Scilab Textbook Companion for
Modern Engineering Thermodynamics
by Robert T.Balmer[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

The beginning

Scilab code Exa 1.1 `The acceleration of the car`

```
// Example 1_1
clc;funcprot(0);
// Given data
V_final=120;// mph
V_initial=85;// mph
t=5;// seconds

// Calculation
a=(V_final-V_initial)/t;// miles/(hour/seconds)
V_initial=V_initial*(5280/3600);// feet/second
V_final=V_final*(5280/3600);// feet/second
a=(V_final-V_initial)/t;// The acceleration in ft/s
   ^2
printf("\nThe acceleration of the car,a=%2.1f ft/s^2
   ",a);
```

Scilab code Exa 1.2 `Convert 55 degrees on the modern Fahrenheit scale`

```
// Example 1_2
clc;funcprot(0);
// Given data
T=55;//  F

// Calculation
// (a)
T_w=0;// The freezing point of water in  N
T_wF=32;// The freezing point of water in  F
T_bh=12;// The temperature of the body in  N
T_bhF=98.6;// The temperature of the body in  F
x=T_bh*(1-((T_bhF-T)/(T_bhF-T_wF)));// The temperature in  N
printf("\n(a)The temperature on the Newton scale,x=%1.2f  N ",x);
// (b)
T_w=0;// The temperature in  Re
T_wF=80;// The temperature in  Re
T_bh=32;// The temperature in  F
T_bhF=212;// The temperature in  F
r=T_wF*(1-((T_bhF-T)/(T_bhF-T_bh)));// The temperature in  Re
printf("\n(b)The temperature on the Reaumur scale,r=%2.1f  Re ",r);
// (c)
T_w=273.15;// The temperature in K
T_wF=373.15;// The temperature in K
T_bh=32;// The temperature in  F
T_bhF=212;// The temperature in  F
z=T_wF-((T_wF-T_w)*(((T_bhF-T)/(T_bhF-T_bh))));// The temperature in K
printf("\n(c)The Kelvin temperature,z=%3.1f K",z);
```

Scilab code Exa 1.3 `Define a new units system`

```
// Example 1_3
clc;funcprot(0);
// Given data
g_c=32.174;//  ft/s^2
F=1;// lbf
m=1;// lbm

// Solution
onechunk=1;// (lbf.s^2)/lbm
// In the Engineering English units system, 1 lbf accelerates 1 lbm at a rate of
a=(F*g_c)/m;// ft/s^2
onechunk=32.174;// ft/s^2
onechunk=32.174/3.281;// m
printf("\n 1 chunk=%1.3f m",onechunk);
```

Scilab code Exa 1.4 The weight of the telescope in Earth orbit

```
// Example 1_4
clc;funcprot(0);
// Given data
W=25000;// Weight in lbf
V=5000;// mph
g=32.174;// ft/s^2
g_orbit=2.50;// ft/s^2

// Calculation
// (a)
g_c=32.174;// ft/s^2
// (b)
m=(W*g_c)/g;// The mass in lbm
W_orbit=(m*g_orbit)/g_c;// lbf
printf("\n(a)The value of g_c in this orbit,g_c=%2.3f ft/s^2 \n(b)The weight in Earth orbit,W_orbit=%4.0f lbf",g_c,W_orbit);
```

Scilab code Exa 1.5 The number of kilogram moles of water in the glass

```
// Example 1_5
clc;funcprot(0);
// Given data
D=0.07;// The diameter in m
R=D/2;// The radius in m
h=0.15;// The height in m
L=(3/4)*h;// m
rho=1000;// The density in kg/m^3
M=18;// kg/kg mole

// Calculation
m=(%pi*R^2*L)*rho;// The mass of water in the glass in kg
n=m/M;// The number of moles in kg moles
printf("\nThe number of kilogram moles of water in the glass,n=%0.3f kgmole",n);
```

Scilab code Exa 1.6 The cross sectional area of the pipe

```
// Example 1_6
clc;funcprot(0);
// Given data
D=2.5;// The inside diameter of a circular water pipe in inches

// Calculation
A=(%pi*D^2)/4;// in^2
printf("\nThe cross-sectional area of the pipe,A=%1.4f in^2",A);
```

Scilab code Exa 1.7 `The potential energy of an automobile`

```
// Example 1_7
clc;funcprot(0);
// Given data
W=2000;// lbf
F=W;// lbf
Z=8.00;// ft
g_c=1;// Dimensionless
g=9.81;// m/s^2

// Calculation
m=((F/0.2248)*g_c)/(g);// kg
Z=Z/3.281;// m
PE=(m*g*Z)/g_c;// kJ
// In the Engineering English units system, we have
Z=8.00;// m
g_c=32.174;// lbm.ft/lbf.s^2
g=32.174;// ft/s^2
m=(F*g_c)/g;// lbm
PE=(m*g*Z)/g_c;// ft.lbf
PE=PE/778.17;// Btu
printf("\nThe potential energy of an automobile,PE=
   %2.1f Btu",PE);
```

Scilab code Exa 1.8 `The translational kinetic energy of a bullet`

```
// Example 1_8
clc;funcprot(0);
// Given data
V_ft=3000;// ft/s
m=10.0;// grams
```

```
g_c=1;// Dimensionless

// Calculation
m=m/1000;// kg
V=V_ft/3.281;// m/s
KE=(m*V_ft^2)/(2*g_c);// kJ
m=(m*2.205);// lbm
// In the Engineering English units system, we have
g_c=32.174;// lbm.ft/(lbf.s^2)
KE=(m*V_ft^2)/(2*g_c);// ft.lbf
KE=KE/778.17;// Btu
printf("\nThe translational kinetic energy of a
   bullet,KE=%1.2f Btu",KE)
```

Scilab code Exa 1.9 `The rotational kinetic energy in the armature of an electric m`

```
// Example 1_9
clc;funcprot(0);
// Given data
m=10.0;// lbm
omega=1800;// rpm
d=4.00;// inches
R=d/2;// inches
g_c=32.174;// lbm.ft/lbf.s^2

// Calculation
I=(m*(R/12)^2)/2;// lbm.ft^2
KE_rot=(I*((2*%pi*omega)/60)^2)/(2*g_c);// lbf
printf("\nThe rotational kinetic energy in the
   armature of an electric motor,KE_rot=%2.1f ft.lbf
   ",KE_rot);
```

Chapter 2

Thermodynamic Concepts

Scilab code Exa 2.1 `The change in chip inventory at the end of each day`

```
// Example 2_1
clc;funcprot(0);
// Given data
C_c=120000;// The number of chips per day to its
    customers in chips/day
C_s=100000;// The number of chips receives per day
    from its suppliers in chips/day
C_m=30000;// The number of chips manufactures of its
    own in chips/day
C_r=3000;// The number of chips are rejected as
    defective and are destroyed in chips/day

// Solution
X_T=C_s-C_c;// The net transport of chips into the
    facility in chips/day
X_P=C_m-C_r;// The net production of chips in chips/
    day
X_G=X_T+X_P;// The net gain in computer chips at the
    end of each day in in chips/day
printf('\nThe net gain in computer chips at the end
    of each day,X_G=%4.0f chips per day.',X_G);
```

Scilab code Exa 2.4 `The muzzle velocity of a weapon fired point blank into a balli`

```
// Example 2_4
clc;funcprot(0);
// Given data
m_pendulum=5.0;// The mass of the pendulum in kg
m_projectile=0.01;// The mass of the projectile in
   kg
g=9.81;// The acceleration due to gravity in m/s^2
R=1.5;// The length of the pendulum support cable in
    m
theta=15;// degree

// Solution
V_projectile=(1+(m_pendulum/m_projectile))*(2*g*R
   *[1-cosd(theta)])^(1/2);// The muzzle velocity in
    m/s
printf('\nThe muzzle velocity, V_projectile=%1.0e m/s
   ',V_projectile);
```

Chapter 3

Thermodynamic Properties

Scilab code Exa 3.2 `The volume of the block`

```
// Example 3_2
clc;funcprot(0);
// Given data
T_1=250;// K
T_2=800;// K
beta_1=48.0*10^-6;// K^-1
beta_2=60.7*10^-6;// K^-1
V_1=1.00;// cm^3

// Solution
beta_avg=(beta_2+beta_1)/2;// K^-1
beta=beta_avg;// K^-1
V_2=V_1*exp(beta*(T_2-T_1));// The final volume in cm^3
printf('\nThe volume of the block,V_2=%1.2f cm^3',V_2);
```

Scilab code Exa 3.3 `The specific enthalpy of the water`

```
// Example 3_3
clc;funcprot(0);
// Given data
u=82.77;// The specific internal energy in kJ/kg
v=0.0009928;// The specific volume of liquid water
   in m^3/kg
T=20.0;//  C
P=20.0;// MPa

// Solution
h=u+(P*10^3*v);// The specific enthalpy of the water
    in kJ/kg
printf('\n The specific enthalpy of the water,h=%3.0
   f kJ/kg',h);
```

Scilab code Exa 3.4 `The mass of water in the liquid and vapor phases`

```
// Example 3_4
clc;funcprot(0);
// Given data
T=212;//  F
V=3.00;// The total volume in ft^3
m=0.200;// lbm
p=14.696;// psia
v_f=0.01672;// ft^3/lbm
v_g=26.80;// ft^3/lbm
u_f=180.1;// Btu/lbm
u_g=1077.6;// Btu/lbm
h_f=180.1;// Btu/lbm
h_g=1150.5;// Btu/lbm

// Solution
// (a)
v=V/m;// The specific volume in ft^3/lbm
// (b)
```

```
v_fg=v_g-v_f;// ft^3/lbm
x=(v-v_f)/v_fg;// The quality
x_m=1-x;// The amount of moisture present
// (c)
u_fg=u_g-u_f;// Btu/lbm
u=u_f+(x*u_fg);// The specific internal energy in Btu/lbm
// (d)
h_fg=h_g-h_f;// Btu/lbm
h=h_f+(x*h_fg);// The specific enthalpy in Btu/lbm
// (e)
m_g=x*m;// The mass of water in the vapor phase in lbm
m_f=m-m_g;// The mass of water in the liquid phase in lbm
printf('\n(a)The specific volume,v=%2.0f ft^3/lbm \n(b)The quality,x=%0.3f (or) %2.1f percentage \n The amount of moisture present,1-x=%0.3f (or) %2.1f percentage \n(c)The specific internal energy,u=%3.0f Btu/lbm \n(d)The specific enthalpy,h=%3.0f Btu/lbm \n(e)The mass of water in the liquid and vapor phases,m_f=%0.3f lbm & m_g=%0.3f lbm',v,x,x*100,x_m,x_m*100,u,h,m_f,m_g);
```

Scilab code Exa 3.5 `The total mass of saturated water`

```
// Example 3_5
clc;funcprot(0);
// Given data
V=0.500;// ft^3
p_c=3203.8;// psia
T_c=1165.1;// R
v_c=0.05053;// ft^3/lbm
p_1=14.696;// psia
T_1=212;//  F
```

```
v_f1=0.01672;// ft^3/lbm
v_g1=26.8;// ft^3/lbm

// Solution
m=V/v_c;// lbm
x_1=((v_c-v_f1)/(v_g1-v_f1))*100;// % percentage
printf('\nThe initial quality in the vessel,x_1=%0.3f percentage vapor',x_1);
```

Scilab code Exa 3.6 The change in specific internal energy and specific enthalpy o

```
// Example 3_6
clc;funcprot(0);
// Given data
T_1=20;//  C
T_2=100;//  C
p_1=0.100;// MPa
p_2=1.00;// MPa
rho=515;// kg/m^3
c=1.76;// kJ/kg.K.

// Solution
deltau=c*((T_2+273.15)-(T_1+273.15));// The change in specific internal energy in kJ/kg
v=1/rho;// The specific volume in m^3/kg
deltah=deltau+(v*((p_2*10^3)-(p_1*10^3)));// The change in specific enthalpy in kJ/kg
printf('\nThe change in specific internal energy,u_2-u_1=%3.0f kJ/kg \nThe change in specific enthalpy,h_2-h_1=%3.0f kJ/kg',deltau,deltah);
```

Scilab code Exa 3.7 The change in specific internal energy and specific enthalpy o

```
// Example 3_7
clc;funcprot(0);
// Given data
T_1=240;//  F
T_2=80;//  F
p_1=150;// psia
p_2=14.7;// psia
c_p=0.240;// Btu/lbm    R
c_v=0.172;// Btu/lbm    R

// Solution
// (a)
deltau=c_v*((T_2+459.67)-(T_1+459.67));// Btu/lbm
deltah=c_p*(T_2-T_1);// Btu/lbm
printf('\n(a)The change in specific internal energy, u_2-u_1=%2.1f Btu/lbm \n    The change in specific enthalpy,h_2-h_1=%2.1f kJ/kg',deltau,deltah);
// (b)
// Values for u and h for variable specific heat air can be found in Table C.16.
T_1=T_1+459.67;// R
h_1=167.56;// Btu/lbm
u_1=119.58;// Btu/lbm
T_2=T_2+459.67;// R
h_2=129.06;// Btu/lbm
u_2=92.04;// Btu/lbm
deltau=u_2-u_1;// Btu/lbm
deltah=h_2-h_1;// Btu/lbm
printf('\n(b)The change in specific internal energy, u_2-u_1=%2.1f Btu/lbm \n    The change in specific enthalpy,h_2-h_1=%2.1f kJ/kg',deltau,deltah);
```

Scilab code Exa 3.8 `The maximum pressure in the breech`

```
// Example 3_8
```

```
clc;funcprot(0);
// Given data
T_max=2830;// The maximum temperature in  C
rho=200;// The density of the propellant gases in kg
   /m^3
R=8314.3;// N.m/(kgmole.K)
M=23.26;// The molecular mass of the propellant
   gases in kg/kgmole
b=0.960*10^-3;// The volume occupied by the
   molecules of the propellant gases in m^3/kg

// Solution
v=1/rho;// m^3/kg
p_max=(R*(T_max+273.15))/(M*(v-b));// N/m^2
p_max=p_max/6894.76;// lbf/ in^2 absolute
printf('\nThe maximum pressure in the breech as the
   cannon fires,p_max=%5.0f psia',p_max);
```

Scilab code Exa 3.9 `The specific volume and specific enthalpy of Refrigerant 134a`

```
// Example 3_9
clc;funcprot(0);
// Given data
T=100;//  F
p=95.0;// psia

// Calculation
// From Table C.7a,C.8a of Thermodynamic Tables to
   accompany Modern Engineering Thermodynamics,
v_1=0.5751;// ft^3/lbm (100 F ,90.0 psia)
v_2=0.5086;// ft^3/lbm (100 F ,100.0 psia)
p_i1=100;// psia (Pressure used for interpolation)
p_i2=90;// psia
v=v_1+(((p-p_i2)/(p_i1-p_i2))*(v_2-v_1));// ft^3/lbm
    (100 F ,95.0 psia)
```

```
h_1=118.39;// Btu/lbm (100 F ,90 psia)
h_2=117.73;// Btu/lbm (100 F ,100 psia)
h=h_1+(((p-p_i2)/(p_i1-p_i2))*(h_2-h_1));// Btu/lbm (100 F ,95.0 psia)
printf("\nThe specific volume of Refrigerant-134a,v (100 F ,95.0 psia)=%0.5f ft^3/lbm \nThe specific enthalpy of Refrigerant-134a,h (100 F ,95.0 psia)=%3.2f Btu/lbm",v,h);
```

Chapter 4

The First Law of Thermodynamics and Energy Transport Mechanisms

Scilab code Exa 4.1 `What energy transport is required to decelerate the water to z`

```
// Example 4_1
clc;funcprot(0);
// Given data
p_1=10.0;// psia
x_1=1.00;// The quality of saturated vapor
V_1=25000;// mph
Z_1=200;// miles
v_1=38.42;// ft^3/lbm
m=3.0;// lbm
u_2=950.0;// The final specific internal energy in Btu/lbm
v_2=v_1;;// ft^3/lbm
g=32.174;// The acceleration due to gravity in m/s^2

// Solution
// Table C.2a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics gives
```

```
u_1=1072.2;// Btu/lbm
U_1=m*u_1;// Btu
U_2=m*u_2;// Btu
E_T=(U_2-U_1)-([((m/2)*(V_1*(5280/3600))^2)]*((1/(g*778.16))))-[((m*g)/g)*Z_1*5280/778.16];// Btu
printf('\nThe energy transport is required to decelerate the water to zero velocity and bring it down to the surface of the Earth,E_T=%5.0f Btu',E_T);
```

Scilab code Exa 4.2 The energy transport rate for the system

```
// Example 4_2
clc;funcprot(0);
// Given data
E_fuel=15000;// Btu/min
E_exhaust=500;// Btu/min
W_1=200;// hp
W_2=50;// hp
E_thl=180000;// Top heat loss in Btu/h
E_Bhl=54000;// Bottom heat loss in Btu/h

// Solution
Q=-E_thl-E_Bhl;// The net heat transfer into the system in Btu/h
W=W_1+W_2;// The net work rate out of the system in hp
E_massflow=E_fuel-E_exhaust;// The net mass flow of energy into the system in Btu/min
E_T=(Q/60)-(W*42.4)+E_massflow;// The total energy transport rate in Btu/min
printf('\nThe total energy transport rate,E_T=%1.2f Btu/min',E_T);
```

Scilab code Exa 4.4 `The moving system boundary work`

```
// Example 4_4
clc;funcprot(0);
// Given data
p=20.0;// Pressure in psia
D_1=1.00;// Initial diameter in ft
D_2=10.0;// Final diameter in ft

// Solution
W_12=p*144*(%pi/6)*(D_2^3-D_1^3);// ft.lbf
printf('\nThe moving system boundary work,W_12=%1.2e ft.lbf',W_12);
```

Scilab code Exa 4.5 `The moving boundary work required`

```
// Example 4_5
clc;funcprot(0);
// Given data
T_1=20.0;// C
n=1.35;// The polytropic index
m=0.0100;// kg
p_1=0.100;// MPa
m_2=0.0100;// kg
p_2=10.0;// MPa

// Solution
T_2=((T_1+273.15)*(p_2/p_1)^((n-1)/n))-273.15;// C
// Using Table C.13b of Thermodynamic Tables to accompany Modern Engineering Thermodynamics to find the value of the gas constant for methane,
R_methane=0.518;// kJ/kg.K
```

```
W_12=(m*R_methane*((T_2+273.15)-(T_1+273.15)))/(1-n);// kJ
printf('\nThe moving boundary work required,W_12=%1.2f kJ',W_12);
```

Scilab code Exa 4.7 `The amount of surface tension work required to inflate the soa`

```
// Example 4_7
clc;funcprot(0);
// Given data
D_1=0;// m
D_2=0.0500;// m
Sigma_s=0.0400;// N/m (constant)

// Solution
A_1=0;// m^2
R_2=D_2/2;// m
A_2=2*(4*%pi*R_2^2);// m^2
W_12=-Sigma_s*(A_2-A_1);// J
W_12=W_12/1055;// Btu
printf('\nThe amount of surface tension work required to inflate the soap bubble,(W_12)_surface tension=%1.2e Btu',W_12);
```

Scilab code Exa 4.8 `The electrical current work`

```
// Example 4_8
clc;funcprot(0);
// Given data
phi_e=120;// V
R=144;// ohm
t=1.50;// h

```

```
// Solution
// (a)
i_e=phi_e/R;// A
W_12=-phi_e*i_e*t;// The electrical current work in W.h
// (b)
W_ec=-phi_e*i_e;// W
printf('\n(a)The electrical current work,W_12=%3.0f W.h \n(b)The electrical power consumption, W_electrical current=%3.0f W',W_12,W_ec);
```

Scilab code Exa 4.9 `The polarization work required in the charging of the capacito`

```
// Example 4_9
clc;funcprot(0);
// Given data
deltaphi=120;// volts
L=0.0100;// The distance between two plates in m
d=0.100;// The length of the plate on square side in m
epsilon_0=8.85419*10^-12;// The electric permittivity of vacuum in N/V^2

// Solution
E_1=0;//  V/m
A=0.100*0.100;// m^2
V=A*L;// m^3
E_2=deltaphi/L;// V/m
Shi_e=77.5;// The electric susceptibility
W_12=-(epsilon_0*Shi_e*V*(E_2^2-E_1^2))/2;// The polarization work required in the charging of the capacitor in J
printf('\nThe polarization work required in the charging of the capacitor,W_12=%1.2e N.m',W_12);
```

Scilab code Exa 4.10 `Total magnetic and material magnetic work`

```
// Example 4_10
clc;funcprot(0);
// Given data
T=20;//  C
mu_0=4*%pi*10^-7;// V.s/A
Shi_m=-2.20*10^-5;// The electric susceptibility
H_2=1.00*10^3;// A/m
V=5.00*10^-6;// m^3

// Solution
// (a)
H_1=0;// A/m
W_12=-mu_0*V*(1+Shi_m)*((H_2^2-H_1^2)/2);// J
printf('\n(a)The total magnetic work required,(W_12)magnetic=%1.2e J',W_12);
// (b)
W_12=-mu_0*V*Shi_m*((H_2^2-H_1^2)/2);// J
printf('\n(b)The magnetic work required to change the magnetic field strength,(W)_magnetic=%1.2e J',W_12);
```

Scilab code Exa 4.11 `The energy conversion efficiency of the engine`

```
// Example 4_11
clc;funcprot(0);
// Given data
W_actual=150;// hp
W_reversible=233;// hp
m_in=1.10;// lbm/min
E=20.0*10^3;// Btu/lbm
```

```

// Solution
W_in=(E*m_in*60)/2545;// hp
// (a)
n_c=(W_actual/W_in)*100;// The energy conversion efficiency of the engine in %
// (b)
n_W=(W_actual/W_reversible)*100;// The work efficiency of the engine.
printf('\n(a)The energy conversion efficiency of the engine,n_c=%2.1f percentage \n(b)The work efficiency of the engine,n_W=%2.1f percentage',n_c,n_W);
```

Chapter 5

First Law Closed System Applications

Scilab code Exa 5.1 `The heat transport of energy required to raise the temperature`

```
// Example 5_1
clc;funcprot(0);
// Given data
V=1.00;// m^3
m=2.00;// kg
T_1=20.0;//  C
T_2=95.0;//  C

// Calculation
v_1=V/m;// m^3/kg
v_2=v_1;// m^3/kg
// Step 7
// From Table C.1b of Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find that
// At 20.0 C
v_f1=0.001002;// m^3/kg
v_g1=57.79;// m^3/kg
v_fg1=v_g1-v_f1;// m^3/kg
```

```
u_f1=83.9;// kJ/kg
u_g1=2402.9;// kJ/kg
u_fg1=u_g1-u_f1;// kJ/kg
// At 95.0 C
v_f2=0.00104;// m^3/kg
v_g2=1.982;// m^3/kg
v_fg2=v_g2-v_f2;// m^3/kg
u_f2=397.9;// kJ/kg
u_g2=2500.6;// kJ/kg
u_fg2=u_g2-u_f2;// kJ/kg
x_1=(v_1-v_f1)/v_fg1;// The quality in the container when the contents are at 20.0 C
x_1p=x_1*100;// %
x_2=(v_2-v_f2)/v_fg2;// The quality in the container when the contents are at 95.0 C .
x_2p=x_2*100;// %
u_1=u_f1+(x_1*u_fg1);// kJ/kg
u_2=u_f2+(x_2*u_fg2);// kJ/kg
Q_12=m*(u_2-u_1);// kJ
printf('\n(a)The quality in the container when the contents are at 20.0 C ,x_1=%0.3f percentage \n(b)The quality in the container when the contents are at 95.0 C ,x_2=%2.1f percentage \n(c)The heat transport of energy required to raise the temperature of the contents from 20.0 to 95.0 C , Q_12=%4.0f kJ/kg',x_1p,x_2p,Q_12);
```

Scilab code Exa 5.2 The rate of change of internal energy

```
// Example 5_2
clc;funcprot(0);
// Given data
W=100;// W

// Calculation
```

```
// (a)
// Since we are assuming a constant bulb temperature in part a, U=constant and
U=0;// W
Q=U-W;// kW
printf("\n(a)The heat transfer rate of an illuminated 100 W incandescent lightbulb in a room,Q=%3.0f W",Q);
// (b)
Q=0;
Udot=W;// W
printf("\n(b)The rate of change of its internal energy,Udot=%3.0f W",Udot);
```

Scilab code Exa 5.3 The net power of the turbine

```
// Example 5_3
clc;funcprot(0);
// Given data
Q_B=950*10^5;// kJ/h
W_p=23.0;// kW
Q_c=-600*10^5;// kJ/h

// Calculation
Q_net=(Q_B+Q_c);// kJ/h
W_T_net=Q_net/3600;// kJ/h
W_T_net=W_T_net/1000;// MW
W_T_total=(W_T_net*10^3)+W_p;// kW
printf("\nThe net power of the turbine,(W_T)_total=%4.0f kW(round off error)",W_T_total);
// The answer vary due to round off error
```

Scilab code Exa 5.4 The temperature of the water when the machine is turned off

```
// Example 5_4
clc;funcprot(0);
// Given data
W=0.250;// hp
V=1.00;// quart of water
p_1=14.7;// psia
T_1=60.0;//  F
p_2=p_1;// psia
t=10;// min
c=1.00;// Btu/(lbm.R)

// Calculation
V=V*(1/4)*0.13368;// ft^3
v=0.01603;// ft^3/lbm
m=V/v;// lbm
Q_12bymc=0;
T_2=T_1+Q_12bymc-((-W*t*(1/60)*(2545))/(m*c));//  F
printf('\nThe temperature of the water when the machine is turned off,T_2=%3.0f  F',T_2)
```

Scilab code Exa 5.5 The pressure and temperature inside the box after the balloon

```
// Example 5_5
clc;funcprot(0);
// Given data
V_2=0.0400;// m^3
T_1=20.0;//  C
p_1=0.0100;// MPa
Q_12=0.100;// kJ
V_1=0.0100;// m^3
R=0.208;// kJ/kg.K
c_v=0.315;// kJ/kg.K

// Calculation
m=((p_1*10^3)*V_1)/(R*(T_1+273.15));// kg
```

```
T_2=T_1+(Q_12/(m*c_v));// K
p_2=(m*R*(T_2+273.15))/V_2;// kPa
printf('\nThe pressure and temperature inside the
   box after the balloon bursts p_2=%1.2f kPa and
   T_2=%3.0f C',p_2,T_2);
```

Scilab code Exa 5.6 `The final temperature at the end of the isobaric compression`

```
// Example 5_6
clc;funcprot(0);
// Given data
// State 1
m=0.100;// lbm
p_1=100;// psia
T_1=180;//  F
// State 2
p_2=30.0;// psia
T_2=120;//  F
// State 3
p_3=p_2;// psia

// Calculation
// (a)
// From Table C.7e of Thermodynamic Tables to
   accompany Modern Engineering Thermodynamics, we
   find that at p1 = 100 psia and T1 = 180 F ,
v_1=0.6210;// ft^3/lbm
u_1=125.99;// Btu/lbm
// At p2= 30 psia and T2 = 120 F ,
v_2=1.966;// ft^3/lbm
u_2=115.47;// Btu/lbm
W_12=-m*(u_2-u_1);// Btu
// (b)
v_3=v_1/2;// ft^3/lbm
// At p2= 30 psia
```

```
v_f3=0.01209;// ft^3/lbm
v_g3=1.5408;// ft^3/lbm
u_f3=16.24;// Btu/lbm
u_g3=95.40;// Btu/lbm
x_3=(v_3-v_f3)/(v_g3-v_f3);// The quality of steam
x_3p=x_3*100;// %
u_3=u_f3+(x_3*(u_g3-u_f3));// Btu/lbm
Q_23=(m*(u_3-u_2))+(m*(p_3*144)*((v_3-v_2)
   *(1/778.17)));// Btu
// (c)
// From Table C.7b
T_3=15.38;//  F
printf('\n(a)The work transport of energy during the
    adiabatic expansion,W_12=%1.2f Btu \n(b)The heat
    transport of energy during the isobaric
   compression,Q_23=%1.2f Btu \n(c)Since state 3 is
   saturated (a mixture of liquid and vapor), T3
   must be equal to the saturation temperature at
   30.0 psia,which, from Table C.7b, is T_3 =%2.2
   f F',W_12,Q_23,T_3);
```

Scilab code Exa 5.7 The final temperature of the helium and the change in total in

```
// Example 5_7
clc;funcprot(0);
// Given data
D=0.100;// m
T_1=200;//  C
p_1=0.140;// MPa
h=3.50;// W/(m^2.K)
T_infinitive=15.0;//  C
c_v=3.123;// kJ/kg.K
R=2.077;// kJ/kg.K
t=5.00;// seconds

```

```
// Calculation
V=(%pi/6)*D^3;// m^3
A=%pi*D^2;// m^2
m=((p_1*10^3)*V)/(R*(T_1+273.15));// kg
hAbymc_v=(h*A)/(m*c_v*1000);// s^-1
T_2=((T_1-T_infinitive)*exp((-(h*A)/(m*c_v*1000))*t))+T_infinitive;// C
delU=m*c_v*(T_2-T_1);// kJ
printf('\n(a)The final temperature of the helium,T_2=%2.1f C \n(b)The change in total internal energy of the helium,U_2-U_1=%0.3f kJ',T_2,delU);
```

Scilab code Exa 5.8 The explosive energy per unit volume of superheated steam

```
// Example 5_8
clc;funcprot(0);
// Given data
P_1=600;// psia
T_1=800;// F
V=250;// ft^3
gamma_TNT=1400;// Btu/lbm

// Calculation
// From the superheated steam table, Table C.3a of Thermodynamic Tables to accompany Modern Engineering Thermodynamics,we find that at 600. psia and 800. F ,
u_1=1275.4;// Btu/lbm
v_1=1.190;// ft^3/lbm
u_f2=38.1;// Btu/lbm
u_2=u_f2;// Btu/lbm
gamma=(u_1-u_2)/v_1;// Btu/ft^3
Ee=gamma*V;// Btu
n=Ee/gamma_TNT;// The number of one-pound sticks of TNT to match the boiler explosion
```

```
printf('\n(a)The explosive energy per unit volume of superheated steam,gamma=%4.1f Btu/ft^3 \n(b)%3.0f one-pound sticks of TNT to match the boiler explosion',gamma,n);
```

Chapter 6

First Law Open System Applications

Scilab code Exa 6.1 `The mass flow energy transport rate of steam`

```
// Example 6_1
clc;funcprot(0);
// Given data
V=300;// ft/s
D=6/12;// ft
R=D/2;// ft
Z=15;// ft
g=32.174;// ft/s^2
g_c=32.174;// lbm.ft/lbf.s^2

// Calculation
// From the superheated steam table, Table C.3a in
   Thermodynamic Tables to accompany Modern
   Engineering Thermodynamics, we find that, at 100.
    psia and 500. F ,
v=5.587;// ft^3/lbm
h=1279.1;// Btu/lbm
A=%pi*(3/12)^2;// ft^2
mdot=(A*V)/v;// lbm/s
```

```
ke=(V^2)/(2*g_c);// ft.lbf/lbm
ke=ke*(1/778.16);// Btu/lbm
pe=(g*Z)/g_c;// // ft.lbf/lbm
pe=pe*(1/778.16);// Btu/lbm
E_mf=-[mdot*(h+ke+pe)];// Btu/s
printf("\nThe mass flow energy transport rate of steam,E_mass flow=%1.2e Btu/s",E_mf);
```

