Scilab Textbook Companion for Theory And Problems Of Thermodynamics For Engineers
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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

CONCEPTS DEFINITIONS AND BASIC PRINCIPLES

Scilab code Exa 1.5 `The specific weight`

```
// Example 1_5
clc;funcprot(0);
// Given data
V=3*5*20;// The volume of the room in(m*m*m)
m=350;// The mass of air in kg
g=9.81;// The acceleration due to gravity in m/s^2

// Calculation
rho=m/V;// The density in kg/m^3
c=1/rho;// The specific volume in m^3/kg
gamma=rho*g;// The specific weight in N/m^3
printf("\nThe density,rho=%1.3f kg/m^3 \nThe specific volume,c=%0.3f m^3/kg \nThe specific weight,gamma=%2.2f N/m^3",rho,c,gamma);
```

Scilab code Exa 1.6 `The absolute pressure`

```
// Example 1_6
clc;funcprot(0);
// Given data
P_gage=35;// psi
P_atm=100;// The atmospheric pressure in kPa

// Calculation
P_gage=35*144*0.04788;// The gage pressure in kPa
P=P_atm+P_gage;// The absolute pressure in kPa
printf("\nThe absolute pressure,P=%3.0f kPa",P)
```

Scilab code Exa 1.7 `The water pressure`

```
// Example 1_7
clc;funcprot(0);
// Given data
h=0.6;// The manometer reading in m
r=9810;// The weight density in N/m^3
S_gm=13.6;// The specific gravity of mercury

// Calculation
P=(h*S_gm*r)-(h*r);// Pa
printf("\nThe water pressure,P=%5.0f Pa or %2.1f kPa
   ",P,P/10^3);
// The answer vary due to round off error
```

Scilab code Exa 1.8 `The force due to pressure`

```
// Example 1_8
clc;funcprot(0);
// Given data
rho=1000;// The density of water in kg/m^3
g=9.81;// m/s^2
```

```
h=600;// m
d=1;// m

// Calculation
P=rho*g*h;// Pa
A=(%pi*d^2)/4;// m^2
F=P*A;// The force due to pressure in N
printf("\n The force due to pressure,F=%1.2e N",F);
```

Scilab code Exa 1.9 `Temperature`

```
// Example 1_9
clc;funcprot(0);
// Given data
t=50;//  F

// Calculation
t_c=(5/9)*(t-32);//  C
T_K=t_c+273;// K
T_R=t+460;//  R
printf("\nt_c=%2.0f C \nT_K=%3.0f K \nT_R=%3.0f R"
   ,t_c,T_K,T_R);
```

Scilab code Exa 1.10 `The increase in internal energy`

```
// Example 1_10
clc;funcprot(0);
// Given data
m_a=2200;// kg
V_a1=90*(1000/3600);// m/s
V_a2=50*(1000/3600);// m/s
m_b=1000;// kg
V_b2=88*(1000/3600);// m/s
```

```

// Calculation
KE_1=(1/2)*m_a*V_a1^2;// J
KE_2=((1/2)*m_a*V_a2^2)+((1/2)*m_b*V_b2^2);// J
// dU=U_2-U_1
dU=KE_1-KE_2;// J
printf("\nThe increase in internal energy,U_2-U_1=%6.0f J or %3.1f kJ",dU,dU/1000);
// The answer vary due to round off error
```

Chapter 2

PROPERTIES OF PURE SUBSTANCES

Scilab code Exa 2.1 `The specific volume of liquid vapor mixture`

```
// Example 2_1
clc;funcprot(0);
// Given data
P_a=1;// kPa
P_b=100;// kPa
P_c=10000;// kPa
v_ga=129.2;// m^3/kg
v_fa=0.001;// m^3/kg
v_gb=1.694;// m^3/kg
v_fb=0.001;// m^3/kg
v_gc=0.01803;// m^3/kg
v_fc=0.00145;// m^3/kg

// Calculation
// (a)
v_fga=v_ga-v_fa;// m^3/kg
// (b)
v_fgb=v_gb-v_fb;// m^3/kg
// (c)
```

```
v_fgc=v_gc-v_fc;// m^3/kg
printf("\n(a)v_fg=%3.1f m^3/kg \n(b)v_fg=%1.3f m^3/kg \n(c)v_fg=%0.5f m^3/kg",v_fga,v_fgb,v_fgc);
```

Scilab code Exa 2.2 `The volume of the vapor`

```
// Example 2_2
clc;funcprot(0);
// Given data
m=4;// The mass of water in kg
V=1;// m^3
T=150;//  C
v=0.3928;// m^3/kg

// Calculation
// Table C-1 is used
V=m*v;// m^3
// (a)
P=475.8;// The pressure in kPa
// (b)
v=1/4;// m^3/kg
v_f=0.00109;// m^3/kg
v_g=0.3928;// m^3/kg
x=(v-v_f)/(v_g-v_f);// The quality of steam
m_g=m*x;// The mass of vapor in kg
// (c)
V_g=v_g*m_g;// The volume of the vapor in m^3
printf("\n(a)The pressure,P=%3.1f kPa \n(b)The mass of vapor,m_g=%1.3f kg \n(c)The volume of the vapor,V_g=%0.4f m^3",P,m_g,V_g);
```

Scilab code Exa 2.3 `The final volume occupied by the mixture`

```
// Example 2_3
clc;funcprot(0);
// Given data
m=4;// The mass of water in kg
P=220;// kPa
x=0.8;// The quality of steam

// Calculation
// Use Table C-2.To determine the appropriate numbers at 220 kPa we linearly interpolate between 0.2 and 0.3 MPa.
P_1=0.2*10^3;// kPa
P_2=0.3*10^3;// kPa
v_g1=0.8857;// m^3/kg
v_g2=0.6058;// m^3/kg
v_g=(((P-P_1)/(P_2-P_1))*(v_g2-v_g1))+v_g1;// m^3/kg
v_f=0.0011;// m^3/kg
v=v_f+(x*(v_g-v_f));// m^3/kg
V=m*v;// The total volume occupied in m^3
printf("\nThe final volume occupied by the mixture,V=%1.3f m^3",V);
```

Scilab code Exa 2.4 `The final volume of the container`

```
// Example 2_4
clc;funcprot(0);
// Given data
m=2;// The mass of water in lb
P=540;// psia
T=700;//  F

// Calculation
// Use Table C-3E.
v_f=1.3040;// ft^3/lbm
v_g=1.0727;// ft^3/lbm
```

```
x=0.4;// The quality of steam
v=v_f+(x*(v_g-v_f));// ft^3/lbm
V=m*v;// The final volume of the container in ft^3
printf("\nThe final volume of the container,V=%1.3f
   ft^3.",V);
```

Scilab code Exa 2.5 `The mass of air`

```
// Example 2_5
clc;funcprot(0);
// Given data
V=0.6;// m^3
P_gage=200;// The gage pressure in kPa
T=20+273;// K
P_atm=100;// kPa
R=287;// N.m/kg.K

// Calculation
P=P_gage+P_atm;// The absolute pressure in kPa
m=(P*10^3*V)/(R*T);// The mass of air in kg
printf("\nThe mass of air,m=%1.2f kg",m);
```

Scilab code Exa 2.6 `The pressure at an elevation of 3000 m`

```
// Example 2_6
clc;funcprot(0);
// Given data
// T(z)=15-0.00651 C
z_0=0;// m
P=101;// m
z_1=3000;// m

// Calculation
```

```
// Using the given equation for T(z) we have
// dP=P/(29.3)*(288-0.00651 z)
// By solving this equation,we get
P=101*exp(-0.368);// kPa
printf("\nThe pressure at an elevation of 3000 m,P=%2.1f kPa.",P);
```

Scilab code Exa 2.7 `The pressure of the steam`

```
// Example 2_7
clc;funcprot(0);
// Given data
T=500+273;// K
rho=24;// The density in kg/m^3
R=0.462;// kJ/kg.K
v=1/rho;// m^3/kg

// Calculation
// (a)
P=rho*R*T;// kPa
printf("\n(a)Using the ideal gas equation,The pressure of steam(P)=%4.0f kPa.",P);
// (b)
// Using values for a and b from Table B-8,the vander Waals equation provides
a=1.703;
b=0.00169;
P=((R*T)/(v-b))-(a/v^2);// kPa
printf("\n(b)Using the vander Waals equation,the pressure of steam(P)=%4.0f kPa.",P);
// (c)
// Using values for a and b from Table B-8,the Redlich-Kwong equation provides
a=43.9;
b=0.00117;
```

```
P=((R*T)/(v-b))-(a/(v*(v+b)*sqrt(T)));// kPa
printf("\n(c)Using the Redlich-Kwong equation,the
    pressure of steam(P)=%4.0f kPa.",P);
// (d)
T_c=647.4;// The critical temperature in K
T_R=T/T_c;// The reduced temperature
P_c=8000;// The critical pressure in kPa
P_R=P/P_c;// The reduced pressure
// By using the reduced temperature and the reduced
    pressure
Z=0.93;// The compressibilty factor
P=(Z*R*T)/v;// kPa
printf("\n(d)By using the compressibilty factor,the
    pressure of steam(P)=%4.0f kPa.",P);
// (e)
// By using the steam tables,
P=8000;// kPa
printf("\n(e)By using the steam tables,the pressure
    of steam(P)=%4.0f kPa.",P);
```

