Scilab Textbook Companion for Thermodynamics and Heat Power by I. Granet and M. Bluestein[1]

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Book Description

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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

Fundamental Concepts

Scilab code Exa 1.1 Temperature indicated on same on both Fahrenheit and Celsius t

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.1\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.1 (page no. 8)
// Solution

//C=(5/9)*(F-32);
//F=32+(9*C/5);
//Letting C=F in equation;
//F=(5/9)*(F-32);
//Therefore
F=-160/4; //fahrenheit
disp(F,"F=");
printf("Both fahrenheit and celsius temperature
    scales indicate same temperature at %f",F);
```

Scilab code Exa 1.2 Force And Mass

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.2\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.2 (page no. 18)
// Solution

//Given
Mm=0.0123//Unit:lb //Mass of the moon;
Me=1 //Unit:lb //Mass of the earth;
Dm=0.273 //Unit:feet //Diameter of the moon;
De=1 //Unit:feet //Diameter of the earth;
Rm=Dm/2; //Radius of the moon; //Unit:feet
Re=De/2; //Radius of the earth; //Unit:feet

//F=(K*M1*M2)/d^2 //Law of universal gravitation;
//Fe=(K*Me*m)/Re^2; //Fe=Force exerted on the mass;
//Fm=(K*Mm*m)/Rm^2; //Fm=Force exerted on the moon;
F=(Me/Mm)*(Rm/Re)^2; //F=Fe/Fm;
printf("Relation of force exerted on earth to mass
    is")
disp(F,"Fe/Fm =");
```

Scilab code Exa 1.3 Calculating weight

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.3\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.3 (page no. 20)
// Solution

//Given
```

```
M=5; //Unit:kg //mass of body;
g=9.81; //Unit:m/s^2 //the local acceleration of gravity
W=M*g; //W=the weight of the body //Unit:Newton // 1 N= 1 kg*m/s^2
printf("The weight of the body is %f N",W);
```

Scilab code Exa 1.4 Force and mass

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.4\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.4 (page no. 21)
// Solution

printf("Solution for (a)\n");
//given
M=10 //Unit:kg //mass of body;
g=9.5 //Unit:m/s^2 //the local acceleration of gravity
W=M*g; //W=the weight of the body; //Unit:Newton // 1 N= 1 kg*m/s^2
printf("The weight of the body is %f N\n\n",W);

printf("Solution for (b)\n");
//Given
F=10; //Unit:Newton //Horizontal Force
a=F/M; //newton's second law of motion
printf("The horizontal acceleration of the body is %f m/s^2\n",a);
```

Scilab code Exa 1.5 `The SI Unit`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.5\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.5 (page no. 25)
// Solution

//Conversion Problem
// 1 inch=0.0254 meter so, 1=0.0254 meter/inch      //Eq.1
// 1 ft=12 inch so, 1=12 inch/ft.........//Eq.2
//Multiplying Eq.1 & Eq.2  // We get 1=0.0254*12 meter/ft
//Taking Square both side
//1^2=(0.0254*12)^2  meter^2/ft^2
printf("1 ft^2=%f meter^2\n",(0.0254*12)^2);
```

Scilab code Exa 1.7 `Pressure`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.7\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.7 (page no. 33)
// Solution

//The Specific gravity of mercury is 13.6 //Given
//Converting the unit of weight of grams per cubic centimeter to pounds per cubic foot
// 1 lbf=454 gram //1 inch= 2.54 cm
//So 1 gram=1/454 lbf and 1 ft=12*2.54 cm
```

```
//Gamma=(gram/cm^3)*(lb/gram)*(cm^3/ft^3)=lb/ft^3
//Gamma=(1 gram/cm^3)*(1 lbf/454 gram)*(2.54*12)^3 * cm^3/ft^3
Gamma=(1/454)*(2.54*12)^3; //lbf/ft^3 //conversion factor
disp(Gamma,"Conversion Factor=");
p=(1/12)*(Gamma*13.6); //lbf/ft^2 //gage pressure
p=(1/12)*Gamma*13.6*(1/144) //ft^2/inch^2 //gage pressure
printf("Guage Pressure is %f psi\n",p);
printf("Local atmospheric pressure is 14.7 psia\n");
P=p+14.7; //Pressure on the base of the column //Unit:psia
printf(" So Pressure on the base of the column is %f psia",P);
```

Scilab code Exa 1.8 Pressure

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.8\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.8 (page no. 34)
// Solution

//Given
Rho=13.595; //Unit: kg/m^3 //The density of mercury
h=25.4; //Unit: mm //Height of column of mercury
g=9.806; //Unit:m/s^2 //the local acceleration of gravity
//Solution
p=Rho*g*h; //P=Pressure at the base of a column of mercury //Unit:Pa
printf("Pressure at the base of a column of mercury
```

```
    is %f Pa",p);
```

Scilab code Exa 1.9 `Absolute pressure`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.9\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.9 (page no. 34)
// Solution

//Given
Patm=30.0; //in. //pressure of mercury at standard
    temperature
Vacuum=26.5;  //in.  //vaccum pressure
Pabs=Patm-Vacuum; //Absolute pressure of mercury //
    in.
// 1 inch mercury exerts a pressure of 0.491 psi
p=Pabs*0.491; //Absolute pressure in psia
printf("Absolute pressure of mercury in is %f psia",
    p);
```

Scilab code Exa 1.10 `Pressure`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.10\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.10 (page no. 35)
// Solution

```

```
//Given
Rho=2000; //Unit: kg/m^3 //The density of fluid
h=-10; //Unit: mm //Height of column of fluid //the height is negative because it is measured up from the base
g=9.6 //Unit:m/s^2 //the local acceleration of gravity
//Solution
p=-Rho*g*h; //P=Pressure at the base of a column of fluid //Unit:Pa
printf("Pressure at the base of a column of fluid is %f Pa",p);
```

Scilab code Exa 1.11 Absolute pressure

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 1.11\n\n\n");
// Chapter 1: Fundamental Concepts
// Problem 1.11 (page no. 35)
// Solution

//Given
Patm=30.0 //in. //pressure of mercury at standard temperature
Vacuum=26.5  //in.  //vaccum pressure
Pabs=Patm-Vacuum; //Absolute pressure of mercury //in.
// (3.5 inch* (ft/12 inch) * (13.6*62.4)LBf/ft^3 * kg/2.2 LBf * 9.806 N/kg)/((12 inch^2/ft^2) * (0.0254 m/inch)^2)
p=(3.5*(1/12)*13.6*62.4*(1/2.2)*9.806)/(12^2*0.0254^2*1000); //kPa //Absolute pressure in psia
```

```
printf("Absolute pressure of mercury is %f kPa",p)
```

Chapter 2

Work energy and heat

Scilab code Exa 2.2 Work

```
clear;
clc;
printf("\t\t\tProblem Number 2.2\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.2 (page no. 62)
// Solution

//Given
k=100; // Unit:lbf/in. //k=spring constant
l=2; //Unit:inch //l= length of compression of string
work=(1/2)*k*l^2; //force-displacement relation //Unit:in*lbf
printf("Workdone is %f inch*lbf",work);
```

Scilab code Exa 2.3 Work

```
clear;
```

```
clc;
printf("\t\t\tProblem Number 2.3\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.3 (page no. 62)
// Solution

//Given
k=20*1000; // Unit:N/m //k=20kN //k=spring constant
l=0.075; //Unit:meter //l=75 mm //l= length of compression of string
work=(1/2)*k*l^2; //force-displacement relation //Unit:N*m
printf("Workdone is %f Jule",work);
```

Scilab code Exa 2.4 Potential Energy

```
clear;
clc;
printf("\t\t\tProblem Number 2.4\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.4 (page no. 66)
// Solution

//Given
Z=600; //Unit:ft //Z=The distance,the body is raised from its initial position when the force is applied
gc=32.174; //Unit: (lbm*ft)/(lbf*s^2) //gc is constant of proportionality
g=gc; //Unit:ft/s^2 //g=The local gravity
m=1; //Unit:lbm //m=mass
PE=(m*g*Z)/gc; //potential energy //Unit:ft*lbf
printf("%f ft*lbf work is done lifting the water to elevation ",PE)
```

Scilab code Exa 2.5 Potential Energy

```
clear;
clc;
printf("\t\t\tProblem Number 2.5\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.5 (page no. 66)
// Solution


m=1; //Unit:kg //m=mass
g= 9.81 //Unit:m/s^2 //g=The local gravity
Z=50 //Unit:m ////Z=The distance,the body is raised
    from its initial position when the force is
    applied //In this case Z=delivered water from
    well to pump
PE=m*g*Z; //PE=Potential Energy //Unit:Joule
printf("Change in potential energy per kg of water
    is %f J ",PE); //J=Joule=N*m=kg*m^2/s^2
```

Scilab code Exa 2.6 power generated

```
clear;
clc;
printf("\t\t\tProblem Number 2.6\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.6 (page no. 66)
// Solution

Rho=62.4; //Unit:lbm/ft^3 //Rho=The density of water
A=10000; //Flow=10000; gal/min
```

```
V=(231/1728); // 12 inch=1 ft //So,1 ft^3=1728 in^3 // One Gallon is a volumetric measure equal to 231 in^3
//A*V //Unit:ft^3/min

//In example, 2.4:
printf("From example 2.4\n");
Z=600; //Unit:ft //Z=The distance,the body is raised from its initial position when the force is applied
gc=32.174; //Unit: (lbm*ft)/(lbf*s^2) //gc is constant of proportionality
g=gc; //Unit:ft/s^2 //g=The local gravity
m=1; //Unit:lbm //m=mass
PE=(m*g*Z)/gc; //potential energy //Unit:ft*lbf
printf("%f ft*lbf work is done lifting the water to elevation\n ",PE);

//So,
printf("In example 2.5 \n")
M=Rho*A*V; //M=the mass flow
Power=M*PE; //Unit:ft*lbf/lbm
printf("Generated Power is %f ft*lbf/lbm \n",Power);
// 1 horsepower = 33,000 ft*lbf/min
printf("Power = %f hp\n",Power/33000);
```

Scilab code Exa 2.7 Power

```
clear;
clc;
printf("\t\t\tProblem Number 2.7\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.7 (page no. 67)
// Solution

```

```
printf("In problem 2.5\n");
m=1; //Unit:kg //m=mass
g= 9.81 //Unit:m/s^2 //g=The local gravity
Z=50 //Unit:m ////Z=The distance,the body is raised
    from its initial position when the force is
    applied //In this case Z=delivered water from
    well to pump
PE=m*g*Z; //PE=Potential Energy //Unit:Joule
printf("Change in potential energy per kg of water
    is %f J \n",PE); //J=Joule=N*m=kg*m^2/s^2
//Given data in problem 2.7 is
M=1000; //Unit;kg/min//M=Water density
Power=PE*M*(1/60); //1 min=60 seconds //power //unit
    :Joule/s=W
printf("Power is %f Watt\n",Power); //Watt=N*m/s =
    Joule/s =Watt
//1 Hp=746 Watt
printf("Power is %f Horsepower",Power/745);
```

Scilab code Exa 2.8 Kinetic Energy

```
clear;
clc;
printf("\t\t\tProblem Number 2.8\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.8 (page no. 69)
// Solution

m=10; //Unit:lb //m=Mass
V1=88; //Unit://ft/s V1=Velocity before it is slowed
     down
V2=10; //Unit;ft/s //V2=Velocity after it is slowed
    down
gc=32.174; //Unit: (lbm*ft)/(lbf*s^2) //gc is
    constant of proportionality
```

```
KE1=m*V1^2/(2*gc); //The kinetic energy of the body before it is slowed down //Unit:ft*lbf
printf("The kinetic energy of the body before it is slowed down is %f ft*lbf\n",KE1);

KE2=m*V2^2/(2*gc); //The kinetic energy of the body before it is slowed down //Unit:ft*lbf
printf("The kinetic energy of the body before it is slowed down is %f ft*lbf\n",KE2);

KE=KE1-KE2; //KE=Change in kinetic energy //Unit:ft*lbf
printf("Change in kinetic energy is %f ft*lbf",KE);
```

Scilab code Exa 2.9 Change in Kinetic Energy

```
clear;
clc;
printf("\t\t\tProblem Number 2.9\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.9 (page no. 70)
// Solution

m=1500; //Unit:kg //m=mass
V1=50; //Km/hour V1=Velocity before it is slowed down
//V1=(50*1000 m/hour)^2/(3600 s/hour)^2
KE1=(m*(V1*1000)^2/3600^2)/2; //KE1=Initial kinetic energy //Unit:Joule

//After slowing down
V2=30; //Unit:KM/hour //V2=Velocity after it is slowed down
//V2=(30*1000 m/hour)^2/(3600 s/hour)^2
```

```
KE2=(m*(V2*1000)^2/3600^2)/2; //KE2=After slowing
    down, the kinetic energy //Unit:Joule

KE=KE1-KE2; //KE=Change in kinetic energy //Unit:
    Joule
printf("Change in kinetic energy is %f kJ",KE/1000);
```

Scilab code Exa 2.10 `Kinetic Energy`

```
clear;
clc;
printf("\t\t\tProblem Number 2.10\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.10 (page no. 70)
// Solution

m=10 //Unit:kg //m=mass
Z=10 //Unit:m //Z=The distance,the body is raised
    from its initial position when the force is
    applied
g= 9.81 //Unit:m/s^2 //g=The local gravity
//There are no losses in the system
//So,initial potential energy plus initial kinetic
    energy equal to sum of final potential energy
    plus final kinetic energy
//So, PE1+KE1=PE2+KE2
//From the figure,KE1=0; PE2=0;
//So,PE1=KE2;
PE1=m*g*Z; //PE=Potential Energy //Unit:Joule
//KE2=(m*v^2)/2
v=(PE1*2)/m;
V=sqrt(v); //Unit:m/s //velocity
printf("Velocity = %f m/s",V);
KE2=PE1; //kinetic energy //Unit:Joule
printf("\nKinetic energy is %f N*m",PE1);
```

Scilab code Exa 2.11 Flow work

```
clear;
clc;
printf("\t\t\tProblem Number 2.11\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.11 (page no. 74)
// Solution

printf("At the entrance of device,\n");
p1=100; //pressure at the entance //Unit:psia,lbf/in
   ^2
Rho1=62.4; //Unit:lbm/ft^3 //Rho=The density
v1=144*(1/Rho1) //Specific Volume at entrance or
   reciprocal of fluid density // 144 in^2=1 ft^2
//1 Btu = 778 ft*lbf
J=778; //Unit:ft*lbf/Btu //conversion factor
FW1=(p1*v1)/J; //Flow work //Btu/lbm
printf("Flow work = %f Btu/lbm\n",FW1);

printf("At the exit of device,\n");
p2=50; //pressure at the exit //Unit:psia,lbf/in^2
Rho2=30; //Unit:lbm/ft^3 //Rho=The density
v2=144*(1/Rho2) //Specific Volume at exit or
   reciprocal of fluid density // 144 in^2=1 ft^2
//1 Btu = 778 ft*lbf
J=778; //Unit:ft*lbf/Btu //conversion factor
FW2=(p2*v2)/J; //Flow work //Btu/lbm
printf("Flow work = %f Btu/lbm\n",FW2);
```

Scilab code Exa 2.12 Flow work

```
clear;
clc;
printf("\t\t\tProblem Number 2.12\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.12 (page no. 75)
// Solution

printf("At the entrance of device,\n");
p1=200*1000; //200kPa*1000 Pa/kPa //pressure at the
    entrance //Unit:N/m^2
Rho1=1000; //kg/m^3 //Fluid density at entrance
v1=1/Rho1; //Specific Volume at entrance or
    reciprocal of fluid density
FW1=p1*v1; //Flow work at entrance //Unit:N*m/kg
printf("Flow work = %fN*m/kg\n",FW1);

printf("At the exit of device,\n");
p2=100*1000; //200kPa*1000 Pa/kPa //pressure at the
    exit //Unit:N/m^2
Rho2=250; //kg/m^3 //Fluid density at exit
v2=1/Rho2; //Specific Volume at entrance or
    reciprocal of fluid density
FW2=p2*v2; //Flow work at exit//Unit:N*m/kg
printf("Flow work = %f N*m/kg\n",FW2);
```

Scilab code Exa 2.14 `Work done`

```
clear;
clc;
printf("\t\t\tProblem Number 2.14\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.14 (page no. 78)
// Solution

//It is necessary that pressure be expressed as psfa
```

```
when the volume is in cubic feet
//100 psia = 100*144 psfa
p1=100*144; //Unit:psfa //initial pressure
v1=2; //Unit:ft^3/lb //Initial Specific Volume
v2=1; //Unit:ft^3/lb //Final Specific Volume
w=p1*v1*log(v2/v1); //work done on fluid //Unit:ft*lbf/lbm
printf("Work done on fluid = %f ft*lbf/lb\n",w);
//1 Btu = 778 ft*lbf
printf("Work done on the fluid per pound of fluid is %f Btu/lbm",w/778);
```

Scilab code Exa 2.15 `Work done`

```
clear;
clc;
printf("\t\t\tProblem Number 2.15\n\n\n");
// Chapter 2: Work, Energy, and Heat
// Problem 2.15 (page no. 79)
// Solution

//p1*v1=p2*v2
p1=200*1000; //p1=Initial Pressure //Unit:Pa
p2=800*1000; //p2=Final Pressure //Unit:Pa
v1=0.1; //v1=Initial Special Volume //Unit:m^3/kg
v2=(p1/p2)*v1; //v1=final Special Volume //Unit:m^3/kg
w=p1*v1*log(v2/v1); //workdone //Unit:kJ/kg
printf("Work done per kilogram of gas is %f kJ/kg (into the system)",w/1000);
```

Chapter 3

The First Law Of Thermodynamics

Scilab code Exa 3.1 `Change in internal energy`

```
clear;
clc;
printf("\t\t\tProblem Number 3.1\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.1 (page no. 91)
// Solution

//For a constant volume process, 10 Btu/lbm heat is
   added to the system
//We can consider thet a tank having a fixed volume
   has heat added to it
//Under these conditions,the mechanical work done on
    or by the system must be 0
//u2-u1=q
printf("Heat has been converted to internal energy
   of the working fluid\n");
//So,
printf(" So,Change in internal energy u2-u1=10 Btu/
   Lbm");
```

Scilab code Exa 3.4 Change in internal energy

```
clear;
clc;
printf("\t\t\tProblem Number 3.1\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.1 (page no. 91)
// Solution

printf("Solution For (a)\n");
m=10; //Unit:lbm //mass of water
//delataU=U2-U1
Heat=100; //Unit:Btu //heat added
deltaU=Heat/m; //Change in internal energy //unit:
   Btu/lbm
printf("Change in internal energy per pound of water
    is %f Btu/lbm\n",deltaU);

printf("Solution For (b)\n");
printf("In this process,energy crosses the boundary
   of the system by means of fractional work\n");
printf("The contents of the tank will not
   distinguish between the energy if it is added as
   heat or the energy added as fraction work\n");
```

Scilab code Exa 3.5 The mass flow rate and exit velocity

```
clear;
clc;
printf("\t\t\tProblem Number 3.5\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
```

```
// Problem 3.5 (page no. 96)
// Solution

P1=100 //Unit:psia //Pressure at the entrance to a steady-flow device
Rho1=62.4 //Unit:lbm/ft^3 //the density of the fluid
A1V1=10000 //Unit:ft^3/min //Entering fluid
A2=2 //Unit:ft^2 //Exit area
m=Rho1*A1V1; //Unit:lbm/min //mass rate of flow per unit time
printf("Mass flow rate is %f LBm/min\n",m);

Rho2=Rho1; //Unit:lbm/ft^3 //the density of the fluid
//m=Rho2*A2*V2
//So,
V2=m/(Rho2*A2); //velocity at exit //Unit:ft/min
printf("The exit velocity is %f ft/min",V2);
```

Scilab code Exa 3.6 The mass flow rate and the exit velocity

```
clear;
clc;
printf("\t\t\tProblem Number 3.6\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.6 (page no. 97)
// Solution

Rho1=1000 //Unit:kg/m^3 //the density of the fluid at entrance
A1V1=2000 //Unit:m^3/min //Entering fluid
A2=0.5 //Unit:ft^2 //Exit area
m=Rho1*A1V1; //Unit:kg/min //mass rate of flow per unit time
printf("Mass flow rate is %f kg/min\n",m);
```

```

Rho2=Rho1; //Unit:kg/m^3 //the density of the fluid
    at exit
//m=Rho2*A2*V2
//So,
V2=m/(Rho2*A2); //The exit velocity //Unit:m/min
printf("The exit velocity is %f m/min",V2);
```

Scilab code Exa 3.7 The mass flow rate

```
clear;
clc;
printf("\t\t\tProblem Number 3.7\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.7 (page no. 97)
// Solution

Rho=62.4 //Unit:lbm/ft^3 //the density of the fluid
V=100 //Unit:ft/s //Velocity of fluid
d=1 //Unit:in //Diameter
//1 ft^2=144 in^2 //A=(%pi/4)*d^2
A=(%pi*d^2)/(4*144) //Unit:ft^2 //area
m=Rho*A*V; //Unit:lbm/s //mass rate of flow per unit
     time
printf("Mass flow rate is %f lbm/s\n",m);
```

Scilab code Exa 3.8 Velocity at inlet and outlet

```
clear;
clc;
printf("\t\t\tProblem Number 3.8\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.8 (page no. 98)
```

```
// Solution

m1=50000; //Unit:LBm/hr //An inlet steam flow
v1=0.831 //Unit:ft^3/LBm //Specific volume of inlet
    steam
d1=6  //Unit:in //Inlet diameter
A1=(%pi*d1^2)/(4*144) //1 ft^2=144 in^2 //Entering
    area
V1=(m1*v1)/(A1*60*60) //(60 min/hr * 60 s/min) //To
    convert hours into seconds //velocity at inlet
printf("The velocity at inlet is %f ft/s\n",V1);


m2=m1; //Unit:LBm/hr //m2=An outlet steam flow
v2=1.825 //Unit:ft^3/LBm //Specific volume of outlet
     steam
d2=8  //Unit:in //Outlet diameter
A2=(%pi*d2^2)/(4*144) //1 ft^2=144 in^2 //Exit area
V2=(m1*v2)/(A2*60*60) //(60 min/hr * 60 s/min) //To
    convert hours into seconds //velocity at outlet
printf("The velocity at outlet is %f ft/s",V2);
```

Scilab code Exa 3.9 Inlet and outlet velocities

```
clear;
clc;
printf("\t\t\tProblem Number 3.9\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.9 (page no. 99)
// Solution

m1=10000; //Unit:kg/hr //An inlet steam flow
v1=0.05 //Unit:m^3/kg //Specific volume of inlet
    steam
d1=0.1  //Unit:m //Inlet diameter //100 mm =0.1 m
```

```
A1=(%pi/4)*d1^2 //Unit:m^2 //Entering area
V1=(m1*v1)/(A1*60*60) //(60 min/hr * 60 s/min) //To
    convert hours into seconds //velocity at inlet //
    Unit:m/s
printf("The velocity at inlet is %f m/s\n",V1);


m2=m1; //Unit:kg/hr //m2=An outlet steam flow
v2=0.10 //Unit:m^3/kg //Specific volume of outlet
    steam
d2=0.2  //Unit:m //Outlet diameter //200 mm = 0.2 m
A2=(%pi/4)*(d2^2) //Unit:m^2 //Exit area
V2=(m1*v2)/(A2*60*60) //(60 min/hr * 60 s/min) //To
    convert hours into seconds //velocity at outlet
    //Unit:m/s
printf("The velocity at outlet is %f m/s",V2);
```

Scilab code Exa 3.10 `Workdone`

```
clear;
clc;
printf("\t\t\tProblem Number 3.10\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.10 (page no. 105)
// Solution

Cp=0.22; //Unit:Btu/(LBm*R) //Specific heat for
    constant pressure process
Cv=0.17; //Unit:Btu/(LBm*R) //Specific heat for
    constant volume process
q=800/10; //data given:800 Btu as heat is added to
    10 LBm //Unit:Btu/LBm
T1=100; //Unit:Fahrenheit //Initial temperature //T2
    =Final temperature
//For a non-flow,constant pressure process
```

```
//q=deltah=h2-h1=Cp(T2-T1) //deltah=change in
    enthalpy
//deltaT=T2-T1;
deltaT=q/Cp; //Fahrenheit //change in temperature
T2=deltaT+T1; //Fahrenheit //final temperature
//For a constant volume pressure
//u2-u1=Change in internal energy //w=workdone
//q-w=u2-u1
//-w=(u2-u1)-q = Cv*(T2-T1)-q
w=-(Cv*(T2-T1)-q); //Unit:Btu/lbm //workdone
printf("%f Btu/lbm work is taken out of the system
    due to workdone by gas\n",w);
printf("As there is 10 lbm in the system\n")
printf("%f Btu work is taken out of the system due
    to workdone by gas\n",w*10);
```

Scilab code Exa 3.11 Determine the Power Produced

```
clear;
clc;
printf("\t\t\tProblem Number 3.11\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.11 (page no. 111)
// Solution

//Given data
//                      Inlet      Outlet
//Pressure(psia)        1000       1
//Temperature(F)        1000       101.74
//Velocity(ft/s)        125        430
//Inlet position(ft)    +10        0
//Enthalpy(Btu/LBm)     1505.4     940.0
//Steam flow rate of 150000 LBm/hr

//From the table,
```

```
Z1=10; V1=125; h1=1505.4; Z2=0; V2=430; h2=940.0;

//Energy equation is given by
//((Z1/J)*(g/gc)) + (V1^2/(2*gc*J)) + h1 + q = ((Z2/J)*(g/gc)) + (V2^2/(2*gc*J)) + h2 + w/J
printf("Solution for (a) \n");
q=0; //net heat
J=778; //Conversion factor
gc=32.174; //Unit: (LBm*ft)/(LBf*s^2) //gc is constant of proportionality
g=gc; //Unit:ft/s^2 //g=The local gravity
//W1=w/J;
//Energy equation is given by
W1=((Z1/J)*(g/gc)) + (V1^2/(2*gc*J)) + h1 + q - ((Z2/J)*(g/gc)) - (V2^2/(2*gc*J)) - h2; //Unit:Btu/LBm
printf("If heat losses are negligible,\n");
printf("Total work of the turbine is %f Btu/LBm\n",W1);
printf("Total work of the turbine is %f Btu/hr\n",W1*150000);
//(W*150000*778)/(60*33000) //in terms of horsepower //1 hr=60 min //1 hp=33000 (ft*LBf)
printf("Total work of the turbine is %f hp \n",(W1*150000*778)/(60*33000));
//1 hp =0.746 kW
printf("Total work of the turbine is %f kW \n\n",((W1*150000*778)/(60*33000))*0.746);


printf("\nSolution for (b) \n");
//Heat losses equal 50,000 Btu/hr
q=50000/150000; //Unit:Btu/LBm //Heat loss
W2=((Z1/J)*(g/gc)) + (V1^2/(2*gc*J)) + h1 - q - ((Z2/J)*(g/gc)) - (V2^2/(2*gc*J)) - h2; //Unit:Btu/LBm
printf("If heat losses equal 50,000 Btu/hr , Total work of the turbine is %f Btu/LBm\n",W2);
```

Scilab code Exa 3.12 Work output per kg

```
clear;
clc;
printf("\t\t\tProblem Number 3.12\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.12 (page no. 112)
// Solution

Z1=2; //Unit:m //Inlet position
g=9.81 //Unit:m/s^2 //g=The local gravity
V1=40; //Unit:m/s //Inlet velocity
h1=3433.8; //Unit:kJ/kg //Inlet enthalpy
q=1 //Unit:kJ/kg //Heat losses
Z2=0; //Outlet position //unit:m
V2=162; //Unit:m/s //Outlet velocity
h2=2675.5; //Unit:kJ/kg //Outlet enthalpy

//Energy equation is given by
//((Z1*g)) + (V1^2/2) + h1 + q = ((Z2*g) + (V2^2/2)
    + h2 + w

w= ((Z1*g)/1000) + ((V1^2/2)/1000) + h1 - q - ((Z2*g
    )/1000) - ((V2^2/2)/1000) - h2 ; //Unit:kJ/kg //
    Conersation: 1 kJ=1000 J
printf("The work output per kilogram is %f kJ/kg\n",
    w);
```

Scilab code Exa 3.13 The work output per pound

```
clear;
```

```
clc;
printf("\t\t\tProblem Number 3.13\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.13 (page no. 113)
// Solution

p1=150; //Unit:psia //Initial pressure
T1=1000; //Unit:R //Temperature at pressure p1
p2=15; //Unit:psia //Final pressure
T2=600; //Unit:R //Temperature at pressure p2
Cp=0.24; //Unit:Btu/(LBm*R) //Specific heat for constant pressure process
v1=2.47; //Unit:ft^3/LBm //Specific volume at inlet conditions
v2=14.8; //Unit:ft^3/LBm //Specific volume at outlet conditions

//For a non-flow,constant pressure process
//w/J=deltah=h2-h1=Cp(T2-T1) //deltah=change in enthalpy
//W=w/J
W=Cp*(T1-T2); //W=Work output //Unit:Btu/LBm
printf("The work output of the turbine per pound of working fluid is %f Btu/LBm",W);
```

Scilab code Exa 3.14 The work output per pound

```
clear;
clc;
printf("\t\t\tProblem Number 3.14\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.14 (page no. 114)
// Solution

//In problem 3.13 ,
```

```
p1=150; //Unit:psia //Initial pressure
T1=1000; //Unit:R //Temperature at pressure p1
p2=15; //Unit:psia //Final pressure
T2=600; //Unit:R //Temperature at pressure p2
Cp=0.24; //Unit:Btu/(LBm*R) //Specific heat for constant pressure process
v1=2.47; //Unit:ft^3/LBm //Specific volume at inlet conditions
v2=14.8; //Unit:ft^3/LBm //Specific volume at outlet  conditions

//For a non-flow, constant pressure process
//w/J=deltah=h2-h1=Cp(T2-T1) //deltah=change in enthalpy
//W=w/J
W=Cp*(T1-T2); //W=Work output //Unit:Btu/LBm //h2-h1
printf("In problem 3.13,The work output of the turbine per pound of working fluid is %f Btu/LBm \n \n",W);

//Now,In problem 3.14 ,
q=1.1; //Unit:Btu/LBm //Heat losses
//For a non-flow, constant pressure process
//q-w/J=deltah=h2-h1=Cp(T2-T1) //deltah=change in enthalpy
//W1=w/J
W1=-q+W; //W=Work output //Unit:Btu/LBm //W=h2-h1 // Because q  is out of the system, it is a negative quantity
printf("In problem 3.14,heat loss equal to 1.1 Btu/LBm,\n");
printf("The work output of the turbine per pound of working fluid is %f Btu/LBm \n",W1);
```

Scilab code Exa 3.15 Determine the heat transfer

```
clear;
clc;
printf("\t\t\tProblem Number 3.15\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.15 (page no. 115)
// Solution

p1=100; //Unit:psia //Initial pressure
t1=950; //Unit:Fahrenheit //Temperature at pressure p1
p2=76; //Unit:psia //Final pressure
t2=580; //Unit:Fahrenheit //Temperature at pressure p2
v1=4; //Unit:ft^3/LBm //Specific volume at inlet conditions
v2=3.86; //Unit:ft^3/LBm //Specific volume at outlet conditions
Cv=0.32; //Unit:Btu/(LBm*R) //Specific heat for constant volume process

T1=t1+460; //Unit:R //Temperature at pressure p1
T2=t2+460; //Unit:R //Temperature at pressure p2
J=778; //J=Conversion factor

//Z1=Inlet position //Unit:m
//V1=Inlet velocity //Unit:m/s
//Z2=Outlet position //Unit:m
//V2=Outlet velocity Unit:m/s
//u1=internal energy //energy in
//u2=internal energy //energy out

//Energy equation is given by
//((Z1/J)*(g/gc)) + (V1^2/(2*gc*J)) + u1 + ((p1*v1)/J) + q = ((Z2/J)*(g/gc)) + (V2^2/(2*gc*J)) + u2 + ((p2*v2)/J) + w/J; //Unit:Btu/LBm
//Because pipe is horizontal and velocity terms are to be neglected,
// Also no work crosses the boundaries of the system
```

```
, the energy equation is reduced to
//u1 + ((p1*v1)/J) + q = u2 + ((p2*v2)/J)
//u2−u1=Cv*(T2−T1) //For a constant volume process //u2−u1=Chnage in internal energy
//So,
q=Cv*(T2-T1) + (p2*v2*144)/J - (p1*v1*144)/J;  //q=heat transfer //1 ft^2=144 in^2 //Unit:Btu/LBm
printf("%f Btu/LBm heat is transferred from the gas \n",q);
```