Scilab code Exa 6.2 `The outlet velocity from the nozzle`

```
// Example 6_2
clc;funcprot(0);
// Given data
D=1.00;// inch
T=60.0;// F
p=80.0;// psig
mdot=0.800;// lbm/s
v=0.01603;// ft^3/lbm
g_c=32.174;// lbm.ft/lbf.s^2
g=32.174;// ft/s^2

// Calculation
V_in=(4*mdot*v)/(%pi*D^2*(1/12)^2);// ft/s
p_in=94.7;// psia
p_out=14.7;// psia
V_out=[(V_in^2)+(2*g_c*v*(p_in-p_out)*144)]^(1/2);// ft/s
Z_out=V_out^2/(2*g);// ft
printf("\n(a)The outlet velocity from the nozzle,(V_out)_a=%3.0f ft/s \n(b)The height to which the stream of water rises above the nozzle outlet when the nozzle is pointed straight up,(Z_out)_b=%3.0f ft.",V_out,Z_out)
```

Scilab code Exa 6.3 `The quality of the wet steam in the pipe`

```
// Example 6_3
clc;funcprot(0);
// Given data
p_1=2.00;// MPa
p_2=0.100;// MPa
T_2=150;//  C
h_1=2776.4;// kJ/kg
h_2=2776.4;// kJ/kg

// Calculation
h_f1=908.8;// kJ/kg
h_fg1=1890.7;// kJ/kg
h_g1=2799.5;// kJ/kg
x_1=(h_1-h_f1)/h_fg1;// The quality of steam
x_1=x_1*100;// The quality of steam in %
T_1=212.4;//  C
mu_J=(T_1-T_2)/(p_1-p_2);//  C /MPa
printf("\nThe quality of the wet steam in the pipe,x=%2.1f percentage \nJoule-Thomson coefficient, mu_J=%2.1f  C /MPa",x_1,mu_J);
```

Scilab code Exa 6.4 `The flow rate of cooling water`

```
// Example 6_4
clc;funcprot(0);
// Given data
Q=0;// kW
W=0;// kW
m_s=12.0;// kg/min
p_1=1.00;// MPa
```

```
T_1=500;//  C
T_3=15;//  C
T_4=20;//  C

// Calculation
h_1=3478.4;// kJ/kg
h_2=762.8;// kJ/kg
c_w=4.2;// kJ/kg.K
m_w=m_s*(h_1-h_2)/[c_w*(T_4-T_3)];// kg/min
printf("\nThe flow rate of cooling water taken from
   a local river,m_w=%4.0f kg/min",m_w);
```

Scilab code Exa 6.5 `The amount of power produced`

```
// Example 6_5
clc;funcprot(0);
// Given data
p_1=85.0;// psig
p_2=10.0;// psig
t=8.00;// hour
m=20.0;// gal

// Calculation
mv=20.0/8.00;// gal/h
mv=mv*0.13368*(1/3600);// ft^3/s
W_shaft=mv*(p_1-p_2)*144;// ft.lbf/s
W_shaft=W_shaft*(1/550);// hp
W_shaft=W_shaft*746;// W
W_shaft_ins=W_shaft*5*60*(1/2.50);// W
printf("\nThe hydraulic power produced,(W_shaft)
   _instantaneous=%3.0f W",W_shaft_ins);
```

Scilab code Exa 6.6 `The quality of the steam at the outlet of an insulated steam t`

```
// Example 6_6
clc;funcprot(0);
// Given data
p_1=2.00;// MPa
T_1=800;//  C
p_2=1.00;// MPa
Wbymdot=2000;// kJ/kg

// Calculation
h_1=4150.4;// kJ/kg
h_f2=29.30;// kJ/kg
h_fg2=2484.9;// kJ/kg
h_g2=2514.2;// kJ/kg
h_2=h_1-Wbymdot;// kJ/kg
x_2=(h_2-h_f2)/h_fg2;// The quality of steam
x_2=x_2*100;// % vapor at the turbines outlet
printf("\nThe quality of the steam at the outlet of an insulated steam turbine,x_2=%2.1f percentage.",x_2);
```

Scilab code Exa 6.7 `The final temperature of the water in the tank immediately aft`

```
// Example 6_7
clc;funcprot(0);
// Given data
T_in=20.0;//  C
p_in=50.0;// MPa
c=4.126;// kN.m/kg.K

// Calculation
v_f=0.001002;// m^3/kg
v=0.0009804;// m^3/kg
T_finalfilled=T_in+((v*(p_in*10^3))/c);//  C
printf("\nThe final temperature of the water in the tank,T_final filled=%2.1f  C",T_finalfilled);
```

Scilab code Exa 6.8 `The final temperature of the air in the tank immediately after`

```
// Example 6_8
clc;funcprot(0);
// Given data
T_in=20.0;//  C
p_in=1.40;// MPa
k=1.40;// The specific heat ratio

// Calculation
T_finalfilling=k*(T_in+273.15);// K
T_finalfilling=T_finalfilling-273.15;//  C
printf("\nThe final temperature of the air in the tank,T_final filling=%3.0f  C",T_finalfilling);
```

Scilab code Exa 6.9 `The final temperature inside the tank immediately after the ta`

```
// Example 6_9
clc;funcprot(0);
// Given data
// From  Example 6_8
T_initial=137+273.15;// K
k=1.4;// The specific heat ratio

// Calculation
T_finalemptying=T_initial*((2/k)-1);// K
T_finalemptying=T_finalemptying-273.15;//  C
printf("\nThe final temperature inside the tank immediately after the tank is empty,T_final emptying=%2.1f  C.",T_finalemptying);
```

Scilab code Exa 6.10 `The rate of recycle heat transfer required`

```
// Example 6_10
clc;funcprot(0);
// Given data
p_1=2000;// psig
T_1=200+459.67;// R
T_T=70.0+459.67;// R
m_R=0.500;// lbm/s
W_c=-3.00;// hp
k=1.4;// The specific heat ratio of nitrogen

// Calculation
m_Rbym_D=(k-1)/[(k*(T_1/T_T))-1];// The ratio of recycled mass flow rate to discharge mass flow rate
c_p=0.248;// Btu/(lbm.R)
Q_H=(m_R*c_p*(T_1-T_T))+[(W_c)*550*(1/778)];// Btu/s
printf("\nThe rate of recycle heat transfer required,Q_H=%2.1f Btu/s",Q_H);
```

Chapter 7

Second Law of Thermodynamics and Entropy Transport and Production Mechanisms

Scilab code Exa 7.1 `The maximum possible thermal efficiency`

```
// Example 7_1
clc;funcprot(0);
// Given data
T_L=70.0;//  F
T_H=4000.0;//  F

// Solution
n_T_max=(1-((T_L+459.67)/(T_H+459.67)))*100;// The maximum possible thermal efficiency of this engine in %
printf('\nThe maximum possible thermal efficiency of this engine,(n_T)_max=%2.1f percentage',n_T_max);
```

Scilab code Exa 7.2 `The actual thermal efficiency of the power plant`

```
// Example 7_2
clc;funcprot(0);
// Given data
T_L=10;//  C
W_E=5.00;// MW
W_P=100;// kW
Q_L=8.00;// MW

// Solution
// (a)
Q_H=abs(-Q_L)+(W_E-abs(-W_P/10^3));// MW
n_T=((W_E-abs(-W_P/10^3))/Q_H);// The actual thermal efficiency of the power plant
printf('\nThe actual thermal efficiency of the power plant,n_T=%2.1f percentage',n_T*100);
// (b)
T_H=(T_L+273.15)/(1-n_T);// K
T_H=T_H-273.15;//  C
printf('\nThe equivalent heat source temperature,T_H=%3.0f  C',T_H);
```

Scilab code Exa 7.3 `The coefficient of performance`

```
// Example 7_3
clc;funcprot(0);
// Given data
T_H=95;//  F
T_L=70;//  F

// Solution
```

```
COP=(T_L+459.67)/((T_H+459.67)-(T_L+459.67));// Coefficient of performance
printf('\nThe Coefficient of performance,COP_Carnot air conditioner=%2.0f',COP);
```

Scilab code Exa 7.4 `The change in specific entropy of the water`

```
// Example 7_4
clc;funcprot(0);
// Given data
m=1.5;// kg
x_1=0;// The dryness fraction
T_1=20.0;// C
p_1=0.10;// MPa
p_2=0.10;// MPa
c=4.19;// kJ/kg. C

// Solution
T_2=T_1;// C
deltaS=c*log(T_2/T_1);// kJ/kg.K
printf('\nThe change in specific entropy of the water,s_2-s_1=%0.0f.Consequently, the entropy of an incompressible material is not altered by changing its pressure.',deltaS);
```

Scilab code Exa 7.5 `The final temperature and specific volume of the air`

```
// Example 7_5
clc;funcprot(0);
// Given data
m=0.035;// kg
p_1=0.100;// MPa
T_1=20.0;// C
```

```
p_2=5.00;// MPa
k=1.4;// The specific heat ratio for air
R_air=0.286;// kJ/kg.K

// Solution
T_2=((T_1+273.15)*(p_2/p_1)^((k-1)/k))-273.15;//  C
v_1=(m*R_air*(T_1+273.15))/(p_1*10^3);// m^3/kg
v_2=v_1*((T_2+273.15)/(T_1+273.15))^(1/(1-k));// m^3/kg
printf('\nThe final temperature,T_2=%3.0f  C \nThe specific volume of the air,v_2=%0.5f m^3/kg',T_2,v_2);
```

Scilab code Exa 7.6 `The change in total entropy`

```
// Example 7_6
clc;funcprot(0);
// Given dataS
m=3.00;// lbm
T_1=100.0;//  F
x_1=80.0/100;// Quality of steam
p_2=200;// psia
T_2=800.0;//  F
s_f1=0.1296;// Btu/lbm.R
s_fg1=1.8528;// Btu/lbm.R
s_2=1.7662;// Btu/lbm.R

// Solution
s_1=s_f1+(x_1*s_fg1);// Btu/lbm.R
deltaS=m*(s_2-s_1);// Btu/R
printf('\nThe change in total entropy,S_2-S_1=%0.3f Btu/R',deltaS);
```

Scilab code Exa 7.7 `The heat transport rate of entropy`

```
// Example 7_7
clc;funcprot(0);
// Given data
mdot=3.00;// kg/min
x_in=0;// The quality of steam at inlet
x_out=75;// The quality of steam at outlet
T_in=100;//  C
h_fg=2257;// kJ/kg

// Solution
Qdot=mdot*(x_out/100)*h_fg;// kJ/min
S_T_Q=Qdot/(T_in+273.15);// kJ/min.K
printf('\nThe heat transport rate of entropy for this process,(S_T)_Q=%2.1f kJ/min.K',S_T_Q);
```

Scilab code Exa 7.8 `The heat production of entropy inside this motor`

```
// Example 7_8
clc;funcprot(0);
// Given data
V=2.50*10^-3;// m^3
Sigma_Q=53.7;// W/k.m^3
tau=30.0;// min

// Solution
S_pQ=Sigma_Q*V*tau*60;// J/K
printf('\nThe heat production of entropy inside this motor,(S_p)_Q=%3.0f J/K',S_pQ);
```

Scilab code Exa 7.10 `The work mode entropy production`

```
// Example 7_10
clc;funcprot(0);
// Given data
m_1=1.00;// lbm
p_1=14.7;// psia
T_1=70.0;//  F
p_2=50.0;// psia
T_2=T_1;//  F
W_act=-42.0*10^3;// ft.lbf
R=53.34;// ft.lbf

// Solution
P_1=p_1*144;// lbf/ft^2
V_1=(m_1*R*(T_1+459.67))/P_1;// ft^3
W_rev=P_1*V_1*log(p_1/p_2);// ft.lbf
W_in=W_rev-W_act;// ft.lbf
S_pW=W_in/(T_1+459.67);// ft.lbf/R
S_pW=S_pW/778.16;// Btu/R
printf('\nThe work mode entropy production,(S_p)_w=%0.4f Btu/R',S_pW);
```

Scilab code Exa 7.11 The entropy production rate per unit volume

```
// Example 7_11
clc;funcprot(0);
// Given data
T=30;//  C
mu=0.10;// N.s/m^2
dVbydx=1000;// s^-1

// Calculation
Sigma_w=(mu*dVbydx^2)/(T+273.15);// N/m^2.s.K
Sigma_w=Sigma_w/10^3;// kJ/(m^3.s.K)
printf('\nThe entropy production rate per unit volume,Sigma_w-vis=%0.2f kJ/(m^3.s.K)',Sigma_w);
```

Scilab code Exa 7.12 `The entropy production rate of the chip`

```
// Example 7_12
clc;funcprot(0);
// Given data
T=600;// K
I=0.10;// amp
L=10.0*10^-3;// m
b=5.00*10^-3;// m
w=1.00*10^-3;// m
rho_e=0.10;// ohm.m

// Calculation
A=b*w;// m^2
R_e=rho_e*(L/A);// W/A^2
S_pW=(I^2*R_e)/T;// W/K
printf('\nThe entropy production rate of the chip,(
    S_p)_W=%0.4f W/K',S_pW);
```

Chapter 8

Second Law Closed System Applications

Scilab code Exa 8.1 `The heat and work transports of energy for the process`

```
// Example 8_1
clc;funcprot(0);
// Given data
m=2.00;// kg
// State 1
T_1=50.0;//  C
x_1=0;// The quality of steam
// State 2
T_2=50.0;//  C
p_2=5.00;// kPa

// Calculation
s_1=0.7036;// kJ/(kg.K)
s_2=8.4982;// kJ/(kg.K)
u_1=209.3;// kJ/kg
u_2=2444.7;// kJ/kg
T_b=T_1;//  C
Q_12=m*(T_b+273.15)*(s_2-s_1);// kJ
W_12=(m*(u_1-u_2))+Q_12;// kJ
```

```
printf("\nThe heat and work transports of energy for this process,Q_12=%4.0f kJ & W_12=%3.0f kJ",Q_12,W_12);
```

Scilab code Exa 8.2 `The maximum steady state electrical power in kW`

```
// Example 8_2
clc;funcprot(0);
// Given data
Q_solar=100*10^3;// Btu/h
T_river=40+459.67;// R
T_collector=200+459.67;// R

// Calculation
W_e_rev=(Q_solar*(1-(T_river/T_collector)))/3412;// kW
printf("\nThe maximum steady state electrical power (in kW) that can be produced by this power plant,(W_electrical)_rev=%1.2f kW",W_e_rev);
```

Scilab code Exa 8.5 `The entropy production rate`

```
// Example 8_5
clc;funcprot(0);
// Given data
V=1.00;// m^3
m=2.00;// kg
T_1=20.0;//  C
T_2=95.0;//  C
T_b=100.0;//  C

// Calculation
// (a)
```

```
v_1=V/m;// m^3/kg
v_2=v_1;// m^3/kg
// From Table C.1b of Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find that
// At 20.0 C
v_f1=0.001002;// m^3/kg
v_g1=57.79;// m^3/kg
v_fg1=v_g1-v_f1;// m^3/kg
u_f1=83.9;// kJ/kg
u_g1=2402.9;// kJ/kg
u_fg1=u_g1-u_f1;// kJ/kg
// At 95.0 C
v_f2=0.00104;// m^3/kg
v_g2=1.982;// m^3/kg
v_fg2=v_g2-v_f2;// m^3/kg
u_f2=397.9;// kJ/kg
u_g2=2500.6;// kJ/kg
u_fg2=u_g2-u_f2;// kJ/kg
x_1=(v_1-v_f1)/v_fg1;// The quality in the container when the contents are at 20.0 C
x_1p=x_1*100;// %
// (b)
x_2=(v_2-v_f2)/v_fg2;// The quality in the container when the contents are at 95.0 C .
x_2p=x_2*100;// %
// (c)
u_1=u_f1+(x_1*u_fg1);// kJ/kg
u_2=u_f2+(x_2*u_fg2);// kJ/kg
Q_12=m*(u_2-u_1);// kJ
// (d)
s_f1=0.2965;// kJ/kg.K
s_fg1=8.3715;// kJ/kg.K
s_f2=1.2503;// kJ/kg.K
s_fg2=6.1664;// kJ/kg.K
s_1=s_f1+((x_1)*s_fg1);// kJ/kg.K
s_2=s_f2+((x_2)*s_fg2);// kJ/kg.K
S_p_12=((m*(s_2-s_1))-(Q_12/(T_b+273.15)))*1000;// J
```

```
/K
T_b_minimum=Q_12/(m*(s_2-s_1));// K
T_b_minimum=T_b_minimum-273.15;//  C
printf('\n(a)The quality in the container when the contents are at 20.0 C ,x_1=%0.3f percentage \n(b)The quality in the container when the contents are at 95.0 C ,x_2=%2.1f percentage \n(c)The heat transport of energy required to raise the temperature of the contents from 20.0 to 95.0 C , Q_12=%4.0f kJ/kg \n(d)The entropy production,S_P=%3.0f J/K \n   The minimum boundary temperature,(T_b)minimum=%2.1f  C ',x_1p,x_2p,Q_12,S_p_12,T_b_minimum);
```

Scilab code Exa 8.6 `The entropy production rate`

```
// Example 8_6
clc;funcprot(0);
// Given data
W=100;// W
T_b=110.0+273.15;// K

// Calculation
// (a)
// Since we are assuming a constant bulb temperature in part a, U=constant and
U=0;// W
Q=U-W;// kW
printf("\n(a)The heat transfer rate of an illuminated 100. W incandescent lightbulb in a room,Q=%3.0f W",Q);
// (b)
Q_dot=0;
Udot=W;// W
printf("\n(b)The rate of change of its internal
```

```
energy,Udot=%3.0f W",Udot);
Sdot=0;// W/K
S_p=Sdot-(Q/(T_b));// W/K
printf("\n(c)The value of the entropy production rate,S_p=%0.3f W/K",S_p);
```

Scilab code Exa 8.7 `The rate of entropy production of the plant`

```
// Example 8_7
clc;funcprot(0);
// Given data
Q_b=950*10^5;// kJ/h
T_b=500;// K
W_p=-23.0;// kW
Q_c=-600*10^5;// kJ/h
T_c=10.0;//  C

// Calculation
Q_net=(Q_b+Q_c);// kJ/h
W_T_net=Q_net/3600;// kJ/h
W_T_net=W_T_net/1000;// MW
W_T_total=(W_T_net*10^3)+W_p;// kW
S_p=-((Q_b/(T_b+273.15))+(Q_c/(T_c+273.15)));// kJ/(h.K)
Q_in=Q_b;// kJ/h
Q_out=Q_c;// kJ/h
n_T_act=(1-((abs(Q_out))/Q_in))*100;// The actual thermal efficiency of this power plant in %
n_T_rev=(1-((T_c+273.15)/(T_b+273.15)))*100;// The theoretical reversible (Carnot) efficiency in %
printf("\nThe net power of the turbine,(W_T)_total=%4.0f kW(round off error) \nThe rate of entropy production,S_p=%2.1e kJ/(h.K)",W_T_total,S_p);
```

Scilab code Exa 8.8 The temperature of the water and the amount of entropy produce

```
// Example 8_8
clc;funcprot(0);
// Given data
W=0.250;// hp
V=1.00;// quart of water
p_1=14.7;// psia
T_1=60.0;//  F
p_2=p_1;// psia
t=10;// min
c=1.00;// Btu/(lbm.R)

// Calculation
V=V*(1/4)*0.13368;// ft^3
v=0.01603;// ft^3/lbm
m=V/v;// lbm
Q_12bymc=0;// Btu/lbm
T_2=T_1+Q_12bymc-((-W*t*(1/60)*(2545))/(m*c));//  F
S_p12=m*c*log((T_2+459.67)/(T_1+459.67));// Btu/R
printf("\nThe temperature of the water when the
   machine is turned off,T_2=%3.0f F \nThe amount
   of entropy produced,1(S_p)2=%0.3f Btu/R",T_2,
   S_p12);
```

Scilab code Exa 8.9 The pressure and temperature inside the box after the balloon

```
// Example 8_9
clc;funcprot(0);
// Given data
V_2=0.0400;// m^3
T_1=20.0;//  C
```

```
p_1=0.0100;// MPa
Q_12=0.100;// kJ
V_1=0.0100;// m^3
R=0.208;// kJ/kg.K
T_w=400;// K
c_p=0.523;// kJ/kg.K
c_v=0.315;// kJ/kg.K

// Calculation
m=((p_1*10^3)*V_1)/(R*(T_1+273.15));// kg
T_2=T_1+(Q_12/(m*c_v));// K
p_2=(m*R*(T_2+273.15))/V_2;// kPa
S_p12=(m*[(c_p*log((T_2+273.15)/(T_1+273.15)))-(R*
   log(p_2/(p_1*10^3)))])-(Q_12/T_w);// kJ/K
S_p12=S_p12*10^3;// J/K
printf('\nThe pressure and temperature inside the
   box after the balloon bursts p_2=%1.2f kPa and
   T_2=%3.0f C \nThe entropy produced,1(S_P)2=%0.3f
    J/K',p_2,T_2,S_p12);
```

Scilab code Exa 8.10 `The work transport of energy during the adiabatic expansion`

```
// Example 8_10
clc;funcprot(0);
// Given data
// State 1
m=0.100;// lbm
p_1=100;// psia
T_1=180;//  F
v_1=0.6210;// ft^3/lbm
h_1=137.49;// Btu/lbm
s_1=0.2595;// Btu/(lbm.R)
// State 2
p_2=30.0;// psia
T_2=120;//  F
```

```
v_2=1.9662;// ft^3/lbm
h_2=126.39;// Btu/lbm
s_2=0.2635;// Btu/(lbm.R)
// State 3
p_3=p_2;// psia
v_3=v_1/2;// ft^3/lbm
x_3=0.1952;// The quality of steam
s_3=0.07241;// Btu/(lbm.R)
K=5.00;// Btu/R

// Calculation
// (a)
// From Table C.7e of Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find that at p1 = 100 psia and T1 = 180 F ,
v_1=0.6210;// ft^3/lbm
u_1=125.99;// Btu/lbm
// At p2= 30 psia and T2 = 120 F ,
v_2=1.966;// ft^3/lbm
u_2=115.47;// Btu/lbm
W_12=-m*(u_2-u_1);// Btu
// (b)
v_3=v_1/2;// ft^3/lbm
// At p2= 30 psia
v_f3=0.01209;// ft^3/lbm
v_g3=1.5408;// ft^3/lbm
u_f3=16.24;// Btu/lbm
u_g3=95.40;// Btu/lbm
x_3=(v_3-v_f3)/(v_g3-v_f3);// The quality of steam
x_3p=x_3*100;// %
u_3=u_f3+(x_3*(u_g3-u_f3));// Btu/lbm
Q_23=(m*(u_3-u_2))+(m*(p_3*144)*((v_3-v_2)*(1/778.17)));// Btu
// (c)
// From Table C.7b
T_3=15.38;// F
dQ=0;// Btu
S_p12=m*(s_1-s_2)-0;// Btu/R
```

```
s_f3=0.0364;// Btu/(lbm.R)
s_fg3=0.2209;// Btu/(lbm.R)
s_3=s_f3+(x_3*(s_fg3-s_f3));// Btu/(lbm.R)
S_p23=(m*[s_3-s_2])-(K*log((T_3+459.67)/(T_2+459.67)
  ));// Btu/R
S_p13=S_p12+S_p23;// Btu/R
printf('\n(a)The work transport of energy during the
   adiabatic expansion,W_12=%1.2f Btu \n(b)The heat
   transport of energy during the isobaric
  compression,Q_23=%1.2f Btu \n(c)Since state 3 is
  saturated (a mixture of liquid and vapor), T3
  must be equal to the saturation temperature at
  30.0 psia,which, from Table C.7b, is T_3 =%2.2
  f F \n(d)The total entropy production for both
  processes,1(S_p)3=%0.3f Btu/R',W_12,Q_23,T_3,
  S_p13);
```

Scilab code Exa 8.11 `The total entropy production in the helium`

```
// Example 8_11
clc;funcprot(0);
// Given data
// from Example 5.7
D=0.100;// m
T_1=200;// K
p_1=0.140;// MPa
h=3.50;// W/(m^2.K)
T_infinitive=15.0;// K
c_v=3.123;// kJ/kg.K
R=2.077;// kJ/kg.K
t=5.00;// seconds

// Calculation
// (a)
V=(%pi/6)*D^3;// m^3
```

```
A=%pi*D^2;// m^2
m=((p_1*10^3)*V)/(R*(T_1+273.15));// kg
hAbymc_v=(h*A)/(m*c_v*1000);// s^-1
T_2=((T_1-T_infinitive)*exp((-(h*A)/(m*c_v*1000))*t)
   )+T_infinitive;//  C
// (b)
delU=m*c_v*(T_2-T_1);// kJ
// (c)
// Let s_2-s_1=ds
ds=(c_v*log((T_2+273.15)/(T_1+273.15)))+0;// kJ/(kg.
   K)
dQbyT_b=-1.35*10^-4;// kJ/K
S_P=((m*ds)-(dQbyT_b));// kJ/K
S_P=S_P*10^3;// J/K
printf("\n(a)The final temperature of the helium,T_2
   =%2.1f C \n(b)The change in total internal
   energy of the helium,U_2-U_1=%0.3f kJ \n(c)The
   total entropy production in the helium,S_P=%0.4f
   J/K",T_2,delU,S_P);
```

Scilab code Exa 8.12 The entropy production rate for the fin

```
// Example 8_12
clc;funcprot(0);
// Given data
h=3.50;// W/(m^2.K)
A=1.00*10^-4;// m^2
P=0.0400;// m
T_infinitive=20.0+273.15;// K
k_t=204;// W/(m.K)
T_f=95.0+273.15;// K

// Solution
S_P_Q=sqrt(h*P*k_t*A)*((log(T_f/T_infinitive))+(
   T_infinitive/T_f)-1);// W/K
```

```
printf(”\nThe entropy production rate for the fin, S_P=%0.5f W/K”,S_P_Q);
```

Scilab code Exa 8.13 `The rate of entropy production due to laminar viscous losses`

```
// Example 8_13
clc;funcprot(0);
// Given data
T=20.0+273.15;// K
mu=0.700;// N.s/m^2
L=0.100;// m
R_1=0.0500;// m
R_2=0.0510;// m
n=1000;// rev/min

// Solution
omega=(2*%pi*n)/60;// rad/s
S_P_W=((2*%pi*L*omega^2*R_1^4*mu)/((R_2^2-R_1^2)^2*T))*((2*R_2^2*(log(R_2/R_1)))+((R_2^4)/(2*R_1^2))-(R_1^2/2));// W/K
printf(”\nThe rate of entropy production due to laminar viscous losses,(S_P)w=%1.2f W/K”,S_P_W);
```

Scilab code Exa 8.14 `The entropy production rate of the circuit board`

```
// Example 8_14
clc;funcprot(0);
// Given data
T=30.0;//  C
phi=5.00;// V
I=10.0;// mA

// Solution
```

```
S_P_W=(phi*I*10^-3)/(T+273.15);// W/K
printf("\nThe entropy production rate of the circuit
    board,(S_P)_W=%1.2e W/K",S_P_W);
```

Scilab code Exa 8.15 `The entropy produced`

```
// Example 8_15
clc;funcprot(0);
// Given data
m_a=3.00;// g
T_a=10.0;//  C
m_b=200;// g
T_b=80.0;//  C
c=4186;// J/kg.K

// Solution
// Let a=cream,b=coffee
r=m_a/(m_a+m_b);// The mass ratio
S_p12=((m_a+m_b)/1000)*c*log([1+((r*(((T_a+273.15)/(
   T_b+273.15))-1)))]*((T_b+273.15)/(T_a+273.15))^(r
   ));// J/K
printf("\nThe entropy produced,1(S_P)2=%0.3f J/K",
   S_p12);
```

Chapter 9

Second Law Open System Applications

Scilab code Exa 9.1 `The entropy production rate`

```
// Example 9_1
clc;funcprot(0);
// Given data
T_1=15+273.15;// K
T_2=50+273.15;// K
Q=0.100;// The electrical energy in W
c=4.186;// kJ/kg.K
T_b=20+273.15;// K

// Calculation
m=Q/(c*(T_2-T_1));// The expected water flow rate in
    kg/s
// Assume ds=s_out-s_in
ds=c*log(T_2/T_1);// kJ/kg.K
S_p=(m*ds)-(Q/T_b);// kJ/s.K
printf("\nThe entropy production rate,S_p=%1.2e kJ/s
   .K ",S_p);
if(S_p<0)
               printf("\nSince the entropy production
```

```
         rate is negative, this water heater cannot possibly meet the claims of the inventor, so we should reject the patent application.")
        end
```

Scilab code Exa 9.2 `The rate of entropy production`

```
// Example 9_2
clc;funcprot(0);
// Given data
m=0.2000;// lbm/s
// Station 1
p_1=14.7;// psia
T_1=50.00;//  F
// Station 2
p_2=95.00;// psia
D_1=1.000;// The inlet diameter of the nozzle in m
D_2=0.2500;// The outlet diameter of the nozzle in m
c=1.0;// Btu/lbm.R
g_c=32.174;// lbm.ft/(lbf.s^2)

// Calculation
v_f=0.01602;// ft^3/lbm
v=v_f;// ft^3/lbm
V_1=(4*m*v*144)/(%pi*D_1^2);// ft/s
V_2=V_1*(D_1/D_2)^2;// ft/s
T_2=(T_1+459.67)+(v*(((p_2-p_1)*144)/(c*778.17)))-((V_2^2-V_1^2)/(2*c*g_c*778.17));// R
S_p=m*c*log(T_2/(T_1+459.7));// Btu/(s.R)
S_p=S_p*778.17;// ft.lbf/(s.R)
printf("\nThe rate of entropy production,S_p=%0.4f ft.lbf/(s.R)",S_p);
```

Scilab code Exa 9.3 `The rate of entropy production within the diffuser`

```
// Example 9_3
clc;funcprot(0);
// Given data
m=0.800;// kg/s
V_1=93.0;// m/s
// Station 1
p_1=97.0;// kPa
T_1=80.0;//  C
// Station 2
p_2=101.3;// kPa
g_c=1;// The gravitational constant
c_p=523;// J/(kg.K)
R=208;// J/(kg.K)

// Calculation
T_2=(T_1+273.15)+((V_1^2)/(2*g_c*c_p));// K
S_p=m*((c_p*log(T_2/(T_1+273.15)))-(R*log(p_2/p_1)))
    ;// The rate of entropy production within the
    diffuser in W/K
printf("\nThe rate of entropy production within the
    diffuser ,S_p=%1.2f W/K",S_p);
```

