as adiabatic
hp=(hfC3H8-3*(hfCO2)-4*(hfH2O))/Np +hdotbarN2
// using hp we assume temp=1380 K
// then energy for 1380 k is
H1=3*(hfCO2+hbarCO2-hdotbarCO2)+4*(hfH2O+hbarH2O-hdotbarH2O)+7.5*(hfO2-hdotbarO2)+47*(hbarN2-hdotbarN2) // energy assuming temperature to be 1380 K

//this is very large

// now at 1300 K adiabatic temperature
H2=3*(hfCO2+hbarCO2dash-hdotbarCO2)+4*(hfH2O+hbarH2Odash-hdotbarH2O)+7.5*(hfO2dash-hdotbarO2)+47*(hbarN2dash-hdotbarN2) // energy assuming temperature to be 1300 K

 // now interpolation between these two temperatures
Tp=1300-((hp+H2)/(H1-H2))*(1380-1300) // adiabatic temperature by interpolation
printf(”The adiabatic flame temperature is %i K”,Tp)

//The answers is different in textbook as they hav printed the value of hfCO2 with positive sign while calculating H2
```

Scilab code Exa 9.11 the adiabatic flame temperature

```
clc
// initialization of variables

// The reaction equation for theoritical air is
//C3H8 + 5(O2 + 3.76N2) ---> 3CO2 + 4H2O + 18.8N2
```

```

// All the enthalpy of formation values are taken from Table B.5 with units in kJ/mol

Np=18.8+4+3 // number of moles of product
hfCO2=-393520 // enthalpy associated with CO2
hbarCO2=137400 //enthalpy associated with CO2 at 2600 K from table E.4 by interpolation
hbarCO2dash=125152 //enthalpy associated with CO2 at 2400 K from table E.4
hdotbarCO2=9364//enthalpy associated with CO2 at 298 K from table E.4

hfC3H8=-103850// ehthalpy associated with C3H8

hfH2O=-241820 // enthalpy associated with gaseous H2O
hbarH2O=114273 //enthalpy associated with H20 at 2600 K from table E.6
hbarH2Odash=103508 //enthalpy associated with H20 at 2400 K  from table E.6
hdotbarH2O=9904//enthalpy associated with H20 at 298 K from table E.6

hbarN2=86600 //enthalpy associated with N2 at 2600 K from table E.2 by interpolation
hbarN2dash=79320 //enthalpy associated with N2 at 2400 K from table E.2
hdotbarN2=8669//enthalpy associated with N2 at 298K from table E.2

// for adiabatic flame temperature first assume products composed only of nitrogen and Q=0 as adiabatic
hp=(hfC3H8-3*(hfCO2)-4*(hfH2O))/Np +hdotbarN2

// using hp we assume temp=2600 K
// then energy for 2600 k is
```

```
H1=3*(hfCO2+hbarCO2-hdotbarCO2)+4*(hfH2O+hbarH2O-
   hdotbarH2O)+18.8*(hbarN2-hdotbarN2) // energy
   assuming temperature to be 2600 K

// now at 2400 K adiabatic temperature
H2=3*(hfCO2+hbarCO2dash-hdotbarCO2)+4*(hfH2O+
   hbarH2Odash-hdotbarH2O)+18.8*(hbarN2dash-
   hdotbarN2) // energy assuming temperature to be
   2400 K

 // now interpolation between these two temperatures
Tp=2400-((hp+H2)/(H1-H2))*(2600-2400) // adiabatic
   temperature by interpolation
printf("The adiabatic flame temperature is %i K",Tp)

//The answers are slightly different in textbook as
   they have approximated the values while in SCILAB
    results are precise
```