Scilab code Exa 3.16 Determine the heat transfer

```
clear;
clc;
printf("\t\t\tProblem Number 3.16\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.16 (page no. 116)
// Solution

//In problem 3.15,
p1=100; //Unit:psia //Initial pressure
t1=950; //Unit:Fahrenheit //Temperature at pressure p1
p2=76; //Unit:psia //Final pressure
t2=580; //Unit:Fahrenheit //Temperature at pressure p2
v1=4; //Unit:ft^3/LBm //Specific volume at inlet conditions
v2=3.86; //Unit:ft^3/LBm //Specific volume at outlet conditions
Cv=0.32; //Unit:Btu/(LBm*R) //Specific heat for constant volume process

T1=t1+460; //Unit:R //Temperature at pressure p1
T2=t2+460; //Unit:R //Temperature at pressure p2
```

```
J=778; //J=Conversion factor
gc=32.174; //Unit: (LBm*ft)/(LBf*s^2) //gc is constant of proportionality
g=gc; //Unit:ft/s^2 //g=The local gravity

//Z1=Inlet position //Unit:m
//V1=Inlet velocity //Unit:m/s
//Z2=Outlet position //Unit:m
//V2=Outlet velocity Unit:m/s
//u1=internal energy //energy in
//u2=internal energy //energy out

//Energy equation is given by
//((Z1/J)*(g/gc)) + (V1^2/(2*gc*J)) + u1 + ((p1*v1)/J) + q = ((Z2/J)*(g/gc)) + (V2^2/(2*gc*J)) + u2 + ((p2*v2)/J) + w/J; //Unit:Btu/LBm
//In 3.15, the elevation of the pipe at section 1 makes Z1 = 0
// Also no work crosses the boundaries of the system, the energy equation is reduced to
//u1 + ((p1*v1)/J) + q = u2 + ((p2*v2)/J) + ((Z2/J)*(g/gc))
//In problrm 3.16,
Z2=100; //Given //Unit:ft //Outlet position
//u2-u1=Cv*(T2-T1) //For a constant volume process //u2-u1=Chnage in internal energy
//So,
q=Cv*(T2-T1) + (p2*v2*144)/J - (p1*v1*144)/J + ((Z2/J)*(g/gc)) ; //q=heat transfer //1 ft^2=144 in^2 //Unit:Btu/LBm
printf("%f Btu/LBm heat is transferred from the gas \n",q);
//For this problem , neglecting the elevation term leads to an insignificant error
```

Scilab code Exa 3.17 The boiler example

```
clear;
clc;
printf("\t\t\tProblem Number 3.17\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.17 (page no. 117)
// Solution

p1=1000; //Unit:psia //Initial pressure
t1=100;  //Unit:Fahrenheit //Temperature at pressure
    p1
p2=1000; //Unit:psia //Final pressure
t2=1000; //Unit:Fahrenheit //Temperature at pressure
    p2
// feed in 10,000 LBm/hr
h1=70.68  //Unit:Btu/LBm //Inlet enthalpy
h2=1505.9 //Unit:Btu/LBm //Outlet enthalpy

T1=t1+460; //Unit:R //Temperature at pressure p1
T2=t2+460; //Unit:R //Temperature at pressure p2
//Energy equation is given by
J=778; //J=Conversion factor

//Z1=Inlet position //Unit:m
//V1=Inlet velocity //Unit:m/s
//Z2=Outlet position //Unit:m
//V2=Outlet velocity Unit:m/s
//u1=internal energy //energy in
//u2=internal energy //energy out
//h=enthalpy

//Energy equation is given by
//((Z1/J)*(g/gc)) + (V1^2/(2*gc*J)) + u1 + ((p1*v1)/
   J) + q = ((Z2/J)*(g/gc)) + (V2^2/(2*gc*J)) + u2 +
    ((p2*v2)/J) + w/J; //Unit:Btu/LBm

//we can consider this system as a single unit with
```

```
    feed water entering ans steam leaving.
//It well designed,this unit will be thoroughly
    insulated,and heat losse will be reduced to a
    negligible amount
//Alos,no work will be added to the fluid during the
     time it is passing through the unit, and kinetic
     energy differences will be assumed to be
    negligibly small
//Differennces in elevation also be considered
    negligible
//So,the energy equation is reduced to
//u1 + ((p1*v1)/J) + q = u2 + ((p2*v2)/J)
//Because h=u+(p*v/J)
q=h2-h1; //q=net heat losses //Unit:Btu/LBm
printf("Net heat losses is %f Btu/LBm \n",q);
printf("For 10000 LBm/hr,\n");
printf("%f Btu/hr energy has been added to the water
     to convert it to steam",q*10000)
```

Scilab code Exa 3.18 The final velocity of the nozzle

```
clear;
clc;
printf("\t\t\tProblem Number 3.18\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.18 (page no. 119)
// Solution

h1=1220  //Unit:Btu/LBm //Inlet enthalpy
h2=1100 //Unit:Btu/LBm //Outlet enthalpy

//Z1=Inlet position //Unit:m
//V1=Inlet velocity //Unit:m/s
//Z2=Outlet position //Unit:m
//V2=Outlet velocity Unit:m/s
```

```
//u1=internal energy //energy in
//u2=internal energy //energy out
J=778; //J=Conversion factor
gc=32.174; //Unit: (LBm*ft)/(LBf*s^2) //gc is constant of proportionality

//Energy equation is given by
//((Z1/J)*(g/gc)) + (V1^2/(2*gc*J)) + u1 + ((p1*v1)/J) + q = ((Z2/J)*(g/gc)) + (V2^2/(2*gc*J)) + u2 + ((p2*v2)/J) + w/J; //Unit:Btu/LBm

//For this device,differences in elevation are negligible.No work is done on or by the fluid, friction is negligible
//And due to the speed of the fluid flowing and the short length of the nozzle,heat transfer to or from the surroundings is also negligible.
//So,the energy equation is reduced to
//u1 + ((p1*v1)/J) +(V1^2/(2*gc*J)  = u2 + ((p2*v2)/J) + (V2^2/(2*gc*J)
// h1-h2 = ((V2^2-V1^2)/(2*gc*J))

printf("Solution for (a)\n");
//For neglegible entering velocity, V1=0
//So,
V2=sqrt((2*gc*J)*(h1-h2)); //the final velocity //ft/s
printf("It the initial velocity of the system is negligible,the final velocity is %f ft/s \n \n",V2);

printf("Solution for (b)\n");
//If the initial velocity is appreciable,
V1=1000; //Unit:ft/s //the initial velocity
V2=sqrt(((h1-h2)*(2*gc*J)) + V1^2 ) ;
printf("It the initial velocity of the system is appreciable,the final velocity is %f ft/s \n \n",V2);
```

Scilab code Exa 3.19 Nozzle

```
clear;
clc;
printf("\t\t\tProblem Number 3.19\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.19 (page no. 120)
// Solution

h1=3450*1000 //Unit:J/kg //Enthalpy of steam when it
    enters a nozzle
h2=2800*1000 //Unit:J/kg //Enthalpy of steam when it
    leaves a nozzle

//V2^2/2=h1-h2;
V2=sqrt(2*(h1-h2)); //V2=Final velocity //Unit:m/s
printf("Final velocity = %f m/s\n",V2);
```

Scilab code Exa 3.21 The heat exchanger

```
clear;
clc;
printf("\t\t\tProblem Number 3.21\n\n\n");
// Chapter 3 : The First Law Of Thermodynamics
// Problem 3.21 (page no. 125)
// Solution

m=400; //Unit:LBm/min //mass of lubricating oil
Cp=0.85; //Unit:Btu/LBm*R //Specific heat of the oil
T1=215; //Temperature when hot oil is entering //
   Unit:Fahrenheit
```

```
T2=125; //Temperature when hot oil is leaving //Unit:Fahrenheit
DeltaT=T2-T1; //Unit:Fahrenheit  //change in temperature
Qoil=m*Cp*DeltaT; //Heat out of oil //Btu/min
printf("Heat out of oil is %f Btu/min (Out of oil)\n",Qoil);
//Heat out of oil is the heat into the water
//Mw=Water flow rate
//M*Cpw*DeltaTw=Qoil
Cpw=1.0; //Unit:Btu/LBm*R //Specific heat of the water
T3=60; //Temperature when water is entering //Unit:Fahrenheit
T4=90; //Temperature when water is leaving //Unit:Fahrenheit
DeltaTw=T4-T3; //Unit:Fahrenheit //change in temperature
Mw=Qoil/(Cpw*DeltaTw); //The Required water flow rate  //Unit;lbm/Min
printf("The Required water flow rate is %f lbm/Min\n",abs(Mw));
```

Chapter 4

The Second Law Of Thermodynamics

Scilab code Exa 4.1 Efficiency

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.1\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.1  (page no. 148)
// Solution

//given data
t1=1000;  //(unit:fahrenheit) //Source temperature
t2=80;    //(unit:fahrenheit) //Sink temperature
//solution
//converting temperatures to absolute temperatures;
T1=t1+460; //Source temperature //Unit:R
T2=t2+460; //Sink temperature //Unit:R

printf("Solution for (a)\n");
ans=((T1-T2)/T1)*100;//(ans in %)  //Efficiency of
   the engine
```

```
printf("Efficiency of the engine is %f percentage\n\n",ans);

printf("Solution for (b)\n");
T1=2000+460; //Source temperature //Unit:R
T2=t2+460;  //Sink temperature //Unit:R
ans=((T1-T2)/T1)*100;//(ans in %) //Efficiency of the engine
printf("When the upper tempretrature is increased upto certain ,Efficiency of the engine is %f percentage \n\n",ans);

printf("Solution for (c)\n");
T1=t1+460; //Source temperature //Unit:R
T2=160+460;  //Sink temperature //Unit:R
ans=((T1-T2)/T1)*100;//(ans in %) //Efficiency of the engine
printf("When the lower tempretrature is increased upto certain ,Efficiency of the engine is %f percentage \n\n",ans);
```

Scilab code Exa 4.2 Work and the heat removed from reservoir

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.2\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.2  (page no. 149)
// Solution

//given data
Qin=100; //heat added to the cycle

printf("In problem 4.1,\n")
```

```
//given data
t1=1000;  //(unit:fahrenheit) //Source temperature
t2=80;   //(unit:fahrenheit)  //Sink temperature
//solution
//converting temperatures to absolute temperatures;
T1=t1+460; //Source temperature //Unit:R
T2=t2+460;  //Sink temperature //Unit:R
printf("Solution for (a)\n");
printf("Efficiency of the engine is %f percentage\n\n",((T1-T2)/T1)*100);

printf("Now in problem 4.2,\n")
W=0.63*Qin; //W=W/J; //Efficiency in problem 4.1
W=Qin*(W/Qin); //amount of work
Qr=Qin-W; //Qin-Qr=W/J  //Qr=heat rejected by the cycle
printf("The heat removed from the reservoir %f units",Qr);
```

Scilab code Exa 4.3 Minimum input required

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.3\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.3  (page no. 149)
// Solution

//given data
t1=70; //(unit:fahrenheit) //Source temperature
t2=15; //(unit:fahrenheit)  //Sink temperature
Qin=125000; //(unit=Btu/hr) //Qin=heat added to the cycle
//converting temperatures to absolute temperatures;
```

```
T1=t1+460; //Source temperature //Unit:R
T2=t2+460; //Sink temperature //Unit:R
Qr=Qin*(T2/T1); //Qr=heat rejected by the cycle
printf("Qr is %f in Btu/hr\n",Qr);
work=Qin-Qr; //reversed cycle requires atleast input
    //work //btu/hr
printf("Work is %f in Btu/hr\n",work);
// 1 hp = 33000 ft*LBf/min
// 1 Btu = 778 ft*LBf //1 hr = 60 min
printf("Minimum horsepower input required is %f hp",
   work*778/(60*33000));
```

Scilab code Exa 4.4 A Carnot engine

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.4\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.4  (page no. 150)
// Solution

W=(50*33000)/778;//output //W=W/J
// 1 hp = 33000 ft*LBf/min
// 1 Btu = 778 ft*LBf
printf("Output is %f in Btu/min\n",W);
t1=1000; //Source temperature //(unit:fahrenheit)
t2=100;  //Sink temperature //(unit:fahrenheit)
//converting temperatures to absolute temperatures;
T1=t1+460; //Source temperature //Unit:R
T2=t2+460; //Sink temperature //Unit:R
n=(1-(T2/T1))*100; //efficiency
printf("Efficiency is %f percentage\n",n);//(in %)
//n=(W/J)/Qin
Qin=W/(n/100);//(unit Btu/hr) //Qin=heat added to
```

```
the cycle
printf("Heat added to the cycle is %f in  Btu/min\n",Qin);
Qr=Qin*(1-(n/100));//(unit Btu/hr) //Qr=heat rejected by the cycle
printf("Heat rejected by the cycle is %f in  Btu/min\n",Qr);
```

Scilab code Exa 4.5 The Carnot engine

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.5\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.5  (page no. 151)
// Solution

t1=700; //Source temperature //Unit:Celcius
t2=20;  //Sink temperature //Unit:Celcius
//converting in F
T1=t1+273;  //Source temperature //Unit:R
T2=t2+273; //Sink temperature //Unit:R
n=(T1-T2)/T1*100; //Efficiency
printf("Efficiency is %f percentage\n",n);//(in %)
output=65;//in hp //Given
work=output*0.746;//(unit kJ/s) // 1 hp = 746 W
printf("Work is %f kJ/s\n",work);
Qin=work/(n/100);//(unit kJ/s) //Qin=heat added to the cycle
printf("Heat added to the cycle is %f kJ/s \n",Qin);
Qr=Qin*(1-(n/100));//(unit kJ/s) //Qr=heat rejected by the cycle
printf("Heat rejected by the cycle is %f  kJ/s \n",Qr);
```

Scilab code Exa 4.7 Two Carnot engines

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.7\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.7 (page no. 152)
// Solution

t1=700; //(unit:fahrenheit) //Source temperature
t2=200; //(unit:fahrenheit) //Sink temperature
//converting temperatures to absolute temperatures;
T1=t1+460; //Source temperature //Unit:R
T2=t2+460; //Sink temperature //Unit:R
//n1=(T1-Ti)/T1 and n2=(Ti-T2)/Ti //n1 & n2 are
    efficiency
//(T1-Ti)/T1=(Ti-T2)/Ti;
Ti=sqrt(T1*T2); //Exhaust temperature //Unit:R
printf("Exhaust temperature of first engine is %f in
    R\n",Ti);
//converting absolute temperature to normal F
    temperature
//Ti(fahrenheit)=Ti(R)-460;
printf("Exhaust temperature of first engine is %f
    fahrenheit\n",Ti-460);
```

Scilab code Exa 4.8 Change in entropy

```
//scilab 5.4.1
clear;
```

```
clc;
printf("\t\t\tProblem Number 4.8\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.8  (page no. 157)
// Solution

//For reversible isothermal process,
q=843.7; //Heat //Unit:Btu //at 200 psia
t=381.86; //(unit:fahrenheit) //temperature
////converting temperatures to absolute temperatures
    ;
T=t+460; //temperature //unit:R
deltaS=(q/T); //Change in entropy  //Unit:Btu/lbm*R
printf("Change in entropy is %f  Btu/lbm*R\n",deltaS
   ); //1 LBm of saturated water
```

Scilab code Exa 4.9 work done per pound and energy rejected

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.9\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.9  (page no. 158)
// Solution

//For reversible isothermal process,
//In problem 4.8,
q=843.7; //Heat //Unit:Btu //at 200 psia
t=381.86; //(unit:fahrenheit)
//converting temperatures to absolute temperatures;
T=t+460; //Unit:R"
deltaS=(q/T);  //Change in entropy //Btu/lbm
printf("Change in entropy is %f  Btu/lbm*R\n",deltaS
   ); //1 LBm of saturated water
```

```
//In problem 4.9
t1=381.86; //(unit:fahrenheit) //Source temperature
t2=50; //(unit:fahrenheit)  //Sink temperature
//converting temperatures to absolute temperatures;
T1=t1+460;  //Source temperature //Unit:R
T2=t2+460; //Sink temperature //Unit:R
qin=q;//heat added to the cycle
n=(1-(T2/T1))*100; //Efficiency
printf("Efficiency is %f percentage\n",n);
wbyJ=qin*n*0.01;//work output
printf("Work output is %f Btu/lbm\n",wbyJ);
Qr=qin-wbyJ; //heat rejected
printf("Heat rejected is %f Btu/lbm\n\n",Qr);
printf("As an alternative solution and refering to
    figure 4.12,\n")
qin=T1*deltaS; //heat added //btu/lbm
Qr=T2*deltaS; //Heat rejected //btu/lbm
printf("Heat rejected is %f Btu/lbm\n",Qr);
wbyJ=qin-Qr; //Work output //Btu/lbm
printf("Work output is %f Btu/lbm\n",wbyJ);
n=(wbyJ/qin)*100; //Efficiency
printf("Efficiency is %f percentage\n",n);
```

Scilab code Exa 4.10 Determine the change in entropy

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.10\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.10  (page no. 159)
// Solution

hfg=1959.7; //Unit:kJ/kg //Evaporative enthalpy
```

```
T=195.07+273; //Converted into Kelvin //Temperature
deltaS=hfg/T; //Change in entropy //kJ/kg*K
printf("Change in entropy at 1.4MPa for the
   vaporization of 1 kg is %f kJ/kg*K",deltaS); //
   Values compares very closely to the Steam Tables
   value
```

Scilab code Exa 4.11 Heat rejected

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.11\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.11  (page no. 159)
// Solution

//Let is assume that a Carnot engine cycle operates
   between two temperatures in each case.
t=1000; //(unit:fahrenheit)
//converting temperatures to absolute temperatures;
T1=t+460;
//T1*deltaS=Qin;
Qin=100; //Unit:Btu //heat added to the cycle
deltaS=Qin/T1; //Change in entropy //Btu/R
T2=50+460; //converting 50 F temperature to absolute
    temperature;
Qr=T2*deltaS; //Heat rejected //Unit:Btu
printf("%f Btu energy is unavailable with respect to
    a receiver at 50 fahrenheit \n",Qr);
T2=0+460; //converting 0 F temperature to absolute
   temperature;
Qr=T2*deltaS; //Heat rejected //unit:Btu
printf("%f Btu energy is unavailable with respect to
    a receiver at 0 fahrenheit \n",Qr);
```

Scilab code Exa 4.12 `energy unavailable at receiver`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.12\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.12  (page no. 160)
// Solution

Qin=1000; //Unit:Joule //heat entered to the system
t=500; //(unit:Celcius)  //temperature
//converting temperature
T1=t+273; //Unit:Kelvin
deltaS=Qin/T1; //Change in entropy //Unit:J/K
printf("Solution for (a),\n");
T2=20+273; //converted 20 Celcius temperature to
   Kelvin;
Qr=T2*deltaS; //Heat rejected at 20 celcius //Joule
printf("%f Joule energy is unavailable with respect
   to a receiver at 20 Celcius\n\n",Qr);

printf("Solution for (b),\n")
T2=0+273; //converted 0 Celcius temperature to
   Kelvin
Qr=T2*deltaS; //heat rejected at 0 celcius //Joule
printf("%f Joule energy is unavailable with respect
   to a receiver at 0 Celcius\n",Qr);
```

Scilab code Exa 4.13 `The final temperature`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.13\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.13 (page no. 161)
// Solution

//deltas=Cp*ln(T2/T1)
//Multiplying both the sides of equation by the mass
    m,
//DeltaS=m*Cp*ln(T2/T1)
m=6; //mass //Unit:lbm
Cp=0.361; //Btu/lbm*R //Specific heat constant
DeltaS=-0.7062; //Unit:Btu/R //change in entropy
t=1440; //(unit:fahrenheit)
//converting temperatures to absolute temperatures;
T1=t+460; //Unit:R
//Rearranging the equation,
T2=T1*exp(DeltaS/(m*Cp)); //final temperature //Unit
    :R
printf("Final temperature is %f R",T2);
printf("or %f fahrenheit",T2-460);
```

Scilab code Exa 4.14 Net Change in entropy

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.14\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.14 (page no. 162)
// Solution

//1 lbm of water at 500F is mixed with 1 lbm of
```

```
water at 100F
m1=1; //Unit:lbm //mass
m2=1; //Unit:lbm //mass
c1=1; //Specific heat constant
c2=1; //Specific heat constant
t1=500; //(unit:fahrenheit)
t2=100; //(unit:fahrenheit)
cmix=1; //Specific heat constant of mixture
//now, m1*c1*t1 +m2*c2*t2 = (m1+m2)*cmix*t
//So,
t=((m1*c1*t1)+(m2*c2*t2))/((m1+m2)*cmix) //resulting temperature of the mixture
printf("The resulting temperature of the mixture is %f fahrenheit\n",t);
//For this problem,the hot steam is cooled
deltas=cmix*log((t+460)/(t1+460)); //temperatures converted to absolute temperatures; //deltas=change in entropy //Unit:Btu/(lbm*R)
//The cold steam is heated
deltaS=cmix*log((t+460)/(t2+460)); //temperatures converted to absolute temperatures; //deltaS=change in entropy //Unit:Btu/(lbm*R)
printf("The net change in entropy is %f Btu/(lbm*R)\n",deltaS+deltas);
```

Scilab code Exa 4.15 Change in entropy

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 4.15\n\n\n");
// Chapter 4 : The Second Law Of Thermodynamics
// Problem 4.15 (page no. 163)
// Solution

```

```
//In problem 4.15,
//1 lbm of water at 500F is mixed with 1 lbm of water at 100F
m1=1; //Unit:lbm //mass
m2=1; //Unit:lbm //mass
c1=1; //Specific heat constant
c2=1; //Specific heat constant
t1=500; //(unit:fahrenheit)
t2=100; //(unit:fahrenheit)
cmix=1; //Specific heat constant of mixture
//now, m1*c1*t1 +m2*c2*t2 = (m1+m2)*cmix*t  //So,
t=((m1*c1*t1)+(m2*c2*t2))/((m1+m2)*cmix) //resulting temperature of the mixture
printf("In problem 4.14,The resulting temperature of the mixture is %f fahrenheit\n",t);

//Now,in problem 4.15,taking 0F as a reference temperature,
//For hot fluid,
deltas=cmix*log((t1+460)/(0+460)); //temperatures converted to absolute temperatures; //deltas=change in entropy //Unit:Btu/(lbm*R)
//For cold fluid,
s=cmix*log((t2+460)/(0+460)); //temperatures converted to absolute temperatures; //s=change in entropy //Unit:Btu/(lbm*R)
//At final mixture temperature of t F,the entropy of each system above 0F is,for the hot fluid
s1=cmix*log((t+460)/(0+460)); //temperatures converted to absolute temperatures; //s1=change in entropy //Unit:Btu/(lbm*R)
//and for the cold fluid,
s2=cmix*log((t+460)/(0+460)); //temperatures converted to absolute temperatures; //s2=change in entropy //Unit:Btu/(lbm*R)
printf("The change in the entropy for hot fluid is %f Btu/(lbm*R)\n",s1-deltas);
printf("The change in the entropy for cold fluid is
```

```
    %f Btu/(lbm*R)\n",s2-s);
printf("The total change in entropy if %f Btu/(lbm*R
    ",s1-deltas+s2-s);
```

Chapter 5

Properties Of Liquids And Gases

Scilab code Exa 5.1 The enthalpy

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.1\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.1  (page no. 182)
// Solution

p=0.6988; //Unit:psia //absolute pressure
vg=467.7; //Unit:ft^3/lbm //Saturated vapour
    specific volume
ug=1040.2; //Unit:Btu/lbm //Saturated vapour
    internal energy
J=778; //J=Conversion factor
// 1 Btu = 778 ft*LBf
//h=u+(p*v)/J
hg=ug+((p*vg*144)/J); //The enthalpy of saturated
    steam //1 ft^2=144 in^2 //Btu/lbm
printf("The enthalpy of saturated steam at 90 F is
```

```
    %f Btu/lbm",hg); //The value is matched with the
    value in table 1
```

Scilab code Exa 5.2 Determine the enthalpy of saturated steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.2\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.2  (page no. 187)
// Solution

p=4.246; //Unit:kPa //absolute pressure
vg=32.894; //Unit:m^3/kg //specific volume
ug=2416.6; //Unit:kJ/kg //internal energy
J=778; //J=Conversion factor
// 1 Btu = 778 ft*LBf
//h=u+(p*v)
hg=ug+(p*vg); //The enthalpy of saturated steam //1
    ft^2=144 in^2 //unit:kJ/kg
printf("The enthalpy of saturated steam at 30 C is
    %f kJ/kg",hg); //The value is matched with the
    value in table 1
```

Scilab code Exa 5.3 Determine hg vg sg and ug

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.3\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.3  (page no. 188)
```

```
// Solution

//The necessary interpolations are best done in tabular forms as shown:
//  p    hg
// 115  1190.4  table 2
// 118  1190.8  (hg)118=1190.8
// 120  1191.1
hg=1190.4+(3/5)*(1191.1-1190.4); //Btu/lbm //enthaply
printf("The enthalpy of saturated steam at 118 psia is %f Btu/lbm\n",hg);

//  p    vg
// 115  3.884  table 2
// 118  3.792  (vg)118=3.790
// 120  3.730
vg=3.884-(3/5)*(3.884-3.730); //ft^3/lbm //specific volume
printf("The specific volume of saturated steam at 118 psia is %f ft^3/lbm\n",vg);

//  p    sg
// 115  1.5921  table 2
// 118  1.5900  (sg)118=1.5900
// 120  1.5886
sg=1.5921-(3/5)*(1.5921-1.5886); //entropy
printf("The entropy of saturated steam at 118 psia is %f\n",sg);

//  p    ug
// 115  1107.7  table 2
// 118  1108.06  (ug)118=1180.1
// 120  1108.3
ug=1107.7-(3/5)*(1108.3-1107.7); //internal energy
printf("The internal energy of saturated steam at 118 psia is %f\n",ug);
//The interpolation process that was done in tabular
```

```
form for this problem can also be demonstated by refering to figure 5.8 for the specific volume. It will be
//seen that the results of this problem and the tabulated values are essentially in exact agreement and that linear interpolation is satisfactory in these tables.
```

Scilab code Exa 5.4 hfg for saturated steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.4\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.4 (page no. 189)
// Solution

//By defination ,
//hg=ug+(p*vg)/J
//hf=uf+(p*vf)/J
//hfg = hg-hf = (ug-uf) + p*(vg-vf)/J = ufg + p*(vg-vf)/J
//From table 2 at 115 psia ,
p=115; //Unit:psia //absolute pressure
ufg=798.8; //Unit:Btu/lbm //Evap. internal energy
ug=3.884; //Unit:ft^3/lbm //Saturated vapour internal energy
vf=0.017850; //Unit:ft^3/lbm //Saturated liquid specific volume
J=778; //J=Conversion factor //Unit:ft*lbf/Btu
//1 ft^2=144 in^2
hfg=ufg+(p*144*(ug-vf))/J; //Evap. Enthalpy //Unit:Btu/lbm
printf("hfg for saturated steam at 115 psia is %f
```

```
Btu/lbm",hfg); //The tabulated values are matched
```

Scilab code Exa 5.5 `find hfg`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.5\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.5  (page no. 190)
// Solution

//From table 2 at 1.0 MPa,
p=1000; //Unit:kN/m^2 //absolute pressure
ufg=1822.0; //Unit:kJ/kg //Evap. internal energy
vf=0.0011273; //Unit:m^3/kg //Saturated liquid specific volume
vg=0.19444; //Unit:m^3/kg //Saturated vapour specific volume
vfg=vg-vf;  //Evap. specific volume //m^3/kg
hfg=ufg+(p*vfg); //Evap. Enthalpy //Unit:kJ/kg
printf("hfg for saturated steam at 1.0 MPa is %f kJ/kg",hfg); //The tabulated values are matched
```

Scilab code Exa 5.6 `Determine hfg`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.6\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.6  (page no. 190)
// Solution
```

```

//For constant-temperature,reversible vaporization, hfg=deltah=T*deltas=T*sfg
hfg=(388.12+460)*(1.1042); //Evap. Enthalpy //Unit:Btu/lbm
printf("By considering the process to be a reversible,constant-temperature,hfg for saturated steam at 115 psia is %f Btu/lbm",hfg); //ans is wrong in the book
//Values are matched with tabulated values.Use of -459.67 F for absolute zero,which is the value used in table,gives almost exact agreement.
```

Scilab code Exa 5.7 `Determine sx hx ux and vx`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.7\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.7 (page no. 192)
// Solution

//Using Table 2 ans a quality of 80%(x=0.8),we have
//at 120 psia
x=0.8;
sf=0.49201; //saturated liquid entropy //Unit:Btu/lbm*R
sfg=1.0966; //Evap. Entropy //Unit:Btu/lbm*R
hf=312.67; //saturated liquid enthalpy //Unit:Btu/lbm
hfg=878.5; //Evap. Enthalpy //Unit:Btu/lbm
uf=312.27; //saturated liquid internal energy //Unit:Btu/lbm
ufg=796.0; //Unit:Btu/lbm //Evap. internal energy
```

```
vf=0.017886; //Saturated liquid specific volume //
    Unit:ft^3/lbm
vfg=(3.730-0.017886); //evap. specific volume //Unit
    :ft^3/lbm
sx=sf+(x*sfg); //entropy //Btu/lbm*R
printf("Entropy of a wet steam mixture at 120 psia
    is %f Btu/lbm*R\n",sx);
hx=hf+(x*hfg); //enthalpy  //Btu/lbm*R
printf("Enthalpy of a wet steam mixture at 120 psia
    is %f Btu/lbm\n",hx);
ux=uf+(x*ufg); //internal energy //Btu/lbm*R
printf("Internal energy of a wet steam mixture at
    120 psia is %f Btu/lbm\n",ux);
vx=vf+(x*vfg); ///specific volume //ft^3/lbm
printf("Specific Volume of a wet steam mixture at
    120 psia is %f ft^3/lbm\n",vx);
//As a check,
J=778; //ft*lbf/Btu //Conversion factor
px=120; //psia //pressure
ux=hx-((px*vx*144)/J); //1 ft^2=144 in^2 //internal
    energy
printf("As a check,\n")
printf("Internal energy of a wet steam mixture at
    120 psia is %f Btu/lbm\n",ux);
printf("Which agrees with the values obtained above"
    );
```

Scilab code Exa 5.8 Determine sx hx ux and vx when quality is given

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.8\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.8  (page no. 193)
```

```
// Solution

//Using Table 2 ans a quality of 85%(x=0.85),we have
//at 1.0 MPa
x=0.85;
sf=2.1387; //saturated liquid entropy //Unit:kJ/kg*K
sfg=4.4487; //Evap. Entropy //Unit:kJ/kg*K
hf=762.81; //saturated liquid enthalpy //Unit:kJ/kg
hfg=2015.3; //Evap. Enthalpy //Unit:kJ/kg
uf=761.68; //saturated liquid internal energy //Unit:kJ/kg
ufg=1822.0; //Unit:kJ/kg //Evap. internal energy
vf=1.1273; //Saturated liquid specific volume //Unit:m^3/kg
vfg=(194.44-1.1273); //evap. specific volume //Unit:m^3/kg
sx=sf+(x*sfg); //entropy //kJ/kg*K
printf("Entropy of a wet steam mixture at 1.0 MPa is %f kJ/kg*K\n",sx);
hx=hf+(x*hfg); //enthalpy //kJ/kg*K
printf("Enthalpy of a wet steam mixture at 1.0 MPa is %f kJ/kg\n",hx);
ux=uf+(x*ufg); //internal energy  //kJ/kg*K
printf("Internal energy of a wet steam mixture at 1.0 MPa is %f kJ/kg\n",ux);
vx=(vf+(x*vfg))*(0.001); //specific volume //m^3/kg
printf("Specific Volume of a wet steam mixture at 1.0 MPa is %f m^3/kg\n",vx);
//As a check,
px=10^6; //psia //pressure
ux=hx-((px*vx)/10^3); //1 ft^2=144 in^2 //internal energy
printf("As a check,\n")
printf("Internal energy of a wet steam mixture at 120 psia is %f kJ/kg\n",ux);
printf("Which agrees with the values obtained above");
```

Scilab code Exa 5.9 Quality of the steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.9\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.9  (page no. 193)
// Solution

//For the wet mixture,hx=hf+(x*hfg),solving for x
   gives us
//Using table 1,we have,
hx=900; //Btu/lbm //Enthalpy of wet mixture at 90F
hf=58.07; //Btu/lbm //saturated liquid enthalpy
hfg=1042.7; //Btu/lbm //Evap. Enthalpy
x=(hx-hf)/hfg; //quality
printf("The quality is %f percentage of a wet steam
   at 90F\n",x*100);
```