Scilab code Exa 9.4 `Second Law Open System Applications`

```
// Example 9_4
clc;funcprot(0);
// Given data
m=0.100;// lbm/s
// Station 1
x_1=0.00;// The quality of steam at inlet
```

```
T_1=100;//  F
// Station 2
x_2=0.530;// The quality of steam at exit
T_2=20;//  F
T_b=60.0;//  F

// Calculation
// (a)
// From Table C.7a for R−134a, we find
h_f1=44.23;// Btu/lbm
h_1=h_f1;// Btu/lbm
s_f1=0.0898;// Btu/(lbm.R)
s_1=s_f1;// Btu/(lbm.R)
h_f2=17.74;// Btu/lbm
h_fg2=86.87;// Btu/lbm
s_f2=0.0393;// Btu/(lbm.R)
s_fg2=0.2206-s_f2;// Btu/(lbm.R)
h_2=h_f2+(x_2*h_fg2);// Btu/lbm
s_2=s_f2+(x_2*s_fg2);// Btu/(lbm.R)
Q=m*(h_2-h_1);// Btu/s
S_pa=((m*(s_2-s_1))-(Q/(T_b+459.67)));// The entropy production rate inside the valve in Btu/(s.R)
S_p=S_pa*778.17;// ft.lbf/(s.R)
printf("\n(a)The entropy production rate inside the valve if the valve is not insulated and has an isothermal external surface temperature of 60.0  F ,S_p=%0.4f ft.lbf/(s.R)",S_p);
// (b)
h_2=h_1;// Btu/lbm
x_2=(h_2-h_f2)/h_fg2;// The quality of steam
x_2p=x_2*100;// % (in x_2p,p refers the quality of steam in percentage)
s_2=s_f2+(x_2*s_fg2);// Btu/(lbm.R)
Q=0;// W
S_pb=m*(s_2-s_1)-(Q/T_b);// Btu/(s.R)
S_p=S_pb*778.17;// lbf/(s.R)
printf("\n(b)The entropy production rate inside the valve if it is insulated and assuming it has the
```

```
same inlet conditions and exit temperature,S_p=%0.3f ft.lbf/(s.R)",S_p);
//(c)
S_p_pd=((S_pa-S_pb)/S_pa)*100;// The percentage decrease in S_p brought about by adding the insulation in %
printf("\n(c)The percentage decrease in S_p brought about by adding the insulation is %2.1f percentage.",S_p_pd);
```

Scilab code Exa 9.5 `The required heat exchanger area and the entropy production ra`

```
// Example 9_5
clc;funcprot(0);
// Given data
m_a=0.200;// kg/s
T_ain=90.0;//  C
T_aout=75.0;//  C
T_win=20.0;//  C
T_wout=40.0;//  C
U=140;// W/(m^2.K)
c_pa=1.004;// The specific heat of air in kJ/kg.K
c_pw=4.186;// The specific heat of water in kJ/kg.K

// Calculation
// (a) Parallel flow
delT_LMTDa=((T_aout-T_wout)-(T_ain-T_win))/(log((T_aout-T_wout)/(T_ain-T_win)));// K
//(b) Counter flow
delT_LMTDb=((T_aout-T_win)-(T_ain-T_wout))/(log((T_aout-T_win)/(T_ain-T_wout)));// K
Q=abs(m_a*c_pa*10^3*(T_aout-T_ain));// J/s
A_pf=Q/(U*delT_LMTDa);// m^2
A_cf=Q/(U*delT_LMTDb);// m^2
m_w=m_a*(c_pa/c_pw)*((T_ain-T_aout)/(T_wout-T_win));
```

```
// kg/s
S_p=(m_a*c_pa*10^3*log((T_aout+273.15)/(T_ain+273.15)))+(m_w*c_pw*10^3*log((T_wout+273.15)/(T_win+273.15)));// W/K
printf("\nThe corresponding heat exchanger area for parallel flow, A_parallel flow=%0.3f m^2 \nThe corresponding heat exchanger area for counter flow, A_counter flow=%0.3f m^2 \nThe entropy production rate, S_p=%1.2f W/K",A_pf,A_cf,S_p);
```

Scilab code Exa 9.6 `The critical mass fraction and the value of the maximum entrop`

```
// Example 9_6
clc;funcprot(0);
// Given data
m_H=0.300;// lbm/s
T_H=140.0;//  F
m_C=0.300;// lbm/s
T_C=50.0;//  F
c=1.00;// Btu/(lbm.R)

// Calculation
// (a)
m_M=m_H+m_C;// lbm/s
gamma=m_H/m_M;// The mass flow rate ratio
T_1=T_H;//  F
T_2=T_C;//  F
T_1byT_2=(T_H+459.67)/(T_C+459.67);// The temperature ratio
T_3=T_C+(gamma*(T_H-T_C));//  F
m_3=m_M;// lbm/s
S_p_mixing=m_3*c*log((1+(gamma*(T_1byT_2-1)))*(T_1byT_2)^(-gamma));// Btu/(s.R)
S_p_mixing=S_p_mixing*778.17;// ft.lbf/(s.R)
printf("\n(a)The shower mixture temperature,T_3=%2.0
```

```
   f F \n    The entropy production rate,(S_p)
   _mixing=%1.2f lbf/(s.R)",T_3,S_p_mixing);
// (b)
gamma_c=((1-T_1byT_2)+log(T_1byT_2))/((1-T_1byT_2)*
   log(T_1byT_2));// The critical mass fraction
S_p_mixing=m_3*c*log((1+(gamma_c*(T_1byT_2-1)))*(
   T_1byT_2)^(-gamma_c));// // Btu/(s.R)
S_p_mixing=S_p_mixing*778.17;// ft.lbf/(s.R)
printf("\n(b)The critical mass fraction,gamma_c=%0.3
   f \n    The value of the maximum entropy
   production rate,(S_p)_mixing=%1.2f ft.lbf/(s.R)",
   gamma_c,S_p_mixing);
```

Scilab code Exa 9.7 The maximum power that could be produced

```
// Example 9_7
clc;funcprot(0);
// Given data
mdot=0.500;// kg/s
p_1=8.00;// MPa
T_1=300;//  C
T_2=100;//  C
x_2=1.00;// The quality of steam at station 2
T_b=20.0;//  C
h_1=2785.0;// kJ/kg
h_2=2676.0;// kJ/kg
s_1=5.7914;// kJ/kg.K
s_2=7.3557;// kJ/kg.K

// Calculation
W_max=mdot*[(h_1-((T_b+273.15)*s_1))-(h_2-((T_b
   +273.15)*s_2))];// kW
printf("\nThe maximum (reversible) power,W_max=%3.0f
    kW",W_max);
```

Scilab code Exa 9.8 `The amount of entropy produced`

```
// Example 9_8
clc;funcprot(0);
// Given data
V_2=3.00;// ft^3
T_in=70+459.67;//  F
p_2=2000;// psia

// Calculation
// From Table C.13a of Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find for oxygen
c_p=0.219;// Btu/(lbm.R)
R=48.29;// ft.lbf/(lbm.R)
k=1.39;// The specific heat ratio
T_2_af=k*T_in;// R
T_2_if=T_in;// R
m_2_af=(p_2*144*V_2)/(R*T_2_af);// lbm
m_2_if=(p_2*144*V_2)/(R*T_2_if);// lbm
// (a)
S_p_12_af=m_2_af*c_p*2.303*log10(k);// Btu/R
// (b)
S_p_12_if=m_2_if*R/778.16;// Btu/R
printf("\n(a)The amount of entropy produced when the container is filled adiabatically by insulating it,[1(S_P)2]adiabatic filling=%1.2f Btu/R \n(b)The amount of entropy produced when the container is filled isothermally,[1(S_P)2]isothermal filling=%1.2f Btu/R",S_p_12_af,S_p_12_if)
```

Scilab code Exa 9.9 `The entropy production rate per unit mass flow rate`

```
// Example 9_9
clc;funcprot(0);
// Given data
gamma=0.500;// The specific heat ratio for air
T_in=70.0;// F
p_in_psig=[0.000,20.00,40.00,60.00,80.00,100.00,120.00,140.00];// psig
p_in=[14.7,34.7,54.7,74.7,94.7,114.7,134.7,154.7];// psia
T_hot=[70.0,119.0,141.0,150.0,156.0,161.0,164.0,166.0];// F
T_cold=[70.0,19.5,-3.00,-14.0,-22.0,-29.0,-34.0,-39.0];// F
T_r=[1.000,1.209,1.315,1.368,1.406,1.441,1.465,1.487];// Note:T_r=(T_hot+460)/(T_cold+460)
p_e=14.7;// The exit pressure in psia
R=0.0685;// Btu/(lbm.R)
c_p=0.240;// Btu/(lbm.R)

// Calculation
Sdot_pbymdot_3_1=((c_p*log(((T_r(1)^gamma)/(1+(gamma*(T_r(1)-1))))))+(R*log(p_in(1)/p_e)));// Btu/(lbm.R)
Sdot_pbymdot_3_2=((c_p*log(((T_r(2)^gamma)/(1+(gamma*(T_r(2)-1))))))+(R*log(p_in(2)/p_e)));// Btu/(lbm.R)
Sdot_pbymdot_3_3=((c_p*log(((T_r(3)^gamma)/(1+(gamma*(T_r(3)-1))))))+(R*log(p_in(3)/p_e)));// Btu/(lbm.R)
Sdot_pbymdot_3_4=((c_p*log(((T_r(4)^gamma)/(1+(gamma*(T_r(4)-1))))))+(R*log(p_in(4)/p_e)));// Btu/(lbm.R)
Sdot_pbymdot_3_5=((c_p*log(((T_r(5)^gamma)/(1+(gamma*(T_r(5)-1))))))+(R*log(p_in(5)/p_e)));// Btu/(
```

```
lbm.R)
Sdot_pbymdot_3_6=((c_p*log(((T_r(6)^gamma)/(1+(gamma*(T_r(6)-1))))))+(R*log(p_in(6)/p_e)));// Btu/(lbm.R)
Sdot_pbymdot_3_7=((c_p*log(((T_r(7)^gamma)/(1+(gamma*(T_r(7)-1))))))+(R*log(p_in(7)/p_e)));// Btu/(lbm.R)
Sdot_pbymdot_3_8=((c_p*log(((T_r(8)^gamma)/(1+(gamma*(T_r(8)-1))))))+(R*log(p_in(8)/p_e)));// Btu/(lbm.R)
Sdot_pbymdot_3=[Sdot_pbymdot_3_1,Sdot_pbymdot_3_2,Sdot_pbymdot_3_3,Sdot_pbymdot_3_4,Sdot_pbymdot_3_5,Sdot_pbymdot_3_6,Sdot_pbymdot_3_7,Sdot_pbymdot_3_8];// Btu/(lbm.R)
plot(p_in_psig,Sdot_pbymdot_3);
xlabel('Inlet pressure(psig)');
ylabel('Sdot_p/mdot_3(Btu/lbm.R)');
xtitle('Sdot_p/mdot_3 vs. inlet pressure for a vortex tube');
disp('Remaining Results for Example 9.9');
disp('The entropy production rate per unit mass flow rate for each pressure shown');
disp('Inlet pressure psig');
disp(p_in_psig);
disp('T_1/T_2');
disp(T_r);
disp('Sdot_P/mdot_3 Btu/(lbm R)');
disp(Sdot_pbymdot_3);
```

Scilab code Exa 9.10 `The energy dissipation rate and entropy production rate`

```
// Example 9_10
clc;funcprot(0);
```

```
// Given data
m=500;// lbm/s
T=50.0;//  F
y_1=1.00;// The inlet height in ft
y_2=1.80;// The exit height in ft
v_1=8.00;// The inlet velocity ft/s
v_2=5.14;// The exit velocity in ft/s
g=32.174;// ft/s^2
g_c=32.174;// lbm.ft/(lbf.s^2)
c=1.00; // Btu/(lbm.R)

// Solution
h_L12=(y_2-y_1)^3/(4*y_1*y_2);// ft
E_dr=(m*(g/g_c)*h_L12)/778.17;// The energy dissipation rate in Btu/s
S_p=m*c*log(1+(g*[(h_L12)]/(c*g_c*(T+459.67))));// The entropy production rate in Btu/(s.R)
printf('\nThe energy dissipation rate=%0.4f Btu/s \nThe entropy production rate,S_p=%0.4f Btu/(s.R)',E_dr,S_p);
```

Scilab code Exa 9.11 `The entropy production rate`

```
// Example 9_11
clc;funcprot(0);
// Given data
mu=10.1*10^-3;// The viscosity of the water in kg/(m.s)
L=10.0;// The length of the pipe in m
V_m=0.500;// The maximum velocity of the fluid in m/s
T=20.0;//  C

// Solution
S_pW=(2*%pi*mu*L*V_m^2)/(T+273.15);// The entropy
```

```
    production rate in W/K
printf('\nThe entropy production rate,(S_p)_W=%1.3e
   W/K',S_pW);
```

Chapter 10

Availability Analysis

Scilab code Exa 10.1 `The total availability of the water in the glass relative to`

```
// Example 10_1
clc;funcprot(0);
// Given data
p_0=0.101;// MPa
T=10;// C
T_0=20+273;// K
L=0.150;// m
D=0.0700;// m
R=D/2;// m
rho=1000;// kg/m^3
Z=0.762;// m
g=9.81;// m/s^2
g_c=1;// The gravitational constant

// Calculation
m=%pi*R^2*((3/4)*L)*rho;// kg
// From Table C.1b of Thermodynamic Tables to accompany Modern Engineering Thermodynamics
u=42.0;// kJ/kg
u_0=83.9;// kJ/kg
v=0.001000;// m^3/kg
```

```
v_0=0.001002;// m^3/kg
s=0.1510;// kJ/kg.K
s_0=0.2965;// kJ/kg.K
A=m*[(u-u_0)+((p_0*10^3)*(v-v_0))-(T_0*(s-s_0))+0+((
   g*Z)/g_c)];// kJ
printf("\nThe total availability of the water in the
    glass relative to the floor,A=%1.2f kJ",A);
```

Scilab code Exa 10.2 The specific available energy in a stationary

```
// Example 10_2
clc;funcprot(0);
// Given data
p_0=0.101;// MPa
T_0=20.0+273;// K
p=1.500; // MPa
T=20+273;// K
C_v=0.781;// kJ/kg.K
C_p=1.004;// kJ/kg.K
R=0.286;// kJ/kg.K
g=9.81;// m/s^2
g_c=1;// The gravitational constant

// Calculation
// Assume deltau=u-u_0;deltav=v-v_0;deltas=s-s_0;
deltau=C_v*(T-T_0);// kJ/kg
deltav=R*((T/(p*10^3))-(T_0/(p_0*10^3)));// kJ/kg
deltas=(C_p*log(T/T_0))-(R*log((p*10^3)/(p_0*10^3)))
   ;// kJ/kg
a=deltau+(p_0*10^3*deltav)-(T_0*deltas)+0+0;// kJ/kg
printf("\nThe specific available energy,a=%3.0f kJ/
   kg",a);
```

Scilab code Exa 10.3 `The change in total availability during the landing`

```
// Example 10_3
clc;funcprot(0);
// Given data
T_1=50.0;//  F
V_1=500;// mph
Z=30.0*10^3;// ft
T_0=70.0;//  F
p_0=136.12;// psia
m=5.00;// lbm
g=32.174;// ft/s^2
g_c=32.174;// lbm.ft/lbf.s^2

// Calculation
// State 1 (flying)
x_1=0.00;// The quality of steam
T_1=50.0;//  F
v_1=0.0128;// ft^3/lbm
u_1=24.04;// Btu/lbm
s_1=0.0519;// Btu/lbm.R
V_1=500;// mph
Z_1=30000;// ft
// State 2 (landed)
p_2=100;// psia
T_2=400;//  F
v_2=1.046;// ft^3/lbm
u_2=154.77;// Btu/lbm
s_2=0.31464;// Btu/lbm.R
V_2=0;// mph
Z_2=0;// ft
// Ground state
x_0=0.00;// The quality of steam
T_0=70.0;//  F
v_0=0.01325;// ft^3/lbm
u_0=29.78;// Btu/lbm
s_0=0.06296;// Btu/lbm.R
p_0=136.12;// psia
```

```
A_1=(m*[(u_1-u_0)+((p_0)*(144/778.16)*(v_1-v_0))])-(m*(T_0+459.67)*(s_1-s_0))+(m*[(([V_1*5280*(1/3600)]^2)/(2*g_c*778.16))+((g*Z_1)/(g_c*778.16))]);// Btu
A_2=(m*[(u_2-u_0)+((p_0)*(144/778.16)*(v_2-v_0))])-(m*(T_0+459.67)*(s_2-s_0))+(m*[(([V_2*5280*(1/3600)]^2)/(2*g_c*778.16))+((g*Z_2)/(g_c*778.16))]);// Btu
// (b)
dA=A_2-A_1;// Btu
printf("\n(a)The total availability of the refrigerant before and after the aircraft lands, A_1=%3.0f Btu & A_2=%2.1f Btu. \n(b)The change in total availability during the landing,A_2-A_1=%3.0f Btu",A_1,A_2,dA);
```

Scilab code Exa 10.4 The irreversibility of the process

```
// Example 10_4
clc;funcprot(0);
// Given data
m=1.00;// kg
T_0=20.0;//  C
p_0=0.101;// MPa
T_s=130.0+273;// K
x_1=0.00;// The quality of steam at state 1
T_1=120.0;//  C
x_2=0.500;// The quality of steam at state 1

// Calculation
// State 1
x_1=0;// The quality of steam at state 1
T_1=120.0+273;// K
v_f=0.001060;// m^3/kg
v_1=v_f;// m^3/kg
```

```
u_f=503.5;// kJ/kg
u_1=u_f;// kJ/kg
s_f=1.5280;// kJ/kg.K
s_1=s_f;// kJ/kg.K
// State 2
x_2=0.500;// The quality of steam at state 2
p_sat=198.5;// kN/m^2
p_1=p_sat;// kN/m^2
p_2=p_1;// kN/m^2
v_2=0.44648;// m^3/kg
u_2=1516.4;// kJ/kg
s_2=4.3292;// kJ/kg.K
// Ground state
T_0=20.0+273;// K
p_0=0.101;// MPa
a_2minusa_1=(u_2-u_1)+(p_0*10^3*(v_2-v_1))-(T_0*(s_2
    -s_1));// kJ/kg
W_12=m*p_2*(v_2-v_1);// kJ
Q_12=(m*(u_2-u_1))+W_12;// kJ
I_12=((1-(T_0/T_s))*Q_12)-W_12+(p_0*10^3*(v_2-v_1));
    // kJ
printf("\nThe irreversibility of the process,I_12=%2
    .1f kJ",I_12)
// The answer provided in the textbook is wrong
```

Scilab code Exa 10.5 The irreversibility rate within the room

```
// Example 10_5
clc;funcprot(0);
// Given data
Q=-100;// W
W=-100;// W
T_b=24.0+273;// K
p_0=0.101;// MPa
T_0=15.0+273;// K
```

```

// Calculation
dVbydt=0;
dAbydt=0;
I=((1-(T_0/T_b))*Q)-W+(p_0*dVbydt)-dAbydt;// W
printf(”\nThe irreversibility rate within the room,I=%2.1f W”,I);
```

Scilab code Exa 10.6 The specific flow availabilities at the inlet and outlet of t

```
// Example 10_6
clc;funcprot(0);
// Given data
T_w=50.0+459.67;// R
V_w=3.00;// ft
Z_w=4.00;// ft
T_0=70.0+459.67;// R
p_0=14.7;// psia
c_w=1.00;// Btu/lbm
g=32.174;// ft/s^2
g_c=32.174;// lbm.ft/lbf.s^2

// Calculation
v_w=0.01602;// ft^3/lbm
p_sat=0.1780;// lbf/in^2
p_w=p_0-p_sat;// lbf/in^2
a_f=(c_w*(T_w-T_0))+(v_w*(p_w-p_0)*(144/778.16))-(c_w*T_0*log(T_w/T_0))+((V_w^2)/(2*g_c*778.16))+((g*Z_w)/(g_c*778.16));// Btu/lbm
printf(”\nThe specific flow availability at the exit of a garden hose,a_f=%0.3f Btu/lbm”,a_f);
```

Scilab code Exa 10.7 The specific flow availabilities at the inlet and outlet of t

```
// Example 10_7
clc;funcprot(0);
// Given data
p_1=5000;// psia
T_1=1000;//  F
V_1=50.0;// ft/s
V_2=300.0;// ft/s
x_0=0.00;// The quality of steam
T_0=70.0;//  F
g_c=32.174;// lbm.ft/lbf.s^2
g=32.174;// ft/s^2

// Calculation
// Station 1
p_1=5000;// psia
T_1=1000;//  F
h_1=1363.4;// Btu/lbm
s_1=1.3990;// Btu/lbm.R
// Station 2
p_2=14.696;// psia
h_2=h_1+((V_1^2-V_2^2)/(2*g_c*778.16));// Btu/lbm
h_0=38.1;// Btu/lbm
s_0=0.0746;// Btu/lbm.R
Z_1=0;// ft
Z_2=Z_1;// ft
T_2=655;//  F
s_2=1.9981;// Btu/lbm.R
a_f1=(h_1-h_0)-((T_0+459.67)*(s_1-s_0))+((V_1^2)/(2*g_c*778.16))+((g*Z_1)/g_c);// Btu/lbm
a_f2=(h_2-h_0)-((T_0+459.67)*(s_2-s_0))+((V_2^2)/(2*g_c*778.16))+((g*Z_2)/g_c);// Btu/lbm
Ibym=a_f1-a_f2;// Btu/lbm
printf("\nThe specific flow availabilities at the inlet and outlet of the crack,a_f1=%3.0f Btu/lbm & a_f2=%3.0f Btu/lbm \nThe irreversibility per unit mass of steam exiting the crack,I/m=%3.0f Btu/lbm",a_f1,a_f2,Ibym);
```

Scilab code Exa 10.8 `The irreversibility rate inside the nozzle`

```
// Example 10_8
clc;funcprot(0);
// Given data
m=2.80;// lbm/s
// Station 1
p_1=100;// psia
T_1=500;//  F
h_1=1279.1;// Btu/lbm
s_1=1.7087;// Btu/lbm.R
// Station 2
p_2=10.0;// psia
p_2s=p_2;// psia
s_2f=0.2836;// Btu/lbm.R
s_2fg=1.5043;// Btu/lbm.R
s_2=s_1;// Btu/lbm.R
h_2f=161.4;// Btu/lbm
h_2fg=982.1;// Btu/lbm
h_2s=1091.6;// Btu/lbm
// Ground state
x_0=0;// The quality of steam
T_0=70.0;//  F
s_0=0.0746;// Btu/lbm.R
h_0=38.1;// Btu/lbm
g_c=32.174;// lbm.ft/lbf.s^2
g=32.174;// ft/s^2

// Calculation
// (a)
V_1=0;// ft/s
Z_2=0;// ft
Z_1=Z_2;// ft
V_2s=[2*g_c*(h_1-h_2s)*778.16]^(1/2);// ft/s
```

```
V_2=(95/100)*V_2s;// ft/s
h_2=h_1-((V_2^2)/(2*g_c*778.16));// Btu/lbm
x_2=(h_2-h_2f)/h_2fg;// The quality of steam
s_2=s_2f+(x_2*s_2fg);// Btu/lbm.R
a_f1=(h_1-h_0)-((T_0+459.67)*(s_1-s_0))+(V_1^2/(2*g_c*778.16))+((g*Z_1)/g_c);// Btu/lbm
// (b)
a_f2=(h_2-h_0)-((T_0+459.67)*(s_2-s_0))+(V_2^2/(2*g_c*778.16))+((g*Z_2)/g_c);// Btu/lbm
// (c)
I=m*(a_f1-a_f2);// Btu/s
printf("\n(a)The inlet specific flow availability,a_f1=%3.0f Btu/lbm \n(b)The exit specific flow availability,a_f2=%3.0f Btu/lbm \n(c)The irreversibility rate inside the nozzle,I=%2.1f Btu/s",a_f1,a_f2,I);
// The answer vary due to round off error
```

Scilab code Exa 10.9 The rate of heat loss from the surface of the turbine

```
// Example 10_9
clc;funcprot(0);
// Given data
m=18.0;// kg/s
T_b=350.0;//  C
W=20*10^3;// kW
// Station 1
T_1=500.0;//  C
p_1=3.00;// MPa
h_1=3456.5;// kJ/kg
s_1=7.2346;// kJ/kg.K
// Station 2
p_2=0.0100;// MPa
x_2=0.960;// The quality of steam
h_2f=191.8;// kJ/kg
```

```
h_2fg=2392.8;// kJ/kg
h_2=h_2f+(x_2*h_2fg);// kJ/kg
s_2f=0.6491;// kJ/kg.K
s_2fg=7.5019;// kJ/kg.K
s_2=s_2f+(x_2*s_2fg);// kJ/kg.K
// Ground state
x_0=0.00;// The quality of steam
T_0=20.0;// C
h_0=83.9;// kJ/kg
s_0=0.2965;// kJ/kg.K

// Calculation
a_f1=(h_1-h_0)-((T_0+273.15)*(s_1-s_0));// kJ/kg
a_f2=(h_2-h_0)-((T_0+273.15)*(s_2-s_0));// kJ/kg
Q=(W+(m*(a_f2-a_f1)))/(1-((T_0+273.15)/(T_b+273.15)));// kW
printf("\nThe rate of heat loss from the surface of the turbine,Q=%4.0f kW",Q);
// The answer vary due to round off error
```

Scilab code Exa 10.12 `The second law efficiency of the power plant`

```
// Example 10_12
clc;funcprot(0);
// Given data
Q_H=1.00*10^6;// kJ/s
T_0=5.00;// C
T_H=700;// C
p_0=0.101;// MPa
Q_L=7.00*10^5;// kJ/s
T_L=40.0;// C
W_net=3.00*10^5;// kJ/s

// Calculation
// (a)
```

```
n=(W_net/Q_H)*100;// %
// (b)
A_bin=(1-((T_0+273.15)/(T_H+273.15)))*Q_H;// kJ/s
// (c)
A_cin=(1-((T_0+273.15)/(T_L+273.15)))*Q_L;// kJ/s
// (d)
E_HE=(W_net/(A_bin-A_cin))*100;// %
printf(”\n(a)The first law thermal efficiency of the power plant,n=%2.1f percentage \n(b)The rate at which available energy enters the boiler,A_boiler input=%1.2e kJ/s \n(c)The rate at which available energy enters the condenser,A_boiler output=%0.2e kJ/s \n(d)The second law efficiency of the power plant,E_He=%2.1f percentage”,n,A_bin,A_cin,E_HE);
```

Scilab code Exa 10.13 The second law availability efficiency of the heat pump

```
// Example 10_13
clc;funcprot(0);
// Given data
Q_H=30.0*10^3;// Btu/h
W_in=1.50;// hp
T_0=30.0+459.67;// K
T_H=70.0+459.67;// K

// Calculation
// (a)
COP_act_hp=Q_H/(W_in*2545);// The actual COP of heat pump
n_T=COP_act_hp;// The first law thermal efficiency of the heat pump
// (b)
E_HP=((1-(T_0/T_H))*COP_act_hp)*100;// The second law availability efficiency of the heat pump
```

```
T_L=T_0;//  F
COP_Carnot_hp=T_H/(T_H-T_L);// The COP of Carnot heat pump
E_HP=(COP_act_hp/COP_Carnot_hp)*100;// The second law availability efficiency of the heat pump
printf("\n(a)The first law thermal efficiency of the heat pump,n_T=%1.2f \n(b)The second law availability efficiency of the heat pump,E_HP=%2.1f percentage",n_T,E_HP);
```

Scilab code Exa 10.14 `The second law availability efficiency of this air condition`

```
// Example 10_14
clc;funcprot(0);
// Given data
T_L=20+273.15;// K
T_0=T_L;// K
T_H=35.0+273.15;// K
COP_act=8.92;// Actual Coefficient of Performance

// Calculation
COP_Carnot=T_L/(T_H-T_L);// The coefficient of performance of a Carnot refrigerator or air conditioner
epsilon_RAC=(COP_act/COP_Carnot)*100;// The second law efficiency in %
printf("\nThe second law availability efficiency of this air conditioner,epsilon_R/AC=%2.1f percentage",epsilon_RAC);
```

Scilab code Exa 10.15 `The second law availability efficiency of the preheater`

```
// Example 10_15
```

```
clc;funcprot(0);
// Given data
m_air=0.800;// kg/s
T_air_in=20.0;//  C
T_0=20.0;//  C
p_ein=1.10;// atm
p_eout=1.0;// atm
p_ain=1.50;// atm
p_aout=1.40;// atm
p_0=1.00;// atm
T_ein=500;//  C
T_eout=400;//  C
c_p_exh=0.990;// kJ/(kg.K)
c_p_air=1.004;// kJ/(kg.K)
m_exh=m_air;// kg/s
m_cold=m_air;// kg/s
R_exh=0.272;// kJ/(kg.K)
R_air=0.286;// kJ/(kg.K)

// Calculation
// (a)
c_p_cold=c_p_air;// kJ/(kg.K)
T_air_out=T_air_in+(((m_exh*c_p_exh)/(m_cold*
    c_p_cold))*(T_ein-T_eout));//  C
// (b)
a_f_inexh=(c_p_exh*(T_ein-T_0))-((T_0+273.15)*[(
    c_p_exh*log((T_ein+273.15)/(T_0+273.15)))-(R_exh*
    log(p_ein/p_0))])+0+0;// kJ/kg
a_f_outexh=(c_p_exh*(T_eout-T_0))-((T_0+273.15)*[(
    c_p_exh*log((T_eout+273.15)/(T_0+273.15)))-(R_exh
    *log(p_eout/p_0))])+0+0;// kJ/kg
a_f_inair=(c_p_air*(T_air_in-T_0))-((T_0+273.15)*[(
    c_p_air*log((T_air_in+273.15)/(T_0+273.15)))-(
    R_air*log(p_ain/p_0))])+0+0;// kJ/kg
a_f_outair=(c_p_air*(T_air_out-T_0))-((T_0+273.15)
    *[(c_p_air*log((T_air_out+273.15)/(T_0+273.15)))
    -(R_air*log(p_aout/p_0))])+0+0;// kJ/kg
E_nmHX=((m_air*(a_f_outair-a_f_inair))/(m_exh*(
```

```
    a_f_inexh-a_f_outexh)))*100;// The second law availability efficiency in %
printf("\n(a)The exit temperature of the inlet air,(T_out)_air=%3.0f C \n(b)The second law availability efficiency of the preheater,E_nonmixingHX=%2.1f percentage",T_air_out,E_nmHX);
```

Scilab code Exa 10.16 The second law availability efficiency of the sink as a mixi

```
// Example 10_16
clc;funcprot(0);
// Given data
m_H=0.180;// lbm/s
T_H=130;//  F
m_C=0.270;// lbm/s
T_C=60.0;//  F
T_0=55.0;//  F
p_0=14.7;// psia
C_w=1.00;// Btu/(lbm.R)

// Calculation
// (a)
T_M=((m_H*(T_H+459.67))+(m_C*(T_C+459.67)))/(m_H+m_C);// R
T_M=T_M-459.67;//  F
// (b)
a_fH=(C_w*(T_H-T_0))-(C_w*(T_0+459.67)*log((T_H+459.67)/(T_0+459.67)));// Btu/lbm
a_fC=(C_w*(T_C-T_0))-(C_w*(T_0+459.67)*log((T_C+459.67)/(T_0+459.67)));// Btu/lbm
a_fm=(C_w*(T_M-T_0))-(C_w*(T_0+459.67)*log((T_M+459.67)/(T_0+459.67)));// Btu/lbm
m_m=m_H+m_C;// lbm/s
gamma=m_H/m_m;// The second law availability
```

```
efficiency
epsilon_mixingHX=(((1-gamma)*(a_fm-a_fC))/(gamma*(a_fH-a_fm)))*100;// %
printf("\n(a)The temperature of the mixed water in the sink,T_M=%2.0f F \n(b)The second law availability efficiency of the sink as a mixing-type heat exchanger,epsilon_mixingHX=%2.1f percentage",T_M,epsilon_mixingHX)
```