Chapter 3

WORK AND HEAT

Scilab code Exa 3.1 `The work done by the steam`

```
// Example 3_1
clc;funcprot(0);
// Given data
m=1;// The mass of steam in kg
x=20/100;// The quality of steam
P=200;// kPa
T_2=400;//   C

// Calculation
// Using Table C-2 we find
v_f=0.001061;// m^3/kg
v_g=0.8857;// m^3/kg
v_1=v_f+(x*(v_g-v_f));// m^3/kg
v_2=1.549;// m^3/kg
W=m*P*(v_2-v_1);// kJ
printf("\nThe work done by the steam,W=%3.1f kJ",W);
```

Scilab code Exa 3.2 `The work done`

```
// Example 3_2
clc;funcprot(0);
// Given data
d=110/10^3;// The diameter of the cylinder in m
V_1=100;// The volume of the water in cm^3
m=50;// kg
g=9.81;// The acceleration due to gravity in m/s^2
P_atm=1*10^5;// Pa

// Calculation
A=(%pi*d^2)/4;// m^2
P=((m*g)/A)+P_atm;// Pa
V_1=V_1*10^-6;// m^3
v_1=0.001017;// m^3/kg
m=V_1/v_1;// kg
v_2=1.444;// m^3/kg
V_2=m*v_2;// m^3
W=P*(V_2-V_1);// The work done in J
printf(”\nThe work done,W=%5.0f J or %2.1f kJ”,W,W
   /10^3);
```

Scilab code Exa 3.3 `The work done by the gas`

```
// Example 3_3
clc;funcprot(0);
// Given data
P_1=200;// The initial pressure in kPa
V_1=2;// The initial volume in m^3
P_2=100;// The final pressure in kPa

// Calculation
C=P_1*V_1;// The constant
V_2=(P_1*V_1)/P_2;// The final volume in m^3
W_12=integrate(”C/V”,’V’,V_1,V_2);// kJ
printf(”\nThe work done by the gas,W_12=%3.0f kJ”,
```

```
  W_12);
```

Scilab code Exa 3.4 `The required horse power`

```
// Example 3_4
clc;funcprot(0);
// Given data
V=90;// km/h
C_D=0.2;// The drag coefficient
rho=1.23;// The density of air in kg/m^3
A=2.3;// m^2

// Calculation
V=V*(1000/3600);// The velocity in m/s
F_D=(1/2)*rho*(V^2)*A*C_D;// The drag force in N
W=F_D*V;// The work done in W
Hp=W/746;// The required horse power in hp
printf("\nThe required horse power,Hp=%1.2f hp",Hp);
```

Scilab code Exa 3.5 `The net work done`

```
// Example 3_5
clc;funcprot(0);
// Given data
m=100;// kg
d=3;// m
V=0.002;// m^3
P_gage=100;// The gage pressure in kPa
g=9.81;// m/s^2

// Calculation
F=m*g;// N
W=-(F)*(d);// J
```

```
P_abs=200;// The absolute pressure in kPa
W_p=P_abs*10^3*V;// The work done on the system in J
W_net=W+W_p;// The net work done in J
printf("\nThe net work done,W_net=%4.0f J",W_net);
```

Scilab code Exa 3.6 The horse power delivered

```
// Example 3_6
clc;funcprot(0);
// Given data
T=100;// The torque in N.m
n=3000;// rpm

// Calculation
omega=n*(2*%pi)*(1/60);// rad/s
W=T*omega;// The power in W
Hp=W/746;// The horse power in hp
printf("\nThe horse power delivered,Hp=%2.1f hp",Hp)
    ;
```

Scilab code Exa 3.7 The total work

```
// Example 3_7
clc;funcprot(0);
// Given data
d=50*10^-3;// The distance in m
K=2500;// N/m
m=50;// kg
d_p=10/100;// m
P_atm=100;// The atmospheric pressure in kPa
g=9.81;// m/s^2

// Calculation
```

```
W=m*g;// The weight in N
A=(%pi*d_p^2)/4;
P_1=((P_atm*10^3*A)+W)/A;// The pressure in the cylinder in Pa
W_1=(P_1*A)*d;// J
x_1=0;// m
x_2=d;// m
W_2=(1/2)*K*((x_2^2)-(x_1^2));// The work required to compress in J
W_total=W_1+W_2;// The total work in J
printf("\nThe total work,W_total=%2.2f J",W_total);
```

Scilab code Exa 3.8 `How much heat must be transferred to result in an equivalent e`

```
// Example 3_8
clc;funcprot(0);
// Given data
m=50;// The mass in kg
g=9.81;// The acceleration due to gravity in m/s^2
d=2;// The distance in m

// Calculation
W=m*g*d;// J
printf("\nThe heat Q that must be transferred equals the work,%3.0f J",W);
```

Chapter 4

THE FIRST LAW OF THERMODYNAMICS

Scilab code Exa 4.1 `The work done by the spring on the system`

```
// Example 4_1
clc;funcprot(0);
// Given data
s_0=0;// m
s_1=0.8;// The distance in m

// Calculation
W_12=integrate('100*x','x',s_0,s_1);// N.m
printf("\nThe work done by the spring on the system,
   W_12=%2.0f J",W_12);
```

Scilab code Exa 4.2 `The increase in internal energy`

```
// Example 4_2
clc;funcprot(0);
// Given data
```

```
P_in=5;// hp
t=1;// hour
// By assumption
Q=0;// J
delPE=0;// J
delKE=0;// J

// Calculation
W=-P_in*t*(746)*(3600);// The work input in J
delU=-W;// The increase in internal energy in J
printf(”\nThe increase in internal energy,delU=%1.3e
   J”,delU);
```

Scilab code Exa 4.3 `The final temperature`

```
// Example 4_3
clc;funcprot(0);
// Given data
V=6;// ft^3
p=400;// psia
T=900;//  F
Q=800;// Btu

// Calculation
u_1=1324;// Btu/lbm
v_1=1.978;// ft^3/lbm
m=V/v_1;// lbm
u_2=(Q/m)+u_1;// Btu/lbm
// At 500 psia
v_a=1.978;// ft^3/lbm
u_a=1459;// Btu/lbm
T_a=1221;//  F
// At 600 psia
v_b=1.978;// ft^3/lbm
u_b=1603;// Btu/lbm
```

```
T_b=1546;//  F
T_2=T_b-(((u_b-u_2)/(u_b-u_a))*(T_b-T_a));//  F
printf("\nThe final temperature,T_2=%4.0f F",T_2);
```

Scilab code Exa 4.4 `The final temperature`

```
// Example 4_4
clc;funcprot(0);
// Given data
P=400;// kPa
V_1=2;// m^3
T_2=200;//  C
Q=3500;// The amount of heat added in kJ

// Calculation
// Using the steam tables
v_1=0.5342;// m^3/kg
u_1=2674;// kJ/kg
m=V_1/v_1;// kg
// V_2=m*v_2
// Q-(P*(V_2-V_1))=(u_2-u_1)*m----->(a)
// This requires the trial and error process.
// For example,guess
v_2=1.0;// m^3/kg
u_2=((Q-(P*((m*v_2)-V_1)))/m)+u_1;// kJ/kg
// From the steam tables at P=0.4 MPa
T_2=654;//  C
// The v_2 gives
T_2=600;//  C
// Guess
v_2=1.06;// m^3/kg
u_2=((Q-(P*((m*v_2)-V_1)))/m)+u_1;// kJ/kg
// The tables are interpolated to give
T_2=640;//  C
// The v_2 gives
```

```
T_2=647;//   C
// The final temperature being approximately
T_2=644;//   C
printf("\nThe final temperature being approximately ,T_2=%3.0f C ",T_2);
```

Scilab code Exa 4.5 `The final temperature`

```
// Example 4_5
clc;funcprot(0);
// Given data
Q=3500;// kJ
V=2;// m^3
v=0.5342;// m^3/kg
h_1=2860;// kJ

// Calculation
m=V/v;// kg
h_2=(Q/m)+h_1;// kJ/kg
// From the steam tables this interpolates to
T_2=600+((92.6/224)*(100));//   C
printf("\nThe final temperature ,T_2=%3.0f C ",T_2);
```

Scilab code Exa 4.6 `The enthalpy change`

```
// Example 4_6
clc;funcprot(0);
// Given data
T_1=300;//   C
T_2=700;//   C
m=3;// kg

// Calculation
```

```
// (a)
delH=m*integrate('(2.07+((T-400)/1480))','T',T_1,T_2);
printf("\n(a)The enthalpy change,delH=%4.0f kJ",delH);
// From steam tables
h_1=3073;// kJ/kg
h_2=3928;// kJ/kg
delH=m*(h_2-h_1);// kJ/kg
printf("\n   Using the values from steam tables,the enthalpy change,delH=%4.0f kJ",delH);
// (b)
delT=T_2-T_1;//  C
c_pav=(m*integrate('(2.07+((T-400)/1480))','T',T_1,T_2))/(m*delT);// kJ/kg. C
printf("\n(b)The average value of c_p=%1.2f kJ/kg. C",c_pav);
// Using the values from steam tables
c_pav=(h_2-h_1)/delT;// kJ/kg. C
printf("\n   Using the values from steam tables,the average value of c_p=%1.2f kJ/kg. C",c_pav);
```