Scilab code Exa 5.10 Determine the quality

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.10\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.10  (page no. 194)
// Solution

//For the wet mixture,hx=hf+(x*hfg),solving for x
   gives us
```

```
//Using table 1,we have,
hx=2000; //kJ/kg //Enthalpy of wet mixture at 30 C
hf=125.79; //kJ/kg //saturated liquid enthalpy
hfg=2430.5; // //Evap. Enthalpy //kJ/kg
x=(hx-hf)/hfg; //quality
printf("The quality is %f percentage of a wet steam
    at 30 C\n",x*100);
```

Scilab code Exa 5.11 Determine h v u and s of superheated steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.11\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.11 (page no. 197)
// Solution

//The values of temperature and pressure are listed
    in Table 3(Figure 5.10) and can be read directly.
printf("Specific volume of superheated steam at 330
    psia and 450F is v=1.4691 ft^3/lbm\n");
printf("Internal Energy of superheated steam at 330
    psia and 450F is u=1131.8 Btu/lbm\n");
printf("Enthalpy of superheated steam at 330 psia
    and 450F is h=1221.5 Btu/lbm\n");
printf("Entropy of superheated steam at 330 psia and
     450F is s=1.5219 Btu/lbm*R\n");
```

Scilab code Exa 5.12 Determine v u h and s of superheated steam

```
//scilab 5.4.1
clear;
```

```
clc;
printf("\t\t\tProblem Number 5.12\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.12  (page no. 197)
// Solution

//The values of temperature and pressure are listed
   in Table 3(Figure 5.10) and can be read directly.
printf("Specific volume of superheated steam at 2.0
   MPa and 240 C is v=0.10845 m^3/lbm\n");
printf("Internal Energy of superheated steam at 2.0
   MPa and 240 C is u=2659.6 kJ/kg\n");
printf("Enthalpy of superheated steam at 2.0 MPa and
    240 C is h=2876.5 kJ/kg\n");
printf("Entropy of superheated steam at 2.0 MPa and
   240 C is s=6.4952 kJ/kg*K\n");
```

Scilab code Exa 5.13 `Determine v h s and u of superheated steam`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.13\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.13  (page no. 197)
// Solution


//The necessary interpolations(between 450F and 460F
    at 330 psia) are best done in tabular forms as
   shown:
//  t    v
// 460  1.4945
// 455  1.4818
// 450  1.4691
```

```
v=1.4691+(1/2)*(1.4945-1.4691); //ft^3/lbm //specific volume
printf("The specific volume of saturated steam at 330 psia & 455F is %f ft^3/lbm\n",v);

//  t    u
// 460  1137.0
// 455  1134.4
// 450  1131.8
u=1131.8+(1/2)*(1137.0-1131.8); //Btu/lbm //internal energy
printf("The internal energy of saturated steam at 330 psia & 455F is %f Btu/lbm\n",u);

//  t    h
// 460  1228.2
// 455  1224.9
// 450  1221.5
h=1221.5+(1/2)*(1228.2-1221.5); //enthaply //Btu/lbm
printf("The enthalpy of saturated steam at 330 psia & 455F is %f Btu/lbm\n",h);

//  t    s
// 460  1.5293
// 455  1.5256
// 450  1.5219
s=1.5219+(1/2)*(1.5293-1.5219); //entropy //Btu/lbm*R
printf("The entropy of saturated steam at 330 psia & 455F is %f Btu/lbm*R\n",s);
```

Scilab code Exa 5.14 Determine specific volume and enthalpy of superheated steam

```
//scilab 5.4.1
clear;
```

```
clc;
printf("\t\t\tProblem Number 5.14\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.14  (page no. 198)
// Solution

//From Table3, we first obtain the properties at 337 psia and 460 F and then 337 psia and 470 F.
//The necessary interpolations are best done in tabular forms as shown:
//Proceeding with the calculation,at 460 F,
//  p    v                                            //  p   h
// 340  1.4448                                        // 340  1226.7
// 337  1.4595                                        // 337  1227.2
// 335  1.4693                                        // 335  1227.5
v=1.4696-(2/5)*(1.4693-1.4448);                       h=1227.5-(2/5)*(1227.5-1226.7);
//ft^3/lbm //specific volume                          //Btu/lbm //enthaply

//And at 470 F,
//  p    v                                            //  p   h
// 340  1.4693                                        // 340  1233.4
// 337  1.4841                                        // 337  1233.9
// 335  1.4940                                        // 335  1234.2
v=1.4640-(2/5)*(1.4640-1.4693);                       h=1234.2-(2/5)*(1234.2-1233.4);
//ft^3/lbm //specific volume                          //Btu/lbm //enthaply

```

```
//Therefore,at 337 psia and 465 F
//   t      v                              //   t        h
// 470   1.4841                            // 470     1233.9
// 465   1.4718                            // 465     1230.7
// 460   1.4595                            // 460     1227.5
v=1.4595+(1/2)*(1.4841-1.4595);            h=1227.5+(1/2)*(1233.9-1227.5);
//ft^3/lbm //specific volume               //Btu/lbm //enthaply
printf("At 465 F and 337 psia,specific volume=%f ft^3/lbm and enthalpy=%f Btu/lbm\n",v,h);
```

Scilab code Exa 5.15 Determine h s v and u of subcooled water

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.15\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.15  (page no. 202)
// Solution

//The values of temperature and pressure are listed in Table 4(Figure 5.10) and can be read directly.
printf("Specific volume of subcooled water at 1000 psia and 300F is v=0.017379 ft^3/lbm\n");
printf("Internal Energy of subcooled water at 1000 psia and 300F is u=268.24 Btu/lbm\n");
printf("Enthalpy of subcooled water at 1000 psia and 300F is h=271.46 Btu/lbm\n");
printf("Entropy of subcooled water at 1000 psia and
```

```
300F is s=0.43552 Btu/lbm*R\n");
```

Scilab code Exa 5.16 Determine enthalpy of subcooled water

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.16\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.16 (page no. 202)
// Solution

//It is necessary to ontain the saturation values corresponding to 300 F.This is done by reading Table A.1 in Appendix 3,which gives
pf=66.98; //psia //pressure
vf=0.017448; //ft^3/lbm //specific volume
hf=269.73; //Btu/lbm //enthaply
//Now,
p=1000; //psia //pressure
J=778; //Conversion factor //ft*lbf/Btu
//From eq.5.5,
h=hf+((p-pf)*vf*144)/J; //1ft^2=144 in^2 //The enthalpy of subcooled water //Btu/lbm
printf("The enthalpy of subcooled water is %f Btu/lbm\n",h);
//The difference between this value and the value found in problem 5.15,expressed as a percentage is
percentoferror=(h-271.46)/271.46;
printf("Percent of error is %f\n",percentoferror*100);
```

Scilab code Exa 5.25 `the enthalpy of saturated steam`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.25\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.25  (page no. 211)
// Solution

//On a chart in Appendix 3,it is necessary to
    estimate the 90 F point on the saturation line.
    From the chart or the table in the upper left of
    the chart,we note that 90 F is between 1.4 and
    1.5 in. of mercury.Estimating the intersection of
     this value with the saturation curve yields
printf("Enthalpy of saturated steam hg=1100 Btu/lbm\
    n");
//This is a good agreement with results of problem
    5.1
```

Scilab code Exa 5.26 `Enthalpy of a wet steam`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.26\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.26  (page no. 212)
// Solution

//The Mollier chart has lines of constant moisture
    in the wet region which correspond to (1-x).
    Therefore,we read at 20% moisture(80% Quality)
    and 120 psia,
```

```
printf("The enthalpy of a wet steam mixture at 120
    psia having quality 80 percent is 1015 Btu/lbm\n"
    );
//Which also agrees well with the calculated value
    in problem 5.7
```

Scilab code Exa 5.27 quality of a wet steam mixture

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.27\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.27 (page no. 213)
// Solution

//Entering the Mollier chart at 900 Btu/lbm and
    estimating 90 F(near the 1.5-in. Hg dashed line)
    yields a constant moisture percent of 19.2%.
printf("The quality is %f percent\n",(1-0.192)*100);
//We show good agreement with the calculated value.
```

Scilab code Exa 5.28 determine the enthalpy of steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.28\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.28 (page no. 214)
// Solution

//From the chart,
```

```
printf("The enthalpy of steam at 330 psia is h=1220
   Btu/lbm\n");
//Compared to 1221.5 Btu/lbm found in problem 5.11
```

Scilab code Exa 5.29 Determine the enthalpy and entropy of steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.29\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.29  (page no. 214)
// Solution

//We note that the steam is superheated.From the
   Mollier chart in SI units,
printf("The enthalpy h=2876.5 kJ/kg and entropy s
   =6.4952 kJ/kg*K\n");
//Values are matched with problem 5.12
```

Scilab code Exa 5.30 Determine the enthalpy of steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.30\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.30  (page no. 215)
// Solution

//Because neither pressure nor temperature is shown
   directly,it is necessary to estimate to obtain
   the desired value.
```

```
printf("The enthalpy of steam is h=1231 Btu/lbm\n");
//In problem 5.14,h=1230.7 Btu/lbm,Which is matched
    here.
```

Scilab code Exa 5.31 `determine hg`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.31\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.31  (page no. 215)
// Solution

//Reading the chart at 30 C and saturation gives us,
printf("The enthalpy of saturated steam is hg=2556
    kJ/kg\n");
//Which matches with value of problem 5.2
```

Scilab code Exa 5.32 `Determine hx and sx`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.32\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.32  (page no. 215)
// Solution

//Reading the chart in wet region at 1.0 MPa and x
    =0.85(moisture of 15%) gives us
printf("hx=2476 kJ/kg and sx=5.92 kJ/kg*K\n");
//The chart does not give ux or vx directly
```

Scilab code Exa 5.33 Determine the quality of steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.33\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.33  (page no. 215)
// Solution

//Locate 30 C on the saturation line.Now follow a line of constant pressure,which is also a line of constant temperature in wet region,until an enthalpy of 2000kJ/kg is reached.
printf("The moisture content is 23 percent or x=77 percent\n");
```

Scilab code Exa 5.34 Determine entropy and enthalpy

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.34\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.34  (page no. 216)
// Solution

//We enter the chart in the superheat region at 2.0 MPa and 240 C to read the enthalpy and entropy. This procedure gives
printf("Enthalpy h=2877 kJ/kg and entropy s=6.495 kJ/kg*K\n");
```

```
//The other properties cant be obtained directly
   from the chart
```

Scilab code Exa 5.35 Determine the moisture in the steam flowing in the pipe

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.35\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.35 (page no. 218)
// Solution

//As already noted,h1=h2 for this process.On the
   Mollier chart,h2 is found to be 1170 Btu/lbm at
   14.7 psia and 250 F.Proceeding to the left on the
    chart,the constant−enthalpy value of 1170 Btu/
   lbm to 150 psia yields a moisture of 3% or a
   quality of 97%.
//If we use the tables to obtain the solution to
   this problem,we would first obtain h2 from the
   superheated vapor tables as 1168.8 Btu/lbm.
   Because hx=hf+(x*hfg),we    obtain x as
hx=1168.8; //Btu/lbm
hf=330.75; //Btu/lbm //values of 150 psia
hfg=864.2; //Btulbm //values of 150 psia
x=(hx-hf)/hfg; //Quality
printf("Moisture in the steam flowing in the pipe is
    %f percent\n",(1-x)*100);
printf("or quality of the steam is %f percent\n",x
   *100);
//very often,it is necessary to perform multiple
   interpolations if the tables are used,and the
   Mollier chart yields results within the rquired
   accuracy for most engineering problems and saves
```

```
considerable time.
//We can also use the computerised programs to solve this program.We first enter the 250F and 14.7 psia to obtain h of 1168.7 Btu/lbm.We then continue by entering h of 1168.7 Btu/lbm and p of 150 psia.The printout gives us x of 0.9699 or 97 %.While the computer solution is quick and easy to use,you should still sketch out the  problem on an h-s or T-s diagram to show the path of the process.

// Saturation Properties
//----------------------------
// T=250.00 degF
// P=29.814 psia
//          z          z1         zg
// v(ft^3/lbm)    0.01700    13.830
// h(Btu/lbm)      218.62    1164.1
// s(Btu/lbm*F)   0.3678     1.7001
// u(Btu/lbm)     218.52     1087.8

//Thermo Properties
//---------------------------
// T= 250.00 degF
// P= 14.700 psia
// v= 28.417 ft^3/lbm
// h= 1168.7 Btu/lbm
// s= 1.7831 Btu/lbm*F
// u= 1091.4 Btu/lbm

// Saturation Properties
//----------------------------
// T=340.06 degF
// P=118.00 psia
//          z          z1         zg
// v(ft^3/lbm)    0.01787    3.7891
// h(Btu/lbm)     311.39     1190.7
// s(Btu/lbm*F)   0.4904     1.5899
```

```
// u(Btu/lbm)      311.00      1108.0

//Thermo Properties
//------------------------------
// T= 358.49 degF
// P= 150.00 psia
// v= 2.9248 ft^3/lbm
// h= 1168.7 Btu/lbm
// s= 1.5384 Btu/lbm*F
// u= 1087.5 Btu/lbm
// x= 0.9699

//Region:Saturated
```

Scilab code Exa 5.36 The final pressure of the steam and the heat added

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.36\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.36  (page no. 219)
// Solution

//Because the tank volume is 10 ft^3,the final
   specific volume of the steam is 10 ft^3/lbm.
   Interpolations in Table A.2 yield a final
   pressure of 42 psia.The heat   added is simply
   difference in internal energy between the two
   states.
u2=1093.0; //internal energy //Btu/lbm
u1=117.95; //internal energy //Btu/lbm
q=u2-u1; //heat added //Btu/lbm
printf("The final pressure is 42 psia and the heat
   added is %f Btu/lbm\n",q);
```

Scilab code Exa 5.37 Heat added per unit mass

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.37\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.37  (page no. 220)
// Solution

//The mass in the tank is constant,and the heat
   added will be the change in internal energy of
   the contents of the tank between the two states.
   The initial mass in      the tank is found as
   follows:
Vf=45; //volume of water //ft^2
vf=0.016715;
Vg=15; //Volume of steam //ft^2
vg=26.80;
mf=Vf/vf; //lbm
mg=Vg/vg; //lbm
total=mf+mg; //total mass
//The internal energy is the sum of the internal
   energy of the liquid plus vapor:
ug=1077.6;
uf=180.1;
Ug=mg*ug; //Btu
Uf=mf*uf; //Btu
Total=Ug+Uf; //total internal energy
printf("The total internal energy is %f Btu\n",Total
   );
//Because the mass in the tank is constant,the final
    specific volume must equal the initial specific
   volume,or
```

```
vx=(Vf+Vg)/(mf+mg); //ft^3/lbm
//But vx=vf+(x*vfg). Therefore using table A.2 at 800 psia,
vx=0.022282;
vf=0.02087;
vfg=0.5691-0.02087;
x=(vx-vf)/vfg;
printf("The final amount of vapor is %f lbm\n",x*total); //x*total mass
mg=x*total;
printf("The final amount of liquid is %f lbm\n",total-(x*total)); //total mass minus final amount of vapor
mf=total-(x*total);
//The final internal energy is found as before:
ug=1115.0;
uf=506.6;
Ug=mg*ug; //Btu
Uf=mf*uf; //Btu
Total1=Ug+Uf;
difference=Total1-Total; //final internal energy-initial internal energy
//per unit mass heat added is,
printf("The heat added per unit is %f Btu/lbm\n",difference/total); //the difference of internal energy/total mass
```

Scilab code Exa 5.38 Determine the change in enthalpy

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.38\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.38 (page no. 222)
```

```
// Solution

//As shown in Fig. 5.21b,the process dscribed in this problem is a vertical line on the Mollier Chart.For 800 psia and 600F,the Mollier chart yeilds h1=1270 Btu/lbm and s1=1.485.Proceeding vertically down the chart at constant s to 200 psia yields a final enthalpy h2=1148 Btu/lbm.The change in enthaly using the process is 1270-1148=122 Btu/lbm.
//We may also solve this problem using the steam tables in Appendix 3.Thus,the enthalpy at 800 psia and 600 F is 1270.4 Btu/lbm,and its entropy is 1.4861 Btu/lbm*R.
//Because the process is isentropic,the final entropy at 200psia must be 1.4861.From the saaturation table,the entropy of saturated steam at 200 psia is 1.5464,which indicates the final steam condition must be wet because the entropy of the final steam is less than the entropy of saturation.Using the wet steam relation yields,
//sx=sf+(x*sfg)
h1=1270.4; sx=1.4861; sf=0.5440; sfg=1.0025 ;hf=355.6; hfg=843.7;
x=(sx-sf)/sfg; //Quality
//Therefore,the final enthalpy is
hx=hf+(x*hfg); //Btu/lbm
printf("The final enthalpy is %f Btu/lbm\n",hx);
printf("The change in enthalpy is %f Btu/lbm\n",h1-hx); //Note the agreement with the Mollier chart solution
//we can also use the computer program to solve this problem.For 600F and 800 psia, h=1270. Btu/lbm and s=1.4857 Btu/lbm*R.Now using p=200 psia and s=1.4857,we obtain
//h=1148.1 Btu/lbm.The change in enthalpy is 1270.0-1148.1=121.9 Btu/lbm.Note the effort saved using either the Mollier chart or the computer
```

```
    program.

// Saturation Properties
//----------------------------
// T=600.00 degF
// P=1541.7 psia
//          z           z1          zg
// v(ft^3/lbm)     0.02362     0.2675
// h(Btu/lbm)      616.59      1166.2
// s(Btu/lbm*F)    0.8129      1.3316
// u(Btu/lbm)      609.85      1089.9

//Thermo Properties
//---------------------------
// T= 600.00 degF
// P= 800.00 psia
// v= 0. ft^3/lbm
// h= 1168.7 Btu/lbm
// s= 1.5384 Btu/lbm*F
// u= 1087.5 Btu/lbm
//Region:Superheated

// Saturation Properties
//----------------------------
// T=381.87 degF
// P=200.00 psia
//          z           z1          zg
// v(ft^3/lbm)     0.01839     2.2883
// h(Btu/lbm)      355.60      1199.0
// s(Btu/lbm*F)    0.5440      1.5462
// u(Btu/lbm)      354.92      1114.3

//Thermo Properties
//---------------------------
// T= 381.87 degF
// P= 200.00 psia
// v= 2.1512 ft^3/lbm
// h= 1148.1 Btu/lbm
```

```
//  s= 1.4857  Btu/lbm*F
//  u= 1068.5  Btu/lbm
//  x= 0.9396

//Region:Saturated
```

Scilab code Exa 5.39 Determine the final state of the steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.39\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.39  (page no. 226)
// Solution

//As refering to figure 5.21,it will be seen that
   the final temperature and enthalpy will both be
   higher than for the isentropic case.
//80% of the isentropic enthalpy difference
deltah=0.8*122; //change in enthalpy //Btu/lbm
h1=1270; //Btu/lbm //initial enthalpy
h2=h1-deltah; //the final enthalpy //Btu/lbm
printf("The final enthalpy is %f Btu/lbm\n",h2);
printf("and the final pressure is 200 psia\n");
printf("The Mollier chart indicates the final state
   to be in the wet region,\n");
printf("with 3.1percent moisture content and an
   entropy of 1.514 Btu/lbm*R");
```

Scilab code Exa 5.40 Change in enthalpy

```
//scilab 5.4.1
```

```
clear;
clc;
printf("\t\t\tProblem Number 5.40\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.40  (page no. 226)
// Solution

//Using the Mollier chart ,
h1=2942; //kJ/kg //initial enthalpy
//Proceeding as shown in figure 5.21b,that is ,
   vertically at constant entropy to a pressure of
   0.1 MPa,gives us
h2=2512; //kJ/kg //final enthalpy
printf("Neglecting kinetic & potential energy ,The
   change in enthalpy of the steam is %f kJ/kg",h1-
   h2);
```

Scilab code Exa 5.41 Determine Final velocity of the steam

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.41\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.41  (page no. 226)
// Solution

//From the conditions given in problem 5.38,the
   isentropic change in enthalpy is 122 Btu/lbm
//So,
h1minush2=122; //Btu/lbm //change in enthalpy
J=778; //Conversion factor
gc=32.17; //lbm*ft/lbf*s^2 //constant of
   proportionality
V2=sqrt(2*gc*J*(h1minush2)); //final velocity //ft/s
```

```
printf("As the steam leaves the nozzle,The final velocity is %f ft/s",V2);
```

Scilab code Exa 5.42 Determine the final velocity

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.42\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.42 (page no. 227)
// Solution

//Because the process is irreversible,we cannot show it on the Mollier diagram.However,the analysis of problem 3.22 for the nozzle is still valid,and all that is      needed is the enthalpy at the beginning and the end of the expansion.From the problem 5.38,
h1=1270; //Btu/lbm //initial enthalpy
//For h2 we locate the state point on the Mollier diagram as being saturated vapor at 200 psia.This gives us
h2=1199; //Btu/lbm //final enthalpy
J=778; //Conversion factor
gc=32.17; //lbm*ft/lbf*s^2 //constant of proportionality
V2=sqrt(2*gc*J*(h1-h2)); //final velocity //Ft/s
printf("As the steam leaves the nozzle,The final velocity is %f ft/s",V2);
```

Scilab code Exa 5.43 Heat added per pound

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.43\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.43  (page no. 229)
// Solution

//From the saturation table,500 psia corresponds to
   a temperature of 467.13F,and the saturated vapor
   has an enthalpy of 1205.3 Btu/lbm.At 500 psia and
    800 F,the        saturated vapor has an enthalpy
   of 1412.1 Btu/lbm.Because this process is a
   steady-flow process at constant pressure,the
   energy equation becomes q=h2-h1,assuming    that
   differences in the kinetic energy and potential
   energy terms are negligible.Therefore,
h2=1412.1; //Btu/lbm //final enthalpy
h1=1205.3; //Btu/lbm //initial enthalpy
q=h2-h1; //heat added //Btu/lbm
printf("%f Btu/lbm heat per pound of steam was added
   \n",q);
```

Scilab code Exa 5.44 Heat removed

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 5.44\n\n\n");
// Chapter 5 : Properties Of Liquids And Gases
// Problem 5.44  (page no. 229)
// Solution

//From the saturation table at 1 psia,
hf=69.74; //Btu/lbm //saturated liquid enthalpy
```

```
hfg=1036.0; //Btu/lbm //Evap. Enthalpy
hg=1105.8; //Btu/lbm //The enthalpy of saturated steam
x=0.97; //Quality
//Because the condensation process is carried out at constant pressure,the energy equation is q=deltah.
hx=hf+(x*hfg); //the initial enthalpy //Btu/lbm
printf("The initial enthalpy is %f Btu/lbm\n",hx);
//The final enthalpy is hf=69.74.So,
deltah=hx-hf; //The enthalpy difference //Btu/lbm
printf("At 1 psia,The enthalpy difference is %f Btu/lbm\n",deltah);
printf("By the computer solution,the enthalpy difference is 1004.6 Btu/lbm");
// Saturation Properties
//------------------------------
// T=101.71 degF
// P=1.0000 psia
//          z          z1          zg
// v(ft^3/lbm)     0.01614     333.55
// h(Btu/lbm)      69.725      1105.4
// s(Btu/lbm*F)    0.1326      1.9774
// u(Btu/lbm)      69.722      1043.6

//Thermo Properties
//----------------------------
// T= 101.71 degF
// P= 1.0000 psia
// v= 323.55 ft^3/lbm
// h= 1074.3 Btu/lbm
// s= 1.9221 Btu/lbm*F
// u= 1014.4 Btu/lbm
// x= 0.9700

//Region:Saturated
```

Chapter 6

The Ideal Gas

Scilab code Exa 6.1 `Boyles law`

```
clear;
clc;
printf("\t\t\tProblem Number 6.1\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.1 (page no. 241)
// Solution

P1=100; //Pressure at volume V1=100 ft^3 //Unit:psia
V1=100; //Unit:ft^3 //V1=Volume at 100 psia
P2=30 // Reduced Pressure //Unit:psia
//Boyle's law,P1*V1=P2*V2
V2=(P1*V1)/P2; //Volume occupied by the gas //ft^3
printf("Volume occupied by the gas = %f ft^3",V2);
```

Scilab code Exa 6.2 `Boyles law`

```
clear;
clc;
```

```
printf("\t\t\tProblem Number 6.2\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.2 (page no. 241)
// Solution

P1=10^6; //Pressure at volume V1=2 m^3 //Unit:Pa
V1=2; //Unit:m^3 //V1=Volume at 10^6 Pa
P2=8*10^6 // Increased Pressure //Unit:Pa
//Boyle's law,P1*V1=P2*V2
V2=(P1*V1)/P2; //Volume occupied by gas //unit:m^3
printf("Volume occupied by gas = %f m^3",V2);
```

Scilab code Exa 6.3 Charles law

```
clear;
clc;
printf("\t\t\tProblem Number 6.3\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.3 (page no. 242)
// Solution

T1=32+460; //Temperature at volume V1=150 ft^3 //Unit:R
V1=150; //Unit:ft^3 //V1=Volume at 32 F
T2=100+460 // Increased Temperature //Unit:R
//Charles's law,V1/V2 = T1/T2
V2=(T2*V1)/T1; //Volume occupied by gas //unit:m^3
printf("Volume occupied by gas = %f m^3",V2);
```

Scilab code Exa 6.4 Percent increase in ideal gas

```
clear;
clc;
```

```
printf("\t\t\tProblem Number 6.4\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.4 (page no. 242)
// Solution

//If for this process T2=1.25*T1,
// T2/T1 = 1.25
//Therefore,
// p2/p1 = T2/T1 //Charles's law(volume constant)
//Thus,
printf("The absolute gas pressure increases by 25 percent\n");
```

Scilab code Exa 6.5 `Determine Final volume`

```
clear;
clc;
printf("\t\t\tProblem Number 6.5\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.5 (page no. 242)
// Solution

V1=4; //m^3 //initial volume
T2=0+273; //celsius converted to kelvin  //gas is cooled to 0 C //final temperature
T1=100+273; //celsius converted to kelvin //initial temperature
V2=V1*(T2/T1); //final volume //Charles's law(pressure constant) //unit:m^3
printf("The final volume is %f m^3",V2);
```

Scilab code Exa 6.6 `The gas in the container`

```
clear;
clc;
printf("\t\t\tProblem Number 6.6\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.6 (page no. 245)
// Solution

//Let us first put each of the given variables into a consistent set of units:
p=(200+14.7)*(144); //Unit:psfa*(lbf/ft^2) //1 ft^2=144 in^2 //pressure
T=(460+73); //Fahrenheit temperature converted to absolute temperature //unit:R
V=120/1728;  //1 ft^3=1728 in^3 //total volume //unit:ft^3
R=1545/28; //Unit:ft*lbf/lbm*R //because the molecular weight of nitrogen is 28 //constant of proportionality
//Applying, p*v=R*T, //ideal gas law
v=(R*T)/p; //Unit:ft^3/lbm //specific volume
printf("The specific volume is %f ft^3/lbm\n",v);
//The mass of gas is the total volume divided by the specific volume
printf("The gas in the container is %f lbm\n",V/v);
//The same result is obtained by direct use of eq. p*V=m*R*T
m=(p*V)/(R*T); //The gas in the container //unit:lbm //ideal gas law
printf("The gas in the container is %f lbm\n",m);
```

Scilab code Exa 6.7 `Determine final pressure`

```
clear;
clc;
printf("\t\t\tProblem Number 6.7\n\n\n");
```

```
// Chapter 6: The Ideal Gas
// Problem 6.7 (page no. 245)
// Solution

//Applying , (p1*V1)/T1 = (p2*V2)/T2
//and p2=p1*(T2/T1) because V1=V2
p1=200+14.7; //Unit:psia //initial pressure
T2=460+200; //final temperature is 200 F //Fahrenheit temperature converted to absolute temperature //unit:R
T1=460+73; //Fahrenheit temperature converted to absolute temperature //unit:R
p2=p1*(T2/T1); //final pressure //Unit:psia //Charles's law(volume constant)
printf("The final pressure is %f psia",p2);
```

Scilab code Exa 6.8 `Determine the gas in the tank`

```
clear;
clc;
printf("\t\t\tProblem Number 6.8\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.8 (page no. 246)
// Solution

//For CO2,
R=8.314/44; //Unit:kJ/kg*K //constant of proportionality //Molecular weight of CO2=44
p=500; //Unit:kPa //pressure
V=0.5; //Unit:m^3 //volume
T=(100+273); //Unit:K //Celsius converted to kelvin
//Applying p*V=m*R*T ,
m=(p*V)/(R*T); //mass //kg //ideal gas law
printf("The mass of gas in the tank is %f kg\n",m);
```

Scilab code Exa 6.9 `Determine the mean specific heat`

```
clear;
clc;
printf("\t\t\tProblem Number 6.9\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.9 (page no. 252)
// Solution

T2=500+460;  //absolute  final temperature  //unit:R
T1=80+460;  //absolute initial temperature //unit:R
//The equation cpbar= 0.338-(1.24*10^2/T)+(4.15*10^4)/T^2 has a form , cbar= Adash+(Bdash/T)+(Ddash/T^2)
//So,
Adash=0.338;       //constant
Bdash=-1.24*10^2; //constant
Ddash=4.15*10^4;  //constant
//Therefore,from equation,cbar=Adash+((Bdash*log(T2/T1))/(T2-T1))+(Ddash/(T2*T1))
cpbar=Adash+((Bdash*log(T2/T1))/(T2-T1))+(Ddash/(T2*T1)); //The mean specific heat //Btu/lbm*R
printf("The mean specific heat at constant pressure between 80F and 500F is %f Btu/lbm*R\n",cpbar);
```

Scilab code Exa 6.10 `The mean specific heat at constant pressure`

```
clear;
clc;
printf("\t\t\tProblem Number 6.10\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.10 (page no. 252)
```

```
// Solution

//The table in Appendix 3 does not give us the
    enthalpy data at 960R and 540R that we need.
    Interpolating yields
//  T    hbar      T    hbar
// 537  3729.5    900  6268.1
// 540  3750.4    960  6694.0
// 600  4167.9    1000 6977.9
//So,
hbar540=3729.5+(3/63)*(4167.9-3729.5); //enthalpy //
    unit:Btu/lbm
hbar960=6268.1+(60/100)*(6977.9-6268.1);  //enthalpy
     //unit:Btu/lbm
//Note that hbar is given for a mass of 1 lb mole.To
     obtain the enthalpy per pound,it is necessary to
     divide the values og h by the molecular weight
    ,28.
h2=6694.0;  //enthalpy //unit:Btu/lbm
h1=3750.4;  //enthalpy //unit:Btu/lbm
T2=500+460; //absolute  final temperature //unit:R
T1=80+460; //absolute initial temperature //unit:R
cbar=(h2-h1)/(28*(T2-T1)); //The mean specific heat
    at constant pressure  //unit:Btu/lbm*R
printf("The mean specific heat at constant pressure
    is %f Btu/lbm*R\n",cbar);
//With the more extesive Gas tables,these
    interpolations are avoided.The Gas Tables provide
     a relatively easy and accurate method of
    obtaining average specific heats.Also,these
    tables have been computerized for ease of
    application.
```