Chapter 11

More Thermodynamic Relations

Scilab code Exa 11.2 `The specific Helmholtz and Gibbs functions for superheated wa`

```
// Example 11_2
clc;funcprot(0);
// Given data
p=200;// psia
T=400;//  F

// Solution
// From Table C.3a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find that, at this state,
u=1123.5;// Btu/lbm
h=1210.8;// Btu/lbm
s=1.5602;// Btu/lbm.R
f=u-((T+459.67)*s);// Btu/lbm
g=h-((T+459.67)*s);// Btu/lbm
printf("\nThe value of the specific Helmholtz function for superheated water vapor,f=%3.0f Btu/lbm \nThe value of the specific Gibbs function for superheated water vapor,g=%3.0f Btu/lbm",f,g)
```

```
;
```

Scilab code Exa 11.3 `The phase change entropy for water`

```
// Example 11_3
clc;funcprot(0);
// Given data
p=1.00;// MPa

// Solution
// From Table C.2b at p = 1.00 MPa, we find that,
h_fg=2015.3;// kJ/kg
T_sat=179.90;//  C
s_fg=h_fg/(T_sat+273.15);// kJ/kg .K
printf("\nThe phase change entropy for water,s_fg=%1.4f kJ/kg.K",s_fg);
```

Scilab code Exa 11.6 `The heat transfer required when the rubber band is stretched`

```
// Example 11_6
clc;funcprot(0);
// Given data
L_0=0.0700;// m
L=0.200;// m
T=20.0;//  C
K=0.150;// N/K

// Solution
Q_12=(-K*(T+273.15)*L_0*((L/L_0)-1)^3)/3;// N.m
printf("\n(c)The required heat transfer,Q_12=%1.2f N.m",Q_12);
```

Scilab code Exa 11.7 Error percentage

```
// Example 11_7
clc;funcprot(0);
// Given data
// ln p_sat=14.05-(6289.78/T_sat)-(913998.2/T_sat^2);
// T_sat= F  + 461.2
T=212;//  F
R=0.1102;// Btu/(lbm.R)

// Solution
T_sat=T+461.2;// R
// From Table C.13a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics
h_fg=[(6289.78)+((1827997.8)/(T_sat))]*R;// Btu/lbm
// Table C.1a gives
h_fg_212F=970.4;// Btu/lbm
p_error=((h_fg-h_fg_212F)/h_fg_212F)*100;// %
printf("\nThus, the value obtained from Rankines equation is in error by only %1.2f percentage.",p_error);
```

Scilab code Exa 11.10 The difference between cp and cv for saturated liquid water

```
// Example 11_10
clc;funcprot(0);
// Given data
T=20.0;//  C
beta=0.207*10^-6;// K^-1
k=45.9*10^-11;// m^2/N

```

```
// Solution
v_f=0.001002;// m^3/kg
v=v_f;// m^3/kg
c_pminusc_v=(((T+273.15)*beta^2*v)/k)*10^-3;// kJ/(kg.K)
printf("\nThe difference between c_p and c_v for saturated liquid water,c_p-c_v=%1.2e kJ/(kg.K)",c_pminusc_v);
```

Scilab code Exa 11.12 The final temperature and pressure of the air at the end of

```
// Example 11_12
clc;funcprot(0);
// Given data
T=60.0;//  F
p_1=14.7;// psia
r_c=19.2:1;// Compression ratio

// Solution
// From Table C.16a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics,we find that , at 60.0 F  = 520.R,
u_1=88.62;// Btu/lbm
p_r1=1.2147;
v_r1=158.58;
v_2byv_1=1/19.2;
v_r2=v_r1*v_2byv_1;
// Scanning down the v_r column in Table C.16a, we find that vr = 8.26 at about
T_2=1600-459.67;//  F
u_2=286.06;// Btu/lbm
p_r2=71.73;
p_2=p_1*(p_r2/p_r1);// psia
W_12bym=u_1-u_2;// Btu/lbm
printf("\nThe final temperature and pressure of the
```

```
air at the end of the compression stroke,T_2=%4.0f F and p_2=%3.1f psia. \nThe work required per lbm of air present,1W2/m=%3.2f Btu/lbm",T_2,p_2,W_12bym);
```

Scilab code Exa 11.13 The pressure exerted by the carbon monoxide

```
// Example 11_13
clc;funcprot(0);
// Given data
m=8.20;// lbm
V=1.00;// ft^3
T=-78.0;//  F

// Solution
// From Table C.12a, we find that
T_c=240;// R
p_c=507;// psia
v_c=1.49/28.011;// ft^3/lbm
// Also, from Table C.13a, we find that
R=0.0709;// Btu/lbm.R
T_R=(T+460)/T_c;
v=V/m;// ft^3/lbm
// Assume 'a' instead of '
v_ca=(R*(T_c*778.16))/(p_c*144);// ft^3/lbm
v_Ra=v/v_ca;
// Using T_R = T/Tc = 1.60 and  v R  = v/ v c  = 0:67, we find from Figure 11.6 that
p_R=2.10;
Z=0.850;
p=p_c*p_R;// psia
printf("\nThe pressure exerted by 8.20 lbm of the carbon monoxide,p=%4.0f psia",p);
// The answer is different due to round off error.
```

Scilab code Exa 11.14 `The maximum pressure in the CNG tank`

```
// Example 11_14
clc;funcprot(0);
// Given data
V=0.100;// m^3
p=20.0;// MPa
m=15.6;// kg
T=1000;//  C

// Solution
// From Table C.12b, we find the critical state properties of methane to be
T_c=191.1;// K
p_c=4.64;// MPa
v=V/m;// m^3/kg
v_1=v;// m^3/kg
v_2=v_1;// m^3/kg
// Table C.13b, gives the gas constant for methane as
R=0.518;// kJ/kg.K
// Assume 'a' instead of '
v_Ra=(v*p_c*10^3)/(R*T_c);
T_R=(T+273.15)/T_c;
p_R=32.0;
p_2byp_c=p_R;
p_2_worstcase=p_R*p_c;// MPa
printf("\nThe maximum pressure in the CNG tank at this worst case temperature,(p_2)_worstcase=%3.0f MPa",p_2_worstcase);
```

Scilab code Exa 11.15 `The exit temperature of the throttle`

```
// Example 11_15
clc;funcprot(0);
// Given data
p_1=20.0;// MPa
T_1=150;//  C
p_2=0.101;// MPa

// Solution
// From Table C.12b, we find the critical
   temperature and pressure for CO2 are
T_c=304.2;// K
p_c=7.39;// MPa
M_CO2=44.01;// kg/kg mole
c_p=0.845;// kJ/kg.K
p_R1=p_1/p_c;
T_R1=(T_1+273.15)/T_c;
// Assume s_1=[(h*-h)/T_c]_1
s_1=14.0;// kJ/kgmole K
p_R2=p_2/p_c;
// Assume s_2=[(h*-h)/T_c]_2
// h_2-h_1=0
T_2=(T_1+273.15)-((s_1/c_p)*(T_c/M_CO2));// K
T_2=T_2-273.15;//  C
printf("\nThe exit temperature of the throttle,T_2=
   %2.1f C",T_2);
```

Scilab code Exa 11.16 The change in specific entropy of the ethylene

```
// Example 11_16
clc;funcprot(0);
// Given data
p_1=150;// psia
p_2=15.0*10^3;// psia
T_1=80.0;//  F
T_2=T_1;//  F
```

```

// Calculation
// (a)
// The properties of ethylene at its critical state and its molecular mass are found in Table C.12a as
T_c=508.3;// R
p_c=742;// psia
M=28.05;// lbm/lbmoles
p_R1=p_1/p_c;
T_R1=(T_1+459.67)/T_c;
p_R2=p_2/p_c;
T_R2=T_R1;
// Using p_R1 and T_R1, Figure 11.9 gives the enthalpy correction for state 1 as
// Assume s_1=[(h*-hbar)/T_c]_1
s_1=1.50;// kJ/kgmole.K
s_1=s_1*(1/4.1865);// Btu/(lbmole.R)
// Using p_R2 and T_R2, Figure 11.9 gives the enthalpy correction for state 2 as
// Assume s_2=[(h*-hbar)/T_c]_2
s_2=31.5;// kJ/kgmole.K
s_2=s_2*(1/4.1865);// Btu/(lbmole.R)
// h*2-h*1=0;
// dh=h_2-h_1;
dh=0-([s_2-s_1]*(T_c/M));// Btu/lbm
// (b)
p_R1=0.202;
T_R1=1.06;
Z_1=0.940;
p_R2=20.2;
T_R2=T_R2;
Z_2=2.15;
R=55.1;// ft.lbf/(lbm.R)
v_1=(Z_1*R*(T_1+459.67))/(p_1*144);// ft^3/lbm
v_2=(Z_2*R*(T_2+459.67))/(p_2*144);// ft^3/lbm
du=dh-(((p_2*144)*v_2*(1/778.16))-((p_1*144)*v_1*(1/778.16)));// Btu/lbm
```

```
// (c)
// s*2-s*1=dS;
dS=(c_p*log(T_2/T_1))-((R/778.16)*log(p_2/p_1));// Btu/lbm.R
// Using p_R1 and T_R1, Figure 11.11 gives the entropy correction for state 1 as
// Assume (s*bar-sbar)_1=S_1
S_1=1.50;// kJ/kgmole.K
S_1=S_1*(1/4.1865);// Btu/(lbmole.R)
// Using p_R2 and T_R2, Figure 11.11 gives the entropy correction for state 2 as
S_2=2.22;// kJ/kgmole.K
S_2=S_2*(1/4.1865);// Btu/(lbmole.R)
// d_s=S_1-S_2
ds=dS-([S_2-S_1]*(1/M));// Btu/(lbm.R)
printf("\n(a)The change in specific enthalpy,h_2-h_1=%3.0f Btu/lbm \n(b)The change in specific internal energy,u_2-u_1=%3.0f Btu/lbm \n(c)The change in specific entropy of the ethylene,s_2-s_1=%0.3f Btu/lbm.R",dh,du,ds);
// The answer vary due to round off error
```

Scilab code Exa 11.17 `The final temperature and pressure`

```
// Example 11_17
clc;funcprot(0);
// Given data
m_A=1.00;// lbm
p_A=1.00;// psia
T_A=200;//  F
m_B=5.00;// lbm
p_B=5.00;// psia
T_B=400;//  F

// Calculation
```

```
T_2=((m_A*(T_A+459.67))+(m_B*(T_B+459.67)))/(m_A+m_B);// R
T_2=T_2-459.67;//  F
p_2=((m_A+m_B)*(T_2+459.67))/(((m_A*(T_A+459.67))/p_A)+((m_B*(T_B+459.67))/p_B));// psia
printf("\nThe final temperature,T_2=%3.0f F \nThe final pressure,p_2=%1.2f psia",T_2,p_2);
```

Chapter 12

Mixtures of Gases and Vapors

Scilab code Exa 12.1 `The mixture composition on a molar basis`

```
// Example 12_1
clc;funcprot(0);
// Given data
w_propane=0.500;// The mass fraction
w_air=0.500;// The mass fraction
R=8.3143;// kJ/kgmole.K

// Calculation
// (a)
// The molecular masses of the components are found in Table C.13 in Thermodynamic Tables to accompany Modern Engineering Thermodynamics as
M_propane=44.09;// kg/kgmole
M_air=28.97;// kg/kgmole
M_m=1/((w_propane/M_propane)+(w_air/M_air));// kg/kgmole
// (b)
X_propane=w_propane*(M_m/M_propane);// The molar value for propane
X_air=w_air*(M_m/M_air);// The molar value for air
w_m=w_propane+w_air;// The mass of the mixture
```

```
X_m=X_propane+X_air;// The molar value of the mixture
// (c)
R_m=R/M_m;// The equivalent gas constant in kJ/kg.K
printf("\n(a)The equivalent molecular mass of the mixture,M_m=%2.1f kg/kgmole \n(b)The mixture composition on a molar basis,X_propane=%0.3f & X_air=%0.3f \n(c)The equivalent gas constant of the mixture,R_m=%0.3f kJ/kg.K",M_m,X_propane,X_air,R_m);
```

Scilab code Exa 12.2 `The composition of air on a mass basis`

```
// Example 12_2
clc;funcprot(0);
// Given data
X_N_2=78.09;// %
X_O_2=20.95;// %
X_Ar=0.930;// %
X_CO_2=0.0300;// %
R=8.3143;// kJ/(kg.mole.K)

// Calculation
// (a)
M_N_2=28.02;// kg/kgmole
M_O_2=32.00;// kg/kgmole
M_Ar=39.94;// kg/kgmole
M_CO_2=44.01;// kg/kgmole
M_air=((X_N_2/100)*M_N_2)+((X_O_2/100)*M_O_2)+((X_Ar/100)*M_Ar)+((X_CO_2/100)*M_CO_2);// kg/kgmole
// (b)
R_air=R/M_air;// kJ/kg.K
// (c)
// Equation (12.13) can be used to determine the corresponding mass or weight fraction composition
```

```
     as
w_N_2=(X_N_2/100)*(M_N_2/M_air)*100;// % by mass
w_O_2=(X_O_2/100)*(M_O_2/M_air)*100;// % by mass
w_Ar=(X_Ar/100)*(M_Ar/M_air)*100;// % by mass
w_CO_2=(X_CO_2/100)*(M_CO_2/M_air)*100;// % by mass
printf("\n(a)The equivalent molecular mass,M_air=%2
    .2f kg/kgmole \n(b)The gas constant for the
    mixture,R_air=%0.3f kJ \n(c)The composition of
    air on a mass (or weight) basis,w_N2=%2.2f
    percentage by mass \n

    w_O2=%2.2f percentage by mass \n

    w_Ar=%1.2f percentage by mass \n

    w_CO2=%0.4f percentage by mass",M_air,R_air,w_N_2
    ,w_O_2,w_Ar,w_CO_2);
```

Scilab code Exa 12.3 The partial pressure of the water vapor in the exhaust gas mi

```
// Example 12_3
clc;funcprot(0);
// Given data
X_CO_2=9.51;// %
X_H_2O=19.01;// %
X_N_2=71.48;// %
M_N_2=28.02;// kg/kgmole
M_CO_2=44.01;// kg/kgmole
M_H_2O=18.02;// kg/kgmole
p_m=14.7;// psia

// Calculation
// (a)
// For ideal gas behavior, Eq. (12.23) tells us that
     the mole fractions, volume fractions, and the
```

```
pressure fractions are all the same, or
Shi_CO_2=X_CO_2;// The volume fraction in %
Shi_H_2O=X_H_2O;// The volume fraction in %
Shi_N_2=X_N_2;// The volume fraction in %
pi_CO_2=X_CO_2;// The pressure fraction in %
pi_H_2O=X_H_2O;// The pressure fraction in %
pi_N_2=X_N_2;// The pressure fraction in %
M_m=(X_CO_2*M_CO_2)+(X_N_2*M_N_2)+(X_H_2O*M_H_2O);// The equivalent molecular mass of this ideal gas mixture in kg/kgmole
w_CO_2=Shi_CO_2*(M_CO_2/M_m);// The mass fraction in %
w_H_2O=Shi_H_2O*(M_H_2O/M_m);// The mass fraction in %
w_N_2=Shi_N_2*(M_N_2/M_m);// The mass fraction in %
// (b)
p_H_2O=p_m*X_H_2O/100;// The partial pressure of the water vapor in the exhaust gas mixture in psia
printf("\n(a)The volume fraction compostion of the mixture,Shi_CO_2=%1.2f percentage \n

Shi_H_2O=%2.2f percentage \n

Shi_N_2=%2.2f percentage \n(b)The partial pressure of the water vapor in the exhaust gas mixture,p_H2O=%1.2f psia",Shi_CO_2,Shi_H_2O,Shi_N_2,p_H_2O);
```

Scilab code Exa 12.4 `The proper helium oxygen breathing mixture composition for a`

```
// Example 12_4
clc;funcprot(0);
// Given data
X_O_2=0.2095;// The mole fraction for oxygen
p_m=0.1013;// MN/m^2
```

```
d=100;// m
M_O_2=32.00;// The molecular mass of oxygen
M_He=4.003;// The molecular mass of helium
R=8.3143;// kJ/(kgmole.K)

// Calculation
// (a)
p_O_2=X_O_2*p_m;// MN/m^2
p_m=1.08;// MN/m^2
X_O_2=p_O_2/p_m;// The mole fraction for oxygen
Shi_O_2=X_O_2;// The volume fraction for oxygen
pi_O_2=X_O_2;// The pressure fraction for oxygen
X_He=1-X_O_2;// The mole fraction for helium
Shi_He=X_He;// The volume fraction for oxygen
M_m=(X_O_2*M_O_2)+(X_He*M_He);// kg/kgmole
w_O_2=X_O_2*(M_O_2/M_m);// The mass fraction for oxygen
w_He=1-w_O_2;// The mass fraction for helium
printf("\n(a)The mole and volume fraction of oxygen,X_O2=Shi_O2=pi_O2=%0.4f \n    The helium mole and volume fractions,X_He=Shi_He=%0.3f \n    The mixture equivalent molecular mass,M_m=%1.2f kg/kgmole",X_O_2,X_He,M_m);
// (b)
R_m=R/M_m;// kJ/(kg.K)
c_vO_2=0.657;// kJ/(kg.K)
c_vHe=3.123;// kJ/(kg.K)
c_pO_2=0.917;// kJ/(kg.K)
c_pHe=5.200;// kJ/(kg.K)
c_vm=(w_O_2*c_vO_2)+(w_He*c_vHe);// kJ/(kg.K)
c_pm=(w_O_2*c_pO_2)+(w_He*c_pHe);// kJ/(kg.K)
k_m=c_pm/c_vm;// The specific heat ratio of the mixture
printf("\n(b)The mixture equivalent gas constant,R_m=%1.2f kJ/(kg.K) \n    The mixture specific heats,c_vm=%1.2f kJ/(kg.K) & c_pm=%1.2f kJ/(kg.K) \n    The specific heat ratio of the mixture,k_m=%1.2f",R_m,c_vm,c_pm,k_m);
```

Scilab code Exa 12.5 `The power per unit mass flow rate required to isentropically`

```
// Example 12_5
clc;funcprot(0);
// Given data
T_m1=20.0+273.15;// K
p_m1=0.101;// MN/m^2
p_m2=1.08;// MN/m^2
k_m=1.66;// The specific heat ratio of the mixture
c_pm=4.61;// kJ/kg.K

// Calculation
T_m2=T_m1*((p_m2/p_m1)^((k_m-1)/k_m));// K
T_m2C=T_m2-273.15;// C
Wbym_m=c_pm*(T_m1-T_m2);// kJ/kg
printf("\nThe power per unit mass flow rate required to isentropically compress the helium-oxygen mixture,Wdot/mdot_m=%4.0f kJ/kg",Wbym_m);
// The answer provided in the textbook is wrong
```

Scilab code Exa 12.6 `The humidity ratio of the atmosphere`

```
// Example 12_6
clc;funcprot(0);
// Given data
T=25.0;// C
p_m=.101*10^3;// MPa
phi=56.8/100;// The relative humidity

// Calculation
// (a)
```

```
// From Table C.1b, we find that
p_sat=0.003169;// MPa
p_w=phi*p_sat*10^3;// kPa
// (b)
// From Daltons law for partial pressure, we can find the partial pressure of the dry air in the mixture as
p_a=p_m-p_w;// kPa
w=0.622*(p_w/p_a);// kg H2O per kg of dry air
// (c)
// Using Eq. (12.27) and Table C.2b, we find the dew point temperature to be
T_sat=15.8;//  C
T_DP=T_sat;//  C
printf("\n(a)The partial pressure of the water vapor in the atmosphere,p_w=%1.2f kPa \n(b)The humidity ratio of the atmosphere,w=%0.4f kg H2O per kg of dry air \n(c)The dew point temperature of the atmosphere,T_DP=%2.1f  C",p_w,w,T_DP);
```

Scilab code Exa 12.8 The humidity ratio in the room

```
// Example 12_8
clc;funcprot(0);
// Given data
T_WB=60.0;//  F
T_DB=70.0;//  F

// Calculation
// From Table C.1a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find
h_g1=1092.0;// Btu/lbm
h_fg2=1059.6;// Btu/lbm
h_f2=28.1;// Btu/lbm
```

```
p_sat=0.2563;// psia
p_w3=p_sat;// psia
p_m=14.7;// psia
w_3=0.622*((p_w3)/(p_m-p_w3));// lbm water per lbm of dry air
c_pa=0.240;// Btu/lbm.R
w_1=((c_pa*(T_WB-T_DB))+(w_3*h_fg2))/(h_g1-h_f2);// lbm water per lbm of dry air
w_1=w_1*7000;// grains of water per lbm of dry air
printf("\nThe humidity ratio (   ) in the room,w_1=%2.1f grains of water per lbm of dry air",w_1);
```

Scilab code Exa 12.10 `The value of h from its definition`

```
// Example 12_10
clc;funcprot(0);
// Given data
T_DB=50.0+273.15;// K
T_ref=0+273.15;// K
phi=40.0/100;// The relative humidity
p_m=0.101;// MPa
c_p=1.004;// kJ/(kg.K)

// Calculation
h_a=c_p*(T_DB-T_ref);// kJ/(kg dry air)
// From Table C.1b,
p_sat=0.01235;// MPa
w=0.622*((phi*p_sat)/(p_m-(phi*p_sat)));// kg watervapor/kg dry air
p_w=phi*p_sat;// MPa
h_w=2593.6;// kJ/kg water vapor
h=h_a+(w*h_w);// kJ/kg dry air
printf("\nThe value of h#=%3.0f kJ/kg dry air",h);
```

Scilab code Exa 12.11 The heat transfer rate per unit mass flow rate of dry air re

```
// Example 12_11
clc;funcprot(0);
// Given data
T_DB1=35.0;// C
phi_1=80/100;// The relative humidity
T_DB3=20.0;// C
phi_2=40.0/100;// The relative humidity

// Calculation
h_1=110;// kJ/kg dry air
h_3=35;// kJ/kg dry air
Qbym_a=h_3-h_1;// kJ/kg dry air
printf("\n The heat transfer rate per unit mass flow rate of dry air required to carry out this process,Q/m_a=%2.0f kJ/kg dry air",Qbym_a);
```

Scilab code Exa 12.12 The reheating heat transfer rate

```
// Example 12_12
clc;funcprot(0);
// Given data
// State 1
T_DB1=25.0;// C
phi_1=80.0/100;// The relative humidity
h_1=67;// kg/(kg da)
w_1=0.016;// kg H2O/(kg da)
// State 2
T_DB2=6.0;// C
phi_2=100/100;// The relative humidity
h_2=21;// kg/(kg da)
```

```
h_f2=25.2;// kg/(kg da)
w_2=0.0056;// kg H2O/(kg da)
// State 3
T_DB3=20.0;//  C
phi_3=40/100;// The relative humidity
h_3=35;// kg/(kg da)
w_3=w_2;// kg H2O/(kg da)

// Calculation
// (a)
dw=w_1-w_2;// kg H2O/(kg dry air)
// (b)
Q_cbym_da=(h_2-h_1)+((w_1-w_2)*h_f2);// kJ/(kg dry
   air)
// (c)
Q_rbym_da=h_3-h_2;// kJ/(kg dry air)
printf("\n(a)The amount of water removed per unit
   mass of dry air,w_1-w_2=%0.3f kg H2O/(kg dry air)
    \n(b)The amount of cooling required per unit
   mass of dry air,Q_cooling/m_dry air=%2.1f kJ/(kg
   dry air) \n(c)The reheating heat transfer rate,
   Q_reheating/m_dry air=%2.0f kJ/(kg dry air)",dw,
   Q_cbym_da,Q_rbym_da);
```

Scilab code Exa 12.13 The dry bulb temperature of the outlet mixture

```
// Example 12_13
clc;funcprot(0);
// Given data
V_a1=2000;// ft^3/min
T_DB1=50.0+459.67;// R
phi_1=80.0/100;// The relative humidity
V_a2=1000;// ft^3/min
T_DB2=100.0+459.67;// R
phi_2=40.0/100;// The relative humidity
```

```
R_a=53.34;// ft.lbf/(lbm.R)
p_m=14.7// lbf/in^2

// Calculation
p_sat1=0.178;// psia
p_w1=phi_1*p_sat1;// psia
p_a1=p_m-p_w1;// lbf/in^2
v_a1=(R_a*T_DB1)/(p_a1*144);// ft^3/(lbm dry air)
p_sat2=0.9503;// psia
p_w2=phi_2*p_sat2;// psia
p_a2=p_m-p_w2;// lbf/in^2
v_a2=(R_a*T_DB2)/(p_a2*144);// ft^3/(lbm dry air)
m_a1=V_a1/v_a1;// lbmdry air/min
m_a2=V_a2/v_a2;// lbmdry air/min
m_a3=m_a1+m_a2;// lbmdry air/min
// Then, from the psychrometric chart (Chart D.5), we find
w_1=44/7000;// lbm water vapor/(lbm dry air)
w_2=115/7000;// lbm water vapor/(lbm dry air)
h_1=19;// Btu/(lbm dry air)
h_2=42;// Btu/(lbm dry air)
w_3=((m_a1/m_a3)*w_1)+((m_a2/m_a3)*w_2);// grains of water vapor/(lbm dry air)
h_3=((m_a1/m_a3)*h_1)+((m_a2/m_a3)*h_2);// Btu/(lbm dry air)
// From the point where the lines  = 65.8 grains/(lbm dry air) = constant and h = 26 Btu/(lbm dry air) = constant intersect on the psychrometric chart, we can read from this chart that
T_DB=63;//  F
T_WB=59;//  F
phi=75;// %
T_DP=56;//  F
printf(”\nThe dry bulb temperature of the outlet mixture,T_DB=%2.0f  F \nThe relative humidity of the outlet mixture,phi=%2.0f percentage”,T_DB,phi);
```

Scilab code Exa 12.14 `The total pressure in the tank`

```
// Example 12_14
clc;funcprot(0);
// Given data
m_methane=3.00;// lbm
m_propane=4.00;// lbm
V_m=1.00;// ft^3
T_m=240.0+459.67;// R
R=1545.35;// ft.lbf/(lb mole.R)

// Calculation
m_m=m_methane+m_propane;// lbm
w_methane=m_methane/m_m;// The mass fraction
w_propane=m_propane/m_m;// The mass fraction
// The molecular masses of the components are found
   in Table C.12a in Thermodynamic Tables to
   accompany Modern Engineering Thermodynamics as
M_methane=16.043;// lbm/lbmole
M_propane=44.097;// lbm/lbmole
M_m=1/((w_methane/M_methane)+(w_propane/M_propane));
   // lbm/lb mole
// From Tables C.12a and C.13a, we find that
p_c_methane=673;// psia
p_c_propane=617;// psia
T_c_methane=343.9;// R
T_c_propane=665.9;// R
R_methane=96.3;// ft.lbf/(lbm.R)
R_propane=35.0;// ft.lbf/(lbm.R)
v_m=V_m/m_m;// ft^3/lbm
T_R_methane=T_m/T_c_methane;// The reduced
   temperature for methane
v_R_methane=(v_m/w_methane)*((p_c_methane*144)/(
   R_methane*T_c_methane));// The reduced
```

```
pseudospecific volume for methane
T_R=2.03;// The reduced temperature for methane
v_R=0.975;// The reduced pseudospecific volume for methane
Z_D_methane=0.975;// The Dalton compressibility factor for methane
T_R=1.05;// The reduced temperature for propane
v_R=0.95;// The reduced pseudospecific volume for propane
Z_D_propane=0.720;// The Dalton compressibility factor for propane
Z_Dm=(((w_methane*M_m)/M_methane)*Z_D_methane)+(((w_propane*M_m)/M_propane)*Z_D_propane);// The Dalton compressibility factor for the  mixture
R_m=R/M_m;// ft.lbf/lbm.R
p_m=(Z_Dm*m_m*R_m*T_m)/V_m;// lbf/ft^2
p_m=p_m/144;// psia
printf("\nThe total pressure in the tank,p_m=%4.0f psia",p_m);
```

Scilab code Exa 12.15 `The volume occupied by this mixture`

```
// Example 12_15
clc;funcprot(0);
// Given data
T_m=500;// K
p_m=20.0;// MPa
R=8.3143;// kJ/(kg mole.K)

// Calculation
// Assume a-ammonia,cl-chlorine,no-nitrous oxide
m_a=1.00;// kg
m_cl=1.00;// kg
m_no=1.00;// kg
m_m=m_a+m_cl+m_no;// kg
```

```
// The mass fractions are
w_a=m_a/m_m;
w_cl=m_cl/m_m;
w_no=m_no/m_m;
M_a=17.030;// kg/kgmole
M_cl=70.906;// kg/kgmole
M_no=44.013;// kg/kgmole
M_m=1/((w_a/M_a)+(w_cl/M_cl)+(w_no/M_no));// The molecular mass of the mixture in kg/kgmole
p_c_a=11.280;// MPa
T_c_a=405.5;// K
p_c_cl=7.710;// MPa
T_c_cl=417.0;// K
p_c_no=7.270;// MPa
T_c_no=309.7;// K
R_a=R/M_a;// kJ/kg.K
R_cl=R/M_cl;// kJ/kg.K
R_no=R/M_no;// kJ/kg.K
// The reduced temperatures and pressures are
T_R_a=T_m/T_c_a;
p_R_a=p_m/p_c_a;
T_R_cl=T_m/T_c_cl;
p_R_cl=p_m/p_c_cl;
T_R_no=T_m/T_c_no;
p_R_no=p_m/p_c_no;
// Using these values on Figure 7.6 gives the following Amagat compressibility factors:
Z_A_a=0.64;
Z_A_cl=0.55;
Z_A_no=0.86;
Z_Am=(((w_a*M_m)/M_a)*Z_A_a)+(((w_cl*M_m)/M_cl)*Z_A_cl)+(((w_no*M_m)/M_no)*Z_A_no);// The Amagat compressibility factor for the mixture
R_m=R/M_m;// kJ/kg.K
V_m=(Z_Am*m_m*R_m*T_m)/(p_m*1000);// m^3
printf("\nThe total volume occupied by the mixture, V_m=%0.4f m^3",V_m);
```