Scilab code Exa 4.7 `The value of Specific heat at constant pressure`

```
// Example 4_7
clc;funcprot(0);
// Given data
T=800;//  F
P=800;// psia

// Calculation
// To determine c_p we use finite difference approximation.We use entries at T=900  F and T=700  F
// From table C-3E
```

```
T_2=700;//  F
T_1=900;//  F
h_1=1455.6;// Btu/lbm
h_2=1338.0;// Btu/lbm
delh=h_1-h_2;// Btu/lbm
delT=T_1-T_2;//  F
c_p=delh/delT;// Btu/lbm- F
printf("\n The value of c_p is %0.3f Btu/lbm- F.",
   c_p);
```

Scilab code Exa 4.8 `The enthalpy change`

```
// Example 4_8
clc;funcprot(0);
// Given data
m=1;// The mass of nitrogen in kg
T_1=300;// K
T_2=1200;// K
M=28;// kg/kmol

// Calculation
// (a)
// Using the gas table in Appendix F,find the
   enthalpy change
h_1=8723;// kJ/kmol
h_2=36777;// kJ/kmol
delh=h_2-h_1;// kJ/mol
delh=delh/M;// kJ/kg
printf("\n(a)The enthalpy change,delh=%5.0f kJ/kmol
   or %4.0f kJ/kg",delh*M,delh);
// (b)
// The expression for c_p(T) is found in Table B-5.
delh=integrate('(39.06-(519.79*(T/100)^(-1.5))
   +(1072.7*(T/100)^(-2))-(820.4*(T/100)^(-3)))','T'
   ,T_1,T_2);// kJ/kmol
```

```
delh=delh/M;// kJ/kg
printf(”\n(b)The enthalpy change,delh=%5.0f kJ/kmol or %4.0f kJ/kg”,delh*M,delh);
// (c)
c_p=1.042;// kJ/kg.K
delh=c_p*(T_2-T_1);// kJ/kg
printf(”\n(c)The enthalpy change,delh=%3.0f kJ/kg”,delh);
```

Scilab code Exa 4.9 `The heat transfer`

```
// Example 4_9
clc;funcprot(0);
// Given data
x=70/100;// The quality of steam
p_1=200;// kPa
p_2=800;// kPa
V=2;// m^3
v_f=0.0011;// m^3/kg
v_fg=0.8857;// m^3/kg
u_f1=504.5;// kJ/kg
u_fg1=2529.5;// kJ/kg

// Calculation
v=v_f+(x*(v_fg-v_f));// m^3/kg
m=V/v;// The mass in kg
u_1=u_f1+(x*(u_fg1-u_f1));// The internal energy at state 1 in kJ/kg
// From the steam tables at 800 kPa we find by extrapolation
v_1=v;// m^3/kg
v_2=v_1;// m^3/kg
u_2=((0.6203-0.6181)/(0.6181-0.5601))*(3661-3476);// kJ/kg
Q=m*(u_2-u_1);// kJ
```

```
printf("\nThe heat transfer,Q=%4.0f kJ",Q);
// The answer provided in the textbook is wrong
```

Scilab code Exa 4.10 The paddel wheel work

```
// Example 4_10
clc;funcprot(0);
// Given data
V=0.02;// m^3
T_1=50;//  C
P=400;// kPa
Q=50;// The amount of heat added in kJ
T_2=700;//  C
R=287;// J/kg.K
c_p=1.00;// kJ/kg.K

// Calculation
m=((P*10^3)*V)/(R*(T_1+273));// The mass in kg
W_paddle=Q-(m*c_p*(T_2-T_1));// The paddel-wheel work in kJ
printf("\nThe paddel-wheel work,W_paddle=%1.3f kJ",W_paddle);
```

Scilab code Exa 4.11 The necessary work to compress air

```
// Example 4_11
clc;funcprot(0);
// Given data
V_1=6;// The initial volume in ft^3
V_2=1.2;// The final volume in ft^3
T_1=50+460;// The initial temperature in R
P_1=30;// psia
R=53.3;// Btu/lbm R
```

```
c_v=0.171;// // Btu/lbm R
k=1.4;// The specific heat ratio

// Calculation
m=((P_1*144)*V_1)/(R*T_1);// The mass in lbm
T_2=T_1*(V_1/V_2)^(k-1);// The final temperature in
   R
W=-m*c_v*(T_2-T_1);// Btu
printf("\nThe necessary work to compress air ,W=%2.1f
    Btu",W);
```

Scilab code Exa 4.12 `The mass flux`

```
// Example 4_12
clc;funcprot(0);
// Given data
d_1=20/10^3;// The diameter at inlet in m
d_2=40/10^3;// The diameter at exit in m
V_1=40;// The velocity at inlet in m/s
rho=1000;// kg/m^3

// Calculation
A_1=(%pi/4)*(d_1^2);// m^2
A_2=(%pi/4)*(d_2^2);// m^2
V_2=(A_1/A_2)*V_1;// The exit velocity of water in m
   /s
m=rho*A_1*V_1;// kg/s
printf("\nThe velocity in the 40 mm section ,V_2=%2.0
   f m/s \nThe mass flux ,m=%2.2f kg/s",V_2,m);
```

Scilab code Exa 4.13 `The specific volume of the steam at exit`

```
// Example 4_13
```

```
clc;funcprot(0);
// Given data
P_1=8000;// kPa
T_1=300;//  C
P_2=1600;// kPa
h_1=2785;// kJ/kg
h_g=2794;// kJ/kg

// Calculation
// By using steam tables
T_2=201.4;// The final temperature in  C
h_f2=859;// kJ/kg
h_fg2=1935;// kJ/kg
h_2=h_1;// kJ/kg
x_2=(h_2-h_f2)/h_fg2;// The quality of steam at exit
v_f2=0.0012;// m^3/kg
v_fg2=0.1238;// m^3/kg
v_2=v_f2+(x_2*(v_fg2-v_f2));// The specific volume of the steam at exit in m^3/kg
printf("\nThe final temperature of the steam,T_2=%3.1f C \nThe specific volume of the steam at exit,v_2=%0.4f m^3/kg",T_2,v_2);
```

Scilab code Exa 4.14 The kinetic energy change

```
// Example 4_14
clc;funcprot(0);
// Given data
P_1=4000;// kPa
T_1=500;//  C
d_1=50;// mm
V_1=200;// m/s
d_2=250;// mm
x_2=1.0;// The quality of steam at state 2

```

```
// Calculation
// (a)
v_1=0.08643;// m^3/kg
A_1=(%pi/4)*(d_1/1000)^2;// m^2
mdot=(1/v_1)*A_1*V_1;// kg/s
// The enthalpies are found from Tables C-3 and C-2 to be
h_1=3445.2;// kJ/kg
h_2=2665.7;// kJ/kg
W_T=-(h_2-h_1)*mdot;// The turbine power output in kJ/s
// (b)
v_2=2.087;// m^3/kg
A_2=(%pi/4)*(d_2/1000)^2;/// m^2
V_2=(A_1*V_1*(1/v_1))/(A_2*(1/v_2));// m/s
d_KE=mdot*((V_2^2-V_1^2)/2);// The kinetic energy change in J/s
printf("\n(a)The turbine power output,W_T=%4.0f kJ/s or %1.3f MW \n(b)The kinetic energy change,delKE=%4.0f J/s or %1.2f kJ/s",W_T,W_T/10^3,d_KE,d_KE/10^3);
```

Scilab code Exa 4.15 The maximum pressure rise

```
// Example 4_15
clc;funcprot(0);
// Given data
W_s=-10;// hp
d_1=1;// The diameter at inlet in inch
d_2=1.5;// The diameter at exit in inch
V_1=30;// The inlet velocity of water in ft/sec

// Calculation
A_1=(%pi/4)*(d_1^2);// in^2
A_2=(%pi/4)*(d_2^2);// in^2
```

```
V_2=(A_1/A_2)*V_1;// The exit velocity of water in ft/sec
rho=62.4;// kg/m^3
m=rho*(A_1/144)*V_1;// The mass flux in lbm/sec
dP=rho*[((-W_s*550)/m)-((V_2^2-V_1^2)/(2*32.4))];// The pressure rise in lbf/ft^2
printf(”\n The maximum pressure rise,P_2−P_1=%5.0f lbf/ft^2 or %3.1f psi”,dP,dP/144);
```

Scilab code Exa 4.16 The exit temperature and the exit diameter

```
// Example 4_16
clc;funcprot(0);
// Given data
P_1=7;// The inlet pressure in kPa
T_1=420;// The inlet temperature in  C
d_1=200;// The inlet diameter in mm
V_1=400;// The inlet velocity in m/s
V_2=700;// The exit velocity in m/s
c_p=1000;// J/kg.K
R=287;// J/kg.K
k=1.4;// The specific heat ratio

// Calculation
// (a)
T_2=((V_1^2-V_2^2)/(2*c_p))+T_1;// The exit temperature in  C
// (b)
rho_1=(P_1*10^3)/(R*(T_1+273));// kg/m^3
A_1=(%pi*(d_1/1000)^2)/4;// m^2
m=rho_1*A_1*V_1;// The mass flux in kg/s
// (c)
rho_2=rho_1*((T_2+273)/(T_1+273))^(1/(k-1));// The density at the exit in kg/m^3
d_2=sqrt((rho_1*(d_1/1000)^2*V_1)/(rho_2*V_2));//
```

```
The exit diameter in m
printf("\n(a)The exit temperature,T_2=%3.0f C \n(b)The mass flux,m=%0.4f kg/s \n(c)The exit diameter,d_2=%0.3f m or %3.0f mm",T_2,m,d_2,d_2*10^3);
```