Scilab code Exa 6.11 Determine the mean specific heat

```
clear;
clc;
printf("\t\t\tProblem Number 6.11\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.11 (page no. 253)
// Solution

T2=500+460; //absolute  final temperature  //unit:R
T1=80+460; //absolute initial temperature  //unit:R
//cp=0.219 + (3.42*10^-5*T) - (2.93*10^-9*T^2); //
    Unit:Btu/lbm*R
//Comparing with c=A+(B*T)+(D*T^2)
A=0.219;          //constant
B=3.42*10^-5;     //constant
D=2.93*10^-9;     //constant
//Using these values and equation cbar=A+((B/2)(T2+
    T1))+((D/3)*(T2^2+(T2*T1)+T1^2))
cpbar=A+((B/2)*(T2+T1))+((D/3)*(T2^2+(T2*T1)+T1^2));
     //The mean specific heat //Btu/lbm*R
printf("The mean specific heat at constant pressure
    for air between 80F and 500F is %f Btu/lbm*R\n",
    cpbar);
```

Scilab code Exa 6.12 Determine cv

```
clear;
clc;
printf("\t\t\tProblem Number 6.12\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.12 (page no. 255)
// Solution

//The molecular weight of oxygen is 32.Therefore,
R=1545/32; //Unit:ft*lbf/lbm*R //constant of
    proportionality
```

```
J=778; //conversion factor
cp=0.24; //Unit:Btu/lbm*R //specific heat at
    constant pressure
//cp-cv=R/J
cv=cp-(R/J); //specific heat at constant volume //
    unit:Btu/lbm*R
printf("Specific heat at constant volume is %f Btu/
    lbm*R\n",cv);
```

Scilab code Exa 6.13 Determine cv and cp in SI units

```
clear;
clc;
printf("\t\t\tProblem Number 6.13\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.13 (page no. 255)
// Solution

//From equation,cv=R/(k-1) ,
R=8.314/32; //constant of proportionality //kJ/kg*K
    //The molecular weight of oxygen is 32
k=1.4 //for oxygen //given //k=cp/cv
cv=R/(k-1); //Specific heat at constant volume //
    unit:kJ/kg*K
printf("Specific heat at constant volume is %f kJ/kg
    *K\n",cv);
cp=k*cv; //specific heat at constant pressure //Unit
    :kJ/kg*K
printf("Specific heat at constant pressure is %f kJ/
    kg*K\n",cp);
```

Scilab code Exa 6.14 Determine k cp and cv for the gas

```
clear;
clc;
printf("\t\t\tProblem Number 6.14\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.14 (page no. 255)
// Solution

R=60; //Unit:ft*lbf/lbm*R //constant of proportionality
deltah=500; //Btu/lbm //change in enthalpy
deltau=350; //Btu/lbm //change in internal energy
J=778; //conversion factor
//Because deltah-(cp*deltaT) and deltau=cv*deltaT
// deltah/deltau=(cp*deltaT)/(cv*deltaT)=cp/cv=k
k=deltah/deltau; //Ratio of specific heats
printf("Ratio of specific heats k is %f\n",k);
//From equation cv=R/(J*(k-1))
cv=R/(J*(k-1)); //specific heat at constant volume //Btu/lbm*R
printf("Specific heat at constant volume is %f Btu/lbm*R\n",cv);
cp=k*cv; //Specific heat at constant pressure //Btu/lbm*R
printf("Specific heat at constant pressure is %f Btu/lbm*R\n",cp);
```

Scilab code Exa 6.15 Find the specific heat at constant pressure

```
clear;
clc;
printf("\t\t\tProblem Number 6.15\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.15 (page no. 256)
// Solution

```

```
//When solving this type of problem,it is necessary to note carefully the information given and to write the correct energy equation for this process.Because the    process is carried out at constant volume,the heat added equals the change in inernal energy.Because the change in internal energy per pound for the ideal gas is       cv*(T2-T1),the total change in internal energy for m pounds must equals the heat added.Thus,
//data given
Q=0.33; //heat
//Initial conditions
V=60; //in^3 //volume
m=0.0116; //lbs //mass
p1=90; //psia //pressure
T1=460+40; //Fahrenheit temperature converted to absolute temperature
//Final condition=Initial condition + heat
V=60; //in^3 //volume
m=0.0116; //lbs //mass
p2=108; //psia //pressure
T2=460+140; //Fahrenheit temperature converted to absolute temperature //unit:R
//Q=m*(u2-u1)=m*cv*(T2-T1)
cv=Q/(m*(T2-T1)); //specific heat at constant volume //Btu/lbm*R
printf("Specific heat at constant volume is %f Btu/lbm*R\n",cv);
//To obtain cp,it is first necessary to obtain R. Enough information was given in the initial conditions of the problem to apply eqn. p*V=m*R*T
R=(144*p1*(V/1728))/(m*T1); //1 ft^2=144 in^2 //1 ft^3=1728 in^3 //Unit:ft*lbf/lbm*R //constant of proportionality
printf("Constant of proportionality R is %f ft*lbf/lbm*R\n",R);
//cp-cv=(R/J)
J=778; //conversion factor
```

```
cp=cv+(R/J); //Specific heat at constant pressure //Btu/lbm*R
printf("Specific heat at constant pressure is %f Btu/lbm*R\n",cp);
```

Scilab code Exa 6.16 Determine the change in entropy

```
clear;
clc;
printf("\t\t\tProblem Number 6.16\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.16 (page no. 260)
// Solution

//data
cp=0.24; //Specific heat at constant pressure //Btu/lbm*R
p2=15; //psia //final pressure
p1=100; //psia //initial pressure
T2=460+0;  //absolute  final temperature //unit:R
T1=460+100; //absolute initial temperature  //unit:R
J=778; //conversion factor
R=1545/29; //moleculer weight=29 //Unit:ft*lbf/lbm*R  //constant of proportionality
 //On the basis of the data given,
deltas=(cp*(log(T2/T1)))-((R/J)*(log(p2/p1))); //change in entropy //Btu/lbm*R
printf("The change in enthalpy is %f Btu/lbm*R\n",deltas);
```

Scilab code Exa 6.17 Determine change in entropy

```
clear;
```

```
clc;
printf("\t\t\tProblem Number 6.17\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.17 (page no. 261)
// Solution

//data of problem6.16
cp=0.24; //Specific heat at constant pressure //Btu/lbm*R
p2=15; //psia //final pressure
p1=100; //psia //initial pressure
T2=460+0;  //absolute final temperature //unit:R
T1=460+100; //absolute initial temperature //unit:R
J=778; //conversion factor
R=1545/29; //moleculer weight=29 //Unit:ft*lbf/lbm*R //constant of proportionality
//Because cp and R are given,let us first solve for cv,
//cp=(R*k)/(J*(k-1))
k=(cp*J)/((cp*J)-R); //k=cp/cv //ratio of specific heats
printf("Ratio of specific heats k is %f\n",k);
//k=cp/cv
cv=cp/k; //Specific heat at constant volume //Btu/lbm*R
printf("Specific heat at constant volume is %f Btu/lbm*R\n",cv);
//Now, deltas=(cv*log(p2/p1))+(cp*log(v2/v1));
//But, v2/v1=(T2*p1)/(T1*p2)
v2byv1=(T2*p1)/(T1*p2); // v2/v1 //unitless
deltas=(cv*log(p2/p1))+(cp*log(v2byv1)); //The change in enthalpy //unit:Btu/lbm*R
printf("The change in enthalpy is %f Btu/lbm*R\n",deltas);
//The agreement is very good.
```

Scilab code Exa 6.18 Determine the change in entropy

```
clear;
clc;
printf("\t\t\tProblem Number 6.18\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.18 (page no. 261)
// Solution

//data,
cp=0.9093; //Specific heat at constant pressure //kJ/kg*R
p2=150; //kPa //final pressure
p1=500; //kPa //initial pressure
T2=273+0;  //final temperature //Celsius converted to kelvin
T1=273+100; //initial temperature //Celsius converted to kelvin
//J=778; //conversion factor
R=8.314/32; //moleculer weight of oxygen=32 //Unit: ft*lbf/lbm*R //constant of proportionality
//Using equation, and dropping J gives,
deltas=(cp*(log(T2/T1))-((R)*(log(p2/p1))); //change in entropy //kJ/kg*K
//For 2 kg,
deltaS=2*deltas; //The change in enthalpy in kJ/K
printf("For 2 kg oxygen,The change in enthalpy is %f kJ/K\n",deltaS);
```

Scilab code Exa 6.19 Determine the increase in pressure

```
clear;
```

```
clc;
printf("\t\t\tProblem Number 6.19\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.19 (page no. 262)
// Solution

//from the equation, deltas/cv = (k*log(v2/v1))+ log
   (p2/p1) //change in entropy
k=1.4; //k=cp/cv //ratio of specific heats
//deltas=(1/4)*cv //so,
// 1/4= (k*log(v2/v1))+ log(p2/p1)
v2=1/2; //Because,v2=(1/2)*v1  //initial specific
   volume
v1=1;   //final specific volume
p2byp1=exp((1/4)-(k*log(v2/v1))); //increase in
   pressure
printf("p2/p1=%f\n",p2byp1);
printf("So,increase in pressure is %f ",p2byp1);
```

Scilab code Exa 6.20 Determine change in entropy

```
clear;
clc;
printf("\t\t\tProblem Number 6.20\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.20 (page no. 264)
// Solution

//data
T2=460+270; //Fahrenheit temperature converted to
   absolute final temperature //unit:R
T1=460+70; //Fahrenheit temperature converted to
   absolute initial temperature //unit:R
cv=0.17; //specific heat at constant volume //Btu/
   lbm*R
```

```
//Now,
deltas=cv*log(T2/T1); //change in entropy //Unit:Btu/lbm*R
//For 1/2 lb,
deltaS=(1/2)*deltas; //The change in enthalpy in Btu/R
printf("For 1/2 lb of gas,The change in enthalpy is %f Btu/R\n",deltaS);
```

Scilab code Exa 6.21 Determine the change in entropy

```
clear;
clc;
printf("\t\t\tProblem Number 6.21\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.21 (page no. 264)
// Solution

//data
T2=100+273; //Celsius temperature converted to Kelvin //final temperature
T1=20+273; //Celsius temperature converted to Kelvin //initial temperature
cv=0.7186; //specific heat at constant volume //kJ/kg*K
//Now,
deltas=cv*log(T2/T1); //change in entropy //Unit:kJ/kg*K
//For 0.2 kg,
deltaS=(0.2)*deltas; //The change in enthalpy in kJ/K
printf("For 0.2 kg of air,The change in enthalpy is %f kJ/K\n",deltaS);
```

Scilab code Exa 6.22 Determine the higher temperature

```
clear;
clc;
printf("\t\t\tProblem Number 6.22\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.22 (page no. 264)
// Solution

//data
deltas=0.0743; //change in entropy //Unit:Btu/lbm*R
T1=460+100; //Fahrenheit temperature converted to
    absolute initial temperature
cv=0.219; //specific heat at constant volume //Btu/
    lbm*R
//Now,
//deltas=cv*log(T2/T1);
T2=T1*exp(deltas/cv); //higher temperature //
    absolute temperature //unit:R
printf("The higher temperature is %f R\n",T2)
```

Scilab code Exa 6.23 Determine the initial temperature

```
clear;
clc;
printf("\t\t\tProblem Number 6.23\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.23 (page no. 265)
// Solution

//data
deltaS=0.4386; //change in entropy //Unit:kJ/K
```

```
T2=273+425; //Celsius temperature converted to kelvin //initial temperature
cv=0.8216; //specific heat at constant volume //kJ/kg*K
m=1.5; //mass //kg
//Now,
//deltas=m*cv*log(T2/T1);
T1=T2/(exp(deltaS/(m*cv))) //initial temperature //unit:K
printf("The initial temperature of the process is %f K or %f C\n",T1,T1-273)
```

Scilab code Exa 6.24 Determine deltas deltas and flow work

```
clear;
clc;
printf("\t\t\tProblem Number 6.24\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.24 (page no. 267)
// Solution

//data given
T2=460+400; //Fahrenheit temperature converted to absolute final temperature //unit:R
T1=460+70; //Fahrenheit temperature converted to absolute initial temperature //unit:R
cp=0.24; //specific heat at constant pressure //Btu/lbm*R
J=778; //conversion factor
R=1545/29; //moleculer weight=29 //Unit:ft*lbf/lbm*R //constant of proportionality
//From the energy equation for the constant-pressure process,the heat transferred is deltah.Therefore,
//q=deltah=cp*(T2-T1)
```

```
deltah=cp*(T2-T1); //heat transferred //Btu/lb //into system
printf("The heat transferred is %f Btu/lb(into system)\n",deltah);
deltas=cp*log(T2/T1); //increase in entropy //Btu/lbm*R
printf("The increase in entropy is %f Btu/lbm*R\n",deltas);
//The flow work change is (p2*v2)/J - (p1*v1)/J = (R/J)*(T2-T1)
flowworkchange=(R/J)*(T2-T1); //Btu/lbm //The flow work change per pound of air
printf("The flow work change per pound of air is %f Btu/lbm\n",flowworkchange);
//In addition to each of the assumptions made in all the process being considered,it has further been tacitly assumed that these processes are carried out quasi-      statically and without friction.
```

Scilab code Exa 6.25 Determine the heat transferred and the increase in entropy pe

```
clear;
clc;
printf("\t\t\tProblem Number 6.25\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.25 (page no. 268)
// Solution

//data given
T2=500+273; //Celsius temperature converted to Kelvin //final temperature
T1=20+273; //Celsius temperature converted to Kelvin //initial temperature
cp=1.0062; //specific heat at constant pressure //kJ/kg*K
```

```
//From the energy equation for the constant-pressure process,the heat transferred is deltah.Therefore,
//q=deltah=cp*(T2-T1)
deltah=cp*(T2-T1); //heat transferred //kJ/kg //into system
printf("The heat transferred is per kilogram of air %f kJ/kg\n",deltah);
deltas=cp*log(T2/T1); //increase in entropy //kJ/kg*K
printf("The increase in entropy per kilogram of air is %f kJ/kg*K\n",deltas);
```

Scilab code Exa 6.26 Determine the heat added and work out of the system

```
clear;
clc;
printf("\t\t\tProblem Number 6.26\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.26 (page no. 270)
// Solution

//data given
v2=2; //Because,v2=(2)*v1 //volume increases to its twice its final volume
v1=1; //initial volume
T=460+200; //Fahrenheit temperature converted to absolute temperature
J=778; //conversion factor
R=1545/28; //moleculer weight of nitrogen=28 //Unit:ft*lbf/lbm*R //constant of proportionality
//From the equation, w/J=q=T*deltas=((R*T)/J)*log(v2/v1)
q=((R*T)/J)*log(v2/v1); //Btu/lbm //the heat added to system
```

```
//For 0.1 lb,
Q=0.1*q; //Btu //the heat added to system
printf("The heat added to system is %f Btu\n",Q);
//The work out of the system is equal to the heat added;thus,
WbyJ=Q; //The work out of the system(out of the system) //unit:Btu
printf("The work out of the system is %f Btu(out of the system)\n",WbyJ);
```

Scilab code Exa 6.27 Determine the heat added and workout of the system

```
clear;
clc;
printf("\t\t\tProblem Number 6.27\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.27 (page no. 270)
// Solution

//data given
T=50+273; //Celsius temperature converted to Kelvin //final temperature //unit:K
v2=1/2; //Because,v2=(1/2)*v1 //volume increases to its half its final volume
v1=1;
R=8.314/32; //moleculer weight of oxygen=32 //Unit:kJ/kg*K //constant of proportionality
//From the equation, q=((R*T))*log(v2/v1)
q=R*T*log(v2/v1); //heat added //kJ/kg
printf("The heat added to system is %f kJ/kg(heat out of system)\n",q);
//The work out of the system is equal to the heat added;thus,
W=q; //The work out of the system //unit:kJ/kg
printf("The work out of the system is %f kJ/kg(into
```

```
system)\n",W);
```

Scilab code Exa 6.28 Determine the change in entropy

```
clear;
clc;
printf("\t\t\tProblem Number 6.28\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.28 (page no. 271)
// Solution

//data given in problem 6.27
T=50+273; //Celsius temperature converted to Kelvin
    //final temperature
v2=1/2; //Because,v2=(1/2)*v1 //volume increases to
    its half its final volume
v1=1;
R=8.314/32; //moleculer weight of oxygen=32 //Unit:
    kJ/kg*K //constant of proportionality
//From the equation, q=((R*T))*log(v2/v1)
q=R*T*log(v2/v1); //heat added //kJ/kg
printf("The heat added to system is %f kJ/kg(heat
    out of system)\n",q);
//For a constant temperature,
deltas=q/T; //Change in entropy //unit:kJ/kg*K
printf("The change in entropy is %f kJ/kg*K\n",
    deltas);
```

Scilab code Exa 6.29 Determine the final state and work done by the air

```
clear;
clc;
printf("\t\t\tProblem Number 6.29\n\n\n");
```

```
// Chapter 6: The Ideal Gas
// Problem 6.29 (page no. 274)
// Solution

//data given
T1=1000; //absolute initial temperature //unit:R
p2=1; //unit:atm //absolute final pressure
p1=5; //unit:atm //absolute initial pressure
J=778; //conversion factor
R=1545/29; //moleculer weight=29 //Unit:ft*lbf/lbm*R //constant of proportionality
k=1.4; //k=cp/cv //ratio of specific heats
//From the equation,
T2=T1*((p2/p1)^((k-1)/k)); //Unit:R //The absolute final temperature
printf("The absolute final temperature is %f R\n",T2);
work=(R*(T2-T1))/(J*(1-k)); //Btu/lbm //The work done by air(out)
printf("The work done by air is %f Btu/lbm(out)\n",work)
```

Scilab code Exa 6.30 Determine the final state and work done

```
clear;
clc;
printf("\t\t\tProblem Number 6.30\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.30 (page no. 274)
// Solution

//data given
//mass of 1 kg
T1=500+273; //Celsius temperature converted to Kelvin //final temperature
```

```
p2=1; //atm //absolute final pressure
p1=5; //atm //absolute initial pressure
J=778; //conversion factor
R=8.314/29; //moleculer weight=29 //Unit:kJ/kg*K //constant of proportionality
k=1.4; //k=cp/cv //ratio of specific heat
//From the equation,
T2=T1*((p2/p1)^((k-1)/k)); //Unit:Kelvin //The absolute final temperature
printf("The absolute final temperature is %f K or %f C\n",T2,T2-273);
work=(R*(T2-T1))/((1-k)); //kJ/kg //The work done by air(out)
printf("The work done by air is %f kJ/kg(out)\n",work)
```

Scilab code Exa 6.31 Determine value of k

```
clear;
clc;
printf("\t\t\tProblem Number 6.31\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.31 (page no. 275)
// Solution

//data given
T1=800+273; //Celsius temperature converted to Kelvin //initial temperature
T2=500+273; //Celsius temperature converted to Kelvin //final temperature
p2=1; //atm //absolute final pressure
p1=5; //atm //absolute initial pressure
//A gas expands isentropically
//From the equation,
//T2/T1=((p2/p1)^((k-1)/k));
```

```
//rearranging,
k=inv(1-((log(T2/T1)/log(p2/p1)))); //k=cp/cv //
   Ratio of specific heats
printf("Ratio of specific heats (k) is %f\n",k);
```

Scilab code Exa 6.32 Determine q work and change in entropy

```
clear;
clc;
printf("\t\t\tProblem Number 6.32\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.32 (page no. 279)
// Solution

//data given
n=1.3; //p*v^1.3=constant
k=1.4; //k=cp/cv Ratio of specific heats
cp=0.24; //specific heat at constant pressure //Btu/
   lbm*R
T2=600; //absolute final temperature //unit:R
T1=1500; //absolute initial temperature //unit:R
R=53.3; //Unit:ft*lbf/lbm*R //constant of
   proportionality
J=778; //conversion factor
cv=cp/k; //specific heat at constant volume //Btu/
   lbm*R
//Therefore,
cn=cv*((k-n)/(1-n)); //Polytropic specific heat //
   Btu/lbm*R
printf("Polytropic specific heat(cn) is %f Btu/lbm*R
   \n",cn);
//The negative sign of cn indicates that either the
   heat transfer for the process comes from the
   system or there is a negative temperature change
   while heat is         transferred to the system.
```

```
//The heat transferred is cn*(T2-T1).Therefore,
q=cn*(T2-T1); //heat transferred //Btu/lbm(to the system)
printf("The heat transferred is %f Btu/lbm(to the system)\n",q);
//The work done can be found using equation,
w=(R*(T2-T1))/(J*(1-n)); //Btu/lbm //the workdone(from the system)
printf("The work done is %f Btu/lbm(from the system)\n",w);
deltas=cn*log(T2/T1)' //change in entropy //Btu/lbm*R
printf("The change in enthalpy is %f Btu/lbm*R\n",deltas);
```

Scilab code Exa 6.33 `Ratio of inlet pressure to outlet pressure`

```
clear;
clc;
printf("\t\t\tProblem Number 6.33\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.33 (page no. 279)
// Solution

//data given in problem 6.32,
n=1.3; //p*v^1.3=constant
k=1.4; //k=cp/cv //ratio of specific heats
cp=0.24; //specific heat at constant pressure //Btu/lbm*R
T2=600; //absolute final temperature //unit:R
T1=1500; //absolute initial temperature //unir:R
R=53.3; //Unit:ft*lbf/lbm*R //constant of proportionality
J=778; //conversion factor
//Equation,
```

```
// T1/T2=((p1/p2)^((n-1)/n));
//rearranging,
p1byp2=exp(log(T1/T2)/((n-1)/n)); //The ratio of
   inlet to outlet pressure
printf("The ratio of inlet to outlet pressure is %f\
   n",p1byp2);
```

Scilab code Exa 6.34 Change in enthalpy internal energy and entropy

```
clear;
clc;
printf("\t\t\tProblem Number 6.34\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.34 (page no. 284)
// Solution

//From the table at 1000 R:                        //
   From the table at 500 R:
h2=240.98;                                          h1
   =119.48;
//Btu/lbm //enthalpy                                //
   Btu/lbm //enthalpy
u2=172.43;                                          u1
   =85.20;
//Btu/lbm //internal energy                         //
   Btu/lbm //internal energy
fy2=0.75042;                                        fy1
   =0.58233;
//Btu/lbm*R                                         //
   Btu/lbm*R

//The change in enthalpy is
deltah=h2-h1; //Btu/lbm
//The change in internal energy is
deltau=u2-u1; //Btu/lbm
```

```
printf("The change in enthalpy is %f Btu/lbm & the change in internal energy is %f Btu/lbm\n",deltah,deltau);
//Because in the constant-pressure process -R*log(p2/p1) is zero,
deltas=fy2-fy1; //Btu/lbm*R //The entropy when air is heated at constant pressure
printf("The entropy when air is heated at constant pressure is %f Btu/lbm/R\n",deltas);
```

Scilab code Exa 6.35 Determine final temperature and workdone

```
clear;
clc;
printf("\t\t\tProblem Number 6.35\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.35 (page no. 285)
// Solution

//In this problem,the air expands from 5 atm absolute to 1 atm absolute from an initial temperature of 1000R,
pr=12.298; //relative pressure //unit:atm
h=240.98; //Btu/lbm //enthalpy
pr=12.298/5; //The value of the final relative pressure //unit:atm
//Interpolation in the air table yields the following:
//    T      pr
//   620    2.249
//          2.4596
//   640    2.514
T=620+(((2.4596-2.249)/(2.514-2.249))*20); //the final temperature //unit:R
printf("The absolute final temperature is %f R\n",T)
```

```
;
u1=172.43; //initial internal energy //Btu/lbm
u2=108.51; //final internal energy //Btu/lbm
work=u1-u2; //Btu/lbm The work done by air in an
   isentropic nonflow expansion //where the value of
    u2 is obtained by interpolation at T
   temperature and the value of u1 is read from the
   air table at 1000 R.
printf("The work done by air in an isentropic
   nonflow expansion is %f Btu/lbm(out)\n",work)
```

Scilab code Exa 6.36 Determine the velocity of sound air and hydrogen

```
clear;
clc;
printf("\t\t\tProblem Number 6.36\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.36 (page no. 288)
// Solution

T=1000+460; //Fahrenheit temperature converted to
   absolute temperature
//The velocity of sound in air at 1000 F is
Va=49.0*sqrt(T); //velocity //ft/s
printf("The velocity of sound air at 1000 F is %f ft
   /s\n",Va);
//Hydrogen has a specific heat ratio of 1.41 and R
   =766.53.Therefore,
khydrogen=1.41; //specific heats ratio for air
kair=1.40; //specific heats ratio for air
Rhydrogen=766.53; //gas constant //ft*lbf/lbm*R
Rair=53.36; //gas constant //ft*lbf/lbm*R
// Vahydrogen/Vaair = sqrt((Rhydrogen*khydrogen)/(
   Rair*kair))
//rearranging,
```

```
Vahydrogen=Va*sqrt((Rhydrogen*khydrogen)/(Rair*kair)
    ); //The velocity of sound in hydrogen at 1000 F
    //unit:ft/s
printf("The velocity of sound in hydrogen at 1000 F
    is %f ft/s\n",Vahydrogen);
```

Scilab code Exa 6.37 Determine the mach number

```
clear;
clc;
printf("\t\t\tProblem Number 6.37\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.37 (page no. 288)
// Solution

T=200+460; //Fahrenheit temperature converted to
    absolute temperature //unit:R
V=1500; //ft/s //the local velocity
Va=49.0*sqrt(T); //velocity of sound air at 200 F
    //unit:ft/s
printf("The velocity of sound air at 200 F is %f ft/
    s\n",Va);
M=V/Va; //The Mach number=the local velocity/
    velocity of sound //unitless
printf("The Mach number is %f\n",M);
```

Scilab code Exa 6.38 Determine the total enthalpy

```
clear;
clc;
printf("\t\t\tProblem Number 6.38\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.38 (page no. 290)
```

```
// Solution

//data given
V=1000; //ft/s //the fluid velocity
gc=32.17; //Unit:(LBm*ft)/(LBf*s^2) //gc is constant
    of proportionality
J=778; //conversion factor
h=1204.4; //Btu/lbm //enthalpy of saturated steam
//h0-h=V^2/(2*gc*J)
h0=h+((V^2)/(2*gc*J)); //Btu/lbm //h0=stagnation
    enthalpy
printf("The total enthalpy is %f Btu/lbm\n",h0);
//It will be noted for this problem that if the
    initial velocity had been 100ft/s,deltah would
    have been 0.2 Btu/lbm,and for most practical
    purpposes,the total     properties and those of
    the flowing fluid would have been essentially the
     same.Thus,for low-velocity fluids,the difference
     in total and steam properties can be
    neglected.
```

Scilab code Exa 6.39 Converging and Diverging Nozzles

```
clear;
clc;
printf("\t\t\tProblem Number 6.39\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.39 (page no. 297)
// Solution

k=1.4; //the specific heats ratio //k=cp/cv
M=1; //(table 6.5) //The Mach number=the local
    velocity/velocity of sound
T0=800; //absolute temperature //unit:R
gc=32.17; //Unit:(LBm*ft)/(LBf*s^2) //gc is constant
```

```
of proportionality
R=53.35; //gas constant //ft*lbf/lbm*R
p0=300; //psia //pressure

// * or "star" subscripts to conditions in which M =1;
// "0" subscript refers to isentropic stagnation
//Refer to figure 6.26,
//Tstar/T0=0.8333
Tstar=T0*0.8333; //temperature when M=1 //unit:R
printf("If the mach number at the outlet is unity, temperature is %f R\n",Tstar);
Vat=sqrt(gc*R*Tstar*k); //ft/s //Vat=V2 //local velocity of sound
printf("If the mach number at the outlet is unity, velocity is %f ft/s\n\n",Vat)

//For A/Astar=2.035
//The table yields
M1=0.3; //mach number at inlet
printf("At inlet,The mach number is %f\n",M1)
//pstar/p0=0.52828
pstar=p0*0.52828;  //pressure when M=1 //psia
//also,
//T1/T0=0.98232 and p1/p0=0.93947
//Therefore,
T1=T0*0.982332; //unit:R //T1=temperature at inlet
printf("At inlet,The temperature is %f R\n",T1);
p1=p0*0.93947; //psia //p1=pressure at inlet
printf("At inlet,The pressure is %f psia\n",p1);
//From the inlet conditions derived,
Va1=sqrt(gc*k*R*T1); //ft/s //V1=velocity at inlet
V1=M1*Va1; //ft/s //velocity
printf("At inlet,The velocity is %f ft/s\n",V1);
//The specific volume at inlet is found from the equation of state for an ideal gas:
v=(R*T1)/(p1*144); //ft^3/lbm //1 ft^2=144 in^2(for conversion of unit) //specific volume
```

```
rho=inv(v); //inverse of specific volume //density
A=2.035; //area //ft^2
m=rho*A*V1; //mass flow //unit:lbm/s
printf("At inlet ,The mass flow is %f lbm/s\n",m);
```

Scilab code Exa 6.40 Converging and Diverging Nozzles

```
clear;
clc;
printf("\t\t\tProblem Number 6.40\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.40 (page no. 299)
// Solution

// * or "star" subscripts to conditions in which M
   =1;
// "0" subscript refers to isentropic stagnation
//This problem will be solved by two methods(A and B
   )
printf("Method A\n"); //By equations:
k=1.4; //the specific heat ratio //k=cp/cv
R=53.3; //gas constant //ft*lbf/lbm*R
M=2.5; //mach number=the local velocity/velocity of
   sound
printf("Solution for (a)\n");
// T/Tstar = (k+1)/(2*(1+((1/2)*(k-1)*M^2)))
// Tstar/T0=2/(k+1)
//Therefore ,
// (Tstar/T0)*(T/Tstar) = (T/T0)=1/(1+((1/2)*(k-1)*M
   ^2))
T0=560; //absolute temperature or stagnation
   temperature //unit:R
T=T0/(1+((1/2)*(k-1)*M^2)); //temperature at M=2.5
printf("The temperature is %f R\n\n",T);
printf("Solution for (b)\n");
```

```
p=0.5; //static pressure //unit:psia
// p0/p = (T0/T)^(k/(k-1))
p0=p*14.7*((T0/T)^(k/(k-1))); //pressure at M=2.5 //unit:psia
printf("The pressure is %f psia\n\n",p0);
printf("Solution for (c)\n");
gc=32.17; //Unit:(LBm*ft)/(LBf*s^2) //gc is constant of proportionality
Va=sqrt(gc*k*R*T); //ft/s //local velocity of sound
V=M*Va; //valocity at M=2.5 //unit:ft/s
printf("The velocity is %f ft/s\n\n",V);
printf("Solution for (d)\n");
v=(R*T)/(p*14.7*144); //ft^3/lbm //1 ft^2=144 in^2 //specific volume at M=2.5
printf("The specific volume is %f ft^3/lbm\n\n",v);
printf("Solution for (e)\n");
//Mass velocity is definrd as the mass flow per unit area
// m/A=(A*V)/(v*A)=V/v
printf("The mass velocity is %f lbm/(s*ft^2)\n\n\n",V/v); //mass velocity at M=2.5


printf("Method B\n"); //By the gas tables: //table 6.5 gives
M=2.5; //mach number=the local velocity/velocity of sound
printf("Solution for (a)\n");
T0=560; //absolute temperature or stagnation temperature
//T/T0=0.44444
T=T0*0.44444; //temperature at M=2.5
printf("The temperature is %f R\n\n",T)
printf("Solution for (b)\n");
p=0.5; //static pressure
//p/p0=0.05853
p0=(p*14.7)/0.05853; //pressure at M=2.5
printf("The pressure is %f psia\n\n",p0);
```

```
printf("Solution for (c)\n");
printf("As before %f ft/s\n\n",V)
printf("Solution for (d)\n");
printf("As before %f ft^3/lbm\n\n",v)
printf("Solution for (e)\n");
printf("As before %f lbm/(s*ft^1)\n",V/v)
```