Scilab code Exa 12.16 `The critical pressure and temperature for air`

```
// Example 12_16
clc;funcprot(0);
// Given data
X_N_2=0.7809;// The mole fraction for nitrogen
X_O_2=0.2095;// The mole fraction for oxygen
X_Ar=0.00930;// The mole fraction for Argon
X_CO_2=0.0003;// The mole fraction for Carbondioxide

// Calculation
// Using Eqs. (12.39) and (12.40), the composition data given in Example 12.2 and the critical point data given in Table C.12b in Thermodynamic Tables to accompany Modern Engineering Thermodynamics give
p_c_N_2=3.39;// MPa
p_c_O_2=5.08;// MPa
p_c_Ar=4.86;// MPa
p_c_CO_2=7.39;// MPa
p_c_air=(X_N_2*p_c_N_2)+(X_O_2*p_c_O_2)+(X_CO_2*p_c_CO_2);// MPa
T_c_N_2=126.2;// K
T_c_O_2=154.8;// K
T_c_Ar=151;// K
T_c_CO_2=304.2;// K
T_c_air=(X_N_2*T_c_N_2)+(X_O_2*T_c_O_2)+(X_CO_2*T_c_CO_2);// K
printf("\nThe critical pressure for air,(p_c)_air=%1.2f MPa \nThe critical temperature for air,(T_c)_air=%3.0f K",p_c_air,T_c_air);
// The answer vary due to round off error
```

Scilab code Exa 12.17 `The molar specific volume of the mixture`

```
// Example 12_17
clc;funcprot(0);
// Given data
T_m=-100;//  F
p_m=1500;// psia
R=1545.35;// ft.lbf/(lbmole.R)
v_ma=1.315;// ft^3/lb mole

// Calculation
// (a)For ideal gas mixture behavior,
v_m=(R*(T_m+459.67))/(p_m*144);// ft^3/lb mole
Error_a=((v_m-v_ma)/v_ma)*100;// % high
printf("Results: \n(a)v_m=%1.2f ft^3/mole \n
   Percentage error=%2.1f percentage high",v_m,
   Error_a);
// (b)The Dalton compressibility factor
// From Table C.12a, we find
p_c_N_2=492;// psia
T_c_N_2=227.1;// R
p_c_CH_4=673;// psia
T_c_CH_4=343.9;// R
x_N_2=0.300;// The mole fraction for Nitrogen
x_CH_4=0.700;// The mole fraction for methane
vbar_m=1.51;// ft^3/lb mole
v_R_N_2=(vbar_m*p_c_N_2*144)/(x_N_2*R*T_c_N_2);//
   The reduced pseudospecific volume for Nitrogen
v_R_CH_4=(vbar_m*p_c_CH_4*144)/(x_CH_4*R*T_c_CH_4);
   // The reduced pseudospecific volume for methane
T_R_N_2=(T_m+459.67)/T_c_N_2;// The reduced
   temperature for Nitrogen
T_R_CH_4=(T_m+459.67)/T_c_CH_4;// The reduced
   temperature for methane
```

```
// From Figure 7.6 in Chapter 7, we find that, for these values
Z_D_N_2=0.91;// The Dalton compressibility factor for Nitrogen
Z_D_CH_4=0.39;// The Dalton compressibility factor for methane
Z_D_m=(x_N_2*Z_D_N_2)+(x_CH_4*Z_D_CH_4);// The Dalton compressibility factor for the mixture
vbar_m=(Z_D_m*(R*(T_m+459.67)))/(p_m*144);// ft^3/lbmole
Error_b=((vbar_m-v_ma)/v_ma)*100;// % high
printf("\n(b)vbar_m=%1.2f ft^3/mole \n    Percentage error=%2.1f percentage high",vbar_m,Error_b);
// (c) The Amagat compressibility factor
p_R_N_2=p_m/p_c_N_2;// The reduced pressure for Nitrogen
T_R_N_2=(T_m+459.67)/T_c_N_2;// The reduced temperature for Nitrogen
p_R_CH_4=p_m/p_c_CH_4;// The reduced pressure for methane
T_R_CH_4=(T_m+459.67)/T_c_CH_4;// The reduced temperature for nitrogen
Z_A_N_2=0.84;// The Amagat compressibility factor
Z_A_CH_4=0.35;// The Amagat compressibility factor
Z_Am=(x_N_2*Z_A_N_2)+(x_CH_4*Z_A_CH_4);// The Amagat compressibility factor
vbar_m=(Z_Am*R*(T_m+459.67))/(p_m*144);// ft^3/lbmole
Error_c=((vbar_m-v_ma)/v_ma)*100;// % high
printf("\n(c)vbar_m=%1.2f ft^3/mole \n    Percentage error=%2.1f percentage high",vbar_m,Error_c);
// (d) Using Kays law, Eqs. (12.39) and (12.40), we get
p_cm=(x_N_2*p_c_N_2)+(x_CH_4*p_c_CH_4);// psia
T_cm=(x_N_2*T_c_N_2)+(x_CH_4*T_c_CH_4);// R
p_Rm=p_m/p_cm;// The reduced pressure
T_Rm=(T_m+459.67)/T_cm;;// The reduced temperature
Z_Km=0.51;// The compressibility factor
```

```
vbar_m=(Z_Km*R*(T_m+459.67))/(p_m*144);// ft^3/lbmole
printf("\n(d)vbar_m=%1.2f ft^3/mole",vbar_m);
// The answer vary due to round off error
```

Chapter 13

Vapor and Gas Power Cycles

Scilab code Exa 13.1 `The duty and thermal efficiency of this engine`

```
// Example 13_1
clc;funcprot(0);
// Given data
d_in=10;// Diameter of piston in inch
d_m=0.254;// Diameter of piston in m
L_in=38.0;// Stroke in inch
L_m=0.965;// Stroke in m
mg=291900;// lbf
h=10.0;// ft
m=84.0;// lbm

// Calculation
Duty=mg*h;// ft.lb
n_T=(Duty/(8.5*10^8))*100;// The thermal efficiency
   of this engine in %
printf("\nThe duty=%7.0f ft.lbf \nThe thermal
   efficiency of this engine=%0.3f percentage",Duty,
   n_T);
```

Scilab code Exa 13.2 The heat rate produced by the boiler

```
// Example 13_2
clc;funcprot(0);
// Given data
D_piston=2.00;// ft
W_out=20;// hp
L=4.00;// ft/stroke
m_b=4000;// lbf
d=15.0;// ft
Duty=35.0*10^6;
N=18.0;// strokes per minute

// Calculation
// (a)
A=(%pi*D_piston^2)/4;// ft^2
W_out=20*33000;// ft.lbf/min
p_avg=W_out/(A*L*N);// lbf/ft^2
p_avg=p_avg/144;// lbf/in^2
// (b)
n_T=(Duty/(8.5*10^8))*100;// The actual thermal
    efficiency of the engine in %
// (c)
W_out=20;// hp
Q_boiler=(W_out*2545)/(n_T/100);// Btu/h
printf("\n(a)The average pressure of the cycle,p_avg
   =%2.1f lbf/in^2 \n(b)The actual thermal
    efficiency of the engine,n_T=%1.2f percentage \n(
   c)The heat rate produced by the boiler,Q_boiler=
   %1.2e Btu/h",p_avg,n_T,Q_boiler);
```

Scilab code Exa 13.3 The maximum possible thermal efficiency and net power output

```
// Example 13_3
clc;funcprot(0);
```

```
// Given data
Q_boiler=300;// W
p_1=20.0;// psia
p_2s=14.7;// psia
T_L=671.67;// R
T_H=687.67;// R

// Solution
// (a)
n_T_Carnot=(1-(T_L/T_H))*100;// %
W_net_Carnot=(n_T_Carnot/100)*Q_boiler;// watts
// (b)
// Station 1-Engine inlet
p_1=20.0;// psia
x_1=1.00;// The quality of steam at Station 1
h_1=1156.4;// Btu/lbm
s_1=1.7322;// Btu/lbm.R
// Station 2s-Engine exit
p_2s=14.7;// psia
s_2s=s_1;// Btu/lbm.R
s_f2=0.3122;// Btu/lbm.R
s_fg2=1.4447;// Btu/lbm.R
x_2s=(s_2s-s_f2)/s_fg2;// The quality of steam at
   Station 2s
h_f2=180.1;// Btu/lbm
h_fg2=970.4;// Btu/lbm
h_2s=h_f2+(x_2s*h_fg2);// Btu/lbm
// Station 3-Condenser exit
p_3=p_2s;// psia
x_3=0;// The quality of steam at Station 3
h_3=h_f2;// Btu/lbm
v_3=0.01672;/// ft^3/lbm
// Station 4s-Boiler inlet
p_4s=p_1;// psia
// s_4s=s_3;
n_T_max=((h_1-h_2s-(v_3*(p_4s-p_3)))*(144/118.16))
   /((h_1-h_3-(v_3*(p_4s-p_3)))*(144/118.16));// The
    isentropic efficiency of the system
```

```
n_T_max=n_T_max*100;// %
printf("\n(a)The Carnot cycle thermal efficiency,(n_T)_Carnot=%1.2f percentage \n The net power output of the engine,W_net=%1.2f watts \n(b)The isentropic efficiency of the Rankine cycle,n_T_max=%1.2f percentage",n_T_Carnot,W_net_Carnot,n_T_max);
```

Scilab code Exa 13.4 `The Rankine cycle thermal efficiency of this engine`

```
// Example 13_4
clc;funcprot(0);
// Given data
D=40.0;// inch
L=10.0;// ft stroke
W_actual=1400;// hp
n=36.0;// rpm
n_s_p=0.650;// The isentropic efficiency of a pump
n_s_pm=0.550;// The isentropic efficiency of an engine
d_fw=30.0;// The diameter of the flywheel in ft
w=56.0;/// tons

// Calculation
// (a)
// Station 1-Engine inlet
p_1=100.0;// psia
x_1=1.00;// The quality of steam at Station 1
h_1=1187.8;// Btu/lbm
s_1=1.6036;// Btu/lbm.R
// Station 2s-Engine exit
p_2s=14.7;// psia
s_2s=s_1;// Btu/lbm.R
s_f2=0.3122;// Btu/lbm.R
s_fg2=1.4447;// Btu/lbm.R
```

```
x_2s=(s_2s-s_f2)/s_fg2;// The quality of steam at Station 2s
h_f2=180.1;// Btu/lbm
h_fg2=970.4;// Btu/lbm
h_2s=h_f2+(x_2s*h_fg2);// Btu/lbm
// Station 3-Condenser exit
p_3=p_2s;// psia
x_3=0;// The quality of steam at Station 3
h_3=h_f2;// Btu/lbm
v_3=0.01672;// ft^3/lbm
// Station 4s-Boiler inlet
p_4s=p_1;// psia
// s_4s=s_3;
n_T_max=((h_1-h_2s-(v_3*(p_4s-p_3)))*(144/118.16))/((h_1-h_3-(v_3*(p_4s-p_3)))*(144/118.16));// The maximum isentropic efficiency of the system
n_T_max=n_T_max*100;// %
// (b)
n_T_Rankine=(((h_1-h_2s)*n_s_pm)-((v_3*(p_4s-p_3)/n_s_p)*(144/118.16)))/((h_1-h_3)-((v_3*(p_4s-p_3)/n_s_p)*(144/118.16)));// The isentropic efficiency of the Rankine system
n_T_Rankine=n_T_Rankine*100;// %
// (c)
mdot=(W_actual*2545)/((h_1-h_2s)*n_s_pm);// lbm/h
printf("\n(a)The maximum isentropic efficiency of the Rankine system,(n_T)_maximum Rankine=%2.1f percentage \n(b)The isentropic efficiency of the Rankine system,(n_T)_Rankine=%1.2f percentage \n(c)The mass flow rate of steam required,mdot=%5.0f lbm/h",n_T_max,n_T_Rankine,mdot);
```

Scilab code Exa 13.5 The isentropic Rankine cycle thermal efficiency of the lawn m

```
// Example 13_5
```

```
clc;funcprot(0);
// Given data
p_1=100;// psia
T_1=500;// F
p_3=1.00;// psia

// Calculation
// Station 1
p_1=100.0;// psia
T_1=500.0;// F
h_1=1279.1;// Btu/lbm
s_1=1.7087;// Btu/lbm.R
// Station 2s

// Station 3
p_3=1.00;// psia
x_3=0.00;// The dryness fraction
s_3=s_f2;// Btu/lbm.R
h_3=h_f2;// Btu/lbm
v_3=0.01614;/// ft^3/lbm
// Station 4s
p_4s=p_1;// psia
s_4s=s_3;// Btu/lbm.R
h_4s=h_3+(v_3*(p_4s-p_3)*(144/778.16));// Btu/lbm

s_2s=s_1;// Btu/lbm.R
s_f2=0.1326;// Btu/lbm.R
s_fg2=1.8455;// Btu/lbm.R
x_2s=(s_2s-s_f2)/s_fg2;// The dryness fraction
h_f2=69.7;// Btu/lbm
h_fg2=1036.0;// Btu/lbm
h_2s=h_f2+(x_2s*h_fg2);// Btu/lbm
// (a)
// The degree of superheat at the outlet of the
   boiler is determined from Table C.2a in
   Thermodynamic Tables to accompany Modern
   Engineering Thermodynamics and Eq. (13.10) as
T_sat=327.8;// F
```

```
Dsh=500-T_sat;// Degree of superheat in  F
// (b)
T_H=T_1+459.67;// R
T_L=101.67+459.67;// R
n_T_carnot=(1-(T_L/T_H))*100;// The Carnot cycle thermal efficiency in %
// (c)
n_T_rankine=((h_1-h_2s-((v_3*(p_4s-p_3))*(144/778.16)))/(h_1-h_3-((v_3*(p_4s-p_3))*(144/778.16))))*100;// The isentropic Rankine cycle thermal efficiency in %
printf("\n(a)The degree of superheat at the boiler outlet=%3.0f  F \n(b)The equivalent Carnot cycle thermal efficiency of the lawn mower,n_T_carnot=%2.1f percentage \n(c)The isentropic Rankine cycle thermal efficiency of the lawn mower,(n_T)_Rankine=%2.1f percentage",Dsh,n_T_carnot,n_T_rankine);
```

Scilab code Exa 13.6 `The isentropic Rankine cycle thermal efficiency of the system`

```
// Example 13_6
clc;funcprot(0);
// Given data
p_1=200;// psia
p_2s=1.00;// psia
p_4=80.0;// psia

// Calculation
// (a)
// Station 1
p_1=200.0;// psia
x_1=1.00;// The dryness fraction
h_1=1199.3;// Btu/lbm
s_1=1.5466;// Btu/lbm.R
```

```
// Station 2s
p_2=1.00;// psia
p_2s=p_2;// psia
s_2s=s_1;// Btu/(lbm.R)
s_f2=0.1326;// Btu/(lbm.R)
s_fg2=1.8455;// Btu/(lbm.R)
h_f2=69.7;// Btu/lbm
h_fg2=1036.0;// Btu/lbm
// Station 3
p_3=1.00;// psia
x_3=0.00;// The dryness fraction
s_3=0.1326;// Btu/(lbm.R)
h_3=69.7;// Btu/lbm
v_3=0.01614;/// ft^3/lbm
// Station 4s
p_4=200;// psia
p_4s=p_4;// psia
s_4s=s_3;// Btu/lbm.R
h_4s=h_3+(v_3*(p_4s-p_3)*(144/778.16));// Btu/lbm
x_2s=(s_2s-s_f2)/s_fg2;// The dryness fraction
h_2s=h_f2+(x_2s*h_fg2);// Btu/lbm
n_T_Rankine=(((h_1-h_2s)-(h_4s-h_3))/(h_1-h_4s))*100;// The thermal efficiency in %
// (b)
// Station 4s
p_4=200;// psia
p_4s=p_4;// psia
s_4s=s_3;// Btu/lbm.R
h_4s=h_3+(v_3*(p_4s-p_3)*(144/778.16));// Btu/lbm
// Station 5s
p_5s=p_4;// psia
s_5s=s_1;// Btu/(lbm.R)
s_f5s=0.4535;// Btu/(lbm.R)
s_fg5s=1.1681;// Btu/(lbm.R)
x_5s=(s_5s-s_f5s)/s_fg5s;// The dryness fraction
h_f5s=282.2;// Btu/lbm
h_fg5s=901.4;// Btu/lbm
h_5s=h_f5s+(x_5s*h_fg5s);// Btu/lbm
```

```
h_5s=1125.7;// Btu/lbm
// Station 6
p_6=80.0;// psia
x_6=0.00;// The dryness fraction
s_6=0.4535;// Btu/(lbm.R)
h_6=282.2;// Btu/lbm
v_6=0.01757;// ft^3/lbm
// Station 7s
p_7=200;// psia
p_7s=p_7;// psia
s_7s=s_6;// Btu/(lbm.R)
h_7s=h_6+(v_6*(p_7-p_6)*(144/778.16));// Btu/lbm
r=(h_6-h_4s)/(h_5s-h_4s);// The mass fraction of steam
n_T_reg=(1-(((h_2s-h_3)/(h_1-h_7s))*(1-r)))*100;// %
printf("\n(a)The isentropic Rankine cycle thermal efficiency of the system without regeneration present,(n_T)_isentropic Rankine=%2.1f percentage.\n(b)The isentropic Rankine cycle thermal efficiency of the system,(n_T)_Rankine cycle with 1 regenerator=%2.1f percentage",n_T_Rankine,n_T_reg);
```

Scilab code Exa 13.7 The Rankine cycle thermal efficiency of the plant with reheat

```
// Example 13_7
clc;funcprot(0);
// Given data
n_s_pm1=84.0/100;// The isentropic efficiency of the first turbine
n_s_pm2=80.0/100;// The isentropic efficiency of the second turbine
n_s_p=61.0/100;// The isentropic efficiency of the boiler feed pump
n_s_pm=82/100;// The isentropic efficiency of the
```

```
   prime mover

// Calculation
// (a)
// Station 1
p_1=600.0;// psia
T_1=700.0;//  F
h_1=1350.6;// Btu/lbm
s_1=1.5874;// Btu/lbm.R
// Station 2s
p_2=100.0;// psia
p_2s=p_2;// psia
s_2s=s_1;// Btu/(lbm.R)
s_f2=0.4745;// Btu/(lbm.R)
s_fg2=1.1291;// Btu/(lbm.R)
h_f2=298.6;// Btu/lbm
h_fg2=889.2;// Btu/lbm
x_2s=(s_2s-s_f2)/s_fg2;// The dryness fraction
h_2s=h_f2+(x_2s*h_fg2);// Btu/lbm
// Station 3
p_3=100.0;// psia
T_3=700.0;//  F
x_3=0.00;// The dryness fraction
s_3=1.8035;// Btu/(lbm.R)
h_3=1379.2;// Btu/lbm
// Station 4s
p_4=1.00;// psia
p_4s=p_4;// psia
s_4s=s_3;// Btu/lbm.R
s_f4=0.1326;// Btu/(lbm.R)
s_fg4=1.8455;// Btu/(lbm.R)
h_f4=69.7;// Btu/lbm
h_fg4=1036.4;// Btu/lbm
x_4s=(s_4s-s_f4)/s_fg4;// The dryness fraction
h_4s=h_f4+(x_4s*h_fg4);// Btu/lbm
// Station 5
p_5=1.00;// psia
x_5=0.00;// The dryness fraction
```

```
s_5=0.1326;// Btu/(lbm.R)
h_5=69.7;// Btu/lbm
v_5=0.01614;// ft^3/lbm
// Station 6s
p_6=600;// psia
p_6s=p_6;// psia
s_6s=s_5;// Btu/(lbm.R)
h_6s=72.5;// Btu/lbm
v_6s=0.01614;// ft^3/lbm
h_7s=h_6s+(v_6s*(p_7-p_6)*(144/778.16));// Btu/lbm
h_2=h_1-((h_1-h_2s)*n_s_pm1);// Btu/lbm
h_6=h_5+((v_5*(p_6*p_5)*(144/778.16))/(n_s_p));// Btu/lbm
n_T_wr=((((h_1-h_2s)*n_s_pm1)+((h_3-h_4s)*n_s_pm2)-((v_5*(p_6-p_5)*(144/778.16))/(n_s_p)))/((h_1-h_6)+(h_3-h_2)))*100;// The Rankine cycle thermal efficiency of the plant with reheat in %
// (b)
s_4s=s_1;// Btu/(lbm.R)
x_4s=(s_4s-s_f4)/s_fg4;// The dryness fraction
h_4s=h_f4+(x_4s*h_fg4);// Btu/lbm
n_T_wor=((((h_1-h_4s)*n_s_pm)-((h_6s-h_5)/n_s_pm))/(h_1-h_6))*100;// The Rankine cycle thermal efficiency of the plant without reheat in %
printf("\n(a)The Rankine cycle thermal efficiency of the plant with reheat,n_T=%2.1f percentage \n(b)The Rankine cycle thermal efficiency of the plant without reheat,n_T=%2.1f percentage",n_T_wr,n_T_wor);
```

Scilab code Exa 13.8 The isentropic efficiency of the turbine generator power unit

```
// Example 13_8
clc;funcprot(0);
// Given data
```

```
p_1=5000.0;// psia
T_1=1200.0;//  F
p_3=1000.0;// psia
p_5=300.0;// psia
p_6s=0.400;// psia
mdot=1.50*10^6;// lbm/h
W_netout=325;// MW

// Calculation
// Station 1-Turbine 1 inlet
p_1=5000.0;// psia
T_1=1200.0;//  F
h_1=1530.8;// Btu/lbm
s_1=1.5068;// Btu/lbm.R
// Station 2s-Turbine 1 exit
p_2s=1000;// psia
s_2s=s_1;// Btu/lbm.R
h_2s=1316.9;// Btu/lbm
// (by interpolation in Table C.3a)
// Station 3-Turbine 2 inlet
p_3=1000.0;// psia
T_3=1000.0;//  F
h_3=1505.9;// Btu/lbm
s_3=1.6532;// Btu/lbm.R
// (by interpolation in Table C.3a)
// Station 4s-Turbine 2 exit
p_4s=1000;// psia
s_4s=s_3;// Btu/lbm.R
h_4s=1343.8;// Btu/lbm
// Station 5-Turbine 3 inlet
p_5=300.0;// psia
T_5=1000.0;//  F
h_5=1526.4;// Btu/lbm
s_5=1.7966;// Btu/lbm.R
// Station 6s-Turbine 3 exit
p_6s=0.400;// psia
s_6s=s_5;// Btu/lbm.R
s_f6s=0.0799;// Btu/lbm.R
```

```
s_fg6s=1.9762;// Btu/lbm.R
x_6s=(s_6s-s_f6s)/s_fg6s;// The dryness fraction
h_f6s=40.9;// Btu/lbm
h_fg6s=1052.4;// Btu/lbm
h_6s=h_f6s+(x_6s*h_fg6s);// Btu/lbm
// Station 7-Condenser exit
p_7=0.400;// psia
x_7=0.00;// The dryness fraction
h_7=40.9;// Btu/lbm
v_7=0.01606;// ft^3/lbm
// Station 8s-Boiler inlet
p_8s=p_1;
// s_8s=s_7;
h_8s=h_7+((v_7*(p_8s-p_7))*(144/778.16));// Btu/lbm
// (a)
n_s_p=1.0;// The isentropic thermal efficiency of this Rankine cycle power plant
n_s_pm2=n_s_p;// The isentropic thermal efficiency of this Rankine cycle power plant
n_s_pm1=n_s_pm2;// The isentropic thermal efficiency of this Rankine cycle power plant
N=(h_1-h_2s)+(h_3-h_4s)+(h_5-h_6s)-(v_7*(p_8s-p_7)*(144/778.16));// The numerator in Btu/lbm
D=(h_1-h_8s)+(h_3-h_2s)+(h_5-h_4s);// The denominator in Btu/lbm
n_T=(N/D)*100;// The isentropic thermal efficiency in %
// (b)
W_netout=(W_netout*10^3)*3412;// Btu/h
W_isen=mdot*[(h_1-h_2s)+(h_3-h_4s)+(h_5-h_6s)-(v_7*(p_8s-p_7*(144/778.16)))];// Btu/h
n_s_tg=(W_netout/W_isen)*100;
printf("\n(a)The isentropic thermal efficiency of this power plant,(n_T)_s=%2.1f percentage \n(b)The isentropic efficiency of the turbine-generator power unit,(n_s)_turbine generator=%2.1f percentage",n_T,n_s_tg);
// The answer vary due to round off error
```

Scilab code Exa 13.9 The Stirling cold ASC thermal efficiency of the engine

```
// Example 13_9
clc;funcprot(0);
// Given data
Pd=0.0110;/// The piston displacement in m^3
V_4=1.00*10^-3;// m^3
V_3=V_4;// m^3
p_1=0.300;// MPa
p_2=0.100;// MPa
T_2=30.0;// C
R=0.286;// kJ/kg.K

// Calculation
// (a)
V_1=Pd-V_3;// m^3
V_2=V_1;// m^3
p_3=p_2*(V_2/V_3);// MPa
// (b)
V_4=V_3;// m^3
p_4=p_1*(V_1/V_4);// MPa
// (c)
m=((p_2*1000)*V_2)/(R*(T_2+273.15));// kg
// (d)
T_1=((p_1*1000)*V_1)/(m*R);// K
// (e)
n_T=(1-((T_2+273.15)/T_1))*100;// %
printf("\n(a)The displacer piston maximum pressure, p_3=%1.2f MPa \n(b)The power piston maximum pressure,p_4=%1.2f MPa\n(c)The mass of air in the engine,m=%0.4f kg \n(d)The heat addition temperature,T_1=%3.0f K \n(e)The Stirling cold ASC thermal efficiency of the engine,n_T=%2.2f percentage",p_3,p_4,m,T_1,n_T);
```

Scilab code Exa 13.10 `The temperatures at the inlet and outlet of the power and di`

```
// Example 13_10
clc;funcprot(0);
// Given data
PR=2.85;// Pressure ratio
p_4byp_1=PR;// Pressure ratio
V_1=0.0110;// m^3
V_3=3.00*10^-3;// m^3
m=0.0500;// kg
R=0.286;// kJ/kg.K

// Calculation
// (a)
p_1=0.500;// MPa
p_2=p_1;// MPa
T_1=(p_1*1000*V_1)/(m*R);// K
T_4=T_1;// K
p_3=p_2*PR;// MPa
p_4=p_3;// MPa
V_4=(m*R*T_4)/(p_4*1000);// m^3
CR=V_1/V_4;// The isentropic compression ratio
V_2=V_3*CR;// m^3
// (b)
p_3=1.43;// MPa
p_4=p_3;// MPa
// (d)
T_2=(p_2*1000*V_2)/(m*R);// K
T_3=T_2;// K
// (e)
n_T_E=(1-(T_2/T_1))*100;// %
printf("\n(a)The compressor inlet pressure and
   volume,p_2=%0.3f MPa & V_2=%0.5f m^3 \n(b)The
   power piston outlet pressure and inlet volume,p_4
```

```
=%1.2f MPa,V_4=%0.5f m^3 \n(c)The compressor
outlet pressure,p_3=%1.2f MPa \n(d)The
temperatures at the inlet and outlet of the power
 and displacer pistons T_1=%3.0f K,T_2=%3.0f K,
T_3=%3.0f K,T_4=%3.0f K \n(e)The Ericsson cold
ASC thermal efficiency of this engine,n_T=%2.1f
percentage",p_2,V_2,p_4,V_4,p_3,T_1,T_2,T_3,T_4,
n_T_E);
```

Scilab code Exa 13.11 `The Lenoir cold ASC thermal efficiency`

```
// Example 13_11
clc;funcprot(0);
// Given data
T_1=800;// R
T_4=530;// R
T_3=T_4;// R
p_4=14.7;// psia
p_3=p_4;// psia
p_2s=p_3;// psia
m=1.00*10^-3;// lbm of air
R=53.34;// ft.lbf/lbm.R
k=1.4;// The specific heat ratio

// Calculation
// (a)
V_4=(m*R*T_4)/(p_4*144);// ft^3
V_1=V_4;// ft^3
p_1=(m*R*T_1)/(V_1*144);// psia
// (b)
T_2s=T_1*(p_2s/p_1)^((k-1)/k);// R
CR=T_2s/T_3;// The isentropic compression ratio
// (c)
n_T_L=(1-((k*T_3*(CR-1))/(T_1-T_4)))*100;// The
   Lenoir cold ASC thermal efficiency in %
```

```
printf(”\n(a)The combustion pressure,p_1=%2.1f psia \n(b)The isentropic compression ratio,CR=%1.2f \n(c)The Lenoir cold ASC thermal efficiency,n_T=%1.2f percentage”,p_1,CR,n_T_L);
// The answer vary due to round off error
```

Scilab code Exa 13.12 `The Brayton cold ASC thermal efficiency`

```
// Example 13_12
clc;funcprot(0);
// Given data
p_4s=0.210;// MPa
p_1=p_4s;// MPa
p_3=0.190;// MPa
p_2s=p_3;// MPa
k=1.4;// The specific heat ratio

// Calculation
// (a)
PR=p_4s/p_3;// The isentropic pressure ratio of a Brayton cycle engine
// (b)
CR=(PR)^(1/k);// The isentropic compression ratio of a Brayton cycle engine
// (c)
n_T_B=(1-((PR)^((1-k)/k)))*100;// The Brayton cold ASC thermal efficiency
printf(”\n(a)The isentropic pressure ratio,PR=%1.2f \n(b)The isentropic compression ratio,CR=%1.2f \n(c)The Brayton cold ASC thermal efficiency,n_T=%1.2f percentage”,PR,CR,n_T_B);
// The answer vary due to round off error
```