Scilab code Exa 4.17 `The minimum mass flux of the water`

```
// Example 4_17
clc;funcprot(0);
// Given data
m_s=100;// kg/s
T_s1=450;// The inlet temperature of sodium in  C
T_s2=350;// The exit temperature of sodium in  C
c_p=1.25;// The specific heat of sodium in kJ/kg C

// Calculation
// Using the given values, we have (use Table C-4 to find h_w1)
h_w1=88.7;// kJ/kg
h_w2=2792.8;// kJ/kg
m_w=(m_s*c_p*(T_s1-T_s2))/(h_w2-h_w1);// The minimum mass flux of the water in kg/s
Q=m_w*(h_w2-h_w1);// The rate of heat transfer in kW
printf("\nThe minimum mass flux of the water,m_w=%1.3f kg/s \nThe rate of heat transfer,Q=%5.0f kW or %2.1f MW",m_w,Q,Q/10^3);
```

Scilab code Exa 4.18 `The thermal efficiency`

```
// Example 4_18
clc;funcprot(0);
// Given data
P_2=4000;// kPa
```

```
T_2=600;//  C
P_1=20;// kPa
v=0.001;// m^3/kg
m=1;// kg
h_1=251.4;// kJ/kg

// Calculation
w_P=(P_2-P_1)*v;// kJ/kg
h_2=w_P+h_1;// kJ/kg
// From steam tables
h_3=3674;// kJ/kg
h_4=2610;// kJ/kg
q_B=h_3-h_2;// kJ/kg
w_T=h_3-h_4;// The work output in kJ/kg
n=(w_T-w_P)/q_B;// The thermal efficiency
printf("\nThe thermal efficiency,n=%0.3f or %2.1f percentage",n,n*100);
```

Scilab code Exa 4.19 `The temperature of steam in the tank`

```
// Example 4_19
clc;funcprot(0);
// Given data
V=300;// ft^3
T=800;//  C
P=500;// psia
P_4=500;// psia

// Calculation
// (a)
Q=0;// Btu/lbm
m_i=0;// lbm
// From Table C-3E,
h_1=1412.1;// Btu/lbm
u_f=h_1;// Btu/lbm
```

```
// At T=1100,u_f=1406.0;T=1200,u_f=1449.2
T_f=(((u_f-1406.0)/(1449.2-1406.0))*(1200-1100))+1100;//  F
// (b)
v_f=(((T_f-1100)/(1200-1100))*(1.9518-1.8271))+1.8271;// ft^3/lbm
m_f=V/v_f;// lbm
printf("\n(a)The temperature of steam in the tank,T_f=%4.1f F \n(b)The mass of steam that flows into the tank,m=%3.1f lbm",T_f,m_f);
```

Scilab code Exa 4.20 `The final temperature of air in the tank`

```
// Example 4_20
clc;funcprot(0);
// Given data
V=20;// The volume of the air tank in m^3
P_i=10;// The initial pressure in MPa
T_i=25+273;// K
R=287;// J/kg.K
P_f=200;// The final pressure in kPa
k=1.4;// The specific heat ratio

// Calculation
m_i=(P_i*10^6*V)/(R*T_i);// The initial mass of air in kg
m_f=m_i*((P_f*10^3)/(P_i*10^6))^(1/k);// The final mass of air in kg
T_f=T_i*(m_f/m_i)^(k-1);// The final temperature of air in K
printf("\nThe mass of air remaining in the tank,m_f=%4.1f kg \nThe final temperature of air in the tank,T_f=%2.2f K or %3.1f C",m_f,T_f,T_f-273);
```

Chapter 5

THE SECOND LAW OF THERMODYNAMICS

Scilab code Exa 5.4 `The heat transfer from the high and the low temperature reserv`

```
// Example 5_4
clc;funcprot(0);
// Given data
T_H=200+273;// K
T_L=20+273;// K
W=15;// kW

// Calculation
Q_H=W/(1-(T_L/T_H));//kW
Q_L=Q_H-W;// kW
printf("\nThe heat transfer from the high temperature reservoir,Q_H=%2.2f kW \nThe heat transfer from the high temperature reservoir,Q_L=%2.2f kW",Q_H,Q_L);
```

Scilab code Exa 5.5 `The minimum percentage increase in work required`

```
// Example 5_5
clc;funcprot(0);
// Given data
T_H=20+273;// K
T_L1=-5+273;// K
T_L2=-25+273;// K

// Calculation
// W_1=0.0933*Q_L;
// W_2=0.181*Q_L;
// Percentage increase=(W_2-W_1)/W_1
Pi=((0.181-0.0933)/0.0933)*100;// %
printf("\nThe minimum percentage increase in work required is %2.1f percentage.",Pi);
```

Scilab code Exa 5.6 The thermal efficiency

```
// Example 5_6
clc;funcprot(0);
// Given data
T_H=500;// K
T_L=300;// K
P_1=80*10^3;// Pa
v_4=10;// m^3/kg
R=287;// J/kg.K
k=1.4;// The specific heat ratio

// Calculation
n=(1-(T_L/T_H))*100;// %
T_1=T_L;// K
T_2=T_H;// K
v_1=(R*T_1)/P_1;// m^3/kg
v_2=v_1*(T_1/T_2)^(1/(k-1));// m^3/kg
T_4=T_L;// K
T_3=T_H;// K
```

```
v_3=v_4*(T_4/T_3)^(1/(k-1));// m^3/kg
q_H=(R/10^3)*T_H*log(v_3/v_2);// kJ/kg
w=(n/100)*q_H;// kJ/kg
printf("\nThe thermal efficiency,n=%2.0f percentage \nThe work output,w=%3.0f kJ/kg",n,w);
```

Chapter 6

ENTROPY

Scilab code Exa 6.1 `The increase in entropy`

```
// Example 6_1
clc;funcprot(0);
// Given data
T_1=20;//  C
p_1=200;// kPa
W=720;// kJ
V_1=2;// m^3
R=0.287;// kJ/kg.K
c_v=0.717;// kJ/kg.K

// Calculation
m=(p_1*V_1)/(R*(T_1+273));// The mass in kg
T_2=(W/(m*c_v))+(T_1+273);// K
delS=m*c_v*log(T_2/(T_1+273));// kJ/K
printf("\nThe increase in entropy,delS=%1.3f kJ/K",
   delS);
```

Scilab code Exa 6.2 `The work done by the gases`

```
// Example 6_2
clc;funcprot(0);
// Given data
P_1=1200;// kPa
P_2=140;// kPa
T_1=350+273;// K
c_v=0.717;// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
T_2=T_1*(P_2/P_1)^((k-1)/k);// K
w=c_v*(T_1-T_2);// kJ/kg
printf("The work done by the gases ,w=%3.0f kJ/kg",w)
    ;
```

Scilab code Exa 6.3 `The entropy change`

```
// Example 6_3
clc;funcprot(0);
// Given data
T_1=20;//  C
P_1=200;// kPa
W=720;// kJ
V_1=2;// m^3
R=0.287;// kJ/kg.K
c_v=0.717;// kJ/kg.K

// Calculation
m=(P_1*V_1)/(R*(T_1+273));// The mass in kg
u_1=209.1;// kJ/kg
u_2=-(W/m)+u_1;// kJ/kg
T_2=501.2;// K
phi_2=2.222;// The relative humidity at state 2
phi_1=1.678;// The relative humidity at state 1
P_2=P_1*(T_2/(T_1+273));// kPa
```

```
delS=m*(phi_2-phi_1-(R*log(P_2/P_1)));// kJ/K
printf("\nThe entropy change,delS=%1.3f kJ/K",delS);
```

Scilab code Exa 6.4 `The work done by the gases`

```
// Example 6_4
clc;funcprot(0);
// Given data
P_1=1200;// kPa
T_1=350;//   C
P_2=140;// kPa

// Calculation
P_r1=((1/20)*(20.64-18.36))+18.36;// The relative pressure at state 1
P_r2=P_r1*(P_2/P_1);//  The relative pressure at state 2
T_2=(((2.182-2.149)/(2.626-2.149))*(360-340))+340;// K
u_1=((3/20)*(465.5-450.1))+450.1;// kJ/kg
u_2=(((2.182-2.149)/(2.626-2.149))*(257.2-242.8))+242.8;// kJ/kg
w=u_1-u_2;// The work done by the gases in kJ/kg
printf("\nThe work done by the gases,w=%3.1f kJ/kg",w);
```