Scilab code Exa 6.41 Real Gases

```
clear;
clc;
printf("\t\t\tProblem Number 6.41\n\n\n");
// Chapter 6: The Ideal Gas
// Problem 6.41 (page no. 304)
// Solution

//For Methane(CH4,MW=16)
p=500; //evaluate specific volume at p pressure //Unit:psia
pc=674; //critical temperature //Unit:psia
T=50+460; //evaluate specific volume at T temperature //Unit:R
Tc=343; //critical temperature //Unit:R
R=1545/16; //gas constant R = 1545/Molecular Weight //ft*lbf/lbm*R
pr=p/pc; //reduced pressure //unit:psia
Tr=T/Tc; //reduced temperature //unit:R
//Reading figure 6.28 at these values gives
Z=0.93; //compressibility factor
//Z=(p*v)/(R*T)
v=Z*((R*T)/(p*144)); //ft^3/lbm //1 ft^2=144 in^2(for conversion of unit) //specific volume
printf("Using the value of Z=0.93,the specific volume is %f ft^3/lbm\n",v);
//For ideal gas,
```

```
v=(R*T)/(p*144); //ft^3/lbm //1 ft^2=144 in^2(for
    conversion of unit) //specific volume
printf("For the ideal gas,the specific volume is %f
    ft^3/lbm\n",v);
```

Chapter 7

Mixtures Of Ideal Gases

Scilab code Exa 7.1 Dry air mixture of oxygen and nitrogen

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.1\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.1  (page no. 322)
// Solution

//As the basis of the calculation,assume that we
   have 1 lbm of mixture.Also,take the molecular
   weight of oxygen to be 32.00 and nitrogen to be
   28.02.(from table7.1)
printf("Solution for (a)\n");
nO2=0.2315/32; //no of moles of oxygen=ratio of mass
    and molecular weight //0.2315 lb of oxygen per
   pound
printf("The moles of oxygen is %f mole/lbm of
   mixture\n",nO2);
nN2=0.7685/28.02; //no of moles of nitrogen=ratio of
    mass and molecular weight //0.7685 lb of
   nitrogen per pound
```

```
printf("The moles of nitrogen is %f mole/lbm of mixture\n",nN2);
nm=nO2+nN2; //Unit:Mole/lbm //number of moles of gas mixture is sum of the moles of its constituent gases
printf("The total number of moles is %f mole/lbm\n",nm);
xO2=nO2/nm; //mole fraction of oxygen=ratio of no of moles of oxygen and total moles in mixture
xN2=nN2/nm; //mole fraction of nitrogen=ratio of no of moles of oxygen and total moles in mixture
printf("The mole fraction of oxygen is %f and the mole fraction of nitrogen is %f\n",xO2,xN2);
//(Check:xO2+xN2=1)
printf("xO2+xN2=%f\n\n",xO2+xN2);

printf("Solution for (b)\n");
// the air is at 14.7 psia
pO2=xO2*14.7; //the partial pressure of oxygen=pressure of air * the mole fraction of oxygen //psia
printf("The partial pressure of oxygen is %f psia\n",pO2);
pN2=xN2*14.7; //the partial pressure of nitrogen=pressure of air * the mole fraction of nitrogen //psia
printf("The partial pressure of nitrogen is %f psia\n\n",pN2);

printf("Solution for (c)\n");
MWm=(xO2*32) + (xN2*28.02); //the molecular weight of air=sum of products of mole fraction of each gas component
printf("The molecular weight of air is %f\n\n",MWm);

printf("Solution for (d)\n");
Rm=1545/MWm; //the gas constant of air
printf("The gas constant of air is %f\n\n",Rm);
```

Scilab code Exa 7.2 Determine molecular weight and partial pressure

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.2\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.2 (page no. 323)
// Solution

//For Gaseous Freon-12 (CCl2F2)
//MW of air=29 & MW of freon-12=120.9
//initial pressure in tank is atmospheric pressure
    that is 14.7 psia
//final pressure of tank is 1000 psia
//The partial pressure of the Freon-12 is 1000-14.7
printf("The partial pressure of the Freon-12 is %f\n
    ",1000-14.7)
//the mole fraction of air=the initial pressure /
    final pressure
printf("The mole fraction of air is %f\n",14.7/1000)
//the mole fraction of freon=the partial pressure of
     freon / the final pressure
printf("The mole fraction of Freon-12 is %f\n"
    ,(1000-14.7)/1000)
MWm=((14.7/1000)*29) + (((1000-14.7)/1000)*120.9);//
    the molecular weight of mixture=sum of products
    of mole fraction of each gas component
printf("The molecular weight of the mixture is %f",
    MWm);
```

Scilab code Exa 7.3 Determine moles moles fraction molecular weight and gas consta

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.3\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.3 (page no. 323)
// Solution

//Ten pounds of air,1 lb of carbon dioxide,and 5 lb of nitrogen are mixed at constant temperature until the mixture pressure is constant
nair=10/29; //no of moles of air=ratio of mass and molecular weight //10 lb of nitrogen per pound //molecular weight of air=29
printf("The moles of air is %f mole/lbm of mixture\n",nair);
nCO2=1/44; //no of moles of carbon dioxide=ratio of mass and molecular weight //1 lb of per pound //molecular weight of CO2=44
printf("The moles of carbon dioxide is %f mole/lbm of mixture\n",nCO2);
nN2=5/28; //no of moles of nitrogen=ratio of mass and molecular weight //5 lb of nitrogen per pound //molecular weight of N2=28
printf("The moles of nitrogen is %f mole/lbm of mixture\n",nN2);
nm=nair+nCO2+nN2; //Unit:Mole/lbm //number of moles of gas mixture is sum of the moles of its constituent gases
printf("The total number of moles is %f mole/lbm\n\n",nm);

xair=nair/nm //mole fraction of air=ratio of no of moles of air and total moles in mixture
xCO2=nCO2/nm; //mole fraction of carbon dioxide=ratio of no of moles of carbon dioxide and total moles in mixture
xN2=nN2/nm; //mole fraction of nitrogen=ratio of no
```

```
of moles of oxygen and total moles in mixture
printf("The mole fraction of air is %f \n",xair);
printf("The mole fraction of carbon dioxide is %f\n",xCO2)
printf("The mole fraction of nitrogen is %f\n\n",xN2);

//final pressure of is 100 psia
pair=xair*100; //the partial pressure of air= final pressure * the mole fraction of air //psia
printf("The partial pressure of air is %f psia\n",pair);
pCO2=xCO2*100; //the partial pressure of carbon dioxide= final pressure * the mole fraction of CO2 //psia
printf("The partial pressure of carbon dioxide is %f psia\n",pCO2);
pN2=xN2*100; //the partial pressure of nitrogen= final pressure * the mole fraction of nitrogen //psia
printf("The partial pressure of nitrogen is %f psia\n\n",pN2);

//the molecular weight of mixture=sum of products of mole fraction of each gas component
MWm=(xair*29) + (xCO2*44) + (xN2*28); //The molecular weight of air
printf("The molecular weight of air is %f\n\n",MWm);

Rm=1545/MWm; //the gas constant of air
printf("The gas constant of air is %f\n\n",Rm);
```

Scilab code Exa 7.4 Volume of a mixture

```
//scilab 5.4.1
```

```
clear;
clc;
printf("\t\t\tProblem Number 7.4\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.4  (page no. 325)
// Solution

//five moles of oxygen and 10 moles of hydrogen are mixed
//The total number of moles is 10+5=15.Therefore, mole fraction of each constituent is
xO2=5/15; //The mole fraction of oxygen
xH2=10/15; //The mole fraction of hydrogen
printf("The mole fraction of oxygen is %f and of hydrogen is %f\n",xO2,xH2);
//the molecular weight of mixture=sum of products of mole fraction of each gas component(MW of O2=32 and MW of H2=2.016)
printf("The molecular weight of the final mixture is %f\n",((5/15)*32)+((10/15)*2.016));
R=1545/32; //the gas constant of oxygen
T=460+70; //absolute temperature //Unit:R
p=14.7; //pressure //psia
//The partial volume of the oxygen can be found as follows:per pound of oxygen,
//p*vO2=R*T;
vO2=(R*T)/(p*144); //ft^3/lbm //1 in^2=144 ft^2
//Because there are 5 moles of oxygen,each containing 32 lbm,
VO2=vO2*5*32; //ft^3 //partial volume of oxygen
printf("The partial volume of oxygen is %f ft^3\n",VO2);
//For the hydrogen,we can simplify the procedure by noting that the fraction of the total volume occupied by the oxygen is the same as its mole fraction.Therefore,
Vm=3*VO2; //total volume occupied //ft^3
printf("The mixture volume is %f ft^3\n",Vm);
```

```
//and the hydrogen volume
VH2=Vm-VO2; //Ft^2 //partial volume of hydrogen
printf("From simplified procedure,The partial volume
    of hydrogen is %f ft^3\n",VH2);

//We could obtain the partial volume of hydrogen by
   proceeding as we did for the oxygen.Thus,
//p*vH2=R*T;
R=1545/2.016; //the gas constant of hydrogen
vH2=(R*T)/(p*144); //ft^3/lbm //1 in^2=144 ft^2
//Because there are 10 moles of hydrogen,each
   containing 2.016 lbm,
VH2=vH2*10*2.016; //ft^3 //partial volume of
   hydrogen
printf("The partial volume of hydrogen is %f ft^3\n\
   n",VH2);
//Which checks our previous values.


printf("From another method,\n");
//As an alternative to the foregoing,we could also
   use the fact that at 14.7 psia and 32F a mole of
   any gas occupies a volume of 358 ft^3.
printf("At 70F and 14.7 psia,a mole occupies %f ft
   ^3\n",358*((460+70)/(460+32)));
//Therefore, 5 moles of oxygen occupies
VO2=5*358*((460+70)/(460+32)); //The partial volume
   of oxygen //ft^3
printf("The partial volume of oxygen is %f ft^3\n",
   VO2);
//and 10 moles of hydrogen occupies
VH2=10*358*((460+70)/(460+32)); //The partial volume
    of hydrogen //ft^3
printf("The partial volume of hydrogen is %f ft^3\n"
   ,VH2);
//Both values are in good agreement with the
   previous calculations.
```

Scilab code Exa 7.5 The volume of a mixture

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.5\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.5  (page no. 326)
// Solution

//Referring to figure 7.3,we have for CO2,
nCO2=10/44; //mole //no of moles of carbon dioxide=
    ratio of mass and molecular weight //10 lb of per
     pound //molecular weight of CO2=44
//and for N2,
nN2=5/28.02; //mole //no of moles of nitrogen=ratio
    of mass and molecular weight //5 lb of nitrogen
    per pound
printf("The total number of moles in the mixture is
    %f mole\n",nCO2+nN2);
//Therefore,
xCO2=nCO2/(nCO2+nN2); //mole fraction of carbon
    dioxide=ratio of no of moles of carbon dioxide
    and total moles in mixture
xN2=nN2/(nCO2+nN2); //mole fraction of nitrogen=
    ratio of no of moles of oxygen and total moles in
     mixture
printf("The mole fraction of carbon dioxide is %f
    and the mole fraction of nitrogen is %f\n",xCO2,
    xN2);
//the molecular weight of mixture=sum of products of
     mole fraction of each gas component
MWm=(xCO2*44) + (xN2*28.02); //the molecular weight
    of mixture
```

```
printf("The molecular weight of air is %f\n",MWm);
//Because the mixture is 15 lbm (10CO2 + 5N2),the volume of the mixture is found from pm*Vm=mm*Rm*Tm
pm=100; //mixture pressure //psia
Tm=460+70; //mixture temperature //R(absolute temperature)
Rm=1545/37.0; //gas constant of mixture
mm=15; //mass of mixture //Unit:lb
//So,rearranging the equation,gives
Vm=(mm*Rm*Tm)/(pm*144);  //mixture volume //ft^3 //1 in^2= 144 ft^2
printf("The mixture volume is %f ft^3\n",Vm);
//the partial volume of carbon dioxide is the total volume multiplied by the mole fraction.Thus,
VCO2=Vm*xCO2; //the partial volume of CO2 //ft^3
printf("The partial volume of carbon dioxide is %f ft^3\n",VCO2);
VN2=Vm*xN2; //the partial volume of N2 //ft^3
printf("The partial volume of nitrogen is %f ft^3\n",VN2);
//The partial pressure of each constituent is proportional to its mole fraction,for these conditions,
pCO2=pm*xCO2; //the partial pressure of carbon dioxide= final pressure * the mole fraction of CO2 //psia
printf("The partial pressure of carbon dioxide is %f psia\n",pCO2);
pN2=pm*xN2; //the partial pressure of nitrogen=final pressure * the mole fraction of nitrogen //psia
printf("The partial pressure of nitrogen is %f psia\n",pN2);
```

Scilab code Exa 7.6 `Mixture composition`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.6\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.6  (page no. 327)
// Solution

//we will assume that we have 100 volumes of gas
   mixture and set up table 7.2.In first coloumn,we
   tabulate the gas,and in the second coloumn,we
   tabulate the given   volume fractions.Because the
    mole fraction equals to volume fraction,the
   values in coloumn 3 are the same as those in
   coloumn 2.
//The molecular weight is obtained from table 7.1.
   Because the MW of the mixture is the sum of the
   individual mole fraction multiplied by the
   respective molecular      weights,the next
   coloumn tabulates the product of the mole
   fraction multiplied by molecular weight(3*4).The
   sum of these entries is the molecular weight of
   the     mixture,which for this case is 33.4.
printf("Basis:100 volumes of gas mixture\n\n")
printf("gas     Volume         Mole              Molecular
                                     mass   \n")
printf("        fraction      fraction x        weight MW
         (x)MW                       fraction\n")
printf("CO2     0.40          0.40              44.0
              %f                    %f\n",(0.40*44.0)
   ,(0.40*44.0)/33.4)
printf("N2      0.10          0.10              28.02
             %f                    %f                  \n"
   ,(28.02*0.10),(28.02*0.10)/33.4)
printf("H2      0.10          0.10              2.016
             %f                    %f                  \n"
   ,(0.10*2.016),(0.10*2.016)/33.4)
printf("O2      0.40          0.40              32.0
```

```
                  %f                        %f                        \n"
   ,(0.40*32.0),(0.40*32.0)/33.4)
printf("          1.00            1.00
                                             33.4=MWm                    =
   1.000                     \n ")
```

Scilab code Exa 7.7 Mixture Composition

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.7\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.7  (page no. 328)
// Solution

//We will take as a basis 100 lbm of mixture.
//Dividing colomn 2 by 3 gives us mass/molecular
   weight  or moles of each constituents.The total
   number of moles in the mixture is the sum of
   coloumn 4,and the       molecular weight of the
   mixture is the mass of the mixture(100 lbm)
   divided by the number of moles
//In coloumn 5,mole fraction is given by moles/total
    mole

printf("Basis:100 pounds of gas mixture\n\n")
printf("gas      Mass           Molecular         Moles
                        Mole             Percent        \n")
printf("          lbm           weight MW
                                       fraction            Volume
            \n")
printf("CO2     52.7              44.0              1.2
                        %f                   %f     \n",(1.2/3)
   ,(1.2/3)*100)
```

```
printf("N2        8.4                28.02             0.3
                   %f                   %f    \n",(0.3/3)
    ,(0.3/3)*100)
printf("H2        0.6                2.016             0.3
                   %f                   %f    \n",(0.3/3)
    ,(0.3/3)*100)
printf("O2       38.3                32.0              1.2
                   %f                   %f    \n",(1.2/3)
    ,(1.2/3)*100)
printf("           =100.0                              =3.0
                      =1.00                       =  100
                 \n ")
printf("                                         MWm=100/3=33.3
                    ")
```

Scilab code Exa 7.8 Mixture Composition

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.8\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.8  (page no. 329)
// Solution

//We will take as a basis 100 lbm of mixture.
//Dividing colomn 2 by 3 gives us mass/molecular
   weight  or moles of each constituents.The total
   number of moles in the mixture is the sum of
   coloumn 4,and the       molecular weight of the
   mixture is the mass of the mixture(100 lbm)
   divided by the number of moles
//In coloumn 5,mole fraction is given by moles/total
    mole

```

```
printf("Basis:100 pounds of gas mixture\n\n")
printf("gas      Mass          Molecular        Moles          Mole         Percent        \n")
printf("         lbm           weight MW                       fraction          Volume          \n")
printf("O2       23.18          32.00            0.724           %f                 %f    \n",(0.724/3.45),(0.724/3.45)*100)
printf("N2       75.47          28.02            2.693           %f                 %f    \n",(2.692/3.45),(2.692/3.45)*100)
printf("A        1.30           39.90            0.033           %f                 %f    \n",(0.033/3.45),(0.033/3.45)*100)
printf("CO2      0.05           44.00            -               -                  -   \n")
printf("        =100.00                          =3.45           =1.00              = 100          \n ")
printf("                                          MWm =100/3.45=28.99                     ")
```

Scilab code Exa 7.9 Thermodynamic properties of a gas mixture

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.9\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.9  (page no. 331)
// Solution

//Given: cp of oxygen is 0.23 Btu/lbm*R.cp of nitrogen is 0.25 Btu/lbm*R. 160 lbm/hr of oxygen
```

```
   and 196 lbm/hr of nitrogen are mixed.oxygen is at
    500 F and nitrogen  is at 200 F.

//The energy equation for the steady-flow,adiaatic
   mixing process gives us the requirement that the
   enthalpy of the mixture must equal to the
   enthalpies of the      components,because deltah=
   q=0.An alternative statement of this requirement
   is that the gain in enthalpy of the nitrogen must
    equal the decrease in enthalpy of the   oxygen.
   Using the latter statement,that the change in
   enthalpy of nitrogen,yields
// (160*0.23*(500-tm)) = (196*0.25*(tm-200)) where
   tm=mixture temperature
//where m*cp*deltat has been used for deltah. //cp=
   specific heat at constant pressure //Unit for cp
   is Btu/lbm*R
//rearranging the above equation,
tm=((500*160*0.23)+(196*0.25*200))/((196*0.25)
   +(160*0.23)); //tm=mixture temperature //Unit:
   fahrenheit
printf("The final temperature of the mixture is %f F
   \n",tm);
//Using the requirement that the enthalpy of the
   mixture must equal to the sum of the enthalpies
   of the components yields an alternative solution
   to this problem.Let  us assume that at 0 F,the
   enthalpy of each gas and of the mixture is zero.
   The enthalpy of the entering oxygen is
   (160*0.23*(500-0)),and the enthalpy of the
          entering nitrogen is (196*0.25*(200-0)).
   The enthalpy of the mixture is ((160+196)*cpm*(tm
   -0))
//Therefore,  (160*0.23*500)+(196*0.25*200) =
   ((160+196)*cpm*tm)
cpm=((160/(160+196))*0.23)+((196/(160+196))*0.25);
   //specific heat at constant pressure for gas
   mixture //Btu/lbm*R
```

```
printf("For mixture,Specific heat at constant
   pressure is %f Btu/lbm*R\n",cpm);
//therefore,
tm=((160*0.23*500)+(196*0.25*200))/(cpm*(160+196));
   //tm=mixture temperature //Unit:fahrenheit
printf("By using value of cpm,The final temperature
   of the mixture is %f F\n",tm);
//The use of 0 F as a base was arbitrary but
   convenient.Any base would yield the same results.
//The answer of cpm is wrong in the book.
```

Scilab code Exa 7.10 `The final temperature of the mixture`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.10\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.10 (page no. 332)
// Solution

//Problem 7.9 is carried out as a nonflow mixing
   process.
//Given in problem 7.9,: cp of oxygen is 0.23 Btu/
   lbm*R.cp of nitrogen is 0.25 Btu/lbm*R. 160 lbm/
   hr of oxygen and 196 lbm/hr of nitrogen are mixed
   .oxygen is at 500F and nitrogen is at 200 F. //
   cp=specific heat at constant pressure
//Given in problem 7.10,: cv of oxygen is 0.164 Btu/
   lbm*R.cv of nitrogen is 0.178 Btu/lbm*R. //cv=
   specific heat at constant volume

//Because this is a nonflow process,the energy
   equation for this process requires the internal
   energy of the mixture to equal to the sum of the
```

```
internal energy of  its components.
//Alternatively,the decrease in internal energy of the oxygen must equal the increase in internal energy of the nitrogen.Using latter statement gives us,
// (160*0.164*(500-tm)) = (196*0.178*(tm-200))
//where m*cv*deltat has been used for deltau. //Unit for cp & cv is Btu/lbm*R
//rearranging the above equation,
tm=((500*160*0.164)+(196*0.178*200))/((196*0.178)+(160*0.164)); //tm=mixture temperature //Unit:fahrenheit
printf("The final temperature of the mixture is %f F\n",tm);
```

Scilab code Exa 7.12 The change in entropy

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.12\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.12 (page no. 334)
// Solution

//The change in entropy of the mixture is the sum of the changes in entropy of each component.
//Given in problem 7.9,: cp of oxygen is 0.23 Btu/lbm*R.cp of nitrogen is 0.25 Btu/lbm*R. 160 lbm/hr of oxygen and 196 lbm/hr of nitrogen are mixed.oxygen is at 500F and nitrogen  is at 200 F. //cp=specific heat at constant pressure
//In 7.9,for the oxygen,the temperature starts at 500F(960 R) and decreases to 328.7 F.For the nitrogen,the temperature starts at 200F(660 R)
```

```
and increase to 328.7 F.
//deltas = (cp*log(T2/T1)); //Unit:Btu/lbm*R //change in entropy

//For the oxygen,
cp=0.23; //specific heat at constant pressure //Unit:Btu/lbm*R
T2=328.7+460; //Unit:R //final temperature
T1=500+460; //Unit:R //starting temperature
deltas=(cp*log(T2/T1)); //Unit:Btu/lbm*R //change in entropy for oxygen
DeltaS=160*deltas; //Btu/R //The total change in entropy of the oxygen
printf("The total change in entropy of the oxygen is %f Btu/R\n",DeltaS);

//For the nitrogen,
cp=0.25; //specific heat at constant pressure //Unit:Btu/lbm*R
T2=328.7+460; //Unit:R //final temperature
T1=200+460; //Unit:R //starting temperature
deltas=(cp*log(T2/T1)); //Unit:Btu/lbm*R //change in entropy for nitrogen
deltaS=196*deltas; //Btu/R //The total change in entropy of the nitrogen
printf("The total change in entropy of the nitrogen is %f Btu/R\n",deltaS);
deltaS=deltaS+DeltaS; //the total change in entropy for the mixture //Btu/lbm*R
printf("The total change in entropy for the mixture is %f Btu/R\n",deltaS);

//Per pound of mixture,
deltasm=deltaS/(196+160); //increase in entropy per pound mass of mixture
printf("Increase in entropy per pound mass of mixture is %f Btu/lbm*R\n\n",deltasm);

```

```

printf("An alternative solution:\n");
//As an alternative solution,assume an arbitrary datum of 0 F(460 R).
cp=0.23; //specific heat at constant pressure //Unit:Btu/lbm*R
//For initial entropy of oxygen,
T2=500+460; //Unit:R //final temperature
T1=0+460; //Unit:R //starting temperature
deltas=cp*log(T2/T1); //the initial change in entropy for oxygen // Btu/lbm*R
printf("The initial change in entropy for oxygen is %f Btu/lbm*R\n",deltas);
//For final entropy of oxygen,
T2=328.7+460; //Unit:R //final temperature
T1=0+460; //Unit:R //starting temperature
Deltas=cp*log(T2/T1); //the final change in entropy for oxygen // Btu/lbm*R
printf("The final change in entropy for oxygen is %f Btu/lbm*R\n",Deltas);
deltaS=Deltas-deltas; //The entropy change of the oxygen //Btu/lbm*R
printf("The entropy change of the oxygen is %f Btu/lbm*R\n",deltaS);

//For nitrogen,
cp=0.25; //specific heat at constant pressure //Unit:Btu/lbm*R
//For initial entropy of nitrogen,
T2=200+460; //Unit:R //final temperature
T1=0+460; //Unit:R //starting temperature
deltas=cp*log(T2/T1); //the initial change in entropy for nitrogen // Btu/lbm*R
printf("The initial change in entropy for nitrogen is %f Btu/lbm*R\n",deltas);
//For final entropy of nitrogen,
T2=328.7+460; //Unit:R //final temperature
T1=0+460; //Unit:R //starting temperature
```

```
Deltas=cp*log(T2/T1); //the final change in entropy for nitrogen // Btu/lbm*R
printf("The final change in entropy for nitrogen is %f Btu/lbm*R\n",Deltas);
deltaS=Deltas-deltas; //The entropy change of the nitrogen //Btu/lbm*R
printf("The entropy change of the nitrogen is %f Btu/lbm*R\n",deltaS);

//The remainder of the problem is as before.The advantage of using this alternative method is the negative logarithms are avoided by choosing a reference temperature lower than any other temperature in the system
```

Scilab code Exa 7.13 The dew point temperature

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.13\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.13 (page no. 338)
// Solution

//Referring to figure 7.6,it will be seen that the cooling of an air-water vapor mixture from B to A proceeds at constant pressure until the saturation curve is reached.
//At 80 F(the mixture temperature),the Steam Tables give us a saturation pressure of a 0.5073 psia, and because the relative humidity is 50%,the vapor pressure of the water is 0.5*0.5073=0.2537 psia.
//Using the steam tables,the saturation temperature
```

```
corresponding to 0.2537 psia is 60 F.
//So,
printf("The dew point temperature of the air is 60 F\n")
```

Scilab code Exa 7.14 `Air water vapor mixture`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.14\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.14  (page no. 338)
// Solution

//To solve this probelm,it is necessary to determine the properties of the saturated mixture 90 F.If the air is saturated at 90 F,the partial pressure of the water  vapor is found directly from the Steam Tables as 0.6988 psia,and the specific volume of the water vapor is 467.7 ft^3/lbm of vapor.
printf("The partial pressure of the dry air is %f psia\n",14.7-0.6988); //the mixture is at 14.7 psia
R=1545/28.966; //gas constant of dry air=1545/Molecular weight
T=90+460; //temperature of dry air //Unit:R
pdryair=14.0; //psia //pressure of dry air
//Applying the ideal gas equation to the air,
vdryair=(R*T)/(pdryair*144); //volume of dry air //ft^3/lbm //1 in^2=144 Ft^2
//the mass of dry air in the 467.7 ft^3 container
printf("The mass of dry air in the 467.7 ft^3 container is %f lbm\n",467.7/vdryair);
```

```
//To obtain relative humidity(phy),it is necessary
   to determine the mole fraction of water vapor for
    both the saturated mixture and the mixture in
   question.
//The saturated mixture contains 1 lbm of water
   vapor or 1/18.016 moles =0.055 mole of water
   vapor and (467.7/vdryair)/28.966=1.109 moles of
   dry air.
//For the saturated mixture, the ratio of moles of
   water vapor to moles of mixture is
   0.055/(0.055+1.109)=0.0477
//For the actual mixture,the moles of water vapor
   per pound of dry air is 0.005/18.016=0.000278 and
    1 lbm of dry air is 1/28.966=0.0345 mole.So,the
   mole of water vapor per mole of  mixture at the
   conditions of the  mixture is
   0.000278/(0.0345+0.000278)=0.00799
//From the defination of relative humidity,
printf("The relative humidity of the mixture is %f \
   n",(0.00799/0.0477)*100);

//Because the mole ratio is also the ratio of the
   partial pressures for the ideal gas,phy can be
   expressed as the ratio of the partial pressure of
    the water vapor in  the mixture to the partial
   pressure of the water vapor at saturation.
   Therefore,
printf("The partial pressure of the vapor at
   saturation is %f psia\n",(0.00799/0.0477)*0.6988)
   ;
printf("And the partial pressure of the dry air in
   the mixture is %f psia\n",14.7-((0.00799/0.0477)
   *0.6988)); //14.7-The partial pressure of the
   vapor at saturation
//The dew point temperature is the saturation
   temperature corresponding to the partial pressure
    of the water vapor in the mixture.So,
printf("The dew point temperature corresponding to
```

```
%f psia is 39F\n",(0.00799/0.0477)*0.6988);
```

Scilab code Exa 7.15 Determine partial pressure and relative humidity and dew poin

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.15\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.15 (page no. 343)
// Solution

//Problem 7.14 using equations, Rm=((ma/(ma+mv))*Ra)+((mv/(ma+mv))*Rv) and phy*pvs=pv
W=0.005; //Humidity ratio
pm=14.7; //mixture is at 14.7 psia
//W=0.622*(pv/(pm-pv))
//Rearranging,
pv=(W*pm)/(0.622+W); //the partial pressure of the water vapor
printf("The partial pressure of the water vapor is %f psia\n",pv);
pa=pm-pv; //pa=the partial pressure of the dry air in the mixture
printf("The partial pressure of dry air is %f psia\n",pa);
//It is necessary to obtain pvs from the Steam Tables at 90 F.This is 0.6988 psia.
pvs=0.6988; //saturation pressure of water vapor at the temperature of mixture
printf("The partial pressure of the water vapor at saturation is %f psia\n",pvs);
//Therefore,
phy=pv/pvs; //relative humidity
printf("The relative humidity is %f percent\n",phy
```

```
    *100);
//The dew point temperature is the saturation
    temperature corresponding to 0.117 psia,which is
    found from the Steam Tables to be 39 F.
printf("The dew point temperature of the mixture is
    39 F\n");
//The results of this problem and problem 7.14 are
    in good agreement
```

Scilab code Exa 7.16 Determine how much water was removed from the air

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.16\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.16  (page no. 343)
// Solution

pm=14.7; //the barometer is at 14.7 psia //mixture
    is at 14.7 psia
//The amount of water vapor removed (per pound of
    dry air) is the difference between the humidity
    ratio (specific humidity) at inlet and outlet of
    the conditioning   unit.We shall therefore
    evalute W for both specified conditions.Because
    phy=pv/pvs,
//At 90F:
phy=0.7; //relative humidity
pvs=0.6988; //psia //saturation pressure of water
    vapor at the temperature of mixture
pv=phy*pvs; //psia //the partial pressure of the
    water vapor
pa=pm-pv; //psia //pa=the partial pressure of the
    dry air in the mixture
```

```
W=0.622*(pv/pa); //Humidity ratio

//At 80F:
phy=0.4; //relative humidity
pvs=0.5073; //psia //saturation pressure of water
    vapor at the temperature of mixture
pv=phy*pvs; //psia //the partial pressure of the
    water vapor
pa=pm-pv; //psia //pa=the partial pressure of the
    dry air in the mixture
w=0.622*(pv/pa); //Humidity ratio

printf("The amount of water removed per pound of dry
     air is %f\n",W-w);
```

Scilab code Exa 7.17 Determine dew point temperature using psychrometric chart

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.17\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.17 (page no. 347)
// Solution

//Problem 7.13 using the psychrometric chart
//Entering figure 7.11 at a dry-bulb temperature of
    80 F,we proceed vertically until we reach 50%
    humidity curve.At this intersection ,we proceed
    horizontally and    read the dew-point
    temperature as approximately 60 F.
printf("The dew point temperature of air is 60 F\n")
    ;
```

Scilab code Exa 7.18 Determine partial pressure and relative humidity and dew poin

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.18\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.18  (page no. 347)
// Solution

//Problem 7.14 using the psychrometric chart
//In this problem,we are given the moisture content
    of the air to be 0.005 lb per pound of dry air.
//This corresponds to 0.005*7000=35 grains per pound
    of dry air.
//Entering the chart at 90F and proceeding verticaly
    to 35 grains per pound of dry air,we find the
    dew point to be 39F by proceeding horizontally to
    the intersection with the saturation curve.
printf("The dew-point temperature of the mixture is
    39 F\n");
printf("The relative humidity is approximately 17
    percent\n");
//From the leftmost scale,we read the pressure of
    water vapor to be 0.12 psia.
printf("The partial pressure of the air is %f psia\n
    ",14.7-0.12);
//Comparing these results to problem 7.14,indicated
    good agreement between the results obtained by
    chart and by calculation
```

Scilab code Exa 7.19 Determine water removed from the air using psychrometric char

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.19\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.19  (page no. 348)
// Solution

//Problem 7.16 using the psychrometric chart
//The initial conditions are 90 F and 70% relative
   humidity
//Entering the chart at 90 F dry bulb temperature
   and proceeding vertically to 70% relative
   humidity,we find the air to have 150 grains water
    vapor per pound of dry air.At the final
   condition of 80F and 40% relative humidity,we
   read 61 grains of water/lb of dry air.
//So,
printf("The water removed is %f grains per pound of
   dry air\n",150-61);
printf("Or %f lb of water per pound of dry air is
   removed\n",(150-61)/7000);
```

Scilab code Exa 7.20 Determine the heat required

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.22\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.22  (page no. 349)
// Solution

//dry bulb temperature is 50 F
//relative humidity is 50 percent
```

```
//We first locate 50 F and 50 percent relative
   humidity on figure 7.11.At this state,we read 26
   grains of water per pound of dry air and a total
   heat of 16.1 Btu per  pound of a dry air.
//We now proceed horizontally to 80 F at a constant
   value of 26 grains of water per pound of dry air
   and read a total heat of 23.4 Btu per pound of
   dry air.
printf("The heat required is %f Btu per pound of dry
    air",23.4-16.1)
```