Scilab code Exa 13.13 `The static thrust of the engine`

```
// Example 13_13
clc;funcprot(0);
// Given data
V_inlet=0;// ft/s
V_exh=1560;// ft/s
m_exh=270;// lbm/s
g_c=32.174;// lbm.ft/(lbf.s^2)
p_1=190;// psia
T_1=2060;// R
p_2s=28.0;// psia
T_2=1350;// R
p_3=14.7;// psia
T_3=520;// R
p_4s=200;// psia
T_4=1175;// R
k=1.40;// The specific heat ratio

// Calculation
// 1.The engines static thrust is given directly by Eq. (13.29) as
T=m_exh*(V_exh-V_inlet)/g_c;// lbf
// 2a.
T_4s=T_3*((p_4s/p_3)^((k-1)/k));//  F
n_s=((T_4s-T_3)/(T_4-T_3))*100;// The compressors isentropic efficiency in %
T_2s=T_1*(p_2s/p_1)^((k-1)/k);// R
n_s_pm=((T_1-T_2)/(T_1-T_2s))*100;// %
// 3a.
n_T_Bc=((T_1-T_2s-(T_4s-T_3))/(T_1-T_4s))*100;// The Brayton cold ASC thermal efficiency in %
n_T_B=((T_1-T_2-(T_4-T_3))/(T_1-T_4))*100;// The actual thermal efficiency of the engine in %
// 2b.
// By using Table C.16a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics
p_r4=1.2147*(p_4s/p_3);
```

```
T_4s=1084;// R
T_4sF=624;//  F
n_s_c=((T_4s-T_3)/(T_4-T_3))*100;// %
p_r1=196.16;
p_r2=p_r1*(p_2s/p_1);
// By interpolation in Table C.16a,
T_2s=1261-460;//  F
T_2s=1261;// R
n_s_pm2=((T_1-T_2)/(T_1-T_2s))*100;// %
// 3b.
// From Table C.16a,
h_3=124;// Btu/lbm
h_4s=262;// Btu/lbm
h_1=521;// Btu/lbm
h_2s=307;// Btu/lbm
h_4=284.09;// Btu/lbm
h_2=329.9;// Btu/lbm
n_T_Bh=((h_1-h_2s-(h_4s-h_3))/(h_1-h_4s))*100;// %
n_T_B2=((h_1-h_2-(h_4-h_3))/(h_1-h_4))*100;// %
// 3c.
n_T_max=(1-sqrt(T_3/T_1))*100;// The maximum work Brayton cold ASC thermal efficiency in %
printf("\n(1)The engines static thrust is given directly,T=%5.0f lbf \n(2)(a)The compressor and turbine isentropic efficiencies for the Brayton cold air standard cycle,(n_s)_compressor=%2.1f percentage & (n_s)_pm=%2.1f percentage \n    (b)The compressor and turbine isentropic efficiencies for the Brayton hot air standard cycle using the gas tables for air,(n_T)_Brayton hot ASC=%2.1f percentage & (n_T)_Brayton actual=%2.1f percentage \n(3)(a)The ASC and actual thermal efficiencies for the Brayton cold air standard cycle,(n_T)_Brayton cold ASC =%2.1f percentage & (n_T)__Brayton actual=%1.1f percentage \n    (b)The Brayton hot air standard cycle using the gas tables for air,(n_T)_Brayton hot ASC =%2.1f percentage & (n_T)__Brayton actual
```

```
   =%1.1f percentage \n    (c)The maximum work
   Brayton cold ASC thermal efficiency ,(n_T)_max
   work=%2.1f percentage",T,n_s,n_s_pm,n_s_c,n_s_pm2
   ,n_T_Bc,n_T_B,n_T_Bh,n_T_B2,n_T_max);
// The answer provided in the text book is wrong
```

Scilab code Exa 13.14 The air temperature at the end of the isentropic compression

```
// Example 13_14
clc;funcprot(0);
// Given data
CR=8.00/1.00;// The isentropic compression ratio
T_3=70.0;//  F
p_3=14.7;// psia
k=1.4;// The specific heat ratio

// Calculation
// (a)
T_4s=(T_3+459.67)*(CR^(k-1));// R
// (b)
p_4s=p_3*CR^(k);// psia
// (c)
n_T_otto=(1-((CR)^(1-k)))*100;// %
printf("\n(a)The air temperature at the end of the
   isentropic compression stroke ,T_4s=%4.0f R \n(b)
   The pressure at the end of the isentropic
   compression stroke before ignition occurs ,p_4s=%3
   .0f psia \n(c)The Otto cold ASC thermal
   efficiency of this engine ,n_T=%2.1f percentage",
   T_4s,p_4s,n_T_otto);
// The answer vary due to round off error
```

Scilab code Exa 13.15 Actual thermal efficiency of the engine

```
// Example 13_15
clc;funcprot(0);
// Given data
CR=9/1;// The compression ratio
Qbym=20.0*10^3;// Btu/lbm
AbyF_mass=16.0/1;
T_3=60;//  F
p_3=8.00;// psia
c_va=0.172;// Btu/(lbm air.R)
D=260;// The total displacement in in^3
N=4000;// rpm
c=2;// The number of crankshaft revolutions per power stroke
W_Bout=85.0;// hp
k=1.40;// The specific heat ratio
R=0.0685;// Btu/(lbm.R)

// Calculation
// (a)
n_T_c=(1-(CR^(1-k)))*100;// %
// (b)
T_4s=(T_3+459.67)*(CR^(k-1));// R
T_max=T_4s+(Qbym/(AbyF_mass*c_va));// R
p_4s=p_3*((T_4s/(T_3+459.67))^(k/(k-1)));// psia
T_1=T_max;// R
p_max=p_4s*(T_1/T_4s);// psia
p_1=p_max;// psia
// (c)
W_Iout=((n_T_c/100)*Qbym*D*N*p_1/c)/(AbyF_mass*R*T_1*(CR-1)*12*60);// ft.lbf/s
W_Iout=W_Iout/550.0;// hp
// (d)
n_m=(W_Bout/W_Iout)*100;// The mechanical efficiency of the engine in %
// (e)
n_T_act=((n_m/100)*(n_T_c/100))*100;// The actual thermal efficiency of the engine in %
printf("\n(a)Cold ASC thermal efficiency of the
```

```
engine,n_T=%2.1f percentage \n(b)Maximum pressure
 and temperature of the cycle,p_max=%4.0f psia &
T_max=%4.0f R \n(c)Indicated power output of the
engine,|W_I|_out=%3.0f hp \n(d)Mechanical
efficiency of the engine,n_m=%2.1f percentage \n(
e)Actual thermal efficiency of the engine,n_T=%2
.1f percentage",n_T_c,p_max,T_max,W_Iout,n_m,
n_T_act);
// The answer vary due to round off error
```

Scilab code Exa 13.16 The temperature and pressure at all points of the cycle

```
// Example 13_16
clc;funcprot(0);
// Given data
v=3.50;// liter
p_5=200;// kPa
T_5=313;// K
k=1.35;// The specific heat ratio
HV=43300;// kJ/kg
AF=15/1;// Air fuel ratio
CR=8.00/1;// The comprssion ratio
ER=10.0/1;// An expansion ratio
R=0.287;// kJ/kg.K
C_v_air=1;// kJ/kg.K

// Calculation
V_d=v/4;// L
V_d=V_d*10^-3;// m^3
V_c=V_d/(ER-1);// m^3
V_1=V_c;// m^3
V_7s=V_1;// m^3
V_4=V_7s;// m^3
V_6s=V_d+V_c;// m^3
V_2s=V_6s;// m^3
```

```
V_3=V_2s;// m^3
V_5=V_7s*CR;// m^3
p_6s=p_5*(V_5/V_6s)^k;// kPa
T_6s=T_5*(V_5/V_6s)^(k-1);// K
p_7s=p_5*(CR)^k;// kPa
T_7s=T_5*(CR)^(k-1);// K
m_air=(p_6s*V_6s)/(R*T_6s);// kg
m_fuel=m_air/(AF+1);// kg
Q_comb=m_fuel*HV;// kJ
T_1=(Q_comb/(m_air*C_v_air))+T_7s;// K
p_1=(p_7s/10^3)*(T_1/T_7s);// MPa
p_2s=p_1*10^3*(V_1/V_2s)^k;// MPa
T_2s=T_1*(V_1/V_2s)^(k-1);// K
p_3=101;// kPa
p_exhaust=p_3;// kPa
T_3=T_2s*(p_3/p_2s);// K
p_4=p_3;// kPa
printf("\nThe temperature and pressure at all points of the cycle are given below \nState 5:p_5=%3.0f kPa,T_5=%3.0f K \nState 6:p_6s=%3.0f kPa,T_6s=%3.0f K \nState7s:p_7s=%4.0f kPa,T_7s=%3.0f K \nState 1:p_1=%2.2f MPa,T_1=%4.0f K\nState2s:p_2s=%3.0f kPa,T_2s=%4.0f K \nState 3:p_3=%3.0f kPa,T_3=%3.0f K \nState 4:p_4=%3.0f kPa,T_4=atmospheric temperature",p_5,T_5,p_6s,T_6s,p_7s,T_7s,p_1,T_1,p_2s,T_2s,p_3,T_3,p_3);
// The answer provided in the textbook is wrong
```

Scilab code Exa 13.17 The mechanical efficiency of the engine

```
// Example 13_17
clc;funcprot(0);
// Given data
CR=18.0;// The compression ratio
CO=2.32;// The cut off ratio
```

```
HV=45.5*10^3;// The heating value of a fuel in kJ/kg
m_fuel=3.35;// The fuel flow rate of rate in kg/s
W_B=80080;// kW
k=1.40;// The specific heat ratio

// Calculation
// (a)
n_T_disel=(1-(((CR)^-0.40)*([((CO)^k)-1]))/(k*(CO-1)))*100;// The Diesel cold ASC thermal efficiency of the engine in %
// (b)
Q_fuel=HV*m_fuel;// kW
n_T_diselact=(W_B/Q_fuel)*100;// The actual thermal efficiency of the engine in %
// (c)
n_m=(n_T_diselact/n_T_disel)*100;// The mechanical efficiency of the engine in %
printf("\n(a)The Diesel cold ASC thermal efficiency of the engine,n_T=%2.1f percentage \n(b)The actual thermal efficiency of the engine,(n_T)_Diesel actual=%2.1f percentage \n(c)The mechanical efficiency of the engine,n_m=%2.1f percentage",n_T_disel,n_T_diselact,n_m);
```

Chapter 14

Vapor and Gas Refrigeration Cycles

Scilab code Exa 14.1 `The coefficient of performance of a Carnot refrigerator or ai`

```
// Example 14_1
clc;funcprot(0);
// Given data
T_L=20.0+273.15;// K
T_H=200.0+273.15;// K

// Solution
// (a)
n_T_carnot=(1-(T_L/T_H))*100;// The thermal efficiency of a Carnot engine in %
// (b)
COP_Carnot_HP=T_H/(T_H-T_L);// The coefficient of performance of a Carnot heat pump
// (c)
COP_Carnot_RAC=T_L/(T_H-T_L);// The coefficient of performance of a Carnot refrigerator
printf("\n(a)The thermal efficiency of a Carnot engine,(n_T)_Carnot=%2.0f percentage \n(b)The coefficient of performance of a Carnot heat pump,
```

```
COP_Carnot HP=%1.2f \n(c)The coefficient of performance of a Carnot refrigerator or air conditioner,COP_Carnot R/AC=%1.2f",n_T_carnot,COP_Carnot_HP,COP_Carnot_RAC);
```

Scilab code Exa 14.2 `The tons of refrigeration produced`

```
// Example 14_2
clc;funcprot(0);
// Given data
V=2.50*10^16;// m^3
T=0.00;//  C
t=24.0;// s
rho=917;// kg/m^3

// Solution
m_ice=V*rho*2.2046;// lbm
Q=m_ice/(2*10^3);// tons of refrigeration
printf("\nThe tons of refrigeration produced,Q=%1.2e tons of refrigeration",Q);
```

Scilab code Exa 14.3 `A reversed Carnot cycle operating between these temperature l`

```
// Example 14_3
clc;funcprot(0);
// Given data
T_H=20.0+273.15;// K
T_L=-15.0+273.15;// K

// Solution
// (a)
COP_Cr=T_L/(T_H-T_L);// COP of a reversed Carnot cycle
```

```
// From Table C.9b in Thermodynamic Tables to accompany Modern Engineering Thermodynamics, the thermodynamic data at the monitoring stations shown in the schematic are
// Station 1
T_1=-15.0;//  C
s_1=0.89973;// kJ/(kg.K)
s_2s=s_1;// kJ/(kg.K)
x_1=0.9395;// The quality of steam
h_1=231.0;// kJ/kg
s_f1=0.11075;// kJ/(kg.K)
s_fg1=0.83977;// kJ/(kg.K)
h_f1=27.33;// kJ/kg
h_fg1=216.79;// kJ/kg
// Station 2
T_2s=20.0;//  C
x_2s=1.00;// The quality of steam
h_2s=256.5;// kJ/kg
s_2s=0.89973;// kJ/(kg.K)
p_2s=909.9;// kPa
// Station 3
T_3=20.0;//  C
x_3=0.00;// The quality of steam
h_3=68.67;// kJ/kg
s_3=0.25899;// kJ/(kg.K)
p_3=p_2s;// kPa
// Station 4
T_4s=T_1;//  C
s_4s=s_3;// kJ/(kg.K)
x_4s=0.1765;// The quality of steam
h_4s=65.6;// kJ/kg
s_f4=0.11075;// kJ/(kg.K)
s_fg4=0.83977;// kJ/(kg.K)
h_f4=h_f1;// kJ/kg
h_fg4=h_fg1;// kJ/kg
x_1=(s_2s-s_f1)/s_fg1;
h_1=h_f1+(x_1*h_fg1);// kJ/kg
// where we have calculated
```

```
x_4s=(s_3-s_f4)/s_fg4;// The quality of steam
h_4s=h_f4+(x_4s*h_fg4);// kJ/kg
Q_L=h_1-h_4s;// kJ/kg
W_c=h_2s-h_1;// kJ/kg
W_t=h_3-h_4s;// kJ/kg
COP_et=Q_L/(W_c-W_t);// COP for isentropic vapour compressor cycle with expansion turbine
// (c)
// Station 4h
T_4h=T_1;//  C
h_4h=h_3;// kJ/kg
x_4h=(h_4h-h_f4)/h_fg4;// The quality of steam
s_4h=s_f4+(x_4h*s_fg4);// kJ/(kg.K)
Q_L=h_1-h_4h;// kJ/kg
W_c=h_2s-h_1;// kJ/kg
COP_tv=Q_L/W_c;// COP for isentropic vapor-compression cycle with throttling valve
printf("\n(a)COP_carnot refrigerator=%1.2f \n(b)COP_isentropic vapour compressor cycle with expansion turbine=%1.2f \n(c)COP_isentropic vapor-compression cycle with throttling valve=%1.2f",COP_Cr,COP_et,COP_tv);
```

Scilab code Exa 14.4 The coefficient of performance of vapor compression cycle

```
// Example 14_4
clc;funcprot(0);
// Given data
// Station 1
x_1=1.00;// The dryness fraction
T_1=-15.0;//  C
h_1=244.13;// kJ/kg
s_1=0.95052;// kJ/kg.K
// Station 2
p_2s=909.9;// kPa
```

```
s_2s=0.95052;// kJ/kg.K
s_2s=s_1;// kJ/kg.K
h_2s=271.92;// kJ/kg
T_2s=39.3;//  C
// Station 3
T_3=20.0;//  C
x_3=0.00;// The dryness fraction
h_3=68.67;// kJ/kg
s_3=0.25899;// kJ/kg.K
// Station 4h
T_4h=T_1;//  C
h_4h=h_3;// kJ/kg
x_4h=0.1910;// The quality of steam
s_4h=0.27088;// kJ/kg.K
n_c=75.0/100;// The isentropic efficiency of
    compressor

// Calculation
Q=h_1-h_4h;// kJ/kg
W_c=(h_2s-h_1)/n_c;// kJ/kg
COP_vc=Q/W_c;// The coefficient of performance of
    vapor compression cycle
printf("\nCOP_vapor compression cycle R/AC=%1.2f",
    COP_vc);
```

Scilab code Exa 14.6 The pressure ratios across each of the compressors

```
// Example 14_6
clc;funcprot(0);
// Given data
// Loop A
// Station 1A
// Compressor A in
x_1A=1.00;// The dryness fraction
T_1A=-20.0;//  C
```

```
h_1A=242.05;// kJ/kg
s_1A=0.95927;// kJ/kg.K
p_1A=244.8;// kPa
// Station 2sA
// Compressor A out
p_2A=1500;// kPa
s_2A=s_1A;// kJ/kg.K
h_2sA=289.08;// kJ/kg
T_2sA=71.07;//  C
// Station 3A
// Condenser A out
x_3A=0.00;// The dryness fraction
T_3A=25.0;//  C
h_3A=74.91;// kJ/kg
// Station 4hA
// Expansion A out
h_4hA=h_3A;// kJ/kg
// Loop B
// Station 1B
// Compressor B in
x_1B=1.00;// The dryness fraction
T_1B=-50.0;//  C
h_1B=228.51;// kJ/kg
s_1B=1.02512;// kJ/kg.K
p_1B=63.139;// kPa
// Station 2sB
// Compressor B out
p_2B=300;// kPa
s_2B=s_1B;// kJ/kg.K
h_2sB=264.05;// kJ/kg
T_2sB=15.0;//  C
// Station 3B
// Condenser B out
x_3B=0.00;// The dryness fraction
T_3B=-20.0;//  C
h_3B=21.73;// kJ/kg
// Station 4hB
// Expansion B out
```

```
h_4hB=h_3B;// kJ/kg
Q_L=40.0;// tons of refrigeration
n_s=80/100;// The isentropic efficiencies of both compressors

// (a)
m_B=(Q_L*210*1/60)/(h_1B-h_4hB);// kg/s
h_2B=((h_2sB-h_1B)/n_s)+h_1B;// kJ/kg
m_A=m_B*((h_2B-h_3B)/(h_1A-h_4hA));// kg/s
// (b)
COP_dc=(m_B*(h_1B-h_4hB))/(((m_A*(h_2sA-h_1A))/n_s)+((m_B*(h_2sB-h_1B))/n_s));// The coeeficient of performance
// (c)
PR_cA=p_2A/p_1A;// The compressor pressure ratio
PR_cB=p_2B/p_1B;// The compressor pressure ratio
printf("\n(a)The mass flow rate of refrigerant in loops A and B,m_A=%1.2f kg/s & m_B=%0.3f kg/s \n(b)The systems coefficient of performance, COP_dual cascade=%1.2f \n(c)The pressure ratios across each of the compressors,PR_compressorA=%1.2f & PR_compressorA=%1.2f",m_A,m_B,COP_dc,PR_cA,PR_cB);
```

Scilab code Exa 14.7 `The total power required by the compressors`

```
// Example 14_7
clc;funcprot(0);
// Given data
// Loop A
// Station 1A
// Compressor A inlet
p_1A=500;// kPa
h_1A=265.60;// kJ/kg
s_1A=0.9486;// kJ/kg.K
```

```
// Station 2sA
// Compressor A outlet
p_2sA=1600;// kPa
s_2A=s_1A;// kJ/kg.K
h_2A=256.60;// kJ/kg
// Station 3A
// Condenser A outlet
x_3A=0.00;// The quality of steam
p_3A=1600;// kPa
h_3A=134.02;// kJ/kg
// Station 4hA
// Expansion valve A outlet
h_4hA=h_3A;// kJ/kg
// Loop B
// Station 1B
// Compressor B inlet
x_1B=1.00;// The quality of steam
p_1B=100;// kPa
h_1B=231.35;// kJ/kg
s_1B=0.9395;// kJ/kg.K

// Station 2sB
// Compressor B outlet
p_2B=500;// kPa
s_2sB=s_1B;// kJ/kg.K
h_2sB=264.25;// kJ/kg
T_2sB=15.0;//  C
// Station 3B
// Condenser B outlet
x_3B=0.00;// The quality of steam
p_3B=500;// kPa
h_3B=71.33;// kJ/kg
// Station 4hB
// Expansion B outlet
h_4hB=h_3B;// kJ/kg
Q_L=10.0;// tons
n_s_c_A=80/100;// The isentropic efficiency of compressor A
```

```
n_s_c_B=80/100;// The isentropic efficiency of compressor B

// Calculation
// (a)
h_2B=((h_2sB-h_1B)/n_s_c_B)+h_1B;// kJ/kg
h_f_500kPa=71.33;// kJ/kg
h_f_1600kPa=134.02;// kJ/kg
h_fg_500kPa=184.74;// kJ/kg
x_flash=((h_f_1600kPa-h_f_500kPa)/h_fg_500kPa)*100;// The quality of the vapor exiting the flash chamber
h_gflash=252.07;// kJ/kg
h_1A=((x_flash/100)*h_gflash)+((1-(x_flash/100))*h_2B);// kJ/kg
m_B=(Q_L*210*1/60)/(h_1B-h_4hB);// kg/s
m_A=m_B/(1-(x_flash/100));// kg/s
// (b)
h_2sA=292.33;// kJ/kg
COP_ds=[(1-(x_flash/100))*(h_1B-h_4hB)]/[((h_2sA-h_1A)/n_s_c_A)+((1-(x_flash/100))*((h_2B-h_1B)/n_s_c_B))];// The systems coefficient of performance.
// (c)
W_comp=m_A*[((h_2sA-h_1A)/n_s_c_A)+((1-(x_flash/100))*((h_2B-h_1B)/n_s_c_B))];// The total compressor power in kW
printf(”\n(a)The mass flow rate of the two refrigerants ,m_A=%0.3f kg/s & m_B=%0.3f kg/s \n(b)The systems coefficient of performance, COP_dual stage=%1.2f \n(c)The total power required by the compressors,W_compressors=%2.1f kW”,m_A,m_B,COP_ds,W_comp);
```

Scilab code Exa 14.8 `The Carnot absorption refrigeration coefficient of performanc`

```
// Example 14_8
clc;funcprot(0);
// Given data
T_g=100;//  C
T_e=5.00;//  C
T_a=20.0;//  C

// Calculation
COP_Car=((T_e+273.15)/(T_g+273.15))*((T_g-T_a)/(T_a-T_e));// The Carnot absorption refrigeration coefficient of performance
printf("\nThe Carnot absorption refrigeration coefficient of performance,(COP)_Carnot absorption refrigerator=%1.2f",COP_Car);
```

Scilab code Exa 14.9 `The quality at the outlet of the refrigeration evaporator`

```
// Example 14_9
clc;funcprot(0);
// Given data
Q_R=422;// kJ/h
Q_F=422;// kJ/h
// Station 1- Compressor inlet
x_1=1.00;// The quality of steam
T_1=-18.0;//  C
h_1=236.53;// kJ/kg
s_1=0.9315;// kJ/kg.K
// Station 2- Compressor outlet
s_2=s_1;// kJ/kg.K
p_sat=0.770;// MPa
p_3=p_sat;// MPa
p_2s=p_3;// MPa
h_2s=271.0;// kJ/kg
// Station 3- Condenser outlet
x_3=0.00;// The quality of steam
```

```
T_3=30.0;// C
p_3=0.770;// MPa
h_3=91.49;// kJ/kg
// Station 4h−Refrigerator evaporator inlet
h_4h=h_3;// kJ/kg
T_4h=4.00;// C
h_f=55.35;// kJ/kg
h_fg=194.19;// kJ/kg
// Station 5−Refrigerator evaporator outlet
T_5=T_4h;// C
// Station 6h−Freezer evaporator outlet
T_6h=-18.0;// C
n_s_c=0.80;// The isentropic efficency of the compressor

// Calculation
// (a)
COP=(h_1-h_4h)/((h_2s-h_1)/n_s_c);// The coefficient of performance
// (b)
m_ref=((Q_R+Q_F)*(1/60))/(h_1-h_4h);// kg/min
// (c)
h_5=h_4h+((Q_R*1/60)/m_ref);// kJ/kg
x_5=((h_5-h_f)/h_fg)*100;// The quality at the exit of the refrigeration evaporator
printf(”\n(a)The coefficient of performance,COP=%1.2f \n(b)The mass flow rate of refrigerant required,m_ref=%0.4f kg/min \n(c)The quality at the outlet of the refrigeration evaporator,x_5=%2.1f percentage”,COP,m_ref,x_5);
```

Scilab code Exa 14.10 The COP and cycle minimum cooling temperature

```
// Example 14_10
clc;funcprot(0);
```

```
// Given data
PR=2.00;// The pressure ratio
T_1=70+460;// R
T_3=80.0+459.67;// R
n_s_e=65/100;// The isentropic efficiency of the expander
n_s_c=65/100;// The isentropic efficiency of the compressor
k=1.40;// The specific heat ratio

// Calculation
// (a)
COP_rBa=(((PR)^((k-1)/k))-1)^-1;// The COP for a reversed Brayton R/AC ASC
T_4s=T_3/((PR)^((k-1)/k));// R
T_4s=T_4s-459.67;//  F
// (b)
T_4=T_3-((T_3-(T_4s+459.67))*(n_s_e));// R
T_4=T_4-459.67;//  F
T_2s=(T_1*T_3)/(T_4s+459.67);// R
COP_rB=(T_1-(T_4+459.67))/(((T_2s-T_1)/(n_s_c))-((T_3-(T_4s+459.67))*(n_s_e)));// The COP for a reversed Brayton cycle R/AC
printf("\n(a)The COP for a reversed Brayton R/AC ASC,COP=%1.2f \n(b)The COP for a reversed Brayton cycle R/AC,COP=%0.3f",COP_rBa,COP_rB);
// The answer provided in the textbook is wrong
```

Scilab code Exa 14.11 The refrigeration capacity of the unit in tons

```
// Example 14_11
clc;funcprot(0);
// Given data
m=4.00;// lbm/s
T_1=530;// R
```

```
p_1=1;// psia
p_2s=3.00// psia
p_3=3.00;// psia
p_4s=1;// psia
T_3=600;// R
c_p=0.240;// Btu/(lbm.R)
k=1.40;// The specific heat ratio

// Calculation
// (a)
T_4s=T_3*((p_4s/p_3)^((k-1)/k));// R
W_expander=m*c_p*(T_3-T_4s);// Btu/s
// (b)
T_2s=T_1*((p_2s/p_1)^((k-1)/k));// R
W_compressor=m*c_p*(T_1-T_2s);// Btu/s
// (c)
PR=p_3/p_4s;// Pressure ratio
COP=(((PR)^((k-1)/k))-1)^-1;// The coefficient of performance of the unit
// (d)
W_net=(abs(W_compressor)-W_expander);// Btu/s
Q_L=(COP*(W_net)*60*(1/200));// The refrigeration capacity of the unit in tons
printf("\n(a)The expander power,W_expander=%3.0f Btu/s \n(b)The compressor power,W_compressor=%3.0f Btu/s \n(c)The coefficient of performance of the unit,COP=%1.2f \n(d)The refrigeration capacity of the unit in tons,Q_L=%2.1f tons of refrigeration",W_expander,W_compressor,COP,Q_L);
```

Scilab code Exa 14.12 The Stirling ASC coefficient of performance of this refriger

```
// Example 14_12
clc;funcprot(0);
// Given data
```

```
T_H=22.0+273.15;// K
T_L=65;// K
Q_cooling=0.100;// J/s
W_input=3.00;// W
V=12;// V

// Calculation
// (a)
COP_rS=T_L/(T_H-T_L);// The Stirling ASC coefficient of performance of a refrigeration unit
// (b)
COP_rSact=Q_cooling/W_input;// The actual coefficient of performance of the unit
printf("\n(a)The Stirling ASC coefficient of performance of a refrigeration unit,COP_reversed Stirling ASC R/AC=%0.3f \n(b)The actual coefficient of performance of the unit, COP_reversed Stirling actual R/AC=%0.4f",COP_rS,COP_rSact);
```

Scilab code Exa 14.13 `The outlet temperature and COP of a Joule Thomson expansion`

```
// Example 14_13
clc;funcprot(0);
// Given data
mu_j=0.0300;//  F /psi
p_1=300;// psia
p_2=14.7;// psia
T_1=70.0;//  F
n_s_c=90.0/100;// The isentropic efficiency of the air compressor
k=1.40;// The specific heat ratio

// Calculation
dT=mu_j*(p_2-p_1);//  F
```

```
T_2=T_1+dT;// F
COP_RAC=(mu_j*(p_2-p_1))/(((T_1+459.67)*[((p_2/p_1)^((k-1)/k))-1])/n_s_c);// The coefficient of performance
printf("\nThe outlet temperature,T_2=%2.1f F \nCOP of a Joule-Thomson expansion throttling device, COP=%0.4f",T_2,COP_RAC);
```

Scilab code Exa 14.14 `The second law efficiency for a refrigeration system`

```
// Example 14_14
clc;funcprot(0);
// Given data
m_ref=0.500;// kg/s
T_0=25.0;// C
n_c=70.0;// The isentropic efficiency of compressor
// Using Figure 14.36 as the illustration for this example, the properties at the four stations can be found in Tables C.7e, C.7f, and C.8d as
// Station 1
// Compressor inlet
x_1=1.00;// The quality of steam
T_1=-20.0;// C
h_1=235.31;// kJ/kg
s_1=0.9332;// kJ/kg.K
p_1=132.99;// kPa
// Station 2
// Compressor outlet
p_2s=800;// kPa
s_2=s_1;// kJ/kg.K
h_2s=271.10;// kJ/kg
T_2s=39.8;// C
// Station 3
// Condenser outlet
x_3=0.00;// The quality of steam
```

```
p_3=725;// kPa
h_3=87.46;// kJ/kg
s_3=0.3257;// kJ/kg.K
T_3=27.9;// C
// Station 4h
// Expansion valve outlet
h_4h=h_3;// kJ/kg
p_4h=160;// kPa
h_4h=87.46;// kJ/kg
x_4h=0.280;// The quality of steam
s_4h=0.3449;// kJ/kg.K
T_4h=-15.6;// C
T_e=-15.6;// C

// Calculation
// (a)
h_2=((h_2s-h_1)/(n_c/100))+h_1;// kJ/kg
p_2=p_2s;// kPa
//Interpolation in Table C.7f in Thermodynamic Tables to accompany Modern Engineering Thermodynamics (or through the use of an appropriate computer program) gives the following additional properties at this state:
s_2=0.9814;// kJ/kg.K
T_2=54.97;// C
Q_condenser=m_ref*(h_3-h_2);// kJ/s
Q_evaporator=m_ref*(h_1-h_4h);// kJ/s
Q_compressor=m_ref*(h_2-h_1);// kJ/s
I_ac=m_ref*(T_0+273.15)*(s_2-s_1);// kW
I_con=(T_0+273.15)*((m_ref*(s_3-s_2))-(Q_condenser/(T_0+273.15)));// kW
I_ev=m_ref*(T_0+273.15)*(s_4h-s_3);// kW
I_e=(T_0+273.15)*((m_ref*(s_1-s_4h))-(Q_evaporator/(T_e+273.15)));// kW
I_total=I_ac+I_con+I_ev+I_e;// kW
W_compressor=Q_compressor;// kW
// (b)
COP=Q_evaporator/W_compressor;// The system
```

```
coefficient of performance
T_L=T_e;// C
COP_act=2.85;// The second law efficiency for a refrigeration system
E_RAC=(abs(1-((T_0+273.15)/(T_e+273.15)))*COP_act)*100;// %
printf("\n(a)The irreversibility rate of each component in the system are given below: \n I_adiabatic compressor=%1.2f kW \n    I_condenser=%1.2f kW \n    I_expansion valve=%1.2f kW \n    I_evaporator=%1.2f kW \n    The total irreversibility rate of the system,I_total=%2.0f kW \n(b)The system coefficient of performance,COP=%1.2f \n    The second law efficiency for a refrigeration system,E_RAC=%2.1f percentage",I_ac,I_con,I_ev,I_e,I_total,COP,E_RAC);
// The answer provided in the text book is wrong(The value of h_2 changed little bit)
```

Chapter 15

Chemical Thermodynamics

Scilab code Exa 15.2 `The hydrocarbon fuel model for this mixture`

```
// Example 15_2
clc;funcprot(0);
// Given data
CH_4=1.00;// kgmole of methane
C_3H_8=3.00;// kgmoles of propane

// Solution
n=1+(3*(3));// Carbon balance
m=4+(3*(8));// Hydrogen balance
printf("\nThe hydrocarbon fuel model for this mixture is C_%2.0fH_%2.0f.",n,m);
```