Scilab code Exa 6.5 `The entropy change and the heat transfer`

```
// Example 6_5
clc;funcprot(0);
// Given data
P_1=100;// The initial pressure in psia
T_1=600;// The initial temperature in   F
```

```
P_2=10;// The final pressure in psia

// Calculation
// From steam tables
v_2=6.216;// ft^3/lbm
v_1=v_2;// ft^3/lbm
v_f2=0.0166;// ft^3/lbm
v_g2=38.42;// ft^3/lbm
x=(v_2-v_f2)/(v_g2-v_f2);// The quality of steam
// From steam tables
s_f2=0.2836;// Btu/lbm- R
s_fg2=1.5041;// Btu/lbm- R
s_1=1.7582;// Btu/lbm- R
s_2=s_f2+(x*s_fg2);// Btu/lbm- R
dels=s_2-s_1;// Btu/lbm- R
u_f2=161.2;// Btu/lbm
u_fg2=911.01;// Btu/lbm
u_1=1214.2;// Btu/lbm
q=[u_f2+(x*u_fg2)]-u_1;// Btu/lbm
printf(”\nThe entropy change,dels=%1.3f Btu/lbm- R
    \nThe heat transfer,q=%3.0f Btu/lbm”,dels,q);
```

Scilab code Exa 6.6 `The inequality of Clausius`

```
// Example 6_6
clc;funcprot(0);
// Given data
P_1=20;// kPa
P_2=1000;// kPa
P_3=P_2;// kPa
P_4=P_1;// kPa
x_4=0.88;// The quality of steam
m=1;// kg

// Calculation
```

```
// From steam tables
T_B=179.9;//  C
T_C=60.1;//  C
x_1=0.18;// The quality of steam at inlet
h_2=763;// kJ/kg
h_3=2778;// kJ/kg
Q_B=m*(h_3-h_2);// kJ
h_f4=251;// kJ/kg
h_fg4=2358;// kJ/kg
h_4=h_f4+(x_4*h_fg4);// kJ/kg
h_f1=251;// kJ/kg
h_fg1=2358;// kJ/kg
h_1=h_f1+(x_1*h_fg1);// kJ/kg
Q_C=m*(h_4-h_1);// kJ
dQbyT=(Q_B/(T_B+273))-(Q_C/(T_C+273));// kJ/K
printf("\ndQ/T=%0.3f kJ/K.This is negative,as it must be if the proposed power plant is to satisfy the inequality of Clausius.",dQbyT);
```

Scilab code Exa 6.7 The entropy change

```
// Example 6_7
clc;funcprot(0);
// Given data
R=53.3/778;//  Btu/lbm- R

// Calculation
delS=R*log(2);// The entropy change in Btu/lbm- R
printf("\nThe entropy change,delS=%0.5f Btu/lbm- R",delS);
```

Scilab code Exa 6.8 The net entropy change of the process

```
// Example 6_8
clc;funcprot(0);
// Given data
m=2;// The mass of steam in kg
T=400;//  C
P=600;// kPa
T_0=25+273;// K

// Calculation
// From steam tables
s_1=7.7086;// kJ/kg.K
s_2=1.9316;// kJ/kg.K
dS_sys=m*(s_2-s_1);// kJ/K
h_1=3270.2;// kJ/kg
h_2=670.6;// kJ/kg
Q=m*(h_1-h_2);// The heat transfer in kJ
dS_surr=Q/T_0;// kJ/K
dS_univ=dS_surr+dS_sys;// kJ/K
printf("\nThe net entropy change of the process, dS_univ=%1.2f kJ/K",dS_univ);
```

Scilab code Exa 6.9 `The rate of entropy production`

```
// Example 6_9
clc;funcprot(0);
// Given data
m_1=4;// kg/s
m_2=0.5;// kg/s
T_1=45;//  C
T_2=250;//  C
P=600;// kPa

// Calculation
m_3=m_2+m_1;// kg/s
// From steam tables
```

```
h_2=2957.2;// kJ/kg
h_1=188.4;// kJ/kg
h_3=((m_2*h_2)+(m_1*h_1))/m_3;// kJ/kg
// The exiting water temperature is interpolated from the saturated steam tables
h_f=496;// kJ/kg
T_3=(((496-461.3)/(503.7-461.3))*(110-100))+110;// The exiting water temperature in  C
s_3=1.508;// kJ/kg.K
s_2=7.182;// The entropy of the entering superheated steam in kJ/kg.K
s_1=0.639;// The entering entropy of the subcooled water in kJ/kg.K
S_prod=(m_3*s_3)-(m_2*s_2)-(m_1*s_1);// kW/K
printf("\nThe rate of entropy production,S_prod=%0.3f kW/K",S_prod);
```

Scilab code Exa 6.10 `The power output`

```
// Example 6_10
clc;funcprot(0);
// Given data
P_1=140;// The steam pressure at turbine inlet in psia
T_1=1000;// The temperature at turbine inlet in  F
P_2=2;// The steam pressure at turbine exit in psia
m=4;// lbm/sec

// Calculation
// From steam tables
h_1=1531;// Btu/lbm
s_2=1.8827;// Btu/lbm. R
s_1=s_2;// Btu/lbm. R
s_f2=0.1750;// Btu/lbm. R
s_fg2=1.7448;// Btu/lbm. R
```

```
x_2=(s_2-s_f2)/s_fg2;// Btu/lbm. R
h_f2=94.02;// Btu/lbm
h_fg2=1022.1;// Btu/lbm
h_2=h_f2+(x_2*h_fg2);// Btu/lbm
W_T=m*(h_1-h_2);// Btu/sec
printf("\nThe power output,W_T=%4.0f Btu/sec or %4.0f hp",W_T,W_T*1.414);
```

Scilab code Exa 6.11 `The temperature of the final state`

```
// Example 6_11
clc;funcprot(0);
// Given data
// From example 6.10
P_1=140;// The steam pressure at turbine inlet in psia
T_1=1000;// The temperature at turbine inlet in  F
P_2=2;// The steam pressure at turbine exit in psia
m=4;// lbm/sec
W_s=1748;// Btu/sec
n_t=0.80;// The isentropic efficiency of the turbine
h_1=1521;// Btu/lbm

// Calculation
W_a=n_t*W_s;// Btu/sec
h_2a=h_1-(W_a/m);// Btu/lbm
P_2a=2;// psia
T_2a=(((1186-1182)/(1186-1168))*(280-240))+280;// F
s_2a=2.0526;// Btu/lbm. R
printf("\nThe temperature of the final state,T_2a=%3.0f F \nThe entropy of thefinal state,s_2a=%1.4f Btu/lbm. R",T_2a,s_2a);
```

Chapter 7

REVERSIBLE WORK IRREVERSIBILITY AND AVAILABILITY

Scilab code Exa 7.1 `The second law efficiency`

```
// Example 7_1
clc;funcprot(0);
// Given data
P_1=12;// The pressure at turbine inlet in MPa
T_1=700;//  C
P_2=0.6;// The pressure at turbine exit in MPa
n_T=0.88;// The isentropic efficiency of the turbine

// Calculation
// (a)
// From the steam tables
s_1=7.0757;// kJ/kg.K
s_2=s_1;// kJ/kg.K
T_2=225.2;//  C
h_1=3858.4;// kJ/kg
h_2=2904.1;// kJ/kg
w_a=h_1-h_2;// kJ/kg
```

```
T_0=298;// K
w_rev=(h_1-h_2)-(T_0*(s_2-s_1));// kJ/kg
i=w_rev-w_a;// The irreversibility for an ideal turbine in kJ/kg
printf("\n(a)The reversible work,w_rev=%3.1f kJ/kg \n   The irreversibility for an ideal turbine,i=%0.1f kJ/kg",w_rev,i);
// (b)
w_ideal=w_rev;// kJ/kg
w_a=n_T*w_ideal;// The actual work in kJ/kg
h_2=h_1-w_a;// kJ/kg
// From the steam tables
T_2=279.4;//  C
s_2=7.2946;// kJ/kg
w_rev=(h_1-h_2)-(T_0*(s_1-s_2));// kJ/kg
n_II=w_a/w_rev;// The second law efficiency
i=w_rev-w_a;// The irreversibility in kJ/kg
printf("\n(b)The reversible work,w_rev=%3.0f kJ/kg \n   The irreversibility ,i=%2.1f kJ/kg \n   The second law efficiency ,n_II=%0.3f.",w_rev,i,n_II);
```

Scilab code Exa 7.2 `The irreversibility`

```
// Example 7_2
clc;funcprot(0);
// Given data
P_1=15;// The pressure at inlet in psia
P_2=75;// The pressure at exhaust in psia
T_1=80;// The temperature at inlet in  F
T_2=440;// The temperature at exhaust in  F
T_0=537;//  F
R=53.3/778;// Btu/lbmol. R

// Calculation
// Using values from air tables
```

```
phi_1=0.60078;// Btu/lbmol. R
phi_2=0.72438;// Btu/lbmol. R
ds=(phi_2-phi_1)-((R)*log(P_2/P_1));// The entropy
   change in Btu/lbm. R
i=T_0*ds;// The irreversibility in Btu/lbm
printf("\nThe irreversibility,i=%1.2f Btu/lbm",i);
```