Scilab code Exa 7.21 Determine relative humidity

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.21\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.21  (page no. 352)
// Solution

//An evaporative cooling process
//Because the exit air is saturated,we find the exit
    condition on the curve corresponding to a wet-
   bulb temperature of 50 F.The process is carried
   out at constant     total enthalpy,which is along
    a line of constant wet-bulb temperature.
//Proceeding along the 50 F wet-bulb temperature
   line of figure 7.11 diagonally to the right until
    it intersects with the vertical 80 F dry-bulb
   temperature line    yields a relative humidity of
    approximately 4 %
printf("For An evaporative cooling process,The
   relative humidity of the entering air is 4
   percent");
```

Scilab code Exa 7.22 The final mixture composition

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 7.22\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.22  (page no. 356)
// Solution

//As noted from figure 7.27, 1 lb of mixture,4/5 lb
    of indoor air,and 1/5 lb of outdoor air are mixed
     per pound of mixture.
//We now locate the two end states on the
    psychrometric chart and connect them with a
    straight line.The line connecting the end states
    is divided  into 5 equal parts. Using the results
     of equation, (ha-ha2)/(ha-ha1) = (W2-W)/(W-W1) =
     ma1/ma2 = l1/l2  ,we now proceed from the 75 F
    indoor air state 1 part toward the 90F outdoor
    air state.This Locates
printf("The final mixture,which is found to be a dry
    -bulb temperature of approximately 78 F,a wet-
    bulb temperature of 66 F and relative humidity of
     54 percent\n");
```

Scilab code Exa 7.23 The cooling tower

```
//scilab 5.4.1
clear;
clc;
```

```
printf("\t\t\tProblem Number 7.23\n\n\n");
// Chapter 7 : Mixtures Of Ideal Gases
// Problem 7.23  (page no. 358)
// Solution

//The cooling tower
//From the Steam tables,
//For water:
h100F=68.05;  //Btu/lbm //enthalpy at 100 F
h70F=38.09;   //Btu/lbm  //enthalpy at 70 F
//For air:
h=20.4; //Unit:Btu/lb //at inlet,total heat/lb dry air
w=38.2; //Unit:grains/lb  //at inlet,moisture pickup/lb dry air (at 60F D.B. and 50% R.H.)
H=52.1; //Unit:Btu/lb //at outlet,total heat/lb dry air
W=194.0; //Unit:grains/lb //at outlet,moisture pickup/lb dry air (at 90F D.B. and 90% R.H.)

//Per pound of dry air,the heat interchange is H-h Btu per pound of dry air.
//Per pound of dry air,the moisture increase is (W-w)/7000 lb per pound of dry air.
//From the equation, ma*(H-h) = 200000*h100F - mwout*h70F            //ma=mass of air  mwout=mass of cooled water
//and  ma*((W-w)/7000) = 200000 - mwout
//Solving the latter equation for mwout,we have mwout=200000-(ma*((W-w)/7000))
//Substituting this into the heat balance yields,
// ma*(H-h) = 200000*h100F - 200000*h70F + ma*h70F*((W-w)/7000)
//Solving gives us,
ma=(200000*(h100F-h70F))/((H-h)-(h70F*((W-w)/7000))); //The amount of air required per hour //Unit:lbm/hr of dry air
printf("The amount of air required per hour is %f
```

```
    lbm/hr of dry air\n",ma);
printf("The amount of water lost per hour due to
    evaporation is %f lbm/hr\n",ma*((W-w)/7000));
//note that the water evaporated is slightly over 2%
     of the incoming water,and this is the makeup
    that has to be furnished to the tower.
//answer are slightly differ because of value of (W-
    w)/7000 is given 0.0233 instead of 0.0225
```

Chapter 8

Vapor Power Cycles

Scilab code Exa 8.1 Thermal efficiency neglecting pump work and including pump wor

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.1\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.1  (page no. 380)
// Solution

//From the Steam Tables or Mollier chart in Appendix 3,we find that
hf=340.49; //Unit:kJ/kg //at 50kPa //enthalpy
h1=hf; //at 50kPa //hf=enthalpy of saturated liquid //Unit:kJ/kg
h4=3230.9; //Unit:kJ/kg //enthalpy
h5=2407.4; //Unit:kJ/kg ////enthalpy
//Here,point 5 is in the wet steam region.
printf("Solution for (a)\n");
//Neglecting pump work (h2=h1) gives
nR=(h4-h5)/(h4-h1); //Thermal efficiency of the cycle
printf("The thermal efficiency of the cycle is %f
```

```
    percentage\n\n",nR*100);

printf("Solution for (b)\n");
p2=3000; //Unit:kPa //Upper pressure
p1=50; //Unit:kPa //Lower pressure
vf=0.001030; //Specific volume of saturated liquid
    //m^3/kg
Pumpwork=(p2-p1)*vf; //Unit:kJ/kg //pump work
//The efficiency of the cycle including pump work is
nR=((h4-h5)-Pumpwork)/((h4-h1)-Pumpwork); //Thermal
    efficiency of the cycle
printf("The thermal efficiency of the cycle
    including pump work is %f percentage\n\n",nR*100)
    ;
```

Scilab code Exa 8.2 Thermal efficiency using computer disk property values

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.2\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.2 (page no. 381)
// Solution

//Using the computer disk to obtain the neccesary
    properties
printf("Solution for (a)\n");
//For the conditions given in problem8.1,the
    properties are found to be
hf=340.49; //Unit:kJ/kg //at 50kPa //enthalpy
h1=hf; //at 50kPa //hf=enthalpy of saturated liquid
h2=h1; //Enthalpy //Unit:kJ/kg
h4=3230.9; //Unit:kJ/kg //enthalpy
h5=2407.4; //Unit:kJ/kg //enthalpy
```

```
//Neglecting pump work
nR=(h4-h5)/(h4-h2); //Thermal efficiency of the cycle
printf("The thermal efficiency of the cycle is %f percentage\n\n",nR*100);

printf("Solution for (b)\n");
//For the pump work,we do not need the approximation,because the computerized tables give us the necessary values directly.
//Assuming that the condensate leaving the condenser is saturated liquid gives us an enthalpy of 340.54 kJ/kg and an entropy of 1.0912 kJ/kg*K for an isentropic compression, the final cond-ition is the boiler pressure of 3Mpa and an entropy of 1.0912 kJ/kg*K. For these values,the program yields an enthalpy of 343.59 kJ/kg*K.The isentropic pump work is equal to
Pumpwork=343.59-340.54; //Unit:kJ/kg //pumpwork
//The efficiency of the cycle including pump work is
nR=((h4-h5)-Pumpwork)/((h4-h1)-Pumpwork); //Thermal efficiency of the cycle
printf("The thermal efficiency of the cycle including pump work is %f percentage\n\n",nR*100);
//Final results in this problem agree with the result in problem8.1
```

Scilab code Exa 8.3 Thermal efficiency

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.3\n\n\n");
// Chapter 8 : Vapor Power Cycles
```

```
// Problem 8.3  (page no. 382)
// Solution

//Solution for (a)
//Figurre 8.3 with the cycle extending into the superheat region and expanding along 4->5 is the appropriate diagram for this process.

printf("Solution for (b)\n");
//This problem can be solved either by use of the Mollier chart or the Steam Tables.If the chart is used,14.696 psia is first located on the saturated vapor line.Because the expansion,4->5, is isentropic,a vertical line on the chart is the path of the process.The point corresponding to 4 in figure 8.3 is found where this vertical line intersects 400 psia.At this point,the ent-halpy is 1515 Btu/lbm,and the corresponding temperature is approximatelty 980F.Saturated vapor at 14.696 psia  has an enthalpy of 1150.5 Btu/lbm(from the Mollier chart).The Steam Tables sh-ow that saturated liquid at 14.696 psia has an enthalpy of 180.15 Btu/lbm.In terms of figure 8.3,and neglecting pump work,we have
h1=180.15; //Unit:Btu/lbm //enthalpy
h2=h1; //Enthalpy //Unit:Btu/lbm
h4=1515; //Unit:Btu/lbm //enthalpy
h5=1150.5; //Unit:kJ/kg //enthalpy
//Neglecting pump work yields
nR=(h4-h5)/(h4-h2); //Thermal efficiency of the cycle
printf("Neglecting the pump work,The thermal efficiency of the cycle is %f percentage\n\n",nR*100);
p2=400; //Unit:Psia //Upper pressure
p1=14.696; //Unit:Psia //Lower pressure
vf=0.01167; //Specific volume of saturated liquid //ft^3/lbm
```

```
J=778; //Conversion factor
Pumpwork=((p2-p1)*vf*144)/J; //Unit:Btu/lbm //1ft^2=144 in^2 //pumpwork
//The efficiency of the cycle including pump work is
nR=((h4-h5)-Pumpwork)/((h4-h1)-Pumpwork); //Thermal efficiency of the cycle
printf("The thermal efficiency of the cycle including pump work is %f percentage\n\n",nR*100);
//where the denominator is h4-h2=h4-h1-(h2-h1). Neglecting pump work is obviously justified in this case.An alternative solution is obtained by using the Steam Tables:at 14.696 psia ans sat-uration,sg=1.7567 ; at 400 psia,s= 1.7567.From Table 3(at 400 psia)
//    s       h       t
//1.7632  1523.6  1000
//1.7567  1514.2  982.4
//1.7558  1512.9  980
```

Scilab code Exa 8.4 Thermal efficiency using computer generated property values

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.4\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.4  (page no. 383)
// Solution

//Refer to figure8.3.The desired  quantities are obtained as follows:
//at 14.696 psia,saturated vapor (x=1),s=1.7566 Btu/lbm*R
h5=1150.4; //Unit:Btu/lbm //enthaply
```

```
//at 14.696 psia,saturated liquid (x=0),s=0.3122 Btu/lbm*R
h2=180.17; //Unit:Btu/lbm //enthaply
h1=h2;
//at 400 psia,s=1.7566 Btu/lbm*R,
h4=1514.0; //Unit:Btu/lbm //Enthalpy
t=982.07; //Unit:F //tempearature
//at 400 psia,s=0.3122 Btu/lbm*R, //s=entropy
h=181.39; //Unit:Btu/lbm //Enthalpy
//Note the agreement of these values with the ones obtained for problem8.4.Alos,note the temperature of 982.07F compared to 982.4F.Continuing,
//Neglecting pump work
nR=(h4-h5)/(h4-h2); //Thermal efficiency of the cycle
printf("Neglecting the pump work,The thermal efficiency of the cycle is %f percentage\n\n",nR*100);
Pumpwork=h-h2; //Unit:kJ/kg ///pumpwork
//The efficiency of the cycle including pump work is
nR=((h4-h5)-Pumpwork)/((h4-h2)-Pumpwork); //Thermal efficiency of the cycle
printf("The thermal efficiency of the cycle including pump work is %f percentage\n\n",nR*100);
```

Scilab code Exa 8.5 Carnot cycle efficiency and type efficiency

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.5\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.5 (page no. 385)
// Solution
```

```

//The Carnot cycle would operate between 982.4F and 212F.
T1=982.4+460; //temperature converted to absolute temperature //Unit:R
T2=212+460; //temperature converted to absolute temperature //Unit:R
nc=((T1-T2)/T1)*100; //Efficiency of carnot cycle
printf("The efficiency is %f percentage\n",nc);
//In problem 8.3,
nR=27.3; //Thermal efficiency of the cycle neglecting the pump work
typen=(nR/nc)*100; //Type efficiency=ideal thermal efficiency/efficiency of carnot cycle operating between min and max temperature limits
printf("The type efficiency of the ideal Rankine cycle is %f percentage\n",typen);
```

Scilab code Exa 8.6 `Efficiency of Rankine cycle`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.6\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.6 (page no. 385)
// Solution

//For the upper temperature of the cycle,we have 400 C,and for 50kPa,the steam tables give us a saturation temperature of 81.33C.The efficiency of a Carnot cycle operating between the limits would be
T1=400+273; //Celcius temperature converted to fahrenheit temperature
```

```
T2=81.33+273; //temperature converted to fahrenheit temperature
nc=((T1-T2)/T1)*100; //Efficiency of carnot cycle
printf("The efficiency is %f percentage\n",nc);
//In problem 8.1,
nR=28.5; //Thermal efficiency of the cycle neglecting the pump work
typen=(nR/nc)*100; //Type efficiency=ideal thermal efficiency/efficiency of carnot cycle operating between min and max temperature limits
printf("The type efficiency of the ideal Rankine cycle is %f percentage\n",typen);
```

Scilab code Exa 8.7 Thermal efficiency

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.7\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.7  (page no. 386)
// Solution

//From problem 8.3,
work=1515-1150.5; //Unit:Btu/lbm of steam //pump work is neglected //Useful ideal work
//Because of the heat losses, 50 Btu/lbm of the 364.5 Btu/lbm becomes unavailable.
available=364.5-50; //Unit:Btu/lbm
n=available/(1515-180.15); //Thermal efficiency of the cycle neglecting pump work h4=1515; //Unit:Btu/lbm //enthalpy & h1=180.15; //Unit:Btu/lbm //enthalpy
printf("The thermal efficiency of the cycle neglecting pump work is %f percentage\n\n",n*100)
```

```
;
```

Scilab code Exa 8.8 `Heat rate and steam rate per kilowatt hour`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.8\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.8  (page no. 387)
// Solution

//Neglecting the pump work,we have
heatrate=3413/0.273; //Unit:Btu/kWh //0.273=
    efficiency //1 kWh=3413 //heat rate
printf("The heat rate is %f Btu/kWh\n",heatrate);
//Per pound of steam,1515-1150.5=364.5 Btu is
    delivered.
//Because 1 kWh=3413
printf("The steam rate is %f lbm of steam per
    kilowatt-hour\n",3413/(1515-1150.5));
```

Scilab code Exa 8.9 `Efficiency of reheat cycle`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.9\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.9  (page no. 388)
// Solution

```

```
//The Mollier chart provides a convenient way of solving this problem.Expanding from 980F,400 psia ,s=1.7567 to 200 psia yields a final enthalpy of 1413 Btu/lbm.Expanding from 200 psia ans  an enthalpy of 1515 Btu/lbm to 14.696 psia yields a final enthaply of 1205 Btu/lbm.
h4=1515; //Unit:Btu/lbm //enthalpy
h5=1205; //Unit:Btu/lbm //enthalpy
h7=1413; //Unit:Btu/lbm //enthalpy
h1=180.15; //Unit:Btu/lbm //enthalpy
nreheat=((h4-h5)+(h4-h7))/((h4-h1)+(h4-h7)); //The efficiency of the reheat cycle
printf("The efficiency of the reheat cycle is %f percentage",nreheat*100);
//It is apparent that for the conditions of this problem,the increase in efficiency is not very large.The final condition of the fluid after the second expansion is superheated steam at
//14.696 psia.By condensing at this relatively high pressure condition,a large amount of heat is rejected to the condenser cooling water.7
```

Scilab code Exa 8.10 efficiency of reheat cycle by computerized properties

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.10\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.10  (page no. 389)
// Solution

//Some of the property data required was found in problem8.4.In addition we have,
//at 200 psia,s=1.7566 Btu/lbm*R,
```

```
h7=1413.6; //Unit:Btu/lbm //Enthalpy
//at 200 psia,s=1.8320 Btu/lbm*R,
h4=1514.0; //Unit:Btu/lbm //Enthalpy
//at 14.696 psia,s=1.8320 Btu/lbm*R,
h5=1205.2; //Unit:Btu/lbm //Enthalpy
h1=180.17; //Unit:Btu/lbm //enthalpy
//Using these data,
nreheat=((h4-h5)+(h4-h7))/((h4-h1)+(h4-h7)); //The efficiency of the reheat cycle
printf("The efficiency of the reheat cycle is %f percentage",nreheat*100);
```

Scilab code Exa 8.11 `Efficiency of Rankine and regenerative cycle`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.11\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.11 (page no. 394)
// Solution

printf("Solution for (a)\n");
//For the rankine cycle,the Mollier chart gives
h4=1505; //Enthalpy //Unit:Btu/lbm
h5=922; //Enthalpy //Unit:Btu/lbm
h6=h5; //Enthalpy //Unit:Btu/lbm
//and at the condenser,
h1=69.74; //enthalpy //Unit:Btu/lbm
nR=(h4-h5)/(h4-h1); //efficiency of rankine cycle
printf("The efficiency of rankine cycle is %f percentage\n\n",nR*100);

printf("Solution for (b)\n");
//Figure 8.16 shows the regenerative cycle.After
```

```
doing work(isentropically),W lbs of steam are bled from the turbine at 50 psia for each lbm of steam leaving the steam generator,and (1-W) pound goes through the turbine and is condensed in the condenser to saturated liquid at 1 psia. This condensate is pumped to the heater,where it mixes with the extracted steam and leaves as saturated liquid at 50 psia.The required enthalpies are:
//Leaving turbine:
h5=1168; //Btu/lbm at 50 psia
//Leaving condenser:
h7=69.74; //Btu/lbm at 1 psia // is equal to h8 if pump work is neglected
//Leaving heater:
h1=250.24; //Btu/lbm at 50 psia //is equal to h2 if pump work is neglected(saturated liquid)
//A Heat balance around the heater gives
//W*h5 + (1-W)*h7 = 1*h1
W=((1*h1)-h7)/(h5-h7); //Unit:lbm //W lb of steam
printf("W=%f lbm\n",W);
work=(1-W)*(h4-922) + W*(h4-h5); //h5=922 from the mollier chart //Unit:Btu/lbm //The work output
printf("The work output is %f Btu/lbm\n",work);
//Heat into steam generator equals the enthalpy leaving minus the enthalpy of the saturated liquid entering at 50 psia:
qin=h4-h1; //Unit:Btu/lbm //Heat in
n=work/qin; //Efficiency of regenerative cycle
printf("The efficiency of regenerative cycle is %f percentage\n",n*100);
//The efficiency of a regenerative cycle with one open heater is given by
n=1-(((h5-h1)*(h6-h7))/((h4-h1)*(h5-h7))); //efficiency of a regenerative cycle
W=(h1-h7)/(h5-h7); //Unit:lbm //W lb of steam
printf("When the rankine cycle is compared with regenerative cycle,\n");
```

```
printf("W=%f lbm and the efficiency of a regenerative cycle with one open heater is given by %f percentage\n",W,n*100);
```

Scilab code Exa 8.12 The efficiency of the cycle

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.12\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.12  (page no. 396)
// Solution

//Figure 8.16(a) shows the cycle.For this cycle,W2 pounds are extracted at 100 psia,and W1 pounds are extracted at 50 psia for each pound produced by the steam generator.The enthalpies that  are required are:
//Leaving turbine: 922 //Btu/lbm at 1 psia
//Leaving condenser: 69.74 //Btu/lbm at 1 psia (saturated liquid)
//Leaving low pressure heater: 250.24 //Btu/lbm at 50 psia (saturated liquid)
//Leaving high pressure heater: 298.61 //Btu/lbm at 100 psia
//At low pressure extraction: 1168 //Btu/lbm at 50 psia
//At high pressure extraction: 1228.6 //Btulbm at 100 psia
//Entering turbine: 1505 //Btu/lbm
//The heat balance around the high pressure heater gives us
//W2*1228.6 + (1-W2)*250.24 = 1*298.61
W2=((1*298.61)-250.24)/(1228.6-250.24); //lbm //W2
```

```
pounds are extracted at 100 psia
printf("W2=%f lbm\n",W2);
//A heat balance around the low pressure heater yields
//W1*1168 + (1-W1-W2)*69.74 = (1-W2)*250.24
W1=(((1-W2)*250.24)-69.74+(W2*69.74))/(1168-69.74); //lbm //W1 pounds are extracted at 50 psia
printf("W1=%f lbm\n",W1);
work=((1505-1228.6)*1)+((1-W2)*(1228.6-1168))+((1-W1-W2)*(1168-922)); //The work output //Btu/lbm
printf("The work output is %f Btu/lbm\n",work);
//Heat into the steam generator equals the enthalpy leaving minus the enthalpy of saturated liquid at 100 psia:
qin=1505-298.61; //Btu/lbm //Heat in
printf("Heat in = %f Btu/lbm\n",qin);
n=work/qin; //The efficiency
printf("The efficiency is %f percentage\n",n*100);
//In terms of figure 8.16a,
//W2=(h1-h11)/(h5-h11)
//W1=(h5-h1/h6-h9)*(h10-h9/h5-h10) neglecting the pump work
//n=1-(h7-h8/h4-h1)*(h5-h1/h5-h10)*(h6-h10/h6-h8)
//For this problem , h8=h9 , h10=h11 and h1=h2. Thus
W2=(298.61-250.24)/(1228.6-250.24); //lbm //W2 pounds are extracted at 100 psia
printf("Comparing the results,\n");
printf("W2=%f lbm\n",W2);
W1=((1228.6-298.61)*(250.24-69.74))/((1168-69.74)*(1228.6-250.24)); //lbm //W1 pounds are extracted at 50 psia
printf("W1=%f lbm\n",W1);
n=1-(((922-69.74)*(1228.6-298.61)*(1168-250.24))/((1505-298.61)*(1228.6-250.24)*(1168-69.74))); //Efficiency
printf("The efficiency is %f percentage\n",n*100);
```

Scilab code Exa 8.13 efficiency of cycle and comparision

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 8.13\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.13  (page no. 398)
// Solution

//Regenerative cycle
//Assume that 1 lbm of steam leaves the steam
   generator and that W1 lbm is bled off to the
   closed heater at 100psia and that W2 lbm is bled
   off to the open heater at 50 psia.Alos,assume
   that the feedwater leaving the closed heater at
   310F,18F less than the saturation temperature
   corresponding to 100 psia.For calculation
   purposes,we will use hf at 310 F for this
   enthalpy.Using the Mollier diagram and the steam
   tables,we find the following values of enthalpy:

//h to turbine=1505 Btu/lbm(at 1000 psia and 1000F)
//h at first extraction=1228 Btu/lbm(isentropically
   to 100 psia)
//h at second extraction=1168 Btu/lbm(isentropically
    to 100 psia)
//h at turbine exit=922 Btu/lbm (isentropically to 1
    psia)
//hf=298.61 Btu/lbm(at 100 psia)
//hf=250.24 Btu/lbm(at 50 psia)
//hf=280.06 Btu/lbm(at 310 F)
//hf=69.74 Btu/lbm (at 1 psia)
//A heat balance around the high pressure heater
```

```
gives us
//W1*(1228-298.61) = 1*(280.06-250.24)
W1=((1*(280.06-250.24)))/(1228-298.61); //lbm //W1 lbm is extracted at 100 psia
printf("W1=%f lbm\n",W1);
//A heat balance around the open heater gives us
//W2*1168 +(1-W1-W2)*69.74 + W1*268.61 = 1*250.24
W2=((1*250.24)-(W1*268.61)-69.74+(W1*69.74))/(1168-69.74); //lbm //W2 lbm is extracted at 50 psia
printf("W2=%f lbm\n",W2);
//The work output of the cycle consists of the work that 1 lbm does in expanding isentropically to 100 psia,plus the work done by (1-W1)lbm expanding isentropicaly from 100 to 50 psia,plus the work done by (1-W1-W2)lbm expanding isentropically from 50 to 1 psia.
//Numerically,the work is
workoutput=(1*(1505-1228))+((1-W1)*(1228-1168))+((1-W1-W2)*(1168-922)); //Btu/lbm //the work output
printf("The work output is %f Btu/lbm\n",workoutput);
heatinput=1505-280.06; //Btu/lbm //the heat input
printf("The heat input is %f Btu/lbm\n",heatinput);
n=workoutput/heatinput; //Efficiency
printf("The efficiency is %f percentage\n",n*100);
//When compared to 8.11,we conclude that the addition of additional closed heater raises the efficiency.
```

Scilab code Exa 8.14 efficiency of energy utilization and thermal efficiency

```
//scilab 5.4.1
clear;
clc;
```

```
printf("\t\t\tProblem Number 8.14\n\n\n");
// Chapter 8 : Vapor Power Cycles
// Problem 8.14 (page no. 426)
// Solution

//From problem 8.11,
//Leaving turbine:
h5=1168; //Btu/lbm at 50 psia
//For the rankine cycle,the Mollier chart gives
h4=1505; //Enthalpy //Unit:Btu/lbm
h6=922; //Enthalpy //Unit:Btu/lbm //h6=h5;
//and at the condenser,
h1=69.74; //enthalpy //Unit:Btu/lbm
//Leaving condenser:
h7=69.74; //Btu/lbm at 1 psia // is equal to h8 if pump work is neglected
//Leaving heater:
h2=250.24; //Btu/lbm at 50 psia //is equal to h1 if pump work is neglected(saturated liquid)
//A Heat balance around the heater gives
//W*h5 + (1-W)*h7 = 1*h1
W=((1*h2)-h7)/(h5-h7); //Unit:lbm
liquidleaving=(W*h2)+(1-W)*h1; //Btu/lbm //liquid leaving the heatexchange

//Using these data,,
heatin=h4-liquidleaving; //Btu/lbm //heat in the boiler
printf("Heat in at boiler is %f Btu/lbm\n",heatin);
workout=((1-W)*(h4-h6))+(W*(h4-h5)); //Btu/lbm //The work out of turbine
printf("The work out of turbine is %f Btu/lbm\n",workout);
n=workout/heatin; //efficiency //The conventional thermal efficiency
printf("The conventional thermal efficiency is %f percentage\n",n*100);
//If at this time we have define the efficiency of
```

```
   energy utilization to be the ratio of the work
   out plus the useful heat out divided by the heat
   input to the    cycle , nenergyutilization=((w+
   qoutuseful)/qin)*100
qout=W*(h5-h2); //heat out //Btu/lbm
n=(workout+qout)/heatin; //efficiency of energy
   utilization
printf("Efficiency of energy utilization is %f
   percentage\n",n*100);
//Comparing with 8.11, we see that conventional
   thermal efficiency is decreased and efficiency of
    energy utilization is increased
```

Chapter 9

Gas Power Cycles

Scilab code Exa 9.1 The efficiency of Otto cycle and Carnot cycle

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.1\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.1  (page no. 462)
// Solution

Rc=7; //Compression Ratio Rc=v2/v3
k=1.4;  //It is apparent incerease in compression
   ratio yields an increased cycle efficiency
notto=(1-(1/Rc)^(k-1))*100; //Efficiency of an otto
   engine
printf("The efficiency of the otto cycle is %f
   percentage\n",notto);
//For the carnot cycle,
//Nc=1-(T2/T4) //efficiency for the carnot cycle //
   T2=lowest temperature //T4=Highest temperature

T2=70+460; //for converting to R //Conversion of
   unit
```

```
//At 700 F
T4=700+460; //temperatures converted to absolute
    temperatures;
nc=(1-(T2/T4))*100; //efficiency of the carnot cycle
printf("When peak temperature is 700 fahrenheit ,
    efficiency of the carnot cycle is %f percentage\n
    ",nc);

//At 1000 F
T4=1000+460; //temperatures converted to absolute
    temperatures;
nc=(1-(T2/T4))*100; //efficiency of the carnot cycle
printf("When peak temperature is 1000 fahrenheit ,
    efficiency of the carnot cycle is %f percentage\n
    ",nc);

//At 3000 F
T4=3000+460; //temperatures converted to absolute
    temperatures;
nc=(1-(T2/T4))*100; //efficiency of the carnot cycle
printf("When peak temperature is 3000 fahrenheit ,
    efficiency of the carnot cycle is %f percentage\n
    ",nc);
```

Scilab code Exa 9.2 Efficiency and net work out

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.2\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.2 (page no. 463)
// Solution

cv=0.172; //Unit:Btu/(lbm*R) //Specific heat
```

```
constant
Rc=7; //Compression Ratio Rc=v2/v3
k=1.4; //It is apparent incerease in compression
    ratio yields an increased cycle efficiency
T2=70+460; //for converting to R //Conversion of
    unit
//For 1000 F
T4=1000+460; //temperatures converted to absolute
    temperatures;
T3byT2=Rc^(k-1); //Unit less
T3=T3byT2*T2;
qin=cv*(T4-T3); //Unit:Btu/lbm //Heat added
//Qr=cv*(T5-T2)*(T5/T4)=(v2/v3)^(k-1)
Qr=(inv(Rc))^(k-1); //Unit:Btu/lbm //Heat rejected
T5=T4*Qr;
Qr=cv*(T5-T2); //Unit:Btu/lbm //Heat rejected
printf("The net work out is %f Btu/lbm\n",qin-Qr);
notto=((qin-Qr)/qin)*100; //The efficiency of otto
    cycle
printf("The efficiency of otto cycle is %f
    percentage",notto);
//The value agrees with the results of problem 9.1
```

Scilab code Exa 9.3 Determine the Peak temperature

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.3\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.3 (page no. 464)
// Solution

cv=0.7186; //Unit:kJ/(kg*K) //Specific heat constant
    for constant volume process
```

```
Rc=8; //Compression Ratio Rc=v2/v3
k=1.4;  //It is apparent incerease in compression ratio yields an increased cycle efficiency
T2=20+273; //20 C converted to its kelvin value
qin=50; //Heat added //Unit:kJ
T3byT2=Rc^(k-1);
T3=T3byT2*T2; //Unit:K
//qin=cv*(T4-T3) //heat added //Unit:kJ
T4=(qin/cv)+T3; //The peak temperature of the cycle //Unit:K
printf("The peak temperature of the cycle is %f Kelvin i.e. %f Celcius",T4,T4-273);
```

Scilab code Exa 9.4 `Determine temperature pressure and specific volume at each poi`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.4\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.4  (page no. 465)
// Solution

//For an Otto cycle,
rc=7; //Compression Ratio Rc=v2/v3
q=50; //Unit:Btu/lbm //Heat added
p2=14.7; //Unit:psia //pressure at point 2
T2=60+460; //temperatures converted to absolute temperatures; //Unit:R
cp=0.24; //Unit:Btu/(lbm*R) //Specific heat constant for constant pressure process
cv=0.171; //Unit:Btu/(lbm*R) //Specific heat constant for constant volume process
R=53.3; //Unit:ft*lbf/lbm*R //constant of proportionality
```

```
k=1.4;  //It is apparent incerease in compression ratio yields an increased cycle efficiency
//Refering to figure 9.9,
//At (2),we need v2.
//p2*v2=R*T2
v2=(R*T2)/(p2*144); //Unit:ft^3/lbm //1ft^2=144 in^2 //specific volume at point 2
printf("At point (2),\nspecific volume v2=%f ft^3/lbm\n\n",v2);
//For The isentropic path (2)&(3),p3*v3^k=p2*v2^k,so
//So,p3=p2*(v2/v3)^k;
p3=p2*rc^k; //Unit:psia //pressure at point 3
printf("At path(2)&(3)\n");
printf("pressure p3=%f psia\n",p3);
v3=v2/rc; //Unit:ft^3/lbm //specific volume at point 3
printf("specific volume v3=%f ft^3/lbm\n",v3);
T3=(p3*v3*144)/R; //Unit:R //1ft^2=144 in^2 //temperature at point 3
printf("temperature T3=%f R\n\n",T3);
printf("At point(4),\n");
//To obtain the values at (4),we note
v4=v3; //Unit:ft^3/lbm //specific volume at point 4
printf("specific volume v4=%f ft^3/lbm\n",v4);
//qin=cv*(T4-T3)
T4=T3+(q/cv); //Unit:R //temperature at point 4
printf("temperature T4=%f R\n",T4);
//For p4,
p4=(R*T4)/(144*v4); //Unit:psia //1ft^2=144 in^2 //pressure at point 4
printf("pressure p4=%f psia\n\n",p4);
//The last point has the same specific volume as (2),giving
printf("At last point,\n");
v5=v2; //Unit:ft^3/lbm //specific volume at point 5
printf("specific volume v5=%f ft^3/lbm\n",v5);
//The isentropic path equation,p5*v5^k=p4*v4^k,so
p5=p4*(v4/v5)^k; //Unit:psia //pressure at point 5
```