Scilab code Exa 15.3 `The percentage of theoretical air used in the combustion proc`

```
// Example 15_3
clc;funcprot(0);
// Given data
T=20.0;// C
```

```
CO_2=7.10;// %
CO=0.800;// %
O_2=9.90;// %
N_2=82.2;// %
M_air=28.97;// lbmdry air/lbmole dry air

// Solution
// (a)
n=7.10+0.800;// Carbon (C) balance
// m=2*b
a=82.2/3.76;// Nitrogen (N2) balance
b=2*(a-(7.10+(0.800/2)+9.90));// Oxygen (O2) balance
m=2*b;// Hydrogen (H) balance
printf("\n(a)The hydrocarbon model (CnHm) of the fuel is C_%1.2fH_%2.0f",n,m);
// (b)
M_fuel=(7.90*(12))+(18.0*(1));// lbm/lbmole
Fc_C=7.90*12.0*113;// lbm C/lbm fuel
Fc_H=((9.00)*(2.016))/113;// lbmH/lbmfuel
printf("\n(b)The molecular mass of the fuel in this model,M_fuel=%3.0f lbm/lbmole \n   The fuels composition on a mass basis is %0.3f lbmC/lbmfuel and %0.3f lbmH/lbm fuel",M_fuel,Fc_C,Fc_H);
// (c)
n_air=21.9*(1+3.76);// The stoichiometric coefficient of the reaction
n_fuel=1;// The stoichiometric coefficient of the reaction
AF_molar=n_air/n_fuel;// moles air/mole fuel
AF_mass=AF_molar*(28.97/(M_fuel));// lbm air/lbm fuel
printf("\n(c)The air-fuel ratio on a molar and a mass basis,(A/F)_molar=%3.0f moles air/molefuel and (A/F)_mass=%2.1f lbm air/lbm fuel",AF_molar,AF_mass);
// (d)
b=7.90;// Carbon (C) balance
c=18.0;// Hydrogen (H) balance
```

```
a=b+(c/2);// Oxygen (O2) balance
d=3.76*a;// Nitrogen (N2) balance
AF_mt=(12.4*(1+3.76))/1;// mole air/mole fuel
per_ta=(AF_molar/AF_mt)*100;// The percent of theoretical air used in the actual combustion process (%)
printf("\n(d)The percentage of theoretical air used in the combustion process,Percentage of theoritical air=%3.0f percentage or %2.0f percentage excess air",per_ta,(per_ta-100));
```

Scilab code Exa 15.4 `The dew point temperature of the combustion products`

```
// Example 15_4
clc;funcprot(0);
// Given data
m_H2O=9.00;// moles
m_m=109;// moles
p_t=14.7;// The total pressure of the mixture in psia

// Calculation
X_H2O=m_H2O/m_m;// The mole fraction
p_H2O=X_H2O*p_t;// psia
// By interpolation in Table C.1a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find that
T_DP=108;//  F
T_DP=(108-32)/1.8;//  C
printf("\nThus, the exhaust products must be cooled to %3.0f F(%2.1f C)or below to condense the water of combustion and have an essentially dry exhaust gas.",(T_DP*1.8+32),T_DP);
```

Scilab code Exa 15.5 The amount of water carried into the engine in the form of in

```
// Example 15_5
clc;funcprot(0);
// Given data
T_DB=90.0;//  F
T_WB=75.0;//  F
phi=50;// The relative humidity in %
w=105*1/7000;// lbm H2O/lbm dry air
M_da=28.97;// lbmdry air/lbmole dry air
M_H2O=18.016;// lbmH2O/lbmoleH2O

// Calculation
w=w*(M_da/M_H2O);// lbmole H2O/lbmole dry air
// From the balanced reaction equation of part a of Example 15.3, we find that the amount of dry air used per mole of fuel is
a_da=21.9*(1+3.76);// moles
a_w=w*a_da;// moles of water
n_H2O=9.00+a_w;// moles per mole of fuel
n_total=111.5;// moles per mole of fuel
X_H2O=n_H2O/n_total;// The mole fraction of water vapor in the exhaust
p_H2O=X_H2O*14.7;// psia
// Again, interpolating in Table C.1a in Thermodynamic Tables to accompany Modern Engineering Thermodynamics, we find
T_DP=116.0;// F
T_DP=(T_DP-32)/1.8;//  C
T_sat=T_DP;//  C
printf("\n(a)The amount of water carried into the engine in the form of inlet humidity,w=%0.4f lbmole H2O/lbmole dry air \n(b)The new dew point temperature of the exhaust products,T_DP=%2.1f  C
```

```
   ",w,T_DP);
```

Scilab code Exa 15.6 `The heat of formation of methane gas`

```
// Example 15_6
clc;funcprot(0);
// Given data
h_f_CO2=393.522;// MJ/kgmole
h_f_H2O_g=241.827;//MJ/kgmole
h_f_H2O_l=285.838;// MJ/kgmole
HHV_CH4=-890.4;// MJ/kgmole

// Calculation
n=1;// The stoichiometric coefficient for the
   reaction
m=4;// The stoichiometric coefficient for the
   reaction
q_f=-[(n*h_f_CO2)+((m/2)*h_f_H2O_l)+HHV_CH4];// MJ/
   kgmole of CH_4
printf("\nThe heat of formation of methane gas CH4(g
   ) at the standard reference state,(qbar_f)_CH4=%2
   .1f MJ/kgmole of CH_4",q_f);
```

Scilab code Exa 15.7 `The heat transfer required to keep both the reactants and the`

```
// Example 15_7
clc;funcprot(0);
// Given data
m=0.160;// kg of liquid water
T=25.0;//  C
p=0.100;// MPa

// Calculation
```

```
h_f_H2O=285.838;// MJ/kg mole
q_f_H2O=285.838;// MJ/kg mole
q_r=q_f_H2O;// MJ/kg mole
M=18.016;// kg/kgmole
Q_r=m*(-q_r/M);// MJ
printf("\nThe total heat transfer required ,Q_r=%1.2f
    MJ",Q_r);
```

Scilab code Exa 15.8 `The higher and lower heating values of methane`

```
// Example 15_8
clc;funcprot(0);
// Given data
// For 100.% theoretical air , the combustion
   equation for methane is ,CH_4+2.00[O_2+3.76 N_2
   ]-->CO_2+2.00(H_2O)+7.52(N_2)
// From Table 15.1 , we find that
h_f_CH4=-74.873;// MJ/kgmoleCH4
h_R=-74.873;// MJ/kgmoleCH4
h_f_N_2=0;// MJ/kgmole N2
h_f_CO2=-393.522;// MJ/kgmole CO2
h_f_H2O_g=-241.827;// MJ/kgmole H2O_g
h_f_H2O_l=-285.838;// MJ/kgmole H2O_l

// Calculation
h_p_LHV=h_f_CO2+(2*h_f_H2O_g)+(7.52*h_f_N_2);// MJ/
   kgmole CH4
h_p_HHV=h_f_CO2+(2*h_f_H2O_l)+(7.52*h_f_N_2);// MJ/
   kgmole CH4
LHV=h_p_LHV-h_R;// MJ/kgmole CH4
HHV=h_p_HHV-h_R;// MJ/kgmole CH4
h_fg_H2O=44.00;// MJ/kgmole CH4
n_H2O=2.00;// The stoichiometric coefficient for the
    reaction
n_fuel=1.00;// The stoichiometric coefficient for
```

```
   the reaction
HHV=LHV-((n_H2O/n_fuel)*h_fg_H2O);// MJ/kgmole CH4
printf("\nThe higher heating value of methane,LHV=%3
   .2f MJ/kgmole CH4 \nThe lower heating value of
   methane,HHV=%3.2f MJ/kgmole CH4",HHV,LHV);
```

Scilab code Exa 15.9 `The heat of reaction of methane`

```
// Example 15_9
clc;funcprot(0);
// Given data
h_R=-74.873;// MJ/kgmole CH4
h_f_N_2=0;// MJ/kgmole
h_f_CO2=-393.522;// MJ/kgmole
h_f_H2O_g=-241.827;// MJ/kgmole
h_f_H2O_l=-285.838;// MJ/kgmole
c_p_CO2=0.03719;// MJ/kgmole.K
c_p_H2O=0.03364;// MJ/kgmole.K
c_p_N2=0.02908;// MJ/kgmole.K
T=500;//  C
T_0=25;//  C

// Calculation
h_P=h_f_CO2+(2*h_f_H2O_g)+(7.52*h_f_N_2)+([c_p_CO2
   +(2.00*c_p_H2O)+(7.52*c_p_N2)]*(T-T_0));// MJ/
   kgmole CH4
q_r=h_P-h_R;// MJ/kgmole CH4
printf("\nThe heat of reaction of methane,qbar_r=%3
   .3f MJ/kgmole CH4",q_r);
```

Scilab code Exa 15.10 `The closed syste adiabatic flame temperature burning with 10`

```
// Example 15_10
```

```
clc;funcprot(0);
// Given data
T=25.0;//  C
p=0.100;// MPa

// Calculation
// (a)
h_f_C8H18=-249.952;// MJ/kgmole
h_fuel=h_f_C8H18;// MJ/kgmole
h_f_CO2=-393.522;// MJ/kgmole
h_f_H2O_g=-241.827;// MJ/kgmole
h_f_N_2=0;// MJ/kgmole
h_fi=(8*h_f_CO2)+(9*h_f_H2O_g)+(47*h_f_N_2);// MJ/kgmole of C8H18
c_p_CO2=0.05818;// MJ/kgmole.K
c_p_H2O=0.04250;// MJ/kgmole.K
c_p_N2=0.03118;// MJ/kgmole.K
c_pi_avg=(8*c_p_CO2)+(9*c_p_H2O)+(47*c_p_N2);// MJ/kgmole of C8H18.K
T_Aos=((h_f_C8H18-(h_fi))/c_pi_avg)*1.8;//  F
printf("\n(a)The open system (constant pressure) adiabatic flame temperature burning with 100. percent theoretical air,T_A|open system=%4.0f F",T_Aos);
// (b)
c_p_O2=0.03299;// MJ/(kgmole).K
c_pi_avg=(8*c_p_CO2)+(9*c_p_H2O)+(12.5*c_p_O2)+(94*c_p_N2);// MJ/kgmole of C8H18.K
T_Aos=(((h_f_C8H18-(h_fi))/c_pi_avg)+T)*1.8;//  F
printf("\n(b)The open system (constant pressure) adiabatic flame temperature burning with 200. percent theoretical air,T_A|open system=%4.0f F",T_Aos)
// (c)
R=0.0083143;// // MJ/kgmole.K
N=h_fuel-h_fi-((R*(T+273.15))*[1+(12.4*4.76)-(8+9+47)]);// The numerator in  MJ/kgmole of C8H18.K
```

```
c_v_CO2=0.04987;// MJ/kgmole.K
c_v_H2O=0.03419;// MJ/kgmole.K
c_v_N2=0.02287;// MJ/kgmole.K
c_vi_avg=(8*c_v_CO2)+(9*c_v_H2O)+(47*c_v_N2);// MJ/kgmole.K
T_Acs=T+(N/c_vi_avg);// The denominator in  MJ/kgmole of C8H18.K
T_Acs=(T_Acs*1.8)+32;//  F
printf("\n(c)The closed system (constant volume) adiabatic flame temperature burning with 100. percent theoretical air,T_A|closed system=%4.0f F",T_Acs);
```

Scilab code Exa 15.11 The maximum possible explosion pressure inside the bomb

```
// Example 15_11
clc;funcprot(0);
// Given data
T=25+273.15;// K
m_f=0.0100;// kg
M_octane=114;// kg/kg mole
R=1545.35;// ft.lbf/(lbmole.R)
V_p=50.0*10^-3;// ft^3
R_u=0.0083143;// MJ/kgmole.K

// Calculation
m_oct=m_f/M_octane;// kgmole
// The reaction equation for 50.0% excess pure oxygen is C8H18+1.5(12.5)O2--->8(CO2)+9(H2O)+6.25(O2)
n_CO2=8;// The stoichiometric coefficient of the reaction
n_H2O=9;// The stoichiometric coefficient of the reaction
n_O2=6.25;// The stoichiometric coefficient of the
```

```
   reaction
m_oy=m_oct*(n_CO2+n_H2O+n_O2);// kgmole of product
n_p=m_oy*2.2046;// lbmole of product
h_f_C8H18=-249.952;// MJ/kgmole
h_f_CO2=-393.522;// MJ/kgmole
h_f_H2O_g=-241.827;// MJ/kgmole
h_f_N2=0;// MJ/kgmole
h_f_O2=0;// MJ/kgmole
N=h_f_C8H18+(0-(1.5*12.5*R_u*T))-(n_CO2*(h_f_CO2-(
   R_u*T)))-(n_H2O*(h_f_H2O_g-(R_u*T)))-(n_O2*(
   h_f_O2-(R_u*T)));// The numerator in MJ
c_v_CO2=0.04987;// MJ/kgmole.K
c_v_H2O=0.03419;// MJ/kgmole.K
c_v_O2=0.02468;// MJ/kgmole.K
D=(n_CO2*c_v_CO2)+(n_H2O*c_v_H2O)+(n_O2*c_v_O2);//
   The denominator in MJ/K
T_A_bc=(T-273.15)+(N/D);// C
T_A_bc=T_A_bc+273.15;// K
T_A_bc=T_A_bc*1.8;// R
P_max=(n_p*R*T_A_bc)/(V_p*144);// psi
printf("\nThe maximum possible explosion pressure
   inside the bomb,P_max=%5.0f psi",P_max);
// The answer vary due to round off error
```

Scilab code Exa 15.12 The entropy produced per mole of fuel

```
// Example 15_12
clc;funcprot(0);
// Given data
T=25.0+273;// K
p_m=0.100;// MPa
T_b=200+273;// K
q_r=-134.158;// MJ
R=8.3143;// kJ/(kgmole.K)

```

```
// Calculation
// The reaction equation for 100.% theoretical air is CH4+2O2+3.76N2—>CO2+2(H2O)+7.52(N2)
n_CH4=1;// The stoichiometric coefficient of the reaction
n_O2=2;// The stoichiometric coefficient of the reaction
n_N2=7.52;// The stoichiometric coefficient of the reaction
n_R=(n_CH4+n_O2+n_N2);// The stoichiometric coefficient of the reaction
p_CH4=(n_CH4/n_R)*p_m;// kPa
p_O2=(n_O2/n_R)*p_m;// kPa
p_N2=(n_N2/n_R)*p_m;// kPa
n_CO2=1;// The stoichiometric coefficient of the reaction
n_H2O=2;// The stoichiometric coefficient of the reaction
n_N2=7.52;// The stoichiometric coefficient of the reaction
n_P=(n_CO2+n_H2O+n_N2);// The stoichiometric coefficient of the reaction
p_CO2=(n_CO2/n_P)*p_m;// kPa
p_H2O=(n_H2O/n_P)*p_m;// kPa
p_N2=(n_N2/n_P)*p_m;// kPa
s0_CH4=186.256;// kJ/(kgmole.K)
s0_O2=205.138;// kJ/(kgmole.K)
s0_N2=191.610;// kJ/(kgmole.K)
sbar_CH4=s0_CH4-(R*log(p_CH4/p_m));// kJ/(kgmole.K)
sbar_O2=s0_O2-(R*log(p_O2/p_m));// kJ/(kgmole.K)
sbar_N2=s0_N2-(R*log(p_N2/p_m));// kJ/(kgmole.K)
sbar_iR=(n_CH4*sbar_CH4)+(n_O2*sbar_O2)+(n_N2*sbar_N2);// kJ/(kgmole.K)
s0_CO2=213.795;// kJ/(kgmole.K)
s0_H2O=188.833;// kJ/(kgmole.K)
s0_N2=191.610;// kJ/(kgmole.K)
c_p_CO2=37.19;// kJ/(kgmole.K)
c_p_H2O=33.64;// kJ/(kgmole.K)
```

```
c_p_N2=29.08;// kJ/(kgmole.K)
sbar_CO2=s0_CH4+(c_p_CO2*log(T_b/T))-(R*log(p_CO2/p_m));// kJ/(kgmole.K)
sbar_H2O=s0_O2++(c_p_H2O*log(T_b/T))-(R*log(p_H2O/p_m));// kJ/(kgmole.K)
sbar_N2=s0_N2+(c_p_N2*log(T_b/T))-(R*log(p_N2/p_m));// kJ/(kgmole.K)
sbar_iP=(n_CO2*sbar_CO2)+(n_H2O*sbar_H2O)+(n_N2*sbar_N2);// kJ/(kgmole.K)
sbar_p_r=sbar_iP-sbar_iR-((q_r*10^3)/T_b);// kJ/(kgmole.K)
printf("\nThe entropy produced per mole of fuel,(sbar_p)_r=%3.0f kJ/(kgmole.K)",sbar_p_r);
```

Scilab code Exa 15.13 `The molar specific entropy of formation`

```
// Example 15_13
clc;funcprot(0);
// Given data
T=25+273.15;// K
n_C=1;// The stoichiometric coefficient of the reaction
n_H2=2;// The stoichiometric coefficient of the reaction
n_CH4=1;// The stoichiometric coefficient of the reaction
sbar0_CH4=186.256;// kJ/kgmole.K
sbar0_C=5.740;// kJ/kgmole.K
sbar0_H2=130.684;// kJ/kgmole.K
h_f_CH4=-74.873;// MJ/kgmole.K

// Calculation
sbar0_f_CH4=sbar0_CH4-[((n_C/n_CH4)*sbar0_C)+((n_H2/n_CH4)*sbar0_H2)];// kJ/kgmole.K
gbar0_f_CH4=h_f_CH4-(T*sbar0_f_CH4*1/1000);// The
```

```
specific molar Gibbs function of formation of methane in MJ/kgmole
printf(”\nThe molar specific entropy of formation,(sbar0_f)_CH4=%2.3f kJ/kgmole.K \nThe specific molar Gibbs function of formation of methane,(gbar0_f)_CH4=%2.3f MJ/kgmole”,sbar0_f_CH4,gbar0_f_CH4);
```

Scilab code Exa 15.14 `The equilibrium constant`

```
// Example 15_14
clc;funcprot(0);
// Given data
p=0.100;// MPa
T_a=298;// K
T_b=2000;// K
R=0.0083143;// MJ/kgmole.K

// Calculation
// (a)
gbar0_f_H2O=-228.583;// kJ/kgmole
// since H2 and O2 are elements, their molar specific Gibbs function of formation is zero. Then, from Table 15.7,
gbar0_f_H2=0;// kJ/kgmole
gbar0_f_O2=0;// kJ/kgmole
K_e=exp(gbar0_f_H2O/(R*T_a));// The equilibrium constant
printf(”\n(a)The equilibrium constant,K_e=%1.2e”,K_e);
// (b)
T_b_R=T_b*1.8;// R
// Eq. (15.34) with Tables 15.7 and C.16c in Thermodynamic Tables to accompany Modern Engineering Thermodynamics give
```

```
h_a_H2O=4258.3;// Btu/lbmole
h_b_H2O=35540.1;// Btu/lbmole
h_a_H2=3640.3;// Btu/lbmole
h_b_H2=26398.5;// Btu/lbmole
h_a_O2=3725.1;// Btu/lbmole
h_b_O2=29173.5;// Btu/lbmole
s_a_H2O=188.833;// kJ/(kgmole.K)
s_b_H2O=63.221;// Btu/(lbmole.R)
s_a_H2=130.684;// kJ/(kgmole.K)
s_b_H2=44.978;// Btu/(lbmole.R)
s_a_O2=205.138;// kJ/(kgmole.K)
s_b_O2=64.168;// Btu/(lbmole.R)
// Note: The multipliers 2.3258 and 4.1865 in these equations are necessary to convert the Btu/lbmole and Btu/(lbmole.R) values in Table C.16c into kJ/kgmole and kJ/(kgmole.K), respectively.
gbar_f_H2O=(gbar0_f_H2O*10^3)+((h_b_H2O-h_a_H2O)*2.3258)-[((T_b*s_b_H2O)*4.1865)-(T_a*s_a_H2O)];// kJ/kgmole
gbar_f_H2=gbar0_f_H2+((h_b_H2-h_a_H2)*2.3258)-[((T_b*s_b_H2)*4.1865)-(T_a*s_a_H2)];// kJ/kgmole
gbar_f_O2=gbar0_f_O2+((h_b_O2-h_a_O2)*2.3258)-[((T_b*s_b_O2)*4.1865)-(T_a*s_a_O2)];// kJ/kgmole
K_e=exp([gbar_f_H2O-gbar_f_H2-((1/2)*gbar_f_O2)]/(R*10^3*T_b));// The equilibrium constant
printf("\n(b)The equilibrium constant,K_e=%1.2e",K_e);
```

Scilab code Exa 15.17 The equilibrium constant for the reactions

```
// Example 15_17
clc;funcprot(0);
// Given data
T=5000;// K

```

```
// Calculation
// (a)
K_e1=10^0.450;// The equilibrium constant for the reaction
K_e2=1/K_e1;// The equilibrium constant for a second reaction
printf("\n(a)The equilibrium constant for the first reaction,K_e1=%1.2f \n The equilibrium constant for a second reaction,K_e2=%0.3f",K_e1,K_e2);
// (b)
K_e1=10^-0.298;// The equilibrium constant for the reaction
printf("\n(b)The equilibrium constant for the reaction,K_e1=%0.3f",K_e1);
// (c)
alpha=1;// Constant
beta=3.76;// Constant
K_e1=10^(1.719);// The equilibrium constant for the first reaction
K_e2=10^-0.570;// The equilibrium constant for a second reaction
K_e3=(K_e1^alpha)*(K_e2^beta);// The equilibrium constant for a third reaction
printf("\n(c)The equilibrium constant for the first reaction,K_e1=%2.1f \n The equilibrium constant for a second reaction,K_e2=%0.3f \n The equilibrium constant for the combined reaction,K_e3=%0.3f",K_e1,K_e2,K_e3);
```

Scilab code Exa 15.18 `The maximum theoretical reaction efficiency`

```
// Example 15_18
clc;funcprot(0);
// Given data
T=25.0;// C
```

```
p=0.100;// MPa
g_f_H2O=-237.178;// MJ/kgmole
h_f_H2O=-285.838;// MJ/kgmole
j=2;// kgmole of electrons per kgmole of H2
F=96487;// kJ/(V.kgmole electrons)

// Calculation
n_H2=1;// The stoichiometric coefficient of the reaction
n_H2O=1;// The stoichiometric coefficient of the reaction
n_r_max=g_f_H2O/h_f_H2O;// The maximum reaction efficiency
phi_0=([-(n_H2O/n_H2)*(h_f_H2O*10^3)]*[n_r_max])/(j*F);// The theoretical open circuit voltage in V
W_maxbyn_fuel=phi_0*j*F;// kJ/kgmoleH2
printf("\nThe maximum theoretical reaction efficiency,(n_r)max=%2.1f percentage \nThe theoretical open circuit voltage,V=%1.2f V \nThe maximum theoretical work output,W_max/n_fuel=%6.0f kJ/kgmole H2",n_r_max*100,phi_0,W_maxbyn_fuel);
```

Scilab code Exa 15.19 The net molar specific flow availability of the hydrogen oxy

```
// Example 15_19
clc;funcprot(0);
// Given data
T=25;// C
p=0.1;// MPa

// Calculation
n_H2=1;// The stoichiometric coefficient of the reaction
n_O2=0.5;// The stoichiometric coefficient of the reaction
```

```
n_H2O=1;// The stoichiometric coefficient of the reaction
g_f_H2O=-237.178;// MJ/kgmole
// [(abar_f)_i]_chemical=gbar0_i+RT ln[1].
abar_H2O=g_f_H2O;// MJ/kgmole
adot_fc=0+0-[(n_H2O/n_H2)*abar_H2O];// The net molar specific flow availability in MJ/kgmoleH2
printf("\nThe net molar specific flow availability of the hydrogen oxygen fuel cell,(a_flow chemical)_net=%3.3f MJ/kgmoleH2",adot_fc);
```

Chapter 16

Compressible Fluid Flow

Scilab code Exa 16.1 `The air temperature on the center of your palm`

```
// Example 16_1
clc;funcprot(0);
// Given data
T=20+273.15;// K
V=90.0;// km/h
g_c=1;// The gravitational constant
c_p=1.004;// kJ/kg.K

// Solution
T_0=T*(1+(((V*10^3/(3600*1000))^2)/(2*g_c*c_p*T)));// K
T_0=T_0-273.15;// C
printf("\nThe stagnation temperature,T_0=%2.1f C",T_0)
```

Scilab code Exa 16.2 `The isentropic stagnation pressure and isentropic stagnation`

```
// Example 16_2
```

```
clc;funcprot(0);
// Given data
T=20+273.15;// K
V=25.0;// m/s
k=1.40;// The specific heat ratio
p=0.101;// MPa
g_c=1;// The gravitational constant
c_p=1.004;// kJ/kg.K
R=0.286;// kJ/kg.K

// Solution
p_os=p*(1+((V^2/1000)/(2*g_c*c_p*T)))^(k/(k-1));// The isentropic stagnation pressure in MPa
rho=(p*10^3)/(R*T);// kg/m^3
rho_os=rho*(1+((V^2/1000)/(2*g_c*c_p*T)))^(1/(k-1));// The isentropic stagnation density in kg/m^3
printf("\nThe isentropic stagnation pressure,p_os=%0.4f MPa \nThe isentropic stagnation density,rho_os=%1.4f kg/m^3",p_os,rho_os);
```

Scilab code Exa 16.3 The isentropic stagnation temperature pressure and density of

```
// Example 16_3
clc;funcprot(0);
// Given data
p_1=14.7;// psia
T_1=1000;//  F
V_1=1612;// ft/s
g_c=32.174;// lbm.ft/lbf.s^2

// Calculation
// Station 1
p_1=14.7;// psia
T_1=1000;//  F
h_1=1534.4;// Btu/lbm
```

```
s_1=2.1332;// Btu/lbm.R
// Station os
s_os=s_1;// Btu/lbm.R
h_os=h_1+(V_1^2/(2*g_c));// Btu/lbm
//Table C.3a, in Thermodynamic Tables to accompany Modern Engineering Thermodynamics a Mollier diagram for steam
p_os=20.0;// psia
T_os=1100;// F
v_os=46.4;// ft^3/lbm
rho_os=1/v_os;// lbm/ft^3;
printf(”\nThe isentropic stagnation temperature,T_0=%4.0f F \nThe isentropic stagnation pressure,p_os=%2.1f psia \nThe isentropic stagnation density,rho_os=%0.3f lbm/ft^3”,T_os,p_os,rho_os);
```

Scilab code Exa 16.4 The Mach number of the methane

```
// Example 16_4
clc;funcprot(0);
// Given data
T=35+273.15;// K
V=300;// m/s

// Solution
// Using Table C.13b in Thermodynamic Tables to accompany Modern Engineering Thermodynamics for the values of the specific heat ratio and the gas constant for methane, we get
k_methane=1.30;// The specific heat ratio
g_c=1;// The gravitational constant
R_methane=518;// J/kg.K
c_methane=sqrt(k_methane*g_c*R_methane*T);// m/s
M_methane=V/c_methane;//The Mach number
printf(”\nThe Mach number of the methane,M_methane=
```

```
%0.3f",M_methane);
```

Scilab code Exa 16.5 The velocity isentropic stagnation temperature and isentropic

```
// Example 16_5
clc;funcprot(0);
// Given data
T=-20.0+273.15;// K
p=0.500;// atm
M=0.850;// The Mach number
k=1.40;// The specific heat ratio
R=286;// J/kg.K
g_c=1;// The gravitational constant

// Solution
V=M*sqrt(k*g_c*R*T);// m/s
T_os=T*(1+(((k-1)*M^2)/2));// K
T_os=T_os-273.15;//  C
p_os=p*(1+(((k-1)*M^2)/2))^(k/(k-1));// atm
p_os=p_os*1.013*10^2;// kPa
printf("\nThe aircrafts velocity,V=%3.0f m/s \nThe isentropic stagnation temperature,T_os=%2.1f C \nThe isentropic stagnation pressure,p_os=%2.1f KPa",V,T_os,p_os);
```

Scilab code Exa 16.6 The temperature at the throat of the nozzle

```
// Example 16_6
clc;funcprot(0);
// Given data
p_os=1.00;// MPa
T_os=20.0+273.15;// K
k=1.40;// The specific heat ratio
```

```
p=0.1013;// MPa
g_c=1;// The gravitational constant
R=286;// J/kg.K

// Solution
// (a)
p_r=p/p_os;// The pressure ratio
M=((2/(k-1))*(((p_os/p)^((k-1)/k))-1))^(1/2);// The exit Mach number
// (b)
T=(T_os/(1+(((k-1)*M^2)/2)))-273.15;// The exit temperature in C
// (c)
V=M*sqrt(k*g_c*R*(T+273.15));// The exit velocity in m/s
// (d)
p_throat=p_os*[2/(k+1)]^(k/(k-1));// The pressure at the throat of the nozzle in MPa
// (e)
T_throat=T_os*[2/(k+1)];// The temperature at the throat of the nozzle in K
T_throat=T_throat-273.15;// The temperature at the throat of the nozzle in C
printf("\n(a)The exit Mach number,M=%1.2f \n(b)The exit temperature,T=%3.0f C \n(c)The exit velocity,V=%3.0f m/s \n(d)The pressure at the throat of the nozzle,p_throat=%0.3f MPa \n(e)The temperature at the throat of the nozzle,T_throat=%2.1f C",M,T,V,p_throat,T_throat);
```

Scilab code Exa 16.7 The minimum tube diameter necessary to completely fill a sphe

```
// Example 16_7
clc;funcprot(0);
// Given data
```

```
D_bag=3.00;// ft
t_fill=30;// milliseconds
p_air=15.00;// psia
p_os=1500;// psia
T_os=70.0+459.67;// R
k=1.40;// The specific heat ratio
R_air=53.34;// ft.lbf/lbm.R

// Solution
V_bag=(%pi*D_bag^3)/6;// ft^3
T_air=T_os*(2/(k+1));// R
rho_air=(p_air*144)/(R_air*T_air);// lbm/ft^3
m_avg=(rho_air*V_bag)/(t_fill*10^-3);// lbm/s
D_tube=[(4*m_avg*sqrt(T_os+459.67))/(0.532*%pi*p_os)
   ]^(1/2);// in
printf("\nThe minimum tube diameter,D_tube=%1.2f in"
   ,D_tube);
// The answer vary due to round off error
```

Scilab code Exa 16.8 `How long does it take to unchoke`

```
// Example 16_8
clc;funcprot(0);
// Given data
D_exit=0.0938;// in
T_os=70.0;//  F
p_osi=50.0;// psia
V_T=1.00;// ft^3
k=1.40;// The specific heat ratio

// Calculation
// (a)
p_r1=(2/(k+1))^(k/(k-1));// The pressure ratio
p_exit=14.7;// psia
p_exitbyp_os=p_exit/p_osi;// The pressure ratio
```

```
// (b)
p_os=p_exit/p_r1;// psia
p_os=p_os*0.472;// psig
// (c)
A_a=(%pi*D_exit^2)/(4*144);// ft^2
tau=31.95*log(p_osi/(p_os/0.472));// s
printf("\n(a)p_exit/p_os=%0.3f,which is <0.528 therefore, initially, the flow is choked.\n(b)The flow remains choked until the tire deflates to a pressure of p_os=%2.1f psig \n(c)The valve stem unchokes at time,tau=%2.1f s",p_exitbyp_os,p_os,tau);
```