Scilab code Exa 7.3 `The availability of Nitrogen`

```
// Example 7_3
clc;funcprot(0);
// Given data
m_CO2=0.1;// lbm of CO_2
m_N2=0.1;// lbm of N_2
T_0=77+460;// R
P=30;// psia
P_0=14.7;// psia
T=440;// F
R=1.986;// Btu/lbmol- R

// Calculation
// Use table F-4E,for CO_2
h=7597.6;// Btu/lbmol
h_0=4030.2;// Btu/lbmol
phi=56.070;// Btu/lbmol- R
phi_0=51.032;// Btu/lbmol- R
X_CO2=(m_CO2/44)*[(h-h_0)-(T_0*((phi-phi_0)-(R*log(P
   /P_0))))];// The availability of CO_2 in Btu
printf("\nThe availability of CO_2,X=%1.2f Btu",
   X_CO2);
// Use table F-4E,for N_2
h=6268.1;// Btu/lbmol
h_0=3279.5;// Btu/lbmol
phi=49.352;// Btu/lbmol- R
phi_0=45.743;// Btu/lbmol- R
```

```
X_N2=(m_N2/28)*[(h-h_0)-(T_0*((phi-phi_0)-(R*log(P/P_0))))];// The availability of N_2 in Btu
printf("\nThe availability of N_2,X=%1.2f Btu",X_N2);
```

Scilab code Exa 7.4 The amount of useful work wasted in the condenser

```
// Example 7_4
clc;funcprot(0);
// Given data
x=0.85;// The quality of steam
P=5;// kPa
T_0=298;// K

// Calculation
// From steam tables
h_1=2197.2;// kJ/kg
h_2=136.5;// kJ/kg
s_1=7.2136;// kJ/kg.K
s_2=0.4717;// kJ/kg.K
dX=(h_1-h_2)-(T_0*(s_1-s_2));// The amount of useful work wasted in the condenser in kJ/kg
printf("\nThe amount of useful work wasted in the condenser,X_2-X_1=%2.1f kJ/kg",dX);
```

Scilab code Exa 7.5 The exergy of steam

```
// Example 7_5
clc;funcprot(0);
// Given data
T=500;//  F
P=300;// psia
T_0=76;//  F
```

```

// Calculation
// From the superheated steam tables,
h=1257.5;// Btu/lbm
S=1.5701;// Btu/lbm. R
E=h-((T_0+460)*S);// The exergy of steam in Btu/lbm
printf("\nThe exergy of steam,E=%3.1f Btu/lbm",E);
```

Scilab code Exa 7.6 The second law effectiveness for an ideal isentropic nozzle

```
// Example 7_6
clc;funcprot(0);
// Given data
T_1=1000;// K
P_1=0.5;// The inlet pressure in MPa
P_2=0.1;// The exit pressure in MPa
T_0=298;// K
R=0.286;// kJ/kg.K

// Calculation
// From the air tables
phi_1=2.968;// kJ/kg.K
phi_2=phi_1-(R*log(P_1/P_2));// kJ/kg.K
// Thus
T_2=657.5;// K
h_2=667.8;// kJ/kg
h_1=1046.1;// kJ/kg
h_0=298.2;// kJ/kg
V_2=sqrt(2)*((h_1-h_2)*10^3)^(0.5);// m/s
P_0=P_2;// MPa
phi_0=1.695;// kJ/kg.K
X_2=(h_2-h_0)+((V_2)^2/(2*1000))-(T_0*(phi_2-phi_0-(R*log(P_2/P_0))));// kJ/kg
X_1=h_1-h_0-(T_0*(phi_1-phi_0-(R*log(P_1/P_0))));// The availability supplied in kJ/kg
```

```
e_II=X_2/X_1;// The second law effectiveness for an ideal isentropic nozzle
printf("\nThe second law effectiveness for an ideal isentropic nozzle,e_II=%1.2f",e_II);
// The answer provided in the textbook is wrong
```

Scilab code Exa 7.7 The second law effectiveness

```
// Example 7_7
clc;funcprot(0);
// Given data
P_1=1*10^6;// Pa
T_1=300+273;// K
P_2=0.1*10^6;// Pa
P_3=0.01*10^6;// Pa
T_0=25+273;// K
rho=1000;// kg/m^3

// Calculation
// From steam tables
h_1=3051.2;// kJ/kg
s_1=7.1237;// kJ/kg.K
s_2=s_1;// kJ/kg.K
// At P=0.1 MPa,
x_2=0.96;// The quality of steam at state 2
h_2=2587.3;// kJ/kg
s_3=s_2;// kJ/kg.K
// At P=0.01 MPa,
x_3=0.86;// The quality of steam at state 3
h_3=2256.9;// kJ/kg
// The dead state for water is liquid at 25 C and 100 kPa
h_f=104.9;// kJ/kg
h_0=h_f;// kJ/kg
s_f=0.3672;// kJ/kg.K
```

```
s_0=s_f;// kJ/kg.K
m_1=1;// kg
m_2=0.10;// kg
m_3=m_1-(10/100);// kg
m_4=0.10;// kg
s_4=0.6491;// kJ/kg
h_4=191.8;// kJ/kg
h_6=192.8;// kJ/kg
X_2=m_2*[h_2-h_0-(T_0*(s_2-s_0))];// The availability at state 2 in kJ
W_turb=(m_1*(h_1-h_2))+(m_3*(h_2-h_3));// kJ
X_4=m_4*[h_4-h_0-(T_0*(s_4-s_0))];// The availability at state 4 in kJ
W_pump=m_1*((P_1/10^3)-(P_2/10^3))/rho;// kJ
Q_boil=m_1*(h_1-h_6);// kJ
e_II=(X_2+W_turb)/(X_4+W_pump+([1-(T_0/T_1)]*Q_boil));// The second law effectiveness
printf("\nThe second law effectiveness ,e_II=%0.2f",e_II);
```

Chapter 8

POWER AND REFRIGERATION VAPOR CYCLES

Scilab code Exa 8.1 `The maximum possible efficiency from the power cycle`

```
// Example 8_1
clc;funcprot(0);
// Given data
P_1=10;// kPa
P_2=2000;// kPa
T_3=400;//  C
h_f=191.8;// kJ/kg
h_1=h_f;// kJ/kg
h_3=3248;// kJ/kg
s_3=7.1279;// kJ/kg.K

// Calculation
v_1=0.001;// m^3/kg
w_P=v_1*(P_2-P_1);// The pump work in kJ/kg
h_2=h_1+w_P;// kJ/kg
q_B=h_3-h_2;// The heat input in kJ/kg
s_4=s_3;// kJ/kg.K
```

```
x_4=0.8636;// The quality of steam at state 4
h_f4=h_f;// kJ/kg
h_fg4=2393;// kJ/kg
h_4=h_f4+(x_4*h_fg4);// kJ/kg
w_T=h_3-h_4;// kJ/kg
n=(w_T-w_P)/q_B;// The cycle efficiency
printf("\nThe maximum possible efficiency from the power cycle,n=%0.4f or %2.2f percentage.",n,n*100);
```

Scilab code Exa 8.2 `The percentage increase in efficiency`

```
// Example 8_2
clc;funcprot(0);
// Given data
P_1=10;// kPa
P_2=4;// MPa
T_3=400;//  C
h_2=192;// kJ/kg
h_3=3214;// kJ/kg
s_3=6.7698;// kJ/kg.K

// Calculation
s_f4=0.6491;// kJ/kg.K
s_fg4=7.5019;// kJ/kg.K
s_4=s_3;// kJ/kg.K
x_4=(s_4-s_f4)/s_fg4;// The quality of steam at state 4
q_B=h_3-h_2;// The heat input in kJ/kg
h_f4=192;// kJ/kg
h_fg4=2393;// kJ/kg
h_4=h_f4+(x_4*h_fg4);// kJ/kg
w_T=h_3-h_4;// kJ/kg
n_2=w_T/q_B;// The cycle efficiency
// From example 8.1
```

```
n_1=0.3232;// The power cycle efficiency at P_2=2 MPa
Pi=((n_2-n_1)/n_1)*100;// The percentage increase in efficiency
printf(" The percentage increase in efficiency is %1.2f percentage.",Pi);
```

Scilab code Exa 8.3 `The percentage increase in efficiency`

```
// Example 8_3
clc;funcprot(0);
// Given data
P_1=10;// kPa
P_2=2;// MPa
T_3=600;//  C
h_2=192;// kJ/kg
h_3=3690;// kJ/kg
s_3=7.7032;// kJ/kg.K

// Calculation
s_f4=0.6491;// kJ/kg.K
s_fg4=7.5019;// kJ/kg.K
s_4=s_3;// kJ/kg.K
x_4=(s_4-s_f4)/s_fg4;// The quality of steam at state 4
q_B=h_3-h_2;// The heat input in kJ/kg
h_f4=192;// kJ/kg
h_fg4=2393;// kJ/kg
h_4=h_f4+(x_4*h_fg4);// kJ/kg
w_T=h_3-h_4;// kJ/kg
n_2=w_T/q_B;// The cycle efficiency
// From example 8.1
n_1=0.3232;// The power cycle efficiency at T_3=400 C
Pi=((n_2-n_1)/n_1)*100;// The percentage increase in
```

```
efficiency
printf(" The percentage increase in efficiency is %1.1f percentage.",Pi);
```