```
printf("pressure p5=%f psia\n",p5);
T5=(p5*v5*144)/(R); //Unit:R //1ft^2=144 in^2
    temperature at point 5
printf("temperature T5=%f R\n\n",T5);
n=(((T4-T3)-(T5-T2))/(T4-T3))*100; //The efficiency
    of the cycle
printf("The efficiency of the cycle is %f percentage
    ",n);
```

Scilab code Exa 9.7 Determine the horsepower

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.7\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.7 (page no. 468)
// Solution

//For four cycle engine,
//Using the results of problem 9.6,
pm=1000; //Unit:kPa //mean effective pressure //Unit
    :psia
N=4000/2; //Power strokes per minute //2L engine //
    Unit:rpm
LA=2 //Mean //Unit:liters
hp=(pm*LA*N)/44760; //The horsepower //Unit:hp
printf("The horsepower is %f hp",hp);
```

Scilab code Exa 9.9 Compression ratio

```
//scilab 5.4.1
clear;
```

```
clc;
printf("\t\t\tProblem Number 9.9\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.9  (page no. 469)
// Solution

//An otto engine
c=0.2; //clearance equal to 20% of its displacement
//Using results of problem 9.8,
rc=(1+c)/c; //The compression ratio
printf("The compression ratio is %f",rc);
```

Scilab code Exa 9.10 Determine the mean effective pressure

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.10\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.10  (page no. 470)
// Solution

//For four cycle,six cylinder engine,
//Using the results of problem 9.5,
hp=100; //Horsepower //Unit:hp
L=4/12; //Unit:ft //stroke is 4 in.
A=(%pi/4)*(3)^2*6; //Cylinder bore is 3 in.
N=4000/2; //Power strokes per minute //2L engine //
    Unit:rpm
//hp=(pm*LA*N)/33000;
pm=(hp*33000)/(L*A*N); //The mean effective pressure
     //psia
printf("The mean effective pressure is %f psia",pm);
```

Scilab code Exa 9.11 The mean effective pressure

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.11\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.11  (page no. 470)
// Solution

//six cylinder engine,with displacement 3.3L
//Using the results of problem 9.5,
hp=230; //Horsepower //Unit:hp
//3.3L*1000 cm^3/L*(in/2.54 cm)^3
LA=3.3*1000*(1/2.54)^3; //mean //in^3
N=5500/2; //Power strokes per minute //2L engine //Unit:rpm
//hp=(pm*LA*N)/33000;
pm=(hp*33000*12)/(LA*N); //1ft=12inch //The mean effective pressure //psia
printf("The mean effective pressure is %f psia",pm);
```

Scilab code Exa 9.12 Efficiency and temperature of the exhaust

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.12\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.12  (page no. 478)
// Solution

```

```
//An air-standard Diesel engine
rc=16; //Compression Ratio Rc=v2/v3
v4byv3=2; //Cutoff ratio=v4/v3
k=1.4; //with the cycle starting at 14 psia and 100
   F //It is apparent incerease in compression
   ratio yields an increased cycle efficiency
T2=100+460; //temperatures converted to absolute
   temperatures;
ndiesel=1-((inv(rc))^(k-1)*(((v4byv3)^k-1)/(k*(
   v4byv3-1)))); //The efficiency of the diesel
   engine
printf("The efficiency of the diesel engine is %f
   percentage\n",ndiesel*100);
// T3/T2=rc^k-1 and T5/T4=(1/re^k-1) //re=expansion
   ratio=v5/v4
//But T4/T3=v4/v3=rc/re
//So,
T5=T2*(v4byv3)^k; //The temperature of the exhaust
   of the cycle //Unit:R
printf("The temperature of the exhaust of the cycle
   is %f R i.e. %f F",T5,T5-460);
```

Scilab code Exa 9.13 Determine net work and mean effective pressure

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 9.13\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.13 (page no. 479)
// Solution

//Now,in problem 9.12,
//An air-standard Diesel engine
rc=16; //Compression Ratio Rc=v2/v3
```

```
v4byv3=2; //Cutoff ratio=v4/v3
k=1.4; //with the cycle starting at 14 psia and 100 F //It is apparent incerease in compression ratio yields an increased cycle efficiency
T2=100; //Unit:F //temperature
T5=1018; //Unit:F //Found in 9.12 //The temperature of the exhaust of the cycle //Unit:R
ndiesel=0.614 //Efficiency of the diesel engine //Found in 9.12
//Now,in problem 9.13,
cp=0.24; //Unit:Btu/(lbm*R) //Specific heat constant for constant pressure process
cv=0.172; //Unit:Btu/(lbm*R) //Specific heat constant for constant volume process

Qr=cv*(T5-T2); //Heat rejected //Unit:Btu/lbm
//ndeisel=1-(Qr/qin); //Efficiency=ndeisel //qin=heat added
qin=Qr/(1-ndiesel); //Unit:Btu/lbm
J=778; //J=Conversion factor
networkout=J*(qin-Qr); //(ft*lbf)/lbm //Net work out per pound of gas
printf("Net work out per pound of gas is %f (ft*lbf)/lbm\n",networkout);
//The mean effective pressure is net work divided by (v2-v3):
mep=networkout/((16-1)*144); //1ft^2=144 in^2 //Unit:psia //The mean effective pressure
printf("The mean effective pressure is %f psia",mep);
```

Scilab code Exa 9.14 Ddetermine Heat in and heat rejected

```
//scilab 5.4.1
clear;
```

```
clc;
printf("\t\t\tProblem Number 9.14\n\n\n");
// Chapter 9 : Gas Power Cycles
// Problem 9.14 (page no. 489)
// Solution

//A Brayton cycle
rc=7; //Compression Ratio Rc=v2/v3
k=1.4; //It is apparent incerease in compression ratio yields an increased cycle efficiency
cp=0.24; //Unit:Btu/(lbm*R) //Specific heat constant for constant pressure process
T3=1500; //(unit:fahrenheit) //peak tempeature
p1=14.7; //Unit:psia //Initial condition
T1=70+460; //temperatures converted to absolute temperatures; //Initial condition
R=53.3; //Unit:ft*lbf/lbm*R //constant of proportionality
nBrayton=1-((inv(rc))^(k-1)); //A Brayton cycle efficiency
printf("A Brayton cycle efficiency is %f percentage\n",nBrayton*100);
//If we base our calculation on 1 lbm of gas and use subscripts that corresponds to points (1),(2),(3) and (4) of fig.9.22,we have
v1=(R*T1)/p1; //Unit:ft^3/lbm //specific volume at point 1
//Because rc=7 then,
v2=v1/rc; //Unit:ft^3/lbm //specific volume at point 2
//After the isentropic compression, T2*v2^k-1 = T1*v1^k-1
T2=T1*(v1/v2)^(k-1); //Unit:R //temperature at point 2
T2=T2-460; //Unit:fahrenheit //temperature at point 2
qin=cp*(T3-T2); //Heat in //Unit:Btu/lbm
printf("The heat in is %f Btu/lbm\n",qin);
```

```
//Because efficiency can be stated to be work out divided by heat in,
wbyJ=nBrayton*qin; //The work out //Unit:Btu/lbm
printf("The work out is %f Btu/lbm\n",wbyJ); //Answer is wrong in the book.cause they have taken efficiency value wrong
printf("The heat rejected is %f Btu/lbm\n",qin-wbyJ); //Anser is affected because of value of wbyJ
```

Chapter 10

Refrigeration

Scilab code Exa 10.1 `A Carnot Refrigeration Cycle`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.1\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.1 (page no. 503)
// Solution

T1=70+460; //70F=70+460 R //Energy flows into the system at reservoir at constant temperature T1(unit:R)
T2=32+460; //32F=32+460 R //Heat is rejected to the constant temperature T2(Unit:R)
printf("Solution for (a),\n");
COP=T2/(T1-T2); //Coefficient of performance
printf("Coefficient of performance(COP) of the cycle is %f\n\n",COP);
printf("Solution for (b),\n");
Qremoved=1000; //Unit:Btu/min //heat removal
WbyJ=Qremoved/COP; //The power required //Unit:Btu/min
```

```
printf("The power required is %f Btu/min\n\n",WbyJ);
printf("Solution for (c),\n");
Qrej=Qremoved+WbyJ; //The rate of heat rejected to
    the room //Unit:Btu/min
printf("The rate of heat rejected to the room is %f
    Btu/min",Qrej);
```

Scilab code Exa 10.2 A carnot refrigeration cycle

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.2\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.2 (page no. 504)
// Solution

T1=20+273; //20C=20+273 R //Energy flows into the
    system at reservoir at constant temperature T1(
    unit:R)
T2=-5+273; //-5C=-5+273 R //Heat is rejected to the
    constant temperature T2(Unit:R)
printf("Solution for (a),\n");
COP=T2/(T1-T2); //Coefficient of performance
printf("Coefficient of performance(COP) of the cycle
     is %f\n\n",COP);
printf("Solution for (b),\n");
Qremoved=30; //Unit:kW //heat removal
W=Qremoved/COP; //power required //unit:kW
printf("The power required is %f kW \n\n",W);
printf("Solution for (c),\n");
Qrej=Qremoved+W; //The rate of heat rejected to the
    room //Unit:kW
printf("The rate of heat rejected to the room is %f
    kW",Qrej);
```

Scilab code Exa 10.3 Defined Ratings

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.3\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.3 (page no. 505)
// Solution

T1=70+460; //70F=70+460 R //Energy flows into the
    system at reservoir at constant temperature T1(
    unit:R)
T2=20+460; //20F=20+460 R //Heat is rejected to the
    constant temperature T2(Unit:R)
printf("Solution for (a),\n");
COP=T2/(T1-T2); //Coefficient of performance
printf("Coefficient of performance(COP) of the cycle
    is %f\n\n",COP);
printf("Solution for (b),\n");
HPperTOR=4.717/COP; //Horsepower per ton of
    refrigeration //Unit:hp/ton
COPactual=2; //Actual Coefficient of performance(COP
    ) is stated to be 2
HPperTORactual=4.717/COPactual; //Horsepower per ton
    of refrigeration(actual) //Unit:hp/ton
printf("The horsepower required by the actual cycle
    over the minimum is %f hp/ton",HPperTORactual-
    HPperTOR);
```

Scilab code Exa 10.4 Defined Ratings

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.4\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.4 (page no. 506)
// Solution

COP=4.5; //Coefficient of performance //From problem
    10.1
HPperTOR=4.717/COP; //Horsepower per ton of
   refrigeration //Unit:hp/ton
Qremoved=1000; //Unit:Btu/min //From problem 10.1
//1000 Btu/min /200 Btu/min ton = 5 tons of
   refrigeration
HPrequired=HPperTOR*5; //The horsepower required //
   unit:hp
printf("The horsepower required is %f hp\n",
   HPrequired);
//In problem 10.1, 77.2 Btu/min was required
printf("The power required is %f hp\n",77.2*778*inv
   (33000)); //1 Btu=778 ft*lbf //1 min*hp = 33000
   ft*lbf
//The ratio of the power required in each problem is
    the same as the inverse ratio of the COP value
//Therefore,
printf("The power required is %f hp\n",(COP/12.95)*
   HPrequired); //COP(in problem 10.1)=12.95
printf("This checks our results")
```

Scilab code Exa 10.5 Defined Ratings

```
//scilab 5.4.1
clear;
clc;
```

```
printf("\t\t\tProblem Number 10.5\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.5  (page no. 506)
// Solution

COP=10.72; //In the problem 10.2 //Coefficient of
    performance
P=2.8; //In the problem 10.2 //The power was 2.8 kW
COPactual=3.8; //Actual Coefficient of performance(
    COP)
power=P*COP/COPactual; //The power required  //unit:
    kW
printf("The power required is %f kW",power)
```

Scilab code Exa 10.6 Refrigeration cycles

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.6\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.6  (page no. 509)
// Solution

//From Appendix 3,at 120psia,the corresponding
    saturation temperature is 66 F, enthalpies are
h1=116.0; //Unit:Btu/lbm //enthalpy
h2=116.0; //Unit:Btu/lbm //Throttling gives h1=h2 //
    enthalpy
h3=602.4; //Unit:Btu/lbm //enthalpy
//From the consideration that s3=s4,h4 is found at
    15 psia,
s3=1.3938; //s=entropy //Unit:Btu/(lbm*F)
//Therefore by interpolation in the superheat tables
     at 120 psia,
```

```
t4=237.4; //Unit:fahrenheit //temperature
h4=733.4; //Unit:Btu/lbm //enthalpy
printf("Solution for (a),\n");
COP=(h3-h1)/(h4-h3); //Coefficient of performance
printf("Coefficient of performance is %f\n\n",COP);
printf("Solution for (b),\n");
printf("The work of compression is %f Btu/lbm\n\n",
    h4-h3);
printf("Solution for (c),\n");
printf("The refrigatering effect is %f Btu/lbm\n\n",
    h3-h1);
printf("Solution for (d),\n");
tons=30; //capacity of 30 tons is desired
printf("The pounds per minute of ammonia required
    for ciculation is %f lbm/min\n\n",(200*tons)/(h3-
    h1));
printf("Solution for (e),\n");
printf("The ideal horsepower per ton of
    refrigeration is %f hp/ton\n\n",4.717*((h4-h3)/(
    h3-h1)));
```

Scilab code Exa 10.7 Refrigeration cycles

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.7\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.7 (page no. 510)
// Solution

//From Appendix 3,110 psig corresponds to 96 F,
    enthalpies are
h1=30.14; //Unit:Btu/lbm //enthalpy
h2=30.14; //Unit:Btu/lbm //Throttling gives h1=h2 //
```

```
    enthalpy
h3=75.110; //Unit:Btu/lbm //enthalpy
//From the consideration that s3=s4,at −20F,
s3=0.17102; //Unit:Btu/(lbm*F) //s=entropy
//Therefore by interpolation in the Freon−12
    superheat table at these values,
h4=89.293; //Unit:Btu/lbm //enthalpy
printf("Solution for (a),\n");
COP=(h3-h1)/(h4-h3); //Coefficient of performance
printf("Coefficient of performance is %f\n\n",COP);
printf("Solution for (b),\n");
printf("The work of compression is %f Btu/lbm\n\n",
    h4-h3);
printf("Solution for (c),\n");
printf("The refrigatering effect is %f Btu/lbm\n\n",
    h3-h1);
printf("Solution for (d),\n");
tons=30; //capacity of 30 tons is desired
printf("The pounds per minute of ammonia required
    for ciculation is %f lbm/min\n\n",(200*tons)/(h3-
    h1));
printf("Solution for (e),\n");
printf("The ideal horsepower per ton of
    refrigeration is %f hp/ton\n\n",4.717*((h4-h3)/(
    h3-h1)));
```

Scilab code Exa 10.8 An ideal Refrigeration cycle

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.8\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.8 (page no. 517)
// Solution
```

```

//From Appendix 3,using the Freon-12 tables, enthalpies are
h1=28.713; //Unit:Btu/lbm //enthalpy
h2=28.713; //Unit:Btu/lbm //Throttling gives h1=h2 //enthalpy
h3=78.335; //Unit:Btu/lbm //enthalpy
//From the consideration that s3=s4,
s3=0.16798; //Unit:Btu/(lbm*F) //s=entropy
//Therefore by interpolation in the superheat tables at 90 F,
s=0.16798; //entropy at 90F //Btu/lbm*F
h4=87.192; //Unit:Btu/lbm //enthalpy
printf("The heat extracted is %f Btu/lbm\n\n",h3-h1);
printf("The work required is %f Btu/lbm\n\n",h4-h3);
COP=(h3-h1)/(h4-h3); //Coefficient of performance
printf("The Coefficient of performance(COP) of this ideal cycle is %f",COP);
```

Scilab code Exa 10.9 Coefficient of performance

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.9\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.9 (page no. 518)
// Solution

//From Appendix 3,using the HFC-134a tables, enthalpies are
h1=41.6; //Unit:Btu/lbm //enthalpy
h2=41.6; //Unit:Btu/lbm //Throttling gives h1=h2 //enthalpy
```

```
h3=104.6; //Unit:Btu/lbm //enthalpy
//From the consideration that s3=s4,
s3=0.2244; //Unit:Btu/(lbm*F) //s=entropy
h4=116.0; //Unit:Btu/lbm //enthalpy
printf("The heat extracted is %f Btu/lbm\n\n",h3-h1);
printf("The work required is %f Btu/lbm\n\n",h4-h3);
COP=(h3-h1)/(h4-h3); //Coefficient of performance
printf("The Coefficient of performance(COP) of this ideal cycle is %f",COP);
```

Scilab code Exa 10.10 `total work and mass`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.10\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.10 (page no. 518)
// Solution

printf("Solution for (a)\n");
//By defination,the efficiency of the compressor is the ratio of the ideal compression work to actual compression work.
//Based on the points on fig.10.12, //n=(h4-h3)/(h4'-h3);
//There is close correspondence between 5.3 psia and -60F for saturated conditions.Therefore,state 3 is a superheated vapour at 5.3 psia and approximately -20F,because the problem states
//that state 3 has a 40F superheat.Interpolation in the Freon tables in Appendix 3 yields
T=-20; //Unit:F //temperature
// p      h         s
```

```
//7.5   75.719   0.18371
//5.3   76.885   0.18985                  h3=75.886  Btu/lbm
//5.0   75.990   0.19069

//At 100 psia and s=0.18985,
//   t              s        h
// 170F        0.18996   100.571
// 169.6F      0.18985   100.5             h4=100.5  Btu/lbm
// 160F        0.18726   98.884

//The weight of refrigerant is given by
// 200(tons)/(h3-h1) = (200*5)/(75.886-h1)
//In the saturated tables,h1 is
//     p          h
// 101.86     26.832
// 100psia    26.542
// 98.87      26.365

//m=mass flow/min
h1=26.542; //enthalpy //Unit:Btu/lbm
n=0.8; //Efficiency
h4=100.5; //enthalpy //Unit:Btu/lbm
h3=75.886; //enthalpy //Unit:Btu/lbm
m=(200*5)/(75.886-h1); //mass
h4dashminush3=(h4-h3)/n;
//Total work of compression=m*(h4minush3)
J=778; //J=Conversion factor
work=(h4dashminush3*m*J)/33000; //1 horsepower =
    33,000 ft*LBf/min //Unit:hp //work
printf("%f horsepower is required to drive the
    compressor if it has a mechanical efficiency 100
    percentage\n\n",work);

printf("Solution for (b)\n");
//Assuming a specific heat of the water as unity,we
    obtain
//From part (a),
//h4'-h3=h4minush3
```

```
h4dash=h4dashminush3+h3; //Unit:Btu/lbm
mdot=(m*(h4dash-h1))/(70-60); //water enters at 60F and leaves at 70F //the required capacity in lbm/min
printf("%f lbm/min of cooling water i.e. %f gal/min is the required capacity of cooling water to pump ",mdot,mdot/8.3);
```

Scilab code Exa 10.11 `Work and mass`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.11\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.11 (page no. 521)
// Solution

printf("Solution for (a)\n");
//From appendix3,reading the p-h diagram directly,we have
h3=76.2; //Unit:Btu/lbm //Enthalpy
h4=100.5; //Unit:Btu/lbm //Enthalpy
n=0.8; //Efficiency //From 10.10
work=(h4-h3)/n; //Work of compression //Unit:Btu/lbm
//The enthalpy of saturated liquid at 100 psia is given at 26.1 Btu/lbm.Proceeding as before yields
m=(200*5)/(h3-26.1); //Unit:lbm/min //m=massflow/min
J=778; //J=Conversion factor
totalwork=(m*work*J)/33000; //1 horsepower = 33,000 ft*LBf/min //total ideal work //unit:hp
printf("Total ideal work of compression is %f hp\n\n",totalwork);

printf("Solution for (b)\n");
```

```
h4dash=h3+work; //Btu/lbm
mdot=(m*(h4dash-26.5))/(70-60); //water enters at 60 F and leaves at 70F //the required capacity in lbm/min
printf("%f lbm/min of cooling water i.e. %f gal/min is the required capacity of cooling water to pump ",mdot,mdot/8.3);
```

Scilab code Exa 10.12 Determine the airflow required per ton of refrigeration

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.12\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.12 (page no. 526)
// Solution

COP=2.5; //Coefficient of performance
cp=0.24; //Unit:Btu/(lbm*R) //Specific heat constant for constant pressure process
T1=-100+460; //temperatures converted to absolute temperatures; //Unit:R //lowest temperature of the cycle
T3=150+460; //temperatures converted to absolute temperatures; //Unit:R //Upper temperature of the cycle
//T1/T4-T1 = COP
T4=(3.5*T1)/COP; //Unit:R //temperature at point 4
//T2/T3-T2 =COP
T2=(COP*T3)/3.5; //Unit:R //temperature at point 2
printf("The work of the expander is %f Btu/lbm of air\n",cp*(T4-T1));
printf("The work of the compressor is %f Btu/lbm of air\n",cp*(T3-T2));
```

```
printf("The net work required by the cycle is %f Btu/lbm\n",(cp*(T3-T2))-(cp*(T4-T1)));
printf("Per ton of refrigeration,the required airflow is %f lbm/min per ton\n",200/(cp*(T2-T1)));
```

Scilab code Exa 10.13 `A vacuum Refrigeration system`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.13\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.13 (page no. 536)
// Solution

//A VACUUM REFRIGERATION SYSTEM
//A vacuum refrigeration system is used to cool water from 90F to 45F
h1=58.07; //Unit:Btu/lbm //enthalpy
h2=13.04; //Unit:Btu/lbm //enthalpy
h3=1081.1; //Unit:Btu/lbm //enthalpy
m1=1; //mass //unit:lbm
//m2=1-m3 //unit:lbm
//Now, m1*h1 = m2*h2 + m3*h3
//Putting the values and arranging the equation,
m3=(m1*h1-h2)/(h3+h2); //The mass of vapour that must be removed per pound //unit:lbm
printf("The mass of vapour that must be removed per pound of entering water is %f lbm",m3);
```

Scilab code Exa 10.14 `A vacuum Refrigeration system`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.14\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.14 (page no. 536)
// Solution

//In problem 10.13,
//A VACUUM REFRIGERATION SYSTEM
//A vacuum refrigeration system is used to cool
   water from 90F to 45F
h1=58.07; //Unit:Btu/lbm //enthalpy
h2=13.04; //Unit:Btu/lbm  //enthalpy
h3=1081.1; //Unit:Btu/lbm //enthalpy
m1=1; //mass //lbm
//m2=1-m3 //unit:lbm
//Now, m1*h1 = m2*h2 + m3*h3
//Putting the values and arranging the equation,
m3=(m1*h1-h2)/(h3+h2); //The mass of vapour that
   must be removed per pound //unit:lbm
m2=1-m3; //mass //unit:lbm
printf("The mass of vapour that must be removed per
   pound of entering water is %f lbm\n",m3);
//Now,in problem 10.14,
//The refrigeration effect can be determined as m3*(
   h3-h1) or m2*(h1-h2)
printf("The refrigeration effect using eqn m3*(h3-h1
   ) is %f Btu/lbm\n",m3*(h3-h1));
printf("The refrigeration effect using eqn m2*(h1-h2
   ) is %f Btu/lbm\n",m2*(h1-h2));
```

Scilab code Exa 10.15 The heat pump

```
//scilab 5.4.1
```

```
clear;
clc;
printf("\t\t\tProblem Number 10.15\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.15 (page no. 539)
// Solution

//THE HEAT PUMP
T1=70+460; //70F=70+460 R //Energy flows into the system at reservoir at constant temperature T1(unit:R) //from problem 10.1
T2=32+460; //32F=32+460 R //Heat is rejected to the constant temperature T2(Unit:R) //from problem 10.1
COP=T1/(T1-T2); //Coefficient of performance for carnot heat pump
printf("Coefficient of performance(COP) of the carnot cycle is %f\n",COP);
printf("The COP can also be obtained from the energy items solved for in problem 10.1\n")
//In problem 10.1, The power was found to be 77.2 Btu/min and the total tare of heat rejection was 1077.2 Btu/min
//Therefore,
printf("Coefficient of performance(COP) of the cycle is %f\n",1077.2/77.2);
```

Scilab code Exa 10.16 `The heat pump`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 10.16\n\n\n");
// Chapter 10 : Refrigeration
// Problem 10.16 (page no. 539)
```

```
// Solution

//Let us first consider the cycle as a refrigeration cycle
//In problem 10.1
T1=70+460; //70F=70+460 R //Energy flows into the system at reservoir at constant temperature T1(unit:R)
T2=0+460; //0F=32+460 R //Heat is rejected to the constant temperature T2(Unit:R)
COP=T2/(T1-T2); //Coefficient of performance
printf("Coefficient of performance(COP) of the cycle is %f\n\n",COP);
Qremoved=1000; //Unit:Btu/min //heat removal
WbyJ=Qremoved/COP; //the power input //unit:Btu/min
printf("The power input is %f Btu/min\n\n",WbyJ);
Qrej=Qremoved+WbyJ; //The rate of heat rejected to the room //Unit:Btu/min
printf("The rate of heat rejected to the room is %f Btu/min\n",Qrej);
printf("The COP as a heat pump is %f\n",Qrej/WbyJ);
printf("As a check,COP of heat pump is %f = 1 + COP of carnot cycle %f",Qrej/WbyJ,COP);
```

Chapter 11

Heat Transfer

Scilab code Exa 11.1 Heat transfer per square foot of wall

```
clear;
clc;
printf("\t\t\tProblem Number 11.1\n\n\n");
// Chapter 11: Heat Transfer
// Problem 11.1 (page no. 553)
// Solution


deltaX=6/12; //6 inch = 6/12 feet //deltaX=length //unit:feet
k=0.40; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity //From the table
T1=150; //temperature maintained at one face //fahrenheit
T2=80; //tempetatature maintained at other face //fahrenheit
deltaT=T2-T1; //fahrenheit //Change in temperature
Q=(-k*deltaT)/deltaX; //Heat transfer per square foot of wall //Unit:Btu/hr*ft^2
printf("Heat transfer per square foot of wall is %f
```

```
Btu/hr*ft^2",Q);
```

Scilab code Exa 11.2 Heat transfer per unit wall area

```
clear;
clc;
printf("\t\t\tProblem Number 11.2\n\n\n");
// Chapter 11: Heat Transfer
// Problem 11.2 (page no. 553)
// Solution

deltaX=0.150; //Given,150 mm =0.150 meter // //deltaX=length //Unit:meter
k=0.692; //Unit:W/(m*celcius) //k=proportionality constant //k=thermal conductivity
T1=70; //temperature maintained at one face //celcius
T2=30; //tempetature maintained at other face //celcius
deltaT=T2-T1; //celcius //change in temperature
Q=(-k*deltaT)/deltaX; //Heat transfer per square foot of wall //unit:W/m^2
printf("Heat transfer per square foot of wall is %f W/m^2",Q);
```

Scilab code Exa 11.3 determine the resistance needed

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.3\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.3 (page no. 556)
```

```
// Solution

//From example 11.1,
deltaX=6/12; //6 inch = 6/12 feet //deltaX=length //
    unit:feet
A=1; //area  //ft^2
k=0.40; //Unit:Btu/(hr*ft*F) //k=proportionality
    constant //k=thermal conductivity //From the
    table

Rt=deltaX/(k*A); //Thermal resistance //Unit:(hr*f)/
    Btu

//Q=deltaT/Rt //Q=heat transfer //ohm's law (fourier
    's equation)
//i=deltaE/Re //i=current in amperes //deltaE=The
    potential difference //Re=the electrical
    resistance //ohm's law
// Q/i = (deltaT/Rt)*(deltaE/Re)
//Q/i=100; //Given // 1 A correspond to 100 Btu/(hr*
    ft^2)
deltaE=9; //Unit:Volt //potential difference
T1=150; //temperature maintained at one face //
    fahrenheit
T2=80; //tempetature maintained at other face //
    fahrenheit
deltaT=T2-T1; //fahrenheit //Change in temperature
Re=(100*deltaE*Rt)/deltaT; //Unit:Ohms //The
    electrical resistance needed
printf("The electrical resistance needed is %f ohms\
    n",abs(Re));
i=deltaE/Re; //current //Unit:amperes
Q=100*i; //Heat transfer per square foot of wall //
    Unit:Btu/hr*ft^2
printf("Heat transfer per square foot of wall is %f
    Btu/hr*ft^2",abs(Q));
```

Scilab code Exa 11.4 Heat transfer per sqr foot of wall

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.4\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.4  (page no. 558)
// Solution

//For Brick,
deltaX=6/12; //6 inch = 6/12 feet //deltaX=length //unit:ft
A=1; //area  //unit:ft^2
k=0.40; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For brick,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",R);
R1=R;

//For Concrete,
deltaX=(1/2)/12; //(1/2) inch = (1/2)/12 feet //deltaX=length //unit:ft
A=1; //area //ft^2
k=0.80; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For Concrete,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",R);
```

```
R2=R;

//For plaster ,
deltaX=(1/2)/12; // (1/2) inch = 6/12 feet //deltaX=
    length //unit:ft
A=1; //area //ft^2
k=0.30; //Unit:Btu/(hr*ft*F) //k=proportionality
    constant //k=thermal conductivity //From the
    table
R=deltaX/(k*A); //Thermal resistance //Unit:(hr*f)/
    Btu
printf("For plaster ,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",R);
R3=R;

Rot=R1+R2+R3; //Rot=The overall resistance //unit:(
    hr*F)/Btu
printf("The overall resistance is %f (hr*F)/Btu\n\n"
    ,Rot);
T1=70; //temperature maintained at one face //
    fahrenheit
T2=30; //tempetature maintained at other face //
    fahrenheit
deltaT=T2-T1; //fahrenheit //Change in temperature
Q=deltaT/Rot; //Q=Heat transfer //Unit:Btu/(hr*ft^2)
    ; //ohm's law (fourier's equation)
printf("Heat transfer per square foot of wall is %f
    Btu/hr*ft^2",abs(Q));
```

Scilab code Exa 11.5 The interface temperatures

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.5\n\n\n");
```

```
// Chapter 11 : Heat Transfer
// Problem 11.5  (page no. 558)
// Solution

printf("In problem 11.4,\n");
//From example 11.4,,,
//For Brick,
deltaX=6/12; //6 inch = 6/12 feet //deltaX=length //unit:ft
A=1; //area  //unit:ft^2
k=0.40; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For brick,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",R);
R1=R;

//For Concrete,
deltaX=(1/2)/12; //(1/2) inch = (1/2)/12 feet //deltaX=length //unit:ft
A=1; //area //ft^2
k=0.80; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For Concrete,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",R);
R2=R;

//For plaster,
deltaX=(1/2)/12; // (1/2) inch = 6/12 feet //deltaX=length //unit:ft
A=1; //area //ft^2
k=0.30; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity //From the
```

```
table
R=deltaX/(k*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For plaster,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",R);
R3=R;