Scilab code Exa 16.10 The velocity of the jet

```
// Example 16_10
clc;funcprot(0);
// Given data
m=5.00*10^-3;// kg
T=20.0+273.15;// K
p=101.3*10^3;// kg/(m.s^2)
R=286;// m^2/(s^2.K)
D=3.00*10^-3;// m
g=9.81;// m/s^2
g_c=1;// The gravitational constant

// Calculation
W=(m*g)/g_c;// N
rho=p/(R*T);// kg/m^3
V_in=((4*g_c*W)/(rho*%pi*D^2))^(1/2);// m/s
printf("\nThe velocity of the jet,V_in=%2.1f m/s",V_in);
```

Scilab code Exa 16.11 `The pressure temperature and wind velocity directly behind t`

```
// Example 16_11
clc;funcprot(0);
// Given data
M_x=5.50;// The Mach number
p_x=14.7;// lbf/in^2
T_x=70.0+459.67;//  F
k=1.4;// The specific heat ratio
R=53.34;// ft.lbf/lbm.R
g_c=32.174;// lbm.ft/lbf.s^2

// Calculation
M_y=((((k-1)*M_x^2)+2)/((2*k*M_x^2)+1-k))^(1/2);// The Mach number
T_y=T_x*[(1+(((k-1)/2)*M_x^2))/(1+(((k-1)/2)*M_y^2))];// R
p_y=p_x*(M_x/M_y)*(T_y/T_x)^(1/2);// lbf/in^2
V_wind=(M_x*sqrt(k*g_c*R*T_x))-(M_y*sqrt(k*g_c*R*T_y));// ft/s
printf("\nThe pressure directly behind the shock wave,p_y=%3.0f lbf/in^2 \nThe temperature directly behind the shock wave,T_y=%4.0f R \nThe wind velocity directly behind the shock wave, V_wind=%1.0e ft/s",p_y,T_y,V_wind);
```

Scilab code Exa 16.12 `The mass flow rate required for supersonic flow in the diver`

```
// Example 16_12
clc;funcprot(0);
// Given data
p_os=7.00;// MPa
T_os=2000;//  C
D_t=0.0200;// m
D_e=0.100;// m
```

```
k=1.40;// The specific heat ratio
R=286;// m^2/(s^2.K)
g_c=1;// The gravitational constant

// Calculation
// (a)
A_t=(%pi*D_t^2)/4;// m^2
mdot=(0.0404*(p_os*10^6)*A_t)/sqrt(T_os+273.15);// kg/s
// (b)
A_r=(D_e/D_t)^2;// (A_r=A_exit/A*)
M_e=5.00;// Mach number at exit
// Assume p_exit/p_os=p_r
p_r=1.89*10^-3;// Pressure ratio
// Assume T_exit/T_os=T_r
T_r=0.16667;// Temperature ratio
p_e=p_r*p_os*10^3;// The exit pressure in kN/m^2
T_exit=T_r*(T_os+273.15);// K
c_e=sqrt(k*g_c*R*T_exit);// The velocity of sound at the exit in m/s
V_exit=c_e*M_e;// m/s
// (c)
M_x=5.0;// The Mach number
p_x=13.23;// kN/m^2
T_x=378.8;// K
// Table C.19 is a tabular version of these equations, and at Mx = 5.0, we again have a direct entry
M_y=0.415;// The Mach number
// Assume p_osy/p_osx=p_ros
p_ros=0.06172;
// Assume p_y/p_x=p_rxy
p_rxy=29.00;
// Assume p_osy/p_x=p_rosyx
p_rosyx=32.654;
// Assume T_y/T_x=T_yx
T_yx=5.800;
p_osx=p_os*10^3;// kN/m^2
```

```
p_B=p_ros*p_osx;// The required back pressure in kN/m^2
// Alternatively
p_B=p_rosyx*p_x;// The required back pressure in kN/m^2
printf("\n(a)The mass flow rate required for supersonic flow in the diverging section,mdot=%1.2f kg/s \n(b)The Mach number, pressure, temperature and velocity at the exit of the diverging section with this massflow rate,M_exit=%1.2f,p_exit=%2.1f kN/m^2,T_exit=%3.1f K,V_exit=%4.0f m/s \n(c)The outside back pressure required to produce a standing normal shock wave at the exit of the diverging section,p_B=%3.0f kN/m^2",mdot,M_e,p_e,T_exit,V_exit,p_B);
```

Scilab code Exa 16.13 The pressure temperature and velocity at the exit

```
// Example 16_13
clc;funcprot(0);
// Given data
p_os=3.00;// atm
T_os=20.0;//  C
p_B=1.00;// atm
A_r=2.0;// The exit to throat area ratio fo r the nozzle
k=1.4;// The specific heat ratio
R=286;// m^2/(s^2.K)
g_c=1;// The gravitational constant

// Calculation
p_a=p_os*(2/(k+1))^(k/(k-1));// atm
// Since we are given Aexit/A* = A_E/A*= 2.00, we can find ME by inverting Eq. (16.23b).However, in this case, it is again much easier to use Table
```

```
C.18 for this area ratio and read (approximately),
M_E=2.20;// The Mach number at exit
// Assume p_rEos=p_E/p_os
p_rEos=0.09352;
p_E=p_rEos*p_os;// atm
// Assume p_r=p_osy/p_osx
p_r=1.00/3.00;
// From Table C.19 at p_osy/p_osx=0.333
M_x=2.98;// The Mach number
M_y=0.476;// The Mach number
T_e=0.50813*(T_os+273.15);// K
c_exit=sqrt(k*g_c*R*T_e);// m/s
M_exit=M_E;// The Mach number at exit
V_exit=M_exit*c_exit;// m/s
printf("\nThe exit pressure,p_E=%0.3f atm\nThe exit temperature,T_exit=%3.2f K \nThe exit velocity,V_exit=%3.0f m/s",p_E,T_e,V_exit);
```

Scilab code Exa 16.14 `The nozzle Discharge coefficient`

```
// Example 16_14
clc;funcprot(0);
// Given data
p_inlet=456.2;// kN/m^2
T_inlet=283.7;// K
p_exit=370.4;// kN/m^2
T_exit=260.1;// K
V_exit=474.8;// m/s
k=1.67;// The specific heat ratio for helium
R=2077.0;// m^2/(s^2.K)
g_c=1;// The gravitational constant

// Calculation
// (a)
```

```
c_osi=sqrt(k*g_c*R*T_inlet);// m/s
c_inlet=c_osi;// m/s
n_N=((((k-1)/2)*(V_exit/c_inlet)^2)/(1-((p_exit/
   p_inlet)^((k-1)/k))));// The nozzles
   efficiency
// (b)
C_v=sqrt(n_N);// The nozzles velocity coefficient
// (c)
R=2.077;// kJ/kg.K
rho_e=p_exit/(R*T_exit);// kg/m^3
M_exit=1.0;// The exit Mach number
T_os=T_inlet;// K
p_os=p_inlet;// kN/m^2
T_es=T_os*(2/(k+1));// K
rho_es=(p_os/(R*T_os))*[2/(k+1)]^(1/(k-1));// kg/m^3
V_es=sqrt(k*g_c*R*10^3*T_es);// m/s
C_d=(rho_e*V_exit)/(rho_es*V_es);// The nozzles
   discharge coefficient
printf("\n(a)The nozzles efficiency,n_N=%0.3f \n(
   b)The nozzles velocity coefficient,C_v=%0.3f \
   n(c)The nozzles discharge coefficient,C_d=%0.3
   f",n_N,C_v,C_d);
```

Scilab code Exa 16.15 The diffuser efficiency and pressure recovery coefficient

```
// Example 16_15
clc;funcprot(0);
// Given data
M_in=0.890;// The inlet Mach number
p_osi=314.7;// kPa
p_ose=249.3;// kPa
k=1.40;// The specific heat ratio

// Calculation
// (a)
```

```
n_D=(((((1+((((k-1)/2)*M_in^2)))*(p_ose/p_osi)^((k-1)/k)))-1)/(((k-1)*M_in^2)/2))*100;// %
// (b)
p_i=p_osi/((1+(((k-1)/2)*M_in^2))^(k/(k-1)));// kPa
C_p=(p_ose-p_i)/(p_osi-p_i);// The diffusers pressure recovery coefficient
printf("\n(a)The diffusers efficiency,n_D=%2.1f percentage \n(b)The diffusers pressure recovery coefficient,C_p=%0.3f",n_D,C_p);
```

Chapter 17

Thermodynamics of Biological Systems

Scilab code Exa 17.1 `The membrane potential in human cells of sodium potassium and`

```
// Example 17_1
clc;funcprot(0);
// Given data
T=37.0;//  C
// From table 17.2
c_Na_c=14.0;// osmoles/cm^3
c_Na_o=144;// osmoles/cm^3
c_K_c=140;// osmoles/cm^3
c_K_o=4.1;// osmoles/cm^3
c_Cl_c=4.00;// osmoles/cm^3
c_Cl_o=107;// osmoles/cm^3

// Solution
E_Na=(26.7/1)*log(c_Na_o/c_Na_c);// mV
E_K=(26.7/1)*log(c_K_o/c_K_c);// mV
E_Cl=(26.7/-1)*log(c_Cl_o/c_Cl_c);// mV
printf("\nThe membrane potential of sodium in a
   human cell,E_Na+=%2.1f mV \nThe membrane
   potential of potassium in a human cell,E_K+=%2.1f
```

```
   mV \nThe membrane potential of chlorine in a
   human cell ,E_Cl−=%2.1f mV”,E_Na,E_K,E_Cl);
```

Scilab code Exa 17.2 `How much land is required to grow the plants needed to feed t`

```
// Example 17_2
clc;funcprot(0);
// Given data
n_ech=20.0;// The energy conversion efficiency of the plants eaten by grazing herbivores in %
n_ecc=5.0;// The energy conversion efficiency of the carnivores in %
n_o=(0.100*0.200*0.0500)*100;// %
E_avg=15.3;// The average daily solar energy reaching the surface of the Earth MJ/d.mˆ2
E_c=10.0;// MJ/d

// Calculation
// car−carnivore,her−herbivore,ec−energy conversion efficiency
E_car=E_c/(n_ecc/100);// MJ/d
E_her=E_car/(n_ech/100);// MJ/d
n_ec=1/100;// Energy conversion rate
E_hreq=E_her/(n_ec);// MJ/d
A=E_hreq/E_avg;// Area in mˆ2
A_acre=A*(1/4047);// acres
printf(”\n%1.2f acres of land is required to grow the plants needed to feed the herbivores eaten by a large carnivore that requires 10.0 MJ/d to stay alive.”,A_acre);
```

Scilab code Exa 17.3 `The basal metabolic rate per unit mass`

```
// Example 17_3
clc;funcprot(0);
// Given data
m_h=80.0;// kg
m_m=0.008;// kg

// Solution
BMRbym_human=293*(m_h^-0.25);// kJ/kg.d
BMRbym_mouse=293*(m_m^-0.25);// kJ/kg.d
printf(”\nThe BMR per unit mass of an 80.0 kg human,(BMR/m)_human=%2.0f kJ/kg.d \nThe BMR per unit mass of an 8.00 gram mouse,(BMR/m)_mouse=%3.0f kJ/kg.d”,BMRbym_human,BMRbym_mouse);
```

Scilab code Exa 17.4 The specific energy content of an average meal with natural s

```
// Example 17_4
clc;funcprot(0);
// Given data
e=10.5;// MJ
C=45/100;// MJ/kg
P=15.0/100;// MJ/kg
F=40.0/100;// MJ/kg

// Calculation
// (a)
e_C=4.20;// MJ/kg meal
e_P=8.40;// MJ/kg meal
e_F=33.1;// MJ/kg meal
e_avgMeal=(C*e_C)+(P*e_P)+(F*e_F);// MJ/kg meal
// (b)
mdot_avgMeal=(e/e_avgMeal)*2.187;// lbm of average meal/day
printf(”\n(a)The specific energy content of an average meal with natural state foods,e_avg meal=
```

```
   %2.1f MJ/kg meal \n(b)The total mass of an
   average meal,mdot_avg meal=%1.1f lbm of average
   meal/day",e_avgMeal,mdot_avgMeal);
```

Scilab code Exa 17.5 `How many days of total fasting are required to lose 10 kg of`

```
// Example 17_5
clc;funcprot(0);
// Given data
m_h=1.00;// kg
E_me=33.1;// MJ
E_na=10.5;// MJ
m_fat=10.0;// kg

// Calculation
// (a)
mdot_fat=E_na/E_me;// The mass of body fat consumed
   per day in kg of body/d
// (b)
t=m_fat/mdot_fat;// d
printf("\n(a)The mass of body fat consumed per day,
   mdot_fat=%0.3f kg of body/d \n(b)The number of
   fasting days required to lose (consume) 10.0 kg
   of body fat,t=%2.1f d",mdot_fat,t);
```

Scilab code Exa 17.6 `How long will it take to work off the energy content of the i`

```
// Example 17_6
clc;funcprot(0);
// Given data
mg=490;// N
Z=1.00;// m
g_c=1;// The gravitational constant
```

```
delt=1.00;// s

// Calculation
E=(mg*Z)/g_c;// J
W=E/delt;// J/s
n_T_muscle=25/100;// The energy conversion efficiency
U_body=-W/n_T_muscle;// J/s
Q=U_body+W;// J/s
delU=-(1)*(2.51);// MJ
tau=delU/(U_body*10^-6);// s
tau=tau/60;// min
printf("\nThe time required to produce a change in the total internal energy of the system that equals the energy content of one pint of ice cream,tau=%2.1f min",tau);
```

Scilab code Exa 17.7 The heart rate and respiratory rate

```
// Example 17_7
clc;funcprot(0);
// Given data
m_m=0.0300;// kg
m_h=70.0;// kg
m_e=4000;// kg

// Calculation
Hr_m=241*(m_m^(-0.25));// Beats/min
Hr_h=241*(m_h^(-0.25));// Beats/min
Hr_e=241*(m_e^(-0.25));// Beats/min
Br_m=54*(m_m^(-0.25));// Beats/min
Br_h=54*(m_h^(-0.25));// Beats/min
Br_e=54*(m_e^(-0.25));// Beats/min
printf("\nThe heartbeat rates of the mouse, human, and elephant are\n(Heartbeat rate)_mouse=%3.0f
```

```
   Beats/min \n(Heartbeat rate)_house=%2.1f Beats/
   min \n(Heartbeat rate)_elephant=%2.1f Beats/min \
   nThe breathing rates of the mouse, human, and
   elephant are \n(Breathing rate)_mouse=%3.0f
   Breaths/min \n(Breathing rate)_human=%2.1f
   Breaths/min \n(Breathing rate)_elephant=%1.2f
   Breaths/min",Hr_m,Hr_h,Hr_e,Br_m,Br_h,Br_e);
```

Scilab code Exa 17.8 `The critical buckling height of a small tree`

```
// Example 17_8
clc;funcprot(0);
// Given data
d=5.00*10^-3;// The base diameter of the tree in m

// Calculation
h_critical=68.0*(d^(2/3));// The critical buckling
   height of a small tree in m
printf("\nThe critical buckling height of a small
   tree, h_critical=%1.2f m",h_critical);
```

Scilab code Exa 17.9 `The locomotion transport number`

```
// Example 17_9
clc;funcprot(0);
// Given data
m=60.0;// kg
m_bc=15.0;// kg
P=400;// W
V=15.0;// miles/h
g=9.81;// m/s^2

// Calculation
```

```
w=(m+m_bc)*9.81;// N
V=(V*1.609)*1000;// m/h
T=(P*3600)/(w*V);// The locomotion transport number
printf("\nThe locomotion transport number,T=%0.4f",T
   );
```

Scilab code Exa 17.10 `The death rate constant for mice`

```
// Example 17_10
clc;funcprot(0);
// Given data
T=27+273;
k_d=0.0350;

// Calculation
alpha=k_d/(T*exp((9.62*10^4*((T-330)/(330*T)))-33.2)
   );
disp(alpha)
```

Chapter 18

Introduction to Statistical Thermodynamics

Scilab code Exa 18.1 `The total translational internal energy`

```
// Example 18_1
clc;funcprot(0);
// Given data
T=20+273.15;// K
m=1.00;// kg
R=296;// J/kg.K
M=28.0;// kg/kgmole
N_o=6.022*10^26;// molecules/kgmole
k=1.380*10^-23;// J/molecule.K

// Calculation
// (a)
V_rms=sqrt(3*R*T);// The kinetic theory root mean
   square molecular velocity in m/s
// (b)
m_molecule=M/N_o;// kg/molecule
N=m/m_molecule;// molecules
U_trans=(3/2)*(N*k*T)/1000;// The total
   translational internal energy in kJ
```

```
printf("\n(a)The kinetic theory root mean square molecular velocity,V_rms=%3.0f m/s \n(b)The total translational internal energy,U=%3.0f kJ",V_rms,U_trans);
```

Scilab code Exa 18.2 `The collision frequency and mean free path for neon`

```
// Example 18_2
clc;funcprot(0);
// Given data
T=273;// K
p=0.113;// MPa
M=20.183;// kg/kg mole
N_o=6.022*10^26;// molecules/kgmole
k=1.380*10^-23;// J/(molecules.K)


// Calculation
m=M/N_o;// kg/molecule
V_rms=((3*k*T)/m)^(1/2);// m/s
r=1.3*10^-10;// The radius of the neon molecule in m
sigma=4*%pi*r^2;// The collision cross-section in m^2
NbyV=(p*10^6)/(k*T);// molecules/m^3
F=sigma*V_rms*NbyV*(8/(3*%pi))^(1/2);// The collision frequency in collisions/s
lambda=1/(NbyV*sigma);// The molecular mean free path in m
printf("\nThe collision frequency,F=%1.2e collisions/s \nThe molecular mean free path,lambda=%1.2e m",F,lambda);
```

Scilab code Exa 18.3 `The fraction of molecules whose velocities lie in the range f`

```
// Example 18_3
clc;funcprot(0);
// Given data
T=273;// K
m=3.35*10^-26;// kg
k=1.38*10^-23;// J/(molecule.K)

// Calculation
// (a) The fraction having velocities greater than Vmp is given by Eq. (18.26) with x = Vmp/Vmp = 1.0
x=1.00;// The velocity ratio
NV_mpbyN=1-erf(x)+((2/sqrt(%pi))*x*exp(-(x^2)));// The fraction of molecules whose velocities lie in the range from V to infinity
// (b)
x=sqrt(8/(2*%pi));// The velocity ratio
NV_avgbyN=1-erf(x)+((2/sqrt(%pi))*x*exp(-(x^2)));// The fraction of molecules whose velocities lie in the range from V to infinity
// (c)
// x=V_rms/V_mp;
x=sqrt(3/2);// The velocity ratio
NV_rmsbyN=1-erf(x)+((2/sqrt(%pi))*x*exp(-(x^2)));// The fraction of molecules whose velocities lie in the range from V to infinity
// (d)
x=10.0;// The velocity ratio
NVbyN=((2/sqrt(%pi))*x*exp(-(x^2)));// The fraction of molecules whose velocities lie in the range from V to infinity
c=3.00*10^8;// m/s
V_mp=sqrt((2*k*T)/m);// m/s
x=c/V_mp;// The velocity ratio
NcbyN=((2/sqrt(%pi))*x*exp(-(x^2)));// The fraction of molecules whose velocities lie in the range from c to infinity
printf("\n(a)%2.2f percentage of the molecules have
```

```
velocities faster than V_mp. \n(b)%2.2f percentage of the molecules have velocities faster than V_avg. \n(c)%2.2f percentage of the molecules have velocities faster than V_rms. \n(d)The fraction of molecules whose velocities lie in the range from c to infinity is %0.0f.",NV_mpbyN*100,NV_avgbyN*100,NV_rmsbyN*100,NcbyN*100);
```

Scilab code Exa 18.4 The heat transfer rate required to heat low pressure gaseous

```
// Example 18_4
clc;funcprot(0);
// Given data
T_in=500;// K
T_out=1200;// K
mdot=1.00;// kg/min
R_u=8.314;// kJ/(kgmole.K)

// Calculation
// For CC1_4,
b=5;// The number of atoms in the molecule
F=3*b;// The degrees of freedom per molecule
M=12.0+(4*(35.5));// kg/kgmole
R=R_u/M;// kJ/(kg.K)
c_p=(1+(F/2))*R;// kJ/(kg.K)
Qdot=mdot*c_p*(T_out-T_in);// kJ/min
printf("\nThe heat transfer rate required to heat low-pressure gaseous carbon tetrachloride,Qdot=%3.0f kJ/min",Qdot);
```

Scilab code Exa 18.6 The probability that it will be an ace or a spade

```
// Example 18_6
clc;funcprot(0);
// Given data
P_ace=4/52;// The probability of getting ace
P_spade=13/52;// The probability of getting spade
P_aceofspades=1/52;// The probability of getting ace
    of spades

// Calculation
P=(P_ace+P_spade-P_aceofspades)*100;// The
   probability that it will be an ace or a spade in
   %
printf("\nThe probability that it will be an ace or
   a spade,P=%2.1f percentage",P);
```

Scilab code Exa 18.7 Probability

```
// Example 18_7
clc;funcprot(0);
// Given data
N=10;// The number of available students
R=5;// The number of ordered groups

// Calculation
// (a)
P_a=(factorial(N))/(factorial(N-R));// P_using each
   student only once
// (b)
P_b=N^R;// P_using each student more than once
// (c)
P_c=(factorial(N))/(factorial(N-R)*factorial(R));//
   C_using each student only once
// (d)
P_d=(factorial(N+R-1))/(factorial(N-1)*factorial(R))
   ;// C_using each student more than once
```

```
// (e)
R_1=4;
R_2=6
P_e=(factorial(N))/((factorial(R_1))*(factorial(R_2)));
printf("\n(a)P_using each student only once=%5.0f groups \n(b)P_using each student more than once=%5.0f groups \n(c)C_using each student only once=%3.0f groups \n(d)C_using each student more than once=%4.0f groups \n(e)P_4,6=%3.0f groups",P_a,P_b,P_c,P_d,P_e);
```

Scilab code Exa 18.8 The final temperature of the krypton gas after compression

```
// Example 18_8
clc;funcprot(0);
// Given data
m=3.50;// kg
T_1=20.0+273.15;// K
p_1=0.101325;// MPa
p_2=10.0;// MPa
R_u=8.3143;// kJ/kg.K
W_12=-100;// kJ

// Calculation
// (a)
M_krypton=83.80;
R_krypton=R_u/M_krypton;// kJ/kg.K
Q_12=0;// kJ
T_2=T_1-((W_12/(3*m*R_krypton/2)));// K
// (b)
S_p12=m*R_krypton*log(((T_2/T_1)^(5/2))*(p_1/p_2));// kJ/kg.K
printf("\n(a)The final temperature of the krypton gas after compression,T_2=%3.0f K \n(b)The
```

```
entropy production of the compression process,1(S_p)2=%1.2f kJ/kg.K",T_2,S_p12);
// The answer provided in the textbook is wrong
```

Scilab code Exa 18.9 The value of cv by R for nitrous oxide

```
// Example 18_9
clc;funcprot(0);
// Given data
T=20.0+273.15;// K

// Calculation
theta_v=2740;// K
c_vbyR=(5/2)+((((theta_v/T)^2)*exp((theta_v/T)))/(exp(theta_v/T)-1)^2);
Y=8.3143;// kJ/kg.K
M_NO=30.01;// The molecular mass of nitrous oxide
R_NO=Y/M_NO;// kJ/kg.K
c_v_NO=R_NO*c_vbyR;// kJ/kg.K
printf("\nThe value of c_v/R for nitrous oxide is %1.2f.",c_vbyR);
```

Scilab code Exa 18.10 The specific internal energy

```
// Example 18_10
clc;funcprot(0);
// Given data
theta_r=0.562;// K
theta_v1=1932;// K
theta_v3=960;// K
theta_v2=theta_v3;// K
theta_v4=3380;// K
p=101325;// Pa
```

```
T=1000;// K
R_u=8.314;// kJ/kg.K
M=44.01;// The molecular mass of Carbon dioxide
h_c=6.626*10^-34;// Planck's constant
N_o=6.023*10^26;// molecules/kgmole
k=1.38*10^-23;// J/molecule.K


// Calculation
m=M/N_o;// kg/molecule
R=R_u/M;// kJ/kg.K
u_o_vib=R*((theta_v1+theta_v2+theta_v3+theta_v4)/2);// kJ/kg
u_vib=u_o_vib+(R*((theta_v1*exp(theta_v1-1)^-1)+(theta_v2*exp(theta_v2-1)^-1)+(theta_v3*exp(theta_v3-1)^-1)+(theta_v4*exp(theta_v4-1)^-1)));// kJ/kg
u_trans=(3/2)*R*T;// kJ/kg
u_rot=R*T;// kJ/kg
u=u_trans+u_rot+u_vib;// kJ/kg
h=u+(R*T);// kJ/kg
Sigma=2;// molecules/m^3
d=((((2*%pi*m)/(h_c^2))^(3/2))*(k*T)^(5/2))/p;// per molecule
s_trans=R*(log(d)+(5/2));// kJ/kg.K
s_rot=R*(log(T/(Sigma*theta_r))+1);// kJ/kg.K
s_vib=R*[(((log(1-exp(-theta_v1/T))^-1)+((theta_v1/T)*[exp(theta_v1/T)-1]^-1))+((log(1-exp(-theta_v2/T))^-1)+((theta_v2/T)*[exp(theta_v2/T)-1]^-1))+((log(1-exp(-theta_v3/T))^-1)+((theta_v3/T)*[exp(theta_v3/T)-1]^-1))+((log(1-exp(-theta_v4/T))^-1)+((theta_v4/T)*[exp(theta_v4/T)-1]^-1)))];// kJ/kg.K
s=s_trans+s_rot+s_vib;// kJ/kg.K
printf("\nThe specific internal energy of CO2,u=%4.0f kJ/kg \nThe specific enthalpy of CO2,h=%4.0f kJ/kg \nThe specific entropy of CO2=%1.3f kJ/kg.K",u,h,s);
```

```
// The answer provided in the text book is wrong
```

Chapter 19

Introduction to Coupled Phenomena

Scilab code Exa 19.1 `The Peltier heat flow`

```
// Example 19_1
clc;funcprot(0);
// Given data
T=20.0+273.16;// K
d=0.0100;// m
alpha_cu=3.50*10^-6;// V/K
rho_e=5.00*10^-9;// ohm m
dphibydx=1.00;// Voltage gradient in V/m

// Solution
A=(%pi/4)*d^2;// m^2
I=(A/rho_e)*dphibydx;// A
Q_P=alpha_cu*T*I;// W
printf('\nThe Peltier heat flow,Q_P=%2.1f W',Q_P);
```

Scilab code Exa 19.2 `The relative Peltier coefficient`

```
// Example 19_2
clc;funcprot(0);
// Given data
T=100.0;// C

// Solution
// (a)
alpha_fecu=-(-13.4+(0.028*T)+(0.00039*T^2))*10^-6;// V/K
// (b)
pi_fecu=(T+273.16)*alpha_fecu;// V
printf('\n(a)The relative Seebeck coefficient , alpha_fecu=%1.2e V/K \n(b)The relative Peltier coefficient ,pi_fecu=%1.2e V',alpha_fecu,pi_fecu);
```

Scilab code Exa 19.3 `The absolute and relative Peltier coefficients for each chrom`

```
// Example 19_3
clc;funcprot(0);
// Given data
T_H=100;// C
T_C=0;// C
alpha_ch=23.0*10^-6;// V/K
alpha_al=-18.0*10^-6;// V/K

// Solution
// (a)
alpha_chal=alpha_ch-alpha_al;// V/K
phi_alch=alpha_chal*(T_H-T_C);// V
// (b)
pi_ch1=alpha_ch*(T_C+273.15);// V
pi_al1=alpha_al*(T_C+273.15);// V
pi_chal1=pi_ch1-pi_al1;// V
pi_ch2=alpha_ch*(T_H+273.15);// V
pi_al2=alpha_al*(T_H+273.15);// V
```

```
pi_chal2=pi_ch2-pi_al2;// V
printf('\n(a)alpha_ch-al=%2.0e V/K \n    phi_al-ch=%1.1e V \n(b)At the 0.00 C = 273.15 K junction, \npi_ch=%1.2e V \npi_al=%1.2e V \npi_ch-al=%2.1e V \nAt the 100. C = 373.15 K junction,\npi_ch=%1.2e V \npi_al=%1.2e V \npi_ch-al=%2.1e V ',alpha_chal,phi_alch,pi_ch1,pi_al1,pi_chal1,pi_ch2,pi_al2,pi_chal2);
```

Scilab code Exa 19.4 The steady state thermomolecular pressure difference across t

```
// Example 19_4
clc;funcprot(0);
// Given data
mu=1.50*10^-5;// The viscosity of the CO_2 in kg/(m.s)
T_1=300;// K
T_2=305;// K
k_p=1.00*10^-6;// m^2
k_o=2.00*10^4;// The osmotic heat conductivity in m^2/s

// Solution
dp=-((mu*k_o)/k_p)*log(T_2/T_1);// N/m^2
printf('\nThe steady state thermomolecular pressure difference across the membrane,p_2-p_1=%4.0f N/m^2',dp);
```

Scilab code Exa 19.5 The isothermal entropy transport rate induced by the thermome

```
// Example 19_5
clc;funcprot(0);
// Given data
```

```
T_1=30+273.15;// K
T_2=T_1;// K
dp=10.0;// kPa
d=0.0100;// m
rho=996;// kg/m^3
k_p=1.00*10^-12;// m^2
mu=891*10^-6;// kg/(s.m)
dx=0.100;// m
Q=15.0;// The isothermal energy transport rate in this system in J/s

// Solution
// (a)
A=(%pi/4)*d^2;// m^2
m=-((rho*A*k_p)/mu)*((dp*10^3)/dx);// kg/s
// (b)
k_o=-(Q/A)/((-dp*10^3)/dx);// m^2/s
// (c)
S_i=Q/T_1;// J/(s.K)
printf('\n(a)The thermomechanical mass flow rate between the vessels ,m=%1.2e kg/s \n(b)The osmotic heat conductivity coefficient ,k_o=%1.2f m^2/s \n(c)The isothermal entropy transport rate induced by the thermomechanical mass flow rate ,S_i=%0.4f J/(s.K)',m,k_o,S_i);
```

Scilab code Exa 19.6 The induced isobaric mass flow rate and the resulting tempera

```
// Example 19_6
clc;funcprot(0);
// Given data
rho=996;// kg/m^3
Q=8.70;// J/s
T=30+273;// K
k_t=0.610;// J/(s.K.m)
```

```
k_o=1.91;// m^2/s
k_p=1.00*10^-12;// m^2
mu=891*10^-6;// kg/(s.m)
dx=0.100;// m

// Solution
m=(rho*Q)/((T*(k_t/k_o))+(mu*(k_o/k_p)));// kg/s
dTbydx=-(T*m)/(rho*k_o);// K/m
dT=dTbydx*dx;// K
printf('\nThe induced isobaric mass flow rate,m=%1.2e kg/s \nThe resulting temperature difference between the vessels,dT=%1.2e K',m,dT);
```