Scilab code Exa 8.4 `The percentage increase in efficiency`

```
// Example 8_4
clc;funcprot(0);
// Given data
P_1=4;// kPa
P_2=2;// MPa
T_3=400;//  C
h_2=192;// kJ/kg
h_3=3248;// kJ/kg
s_3=7.1279;// kJ/kg.K

// Calculation
s_f4=0.4225;// kJ/kg.K
s_fg4=8.0529;// kJ/kg.K
s_4=s_3;// kJ/kg.K
x_4=(s_4-s_f4)/s_fg4;// The quality of steam at state 4
q_B=h_3-h_2;// The heat input in kJ/kg
h_f4=121;// kJ/kg
h_fg4=2433;// kJ/kg
h_4=h_f4+(x_4*h_fg4);// kJ/kg
w_T=h_3-h_4;// kJ/kg
n_2=w_T/q_B;// The cycle efficiency
// From example 8.1
n_1=0.3232;// The power cycle efficiency at P_1=10 MPa
Pi=((n_2-n_1)/n_1)*100;// The percentage increase in efficiency
printf("\nThe percentage increase in efficiency is %1.1f percentage.",Pi);
```

Scilab code Exa 8.5 `The thermal efficiency`

```
// Example 8_5
clc;funcprot(0);
// Given data
P_3=600;// psia
T_3=1000;//  F
P_4=40;// psia
T_4=600;//  F
P_5=2;// psia

// Calculation
// From Table C-2E
h_2=94;// Btu/lbm
h_1=h_2;// Btu/lbm
// From Table C-3E
h_3=1518;// Btu/lbm
s_3=1.716;// Btu/lbm- R
s_4=s_3;// Btu/lbm- R
h_4=(((1.716-1.712)/(1.737-1.712))*(1217-1197))+1197;// Btu/lbm
// At 40 psuia and 600  F
h_5=1333;// Btu/lbm
s_5=1.862;// Btu/lbm- R
s_6=s_5;// Btu/lbm- R
s_f6=0.175;// Btu/lbm- R
s_fg6=1.745;// Btu/lbm- R
x_6=(s_6-s_f6)/s_fg6;// The quality of steam at state 6
h_f6=94;// Btu/lbm
h_fg6=1022;// Btu/lbm
h_6=h_f6+(x_6*h_fg6);// Btu/lbm
q_B=(h_5-h_4)+(h_3-h_2);// The energy input in Btu/lbm
```

```
w_T=(h_5-h_6)+(h_3-h_4);// The energy output in Btu/lbm
n=w_T/q_B;// The thermal efficiency
printf("\nThe thermal efficiency,n=%0.3f or %2.1f percentage.",n,n*100);
```

Scilab code Exa 8.6 `The percentage increase in efficiency`

```
// Example 8_6
clc;funcprot(0);
// Given data
P_1=10;// kPa
P_2=2;// MPa
P_5=200;// kPa
T_3=600;//  C
h_2=192;// kJ/kg
h_3=3690;// kJ/kg
s_3=7.7032;// kJ/kg.K

// Calculation
// We have from Example 8.3 and the steam tables
h_1=h_2;// kJ/kg
h_7=505;// kJ/kg
h_6=h_7;// kJ/kg
h_4=2442;// kJ/kg
h_5=(((7.7032-7.5074)/(7.7094-7.5074))*(2971-2870))+2870;// kJ/kg
m_6=1;// kg
m_5=((h_6-h_2)/(h_5-h_2))*m_6;// kg
m_2=m_6-m_5;// kg
w_T=(h_3-h_5)+((h_5-h_4)*m_2);// The work output from the turbine in kJ/kg
q_B=h_3-h_7;// kJ/kg
n_2=w_T/q_B;// The cycle efficiency
n_1=0.3568;// The power cycle efficiency from
```

```
example 8.3
Pi=((n_2-n_1)/n_1)*100;// The percentage increase in efficiency
printf(" The percentage increase in efficiency is %1.2f percentage.",Pi);
```

Scilab code Exa 8.7 The efficiency of the reheat regeneration cycle

```
// Example 8_7
clc;funcprot(0);
// Given data
P_3=600;// psia
T_3=1000;// F
P_4=40;// psia
T_4=600;// F
P_6=2;// psia

// Calculation
// We have from Example 8.5 and the steam tables
h_1=94;// Btu/lbm
h_2=h_1;// Btu/lbm
h_8=236;// Btu/lbm
h_3=1518;// Btu/lbm
h_7=h_8;// Btu/lbm
h_5=1333;// Btu/lbm
h_6=1086;// Btu/lbm
h_4=1200;// Btu/lbm
m_6=1;// kg
m_4=((h_8-h_2)/(h_4-h_2))*m_6;// lbm
m_2=m_6-m_4;// lbm
w_T=(h_3-h_4)+((h_5-h_6)*m_2);// The work output from the turbine in Btu/lbm
q_B=h_3-h_8+((h_5-h_4)*m_2);// Btu/lbm
n=w_T/q_B;// The efficiency of the reheat-regeneration cycle
```

```
printf("\nThe efficiency of the reheat−regeneration cycle,n=%0.3f or %2.1f percentage.",n,n*100);
```

Scilab code Exa 8.8 `The maximum possible cycle efficiency`

```
// Example 8_8
clc;funcprot(0);
// Given data
P_1=0.01;// MPa
P_3=0.2;// MPa
P_4=4;// MPa
P_5=30;// MPa
T_6=600;//  C
T_8=T_6;//  C
T_10=350;//  C
mdot=1;// kg/s

// Calculation
// The enthalpies are found frrom the steam tables to be
h_1=192;// kJ/kg
h_2=h_1;// kJ/kg
h_4=1087;// kJ/kg
h_5=h_4;// kJ/kg
h_8=3674;// kJ/kg
h_3=505;// kJ/kg
h_6=3444;// kJ/kg
h_10=3174;// kJ/kg
s_6=6.2339;// kJ/kg.K
s_7=s_6;// kJ/kg.K
h_7=(((6.2239-6.0709)/(6.3622-6.0709))*(2961-2801))+2801;// kJ/kg
s_8=7.3696;// kJ/kg.K
s_9=s_8;// kJ/kg.K
h_9=(((6.2239-6.0709)/(6.3622-6.0709))*(2961-2801))
```

```
+2801;// kJ/kg
s_10=8.0636;// kJ/kg.K
s_11=s_10;// kJ/kg.K
s_f11=0.6491;// kJ/kg.K
s_fg11=7.5019;// kJ/kg.K
x_11=(s_11-s_f11)/s_fg11;// The quality of steam at state 11
h_f11=192;// kJ/kg
h_fg11=2393;// kJ/kg
h_11=h_f11+(x_11*h_fg11);// kJ/kg
mdot7=(h_5-h_3)/(h_7-h_3);// kg/s
mdot9=(((1-mdot7)*h_3)-h_2+(mdot7*h_2))/(h_9-h_2);// kg/s
W_T=((mdot)*(h_6-h_7))+((1-mdot7)*(h_8-h_9))+((1-mdot7-mdot9)*(h_10-h_11));// The power from the turbine in kW
Q_B=((mdot)*(h_6-h_5))+((1-mdot7)*(h_8-h_7))+((1-mdot7-mdot9)*(h_10-h_9));// The boiler energy input in kW
n=W_T/Q_B;// The cycle efficiency
printf(”\nThe maximum possible cycle efficiency,n=%0.3f or %2.1f percentage.”,n,n*100);
```

Scilab code Exa 8.9 `The temperature of steam at tthe turbine outlet`

```
// Example 8_9
clc;funcprot(0);
// Given data
P_1=10;// kPa
P_2=2;// MPa
T_3=600;// C
n_T=80/100;// The efficiency of the turbine

// Calculation
// From the steam tables we find
```

```
h_2=192;// kJ/kg
h_1=h_2;// kJ/kg
h_3=3690;// kJ/kg
s_3=7.7032;// kJ/kg.K
s_4a=s_3;// kJ/kg.K
s_f4a=0.6491;// kJ/kg.K
s_fg4a=7.5019;// kJ/kg.K
x_4a=(s_4a-s_f4a)/s_fg4a;// The quality of steam at state 4'
h_f4a=192;// kJ/kg
h_fg4a=2393;// kJ/kg
h_4a=h_f4a+(x_4a*h_fg4a);// kJ/kg
w_a=n_T*(h_3-h_4a);// kJ/kg
q_B=h_3-h_2;// kJ/kg
n=w_a/q_B;// The cycle efficiency
h_4=h_3-w_a;// kJ/kg
// The temperature is interpolated to be
T_4=(((2692-2688)/(2783-2688))*(150-100))+100;//  C
printf("\nThe cycle efficiency,n=%0.3f or %2.1f percentage. \nThe temperature of steam at tthe turbine outlet,T_4=%3.0f C",n,n*100,T_4);
```