Rot=R1+R2+R3; //Rot=The overall resistance //unit:(hr*F)/Btu
printf("The overall resistance is %f (hr*F)/Btu\n\n",Rot);
T1=70; //temperature maintained at one face //fahrenheit
T2=30; //tempetature maintained at other face //fahrenheit
deltaT=T2-T1; //fahrenheit //Change in temperature
Q=deltaT/Rot; //Q=Heat transfer //Unit:Btu/(hr*ft^2);
printf("Heat transfer per square foot of wall is %f Btu/hr*ft^2",abs(Q));

printf("Now in problem 11.5,\n");
deltaT=R*Q //ohm's law (fourier's equation) //Change in temperature //fahrenheit
//For Brick,
deltaT=Q*R1; //Unit:fahrenheit //ohm's law (fourier's equation) //Change in temperature
t1=deltaT;
//For Concrete,
deltaT=Q*R2; //Unit:fahrenheit //ohm's law (fourier's equation) //Change in temperature
t2=deltaT;
//For plaster,
deltaT=Q*R3; //Unit:fahrenheit //ohm's law (fourier's equation) //Change in temperature
t3=deltaT;

deltaTo=t1+t2+t3; //Overall Change in temperature //
```

```
fahrenheit
printf("The overall change in temperature is %f F\n",abs(deltaTo));
//The interface temperature are:
printf("The interface temperature are:\n");
printf("For brick-concrete : %f fahrenheit\n",abs(T2)+abs(t1));
printf("For concrete-plaster : %f fahrenheit\n",abs(T2)+abs(t1)+abs(t2));
```

Scilab code Exa 11.6 Heat transfer per square meter of wall

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.6\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.6 (page no. 559)
// Solution

//For Brick,
deltaX=0.150; //Unit:m //150 mm = 0.150 m //deltaX=length //unit:meter
A=1; //area //unit:m^2
k=0.692; //Unit:W/(m*C) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:C/W
printf("For brick,\n");
printf("The resistance is %f Celcius/W\n\n",R);
R1=R;

//For Concrete,
deltaX=0.012; //Unit:m //12 mm = 0.0120 m //deltaX=length //unit:meter
A=1; //area //unit:m^2
```

```
k=1.385; //Unit:W/(m*C) //k=proportionality constant
    //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:C/W
printf("For Concrete,\n");
printf("The resistance is %f Celcius/W\n\n",R);
R2=R;

//For plaster,
deltaX=0.0120; //Unit:m //12 mm = 0.0120 m //deltaX=
    length //unit:meter
A=1; //area  //unit:m^2
k=0.519; //Unit:W/(m*C) //k=proportionality constant
    //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:C/W
printf("For plaster,\n");
printf("The resistance is %f Celcius/W\n\n",R);
R3=R;

Ro=R1+R2+R3; //Rot=The overall resistance //unit:C/W
printf("The overall resistance is %f Celcius/W\n",Ro
    );
T1=0; //temperature maintained at one face //Celcius
T2=20; //tempetature maintained at other face //
    Celcius
deltaT=T2-T1; //Change in temperature  //Celcius
Q=deltaT/Ro; //Q=Heat transfer //Unit:W/m^2; //ohm's
    law (fourier's equation)
printf("Heat transfer per square meter of wall is %f
    W/m^2",abs(Q));
```

Scilab code Exa 11.7 The temperature at the interfaces

```
//scilab 5.4.1
clear;
clc;
```

```
printf("\t\t\tProblem Number 11.7\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.7  (page no. 560)
// Solution

printf("In problem 11.6,\n");
//For Brick,
deltaX=0.150; //Unit:m //150 mm = 0.150 m //deltaX=length //unit:meter
A=1; //area //unit:meter^2
k=0.692; //Unit:W/(m*C) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:Celcius/W
printf("For brick,\n");
printf("The resistance is %f Celcius/W\n\n",R);
R1=R;

//For Concrete,
deltaX=0.012; //Unit:m //12 mm = 0.0120 m //deltaX=length //unit:meter
A=1; //area  //unit:meter^2
k=1.385; //Unit:W/(m*C) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:Celcius/W
printf("For Concrete,\n");
printf("The resistance is %f Celcius/W\n\n",R);
R2=R;

//For plaster,
deltaX=0.0120; //Unit:m //12 mm = 0.0120 m //deltaX=length //unit:meter
A=1; //area  //unit:meter^2
k=0.519; //Unit:W/(m*C) //k=proportionality constant //k=thermal conductivity //From the table
R=deltaX/(k*A); //Thermal resistance //Unit:Celcius/W
```

```
printf("For plaster,\n");
printf("The resistance is %f Celcius/W\n\n",R);
R3=R;

Ro=R1+R2+R3; //Rot=The overall resistance Celcius/W
printf("The overall resistance is %f Celcius/W\n",Ro
   );
T1=0; //temperature maintained at one face //Celcius
T2=20; //tempetature maintained at other face //
   Celcius
deltaT=T2-T1; //Change in temperature //Celcius
Q=deltaT/Ro; //Q=Heat transfer //Unit:W/m^2;
printf("Heat transfer per square meter of wall is %f
    W/m^2\n\n",abs(Q));

printf("Now in problem 11.5,\n");
//deltaT=R*Q //ohm's law (fourier's equation)
//For Brick,
deltaT=Q*R1; //Unit:Celcius //Change in temperature
t1=deltaT;
//For Concrete,
deltaT=Q*R2; //Unit:Celcius //Change in temperature
t2=deltaT;
//For plaster,
deltaT=Q*R3; //Unit:Celcius //Change in temperature
t3=deltaT;

deltaTo=t1+t2+t3; //The overall Change in
   temperature //Celcius
printf("The overall change in temperature is %f
   celcius\n",abs(deltaTo));
//The interface temperature are:
printf("The interface temperature are:\n");
printf("%f Celcius\n",abs(deltaTo)-abs(t1));
printf("%f Celcius\n",abs(deltaTo)-abs(t1)-abs(t2));
printf("%f Celcius\n",abs(deltaTo)-abs(t1)-abs(t2)-
   abs(t3));
```

Scilab code Exa 11.8 total heat loss

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.8\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.8 (page no. 561)
// Solution

deltaX=4/12; //4 inch = 6/12 feet //deltaX=length //unit:ft
A=7*2; //area //area=hight*width //unit:ft^2
k=0.090; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity for fir //From the table
Rfir=deltaX/(k*A); //Resistance of fir //Unit:(hr*F)/Btu
printf("For fir,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",Rfir);

deltaX=4/12; //4 inch = 6/12 feet //deltaX=length //unit:ft
A=7*2; //area //area=hight*width //unit:ft^2
k=0.065; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity for pine //From the table
Rpine=deltaX/(k*A); //Resistance of pine //Unit:(hr*F)/Btu
printf("For pine,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",Rpine);

deltaX=4/12; //4 inch = 6/12 feet //deltaX=length //unit:ft
```

```
A=7*2; //area //area=hight*width //unit:ft^2
k=0.025; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity for corkboard //From the table
Rcorkboard=deltaX/(k*A); //Resistance of corkboard //Unit:(hr*F)/Btu
printf("For corkboard,\n");
printf("The resistance is %f (hr*F)/Btu\n\n",Rcorkboard);

Roverall=inv(inv(Rfir)+inv(Rpine)+inv(Rcorkboard));
printf("The overall resistance is %f (hr*F)/Btu\n\n",Roverall);

T1=60; //temperature maintained at one face //unit:fahrenheit
T2=80; //tempetature maintained at other face //unit:fahrenheit
deltaT=T2-T1; //Change in temperature //unit:fahrenheit
Qtotal=deltaT/Roverall; //Q=Total Heat loss //Unit:Btu/hr; //ohm's law (fourier's equation)
printf("Total Heat loss from the wall is %f Btu/hr\n",abs(Qtotal));

//As a check,
Qfir=deltaT/Rfir; //Q=Fir Heat loss //Unit:Btu/hr; //ohm's law (fourier's equation)
printf("Heat loss from the wall made of fir is %f Btu/hr\n",abs(Qfir));
Qpine=deltaT/Rpine; //Q=Pine Heat loss //Unit:Btu/hr; //ohm's law (fourier's equation)
printf("Heat loss from the wall made of pine is %f Btu/hr\n",abs(Qpine));
Qcorkboard=deltaT/Rcorkboard; //Q=corkboard Heat loss //Unit:Btu/hr; //ohm's law (fourier's equation)
printf("Heat loss from the wall made of corkboard is
```

```
    %f Btu/hr\n",abs(Qcorkboard));
Qtotal=Qfir+Qpine+Qcorkboard; //Total Heat loss from
    the wall //unit:Btu/hr
printf("Total Heat loss from the wall is %f Btu/hr\n
    ",abs(Qtotal));
```

Scilab code Exa 11.9 The heat loss from the pipe

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.9\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.9 (page no. 565)
// Solution

//A bare steel pipe
ro=3.50; //Outside diameter //Unit:in.
ri=3.00; //inside diameter //Unit:in.
Ti=240; //Inside temperature //unit:fahrenheit
To=120; //Outside temperature //unit:fahrenheit
L=5; //Length //Unit:ft
deltaT=Ti-To; //Change in temperature //unit:
    fahrenheit
k=26 //Unit:Btu/(hr*ft*F) //k=proportionality
    constant //k=thermal conductivity
Q=(2*%pi*k*L*deltaT)/log(ro/ri); //The heat loss
    from the pipe //unit:Btu/hr
printf("The heat loss from the pipe is %f Btu/hr",Q)
    ;
```

Scilab code Exa 11.10 heat loss from the pipe

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.10\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.10  (page no. 566)
// Solution

//A bare steel pipe
ro=90; //Outside diameter //Unit:mm
ri=75; //inside diameter //Unit:mm
Ti=110; //Inside temperature //Unit:Celcius
To=40; //Outside temperature //Unit:Celcius
L=2; //Length //Unit:m
deltaT=Ti-To; //Change in temperature //Unit:Celcius
k=45 //Unit:W/(m*C) //k=proportionality constant //k
    =thermal conductivity
Q=(2*%pi*k*L*deltaT)/log(ro/ri); //The heat loss
    from the pipe  //unit:W
printf("The heat loss from the pipe is %f W",Q);
```

Scilab code Exa 11.11 heat loss from mineral of wool

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.11\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.11  (page no. 567)
// Solution

//From problem 11.9,
//A bare steel pipe
r2=3.50; //Outside diameter //Unit:in.
r1=3.00; //inside diameter //Unit:in.
```

```
Ti=240; //Inside temperature //unit:fahrenheit
L=5; //Length //Unit:ft
k1=26; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity
ans1=(inv(k1)*log(r2/r1));

//Now,in problem 11.11,
//Mineral wool
r3=5.50; //inside diameter //Unit:in.
r2=3.50; //outside diameter //Unit:in.
To=85; //Outside temperature //unit:fahrenheit
deltaT=Ti-To; //Change in temperature //unit:fahrenheit
k2=0.026 //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity
ans2=(inv(k2)*log(r3/r2));

Q=(2*%pi*L*deltaT)/(ans1+ans2); //The heat loss from the pipe //unit:Btu/hr
printf("The heat loss from the pipe is %f Btu/hr",Q);
```

Scilab code Exa 11.12 Convection

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.12\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.12 (page no. 569)
// Solution

//From problem 11.9,
//The bare pipe
r2=3.50; //Outside diameter //Unit:in.
```

```
r1=3.00; //inside diameter //Unit:in.
Ti=240; //Inside temperature //unit:fahrenheit
L=5; //Length //Unit:ft
k=26; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity
Rpipe=log(r2/r1)/(2*%pi*k*L); //the resistance of pipe //Unit:(hr*F)/Btu
printf("The resistance of pipe is %f (hr*F)/Btu\n",Rpipe);

//Now,in problem 11.12,
To=70; //Outside temperature //unit:fahrenheit
deltaT=Ti-To; //Change in temperature //unit:fahrenheit
h=0.9; //Coefficient of heat transfer //Unit:Btu/(hr*ft^2*F)
A=(%pi*r2)/12*L;  //Area //Unit:ft^2 //1 inch = 1/12 feet //unit:ft^2
Rconvection=inv(h*A); //The resistance due to natural convection to the surrounding air //Unit:(hr*F)/Btu
printf("The resistance due to natural convection to the surrounding air is %f (hr*F)/Btu\n",Rconvection);

Rtotal=Rpipe+Rconvection; //The total resistance //unit:(hr*F)/Btu
printf("The total resistance is %f (hr*F)/Btu\n\n",Rtotal);
Q=deltaT/Rtotal; //ohm's law (fourier's equation) //The heat transfer from the pipe to the surrounding air  //unit:Btu/hr
printf("The heat transfer from the pipe to the surrounding air is %f Btu/hr\n",Q);
```

Scilab code Exa 11.15 Convection

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.15\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.15 (page no. 574)
// Solution

D=3.5/12; //3.5 inch = 3.5/12 feet//Unit:ft //
    Outside diameter
Ti=120; //Inside temperature //unit:fahrenheit
To=70; //Outside temperature //unit:fahrenheit
deltaT=Ti-To; //unit:fahrenheit //Change in
    temperature
h=0.9; //Coefficient of heat transfer //Unit:Btu/(hr
    *ft^2*F)
L=5; //Length //Unit:ft //From problem 11.10
A=(%pi*D)*L; //Area //Unit:ft^2
Q=h*A*deltaT; //The heat loss due to convection //
    Unit:Btu/hr //Newton's law of cooling
printf("The heat loss due to convection is %f Btu/hr
    ",Q);
```

Scilab code Exa 11.16 Determine the heat transfer through the wall and wall temper

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.16\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.16 (page no. 575)
// Solution

```

```
//This problem can not be solved directly,because the individual film resistances aree functions of unknown temperature differences.Therefore,
//From the first approximation,
h=1/2; //Coefficient of heat transfer //unit:Btu/(hr*ft^2*F)
//For area 1 ft^2,
R=(3/12)/0.07; //The wall resistance is deltax/(k*A) //k=0.07 //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity
Roverall=inv(1/2)+inv(1/2)+R; //the overall series resistance //Unit:Btu/(hr*ft*F)
printf("For h=0.5,the overall series resistance is %f Btu/(hr*ft*F)\n",Roverall);
//Using the value of Roverall,we can now obtain Q and individual temperature differences,
Ti=80; //warm air temperature //unit:fahrenheit
To=50; //cold air temperature //unit:fahrenheit
deltaT=Ti-To; //unit:fahrenheit //Change in temperature
Q=deltaT/Roverall; //Unit:Btu/(hr*ft^2) //heat transfer //ohm's law (fourier's equation)
printf("For h=0.5,heat transfer is %f Btu/(hr*ft^2)\n",Q);
printf("For h=0.5,\n");
//deltaT through the hot air film is Q/(1/2)
printf("Temperaure difference through the hot air film is %f F\n",Q/(1/2));
//Throught the wall deltaT is R*Q
printf("Temperaure difference through the wall is %f F\n",Q*R);
//deltaT through the cold air film is Q/(1/2)
printf("Temperaure difference through the cold air film is %f F\n\n",Q/(1/2));

//With these temperature differences,we can now enter figures 11.12 and 11.14 to verify our approximation.From figure 11.14,we find h=0.42
```

```
Btu/(hr*ft*2*F)
//Using h=0.42,we have for the overall resistance (1/0.42)+(1/0.42)+R
h=0.42; //Coefficient of heat transfer  //unit:Btu/(hr*ft^2*F)
Roverall=inv(h)+inv(h)+R; //the overall series resistance //Unit:Btu/(hr*ft*F)
printf("For h=0.42,the overall series resistance is %f Btu/(hr*ft*F)\n",Roverall);
Q=deltaT/Roverall; //Unit:Btu/(hr*ft^2) //heat transfer //ohm's law (fourier's equation)
printf("For h=0.42,heat transfer is %f Btu/(hr*ft^2)\n",Q);
printf("For h=0.42,\n");
// deltat through both air films is Q/h
printf("Temperaure difference through the hot and cold air film is %f F\n",Q/h);
//and through the wall,deltat is Q*R
printf("Temperaure difference through the wall is %f F\n\n",Q*R);

//Entering figure 11.14,we find that h stays essentially 0.42,and our solution is that the heat flow is Q,the "hot" side of the wall is at Ti-(Q/h),the "cold" side  is at To+(Q/h) ,and temperature drop in the wall is Ti-(Q/h)-(To+(Q/h)).
printf("The temperature drop on the hot side of the wall is %f F\n",Ti-(Q/h));
printf("The temperature drop on the cold side of the wall is %f F\n",To+(Q/h));
printf("The temperature drop in the wall is %f F\n",Ti-(Q/h)-(To+(Q/h)));
//Which checks our wall deltat calculation.
```

Scilab code Exa 11.17 Determine the heat transfer coefficient

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.17\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.17 (page no. 578)
// Solution

//The first step is to check Reynolds number.It will be recalled that the Reynolds number is given by (D*V*rho)/mu and is dimensionless.Therefore,we can use D,       diameter in feet;V velocity in ft/hr;rho density in lbm/ft^3 and mu viscosity in lbm/(ft*hr).
//Alternatively,the Reynolds number is given by (D*G)/mu,where G is the mass flow rate per unit area (lbm/(hr*ft^2)).
G=((20*60)*(4*144)/(%pi*0.87^2)); //Unit:lbm/(hr*ft^2)  //Inside diameter=0.87 inch ////1 in.^2=144 ft^2 //20 lbm/min of water(min converted to second)
//the viscosity of air at these conditions is obtained from figure 11.17 as 0.062 lbm/(ft*hr).So,
mu=0.33; //the viscosity of air //unit:lbm/(ft*hr)
D=0.87/12; //Inside diameter //1 in^2=144 ft^2
//Therefore Reynolds number is
Re=(D*G)/mu; //Reynolds number
//which is well into the turbulent flow regime.
printf("The Reynolds number is %f\n",Re);
//The next step is to enter Figure 11.18 at W/1000 of 20*(60/1000)=1.2 and 400F to obtain h1=630.
//From the figure 11.20,we obtain F=1.25 for an inside diameter of 0.87 inch.So,
h1=630; //basic heat transfer coefficient //unit:Btu/(hr*ft^2*F)
```

```
F=1.25; //correction factor
h=h1*F; //heat transfer coefficient //the inside film coefficient //unit:Btu/(hr*ft^2*F)
printf("The heat-transfer coefficient is %f Btu/(hr*ft^2*F)\n",h);
```

Scilab code Exa 11.18 Determine the inside film coefficient

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.18\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.18 (page no. 579)
// Solution

//We first check the Reynolds number and note that G is same as for problem 11.17.So,
//G is the mass flow rate per unit area (lbm/(hr*ft^2)).
G=((20*60)*(4*144))/(%pi*(0.87^2)); //Unit:lbm/(hr*ft^2) //Inside diameter=0.87 inch ////1 in.^2=144 ft^2 //20 lbm/min of water(min converted to second)
//the viscosity of air at these conditions is obtained from figure 11.17 as 0.062 lbm/(ft*hr).So,
mu=0.062; //the viscosity of air //unit:lbm/(ft*hr)
D=0.87/12; //Inside diameter //1 in^2=144 ft^2
//Reynolds number is DG/mu,therefore
Re=(D*G)/mu; //Reynolds number
printf("The Reynolds number is %f\n",Re);
//which places the flow in the turbulent regime. Because W/1000(W=weight flow) is same as for problem 11.17 and equals 1.2,we now enter figure
```

```
11.19 at 1.2 and 400F  to obtain h1=135.Because the inside tube diameter is same as before,F=1.25.Therefore,
h1=135; //basic heat transfer coefficient //unit:Btu/(hr*ft^2*F)
F=1.25; //correction factor
h=h1*F; //heat transfer coefficient //the inside film coefficient //unit:Btu/(hr*ft^2*F)
printf("The inside film coefficient is %f Btu/(hr*ft^2*F)\n",h);
//It is interesting that for equal mass flow rates, water yields a heat-transfer coefficient almost five times greater than air
```

Scilab code Exa 11.19 Determine the heat loss by radiation

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.19\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.19  (page no. 586)
// Solution

//A bare steel pipe
//From the Table 11.5,case 2,
Fe=0.79; //Emissivity factor to allow for the departure of the surfaces interchanging heat from complete blackness;Fe is a function of the surface emissivities and      configurations
FA=1; //geometric factor to allow for the average solid angle through which one surface "sees" the other
sigma=0.173*10^-8; //Stefan-Boltzmann constant //Unit:Btu/(hr*ft^2*R^4)
```

```
T1=120+460; //outside temperature //Unit:R //
   fahrenheit converted to absolute temperature
T2=70+460; //inside temperature //Unit:R //
   fahrenheit converted to absolute temperature
D=3.5/12; //3.5 inch = 3.5/12 feet//Unit:ft //
   Outside diameter
L=5; //Length //Unit:ft //From problem 11.10
A=(%pi*D)*L;  //Area //Unit:ft^2
Q=sigma*Fe*FA*A*(T1^4-T2^4); //The net interchange
   of heat by radiation between two bodies at
   different temperatures //Unit:Btu/hr ////Stefan-
   Boltzmann law
printf("The heat loss by radiation is %f Btu/hr\n",Q
   );
```

Scilab code Exa 11.20 Determine the heat transfer coefficient

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.20\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.20 (page no. 588)
// Solution

//The upper temperature is given as 120 F and the
   temperature difference is
Ti=120; //Inside temperature //unit:fahrenheit
To=70; //Outside temperature //unit:fahrenheit
deltaT=120-70; //unit:fahrenheit //Change in
   temperature
//Using figure 11.28,
hrdash=1.18; //factor for radiation coefficient //
   Unit:Btu/(hr*ft^2*F)
Fe=1; //Emissivity factor to allow for the departure
```

```
of the surfaces interchanging heat from complete blackness;Fe is a function of the surface emissivities and configurations
FA=0.79; //geometric factor to allow for the average solid angle through which one surface "sees" the other
hr=Fe*FA*hrdash; //The radiation heat−transfer coefficient for the pipe //Unit:Btu/(hr*ft^2*F)
printf("The radiation heat−transfer coefficient for the pipe is %f Btu/(hr*ft^2*F)\n",hr);

//As a check,Using the results of problem 11.17,
printf("As a check,using the results of problem 11.17,\n");
D=3.5/12; //3.5 inch = 3.5/12 feet//Unit:ft //Outside diameter
L=5; //Length //Unit:ft //From problem 11.10
A=(%pi*D)*L;  //Area //Unit:ft^2
Q=214.5; //heat loss //Unit:Btu/hr
hr=Q/(A*deltaT); //The radiation heat−transfer coefficient for the pipe //Unit:Btu/(hr*ft^2*F) //Newton's law of cooling
printf("The radiation heat−transfer coefficient for the pipe is %f Btu/(hr*ft^2*F)\n",hr);
```

Scilab code Exa 11.21 Determine the heat loss due to convection

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.21\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.21  (page no. 589)
// Solution

```

```
//Because the conditions of illustrative problem
    11.15 are the same as for problem 11.19 and
    11.20,we can solve this problem in two ways to
    obtain a check.
//Thus,adding the results of these problems yields,
printf("Adding the results of the problems yields,\n
    ")
Qtotal=206.2+214.5; //Unit:Btu/hr //total heat loss
printf("The heat loss due to convection is %f Btu/hr
    \n",Qtotal);

//We can also approach this solution by obtaining
    radiation and convection heat-transfer co-
    efficcient.Thus,
hcombined=0.9+0.94; //Coefficient of heat transfer
    //Unit:Btu/(hr*ft^2*F)
D=3.5/12; //3.5 inch = 3.5/12 feet //Unit:ft //
    Outside diameter
Ti=120; //Inside temperature //unit:fahrenheit
To=70; //Outside temperature //unit:fahrenheit
deltaT=Ti-To; //unit:fahrenheit //Change in
    temperature
L=5; //Length //Unit:ft //From problem 11.10
A=(%pi*D)*L; //Area //Unit:ft^2
Qtotal=hcombined*A*deltaT; //Unit:Btu/hr //total
    heat loss due to convection //Newton's law of
    cooling
printf("By obtaining radiation and convection heat-
    transfer co-efficcient,\n")
printf("The heat loss due to convection is %f Btu/hr
    ",Qtotal);
```

Scilab code Exa 11.22 Determine the overall heat transfer coefficient

```
//scilab 5.4.1
```

```
clear;
clc;
printf("\t\t\tProblem Number 11.22\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.22 (page no. 595)
// Solution

//For brick,concrete,plaster,hot film and cold film,
A=1; //area //Unit:ft^2
//For a plane wall,the areas are all the same,and if
    we use 1 ft^2 of wall surface as the reference
   area,
//For Brick,
deltax=6/12; //6 inch = 6/12 feet //deltax=length //
   unit:ft
k=0.40; //Unit:Btu/(hr*ft*F) //k=proportionality
   constant //k=thermal conductivity //From the
   table
brickResistance=deltax/(k*A); //Thermal resistance
   //Unit:(hr*f)/Btu
printf("For brick,");
printf("The resistance is %f (hr*F)/Btu\n",
   brickResistance);

//For Concrete,
deltax=(1/2)/12; //(1/2) inch = (1/2)/12 feet //
   deltax=length //unit:ft
k=0.80; //Unit:Btu/(hr*ft*F) //k=proportionality
   constant //k=thermal conductivity //From the
   table
concreteResistance=deltax/(k*A); //Thermal
   resistance //Unit:(hr*f)/Btu
printf("For Concrete,");
printf("The resistance is %f (hr*F)/Btu\n",
   concreteResistance);

//For plaster,
deltax=(1/2)/12; // (1/2) inch = 6/12 feet //deltax=
```

```
    length //unit:ft
k=0.30; //Unit:Btu/(hr*ft*F) //k=proportionality constant //k=thermal conductivity //From the table
plasterResistance=deltax/(k*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For plaster,");
printf("The resistance is %f (hr*F)/Btu\n",plasterResistance);

//For "hot film",
h=0.9; //Coefficient of heat transfer //Unit:Btu/(hr*ft^2*F)
hotfilmResistance=inv(h*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For hot film,");
printf("The resistance is %f (hr*F)/Btu\n",hotfilmResistance);

//For "cold film",
h=1.5; //Coefficient of heat transfer //Unit:Btu/(hr*ft^2*F)
coldfilmResistance=inv(h*A); //Thermal resistance //Unit:(hr*f)/Btu
printf("For cold film,");
printf("The resistance is %f (hr*F)/Btu\n\n",coldfilmResistance);

totalResistance=brickResistance+concreteResistance+plasterResistance+hotfilmResistance+coldfilmResistance; //the overall resistance //Unit:(hr*f)/Btu
printf("The overall resistance is %f (hr*F)/Btu\n",totalResistance);

U=inv(totalResistance); //Unit:Btu/(hr*ft^2) //The overall conductance(or overall heat-transfer coefficient)
```

```
printf("The overall conductance(or overall heat-
    transfer coefficient) is %f Btu/(hr/ft^2)\n",U);
//In problem 11.21,the solution is straightforward,
    because the heat-transfer area is constant for
    all series resistances.
```

Scilab code Exa 11.23 Determine the overall heat transfer coefficient of outside a

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.23\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.23  (page no. 596)
// Solution

hi=45; //Film coefficient on the inside of the pipe
    //Unit:Btu/(hr*ft^2*F)
r1=3.0/2; //Inside radius //Unit:inch
k1=26; //Unit:Btu/(hr*ft^2*F) //k=proportionality
    constant for steel pipe //k=thermal conductivity
    for fir //From the table
r2=3.5/2; //outide radius //Unit:inch
k2=0.026; //Unit:Btu/(hr*ft^2*F) //k=proportionality
     constant for mineral wool //k=thermal
    conductivity for fir //From the table
r3=5.50/2; //radius //Unit:inch
ho=0.9; //Film coefficient on the outside of the
    pipe //Unit:Btu/(hr*ft^2*F)
//Results of problem 11.23,
Ui=1/((1/hi)+((r1/(k1*12))*log(r2/r1))+((r1/(k2*12))
    *log(r3/r2))+(1/(ho*(r3/r1)))); //Unit:Btu/(hr*ft
    ^2*F) //1 in.=12 ft //Heat transfer coefficient
    based on inside surface
printf("Heat transfer coefficient based on inside
```

```
surface is %f Btu/(hr*ft^2*F)\n",Ui);
//Because Uo*Ao=Ui*Ai
Uo=Ui*(r1/r3); //Heat transfer coefficient based on outside surface //Unit:Btu/(hr*ft^2*F)
printf("Heat transfer coefficient based on outside surface is %f Btu/(hr*ft^2*F)\n",Uo);
```

Scilab code Exa 11.24 `Determine the outside tube surface required`

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.24\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.24 (page no. 601)
// Solution

//A COUNTERFLOW HEAT EXCHANGER
//Hot oil enters at 215 F and leaves at 125 F
//Water enters the unit at 60 F and leaves at 90 F
//Therefore,From figure 11.34,
thetaA=215-90; //the greatest temperature difference between the fluids(at either inlet or outlet) //Unit:fahrenheit
thetaB=125-60; //the least temperature difference between the fluids(at either inlet or outlet) //Unit:fahrenheit
deltaTm=(thetaA-thetaB)/log(thetaA/thetaB); //logarithmic mean temperature difference //Unit:fahrenheit
//From the oil data,
m=400*60;  //mass //Unit:lb/sec //1 min=60 sec
Cp=0.85; //Specific heat of the oil //Unit:Btu/(lb*F)
deltaT=215-125;  //Change in temperature //Unit:
```

```
    fahrenheit
Q=m*Cp*deltaT //The heat transfer //Unit:Btu/hr
//Q=U*A*deltaTm
U=40;//The overall coefficient of heat transfer of
    the unit //Unit:Btu/(hr*ft^2*F)
A=Q/(U*deltaTm); //Umit:ft^2 //The outside surface
    area
printf("The outside surface area required is %f ft^2
    ",A);
```

Scilab code Exa 11.25 Determine the outside surface area required

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.25\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.25 (page no. 602)
// Solution

//In problem 11.24, A COUNTERFLOW HEAT EXCHANGER is
    operated in the parallel flow
//Hot oil enters at 215 F and leaves at 125 F
//Water enters the unit at 60 F and leaves at 90 F
//Therefore,From figure 11.35,
thetaA=215-60; //the greatest temperature difference
     between the fluids(at either inlet or outlet) //
    Unit:fahrenheit
thetaB=125-90; //the least temperature difference
    between the fluids(at either inlet or outlet) //
    Unit:fahrenheit
deltaTm=(thetaA-thetaB)/log(thetaA/thetaB); //
    logarithmic mean temperature difference //Unit:
    fahrenheit
//From the oil data,
```

```
m=400*60;  //mass //Unit:lb/sec //1 min=60 sec
Cp=0.85; //Specific heat of the oil //Unit:Btu/(lb*F
    )
deltaT=215-125;  //Change in temperature  //Unit:
    fahrenheit
Q=m*Cp*deltaT //The heat transfer //Unit:Btu/hr
//Q=U*A*deltaTm
U=40;//The overall coefficient of heat transfer of
    the unit //Unit:Btu/(hr*ft^2*F)
A=Q/(U*deltaTm); //Umit:ft^2 //The outside surface
    area
printf("The outside surface area required is %f ft^2
    ",A);
```

Scilab code Exa 11.26 the outside surface area required

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.26\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.26  (page no. 603)
// Solution

//From the table 11.7,
//For the oil side,a resistance(fouling factor) of
    0.005 (hr*F*ft^2)/Btu can be used
//and for the water side,a fouling factor of 0.001 (
    hr*F*ft^2)/Btu can be used
//From problem 11.25,
U=40;//The coefficient of heat transfer of the unit
    //Unit:Btu/(hr*ft^2*F)
//therefore,
Roil=0.005; //unit:(hr*ft^2*F)/Btu //resistance at
    oil side
```

```
Rwater=0.001; //unit:(hr*ft^2*F)/Btu //resistance
   for water side
Rcleanunit=inv(U); //unit:(hr*ft^2*F)/Btu //
   resistance at clean unit
Roverall=Roil+Rwater+Rcleanunit; //unit:(hr*ft^2*F)/
   Btu //overall resistance
Uoverall=inv(Roverall); //Unit:Btu/(hr*ft^2*F) //The
    overall coefficient of heat transfer of the unit
//Because all the parameters are the same,the
   surface area required will vary inversely as U
A=569*(U/Uoverall); //A=569 ft^2 in the problem
   11.25 //unit:ft^2 //The outside surface area
printf("The outside surface area required is %f ft^2
   ",A);
```

Scilab code Exa 11.27 True mean temperature difference

```
//scilab 5.4.1
clear;
clc;
printf("\t\t\tProblem Number 11.27\n\n\n");
// Chapter 11 : Heat Transfer
// Problem 11.27 (page no. 605)
// Solution

//HEAT EXCHANGER
//Oil flows in the tube side and is cooled from 280
    F to 140 F
//Therefore,
t2=140; //Unit:fahrenheit
t1=280; //Unit:fahrenheit
//On the shell side,water is heated from 85 F to 115
    F
T1=85; //Unit:fahrenheit
T2=115; //Unit:fahrenheit
```

```
P=(t2-t1)/(T1-t1);
R=(T1-T2)/(t2-t1);
//From the figure,
F=0.91;//Correction factor
LMTD=((t1-T2)-(t2-T1))/log((t1-T2)/(t2-T1)); //LMTD=
    Log mean temperature difference //Unit:fahrenheit
TMTD=F*LMTD; //TMTD=True mean temperature difference
     //Unit:fahrenheit
printf("The true mean temperature is %f fahrenheit",
    TMTD);
```