Scilab code Exa 8.10 The coefficient of performance if the cycle is operated as a

```
// Example 8_10
clc;funcprot(0);
// Given data
T_1=-20;//  C
T_3=41.64;//  C
mdot=0.6;// kg/s

// Calculation
h_1=178.6;// kJ/kg
h_4=76.3;// kJ/kg
h_3=h_4;// kJ/kg
```

```
s_1=0.7082;// kJ/kg.K
s_2=s_1;// kJ/kg.K
h_2=(((0.7082-0.7021)/(0.7254-0.7021))*(217.8-210.2))+210.2;// kJ/kg
Q_E=mdot*(h_1-h_4);// The rate of refrigeration in kW
W_C=mdot*(h_2-h_1);// The power needed to operate the compressor in kW
COP=Q_E/W_C;// The coefficient of performance
printf("\nThe rate of refrigeration,Q_E=%2.1f kW \nThe coefficient of performance,COP=%1.2f",Q_E,COP);
Hp=(W_C/0.746)/(Q_E/3.52);// The rating in Hp/ton
COP=(h_2-h_3)/(h_2-h_1);// The coefficient of performance
printf("\nThe rating in Hp/ton=%1.2f \nThe coefficient of performance if the cycle is operated as a heat pump,COP=%1.2f",Hp,COP);
```

Scilab code Exa 8.11 `The rate of refrigeration`

```
// Example 8_11
clc;funcprot(0);
// Given data
T_1=-10;//  C
T_3=40;//  C
P_1=0.15;// MPa
n_c=0.80;// The efficiency of the compressor
mdot=0.6;// kg/s

// Calculation
// From appendix D we find, using T_3=40 C
h_4=74.5;// kJ/kg
h_3=h_4;// kJ/kg
// From table D-3 at P_1=0.15 MPa and T_1=10 C
```

```
h_1=185;// kJ/kg
s_1=0.732;// kJ/kg.K
s_2a=s_1;// kJ/kg.K
P_2=1.0;// MPa
h_2a=(((0.732-0.7254)/(0.7476-0.7254))*(225.3-217.8))+218;// kJ/kg
h_2=((h_2a-h_1)/n_c)+h_1;// kJ/kg
Q_E=mdot*(h_1-h_4);// The rate of refrigeration in kW
COP=Q_E/(mdot*(h_2-h_1));// The coefficient of performance
printf("\nThe rate of refrigeration,Q_E=%2.1f kW \nThe coefficient of performance,COP=%1.2f",Q_E,COP);
```

Scilab code Exa 8.12 `The coefficient of performance`

```
// Example 8_12
clc;funcprot(0);
// Given data
T_1=-20;//  C
T_3=41.64;//  C
m_L=0.6;// kg/s
P_L=151;// kPa
P_H=1000;// kPa

// Calculation
P_i=(P_L*P_H)^(1/2);// kPa
// From appendix D we find,
h_1=178.6;// kJ/kg
s_1=0.7082;// kJ/kg.K
s_2=s_1;// kJ/kg.K
h_7=76.3;// kJ/kg
h_8=h_7;// kJ/kg
h_3=(((389-320)/(400-320))*(43.6-37.1))+37.1;// kJ/
```

```
kg
h_4=h_3;// kJ/kg
s_6=(((389-320)/(400-320))*(0.6928-0.6960))+0.6960;// kJ/kg.K
s_5=s_6;// kJ/kg.K
h_5=(((389-320)/(400-320))*(190.97-188.0))+188.0;// kJ/kg
// At P_i=389 kPa we interpolate and obtain
// T=10 C s=0.6993 kJ/kg.K h=193.8 kJ/kg
// T=20 C s=0.7226 kJ/kg.K h=200.3 kJ/kg
// This gives
h_2=(((0.7082-0.6993)/(0.7226-0.6993))*(200.3-193.8))+193.8;// kJ/kg
// Also,extrapolating,we find
h_6=(((0.6932-0.7021)/(0.7254-0.7021))*(217.8-210.2))+210.2;// kJ/kg
Q_E=m_L*(h_1-h_4);// kW
m_H=m_L*((h_2-h_3)/(h_5-h_8));// The mass flux in the high pressure stage in kg/s
W_in=(m_L*(h_2-h_1))+(m_H*(h_6-h_5));// The power input to the compressors in kW
COP=Q_E/W_in;// The coefficient of performance
printf("\nThe rate of refrigeration,Q_E=%2.1f kW \nThe coefficient of performance,COP=%1.2f",Q_E,COP);
```

Scilab code Exa 8.13 The cost of the electricity and the gas

```
// Example 8_13
clc;funcprot(0);
// Given data
T_1=-10;// C
P_3=0.9;// MPa
Q_C=300;// kW
C=0.07;// $/kWh
```

```
C_n=0.50;// The cost of operating a furnace in $/therm
q=100000;// kJ/therm

// Calculation
// (a)
// From appendix D we find ,
h_1=183.1;// kJ/kg
s_1=0.7014;// kJ/kg.K
s_2=s_1;// kJ/kg.K
h_3=71.9;// kJ/kg
h_4=h_3;// kJ/kg
h_2=(((0.7014-0.6982)/(0.7131-0.6982))*(211.8-204.2))+204.2;// kJ/kg
mdot=Q_C/(h_2-h_3);// The refrigerant mass flux in kg/s
W_in=mdot*(h_2-h_1);// The compressor power in kW
COP=Q_C/W_in;// The coefficient of performance
// (b)
Coe=W_in*C;// The cost of electricity in $/h
// (c)
Cog=((Q_C*3600)/q)*C_n;// The cost of gas in $/h
printf("\n(a)The coefficient of performance,COP=%1.2f \n(b)The cost of electricity=$%1.2f/h \n(c)The cost of gas=$%1.2f/h",COP,Coe,Cog);
```

Chapter 9

POWER AND REFRIGERATION CYCLES

Scilab code Exa 9.1 `The power required to drive the adiabatic compressor`

```
// Example 9_1
clc;funcprot(0);
// Given data
m=20;// The mass flow rate of air in kg/min
P_2=1600;// kPa
T_1=20+273;// K
P_1=100;// kPa
n=0.90;// The efficiency of the compressor
c_p=1.006;// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
// Assume T_2'=T_2a
T_2a=T_1*(P_2/P_1)^((k-1)/k);// K
T_2=T_1+((1/n)*(T_2a-T_1));// K
W_comp=(m/60)*c_p*(T_2-T_1);// The required power in
    kW
printf("\nThe power required to drive the adiabatic
    compressor,W_comp=%3.1f kW",W_comp);
```

Scilab code Exa 9.2 `The power required to drive the two stage adiabatic compressor`

```
// Example 9_2
clc;funcprot(0);
// Given data
m=20;// The mass flow rate of air in kg/min
P_4=1600;// kPa
T_1=20+273;// K
P_1=100;// kPa
n=0.90;// The efficiency of the compressor
c_p=1.00;// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
P_2=sqrt(P_1*P_4);// kPa
T_3=T_1;// K
T_2a=T_1*(P_2/P_1)^((k-1)/k);// K
// Assume T_2'=T_2a
// P_4/P_3=P_2/P_1
T_4a=T_3*(P_2/P_1)^((k-1)/k);// K
T_2=T_1+((1/n)*(T_2a-T_1));// K
T_4=T_2;// K
W_comp=((m/60)*c_p*(T_2-T_1))+((m/60)*c_p*(T_4-T_3));// The required power in kW
printf(”\nThe power required to drive the two−stage adiabatic compressor,W_comp=%3.0f kW”,W_comp);
```

Scilab code Exa 9.3 `The percent clearance and MEP`

```
// Example 9_3
clc;funcprot(0);
```

```
// Given data
r=12;// The compression ratio
P_1=200;// kPa
P_3=10000;// kPa
k=1.4;// The specific heat ratio

// Calculation
// (a)
c=(1/(12-1))*100;// The percent clearance in %
// (b)
// r=V_1/V_2
P_2=P_1*(r)^k;// kPa
// V_3/V_4=V_2/V_1
P_4=P_3*(1/r)^k;// kPa
// W_cycle=20070*V_2;.............(1)
// W_cycle=MEP*(12V_2-V_2);.......(2)
// Solving equations (1)&(2) we get,
MEP=20070/11;// kPa
printf("\n(a)The percent clearance,c=%1.2f percentage \n(b)MEP=%4.0f kPa",c,MEP);
```

Scilab code Exa 9.4 `The maximum possible efficiency and MEP`

```
// Example 9_4
clc;funcprot(0);
// Given data
r=10;// The compression ratio
T_1=200+273;// K
P_1=200;// kPa
w_net=1000;// kJ/kg
c_v=0.717;// kJ/kg.K
R=0.287;// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
```

```
T_2=T_1*(r)^(k-1);// K
function[X]=temperature(y)
              X(1)=w_net-((c_v*(T_1-T_2))+(c_v*(y(1)
                 -y(2))))
              X(2)=y(1)-(y(2)*(r)^(k-1));
endfunction
y=[1000 1000];
z=fsolve(y,temperature);
T_3=z(1);// K
T_4=z(2);// K
n_carnot=(1-(T_1/T_3));// %
v_1=(R*T_1)/P_1;// m^3/kg
// v_2=v_1/r;
MEP=w_net/(0.9*v_1);// kPa
printf("\nThe maximum possible efficiency ,n_carnot=
   %0.3f or %2.1f percentage.\nMEP=%4.0f kPa",
   n_carnot,n_carnot*100,MEP);
```

Scilab code Exa 9.5 `The thermal efficiency`

```
// Example 9_5
clc;funcprot(0);
// Given data
r=18;// The compression ratio
T_1=200+273;// K
P_1=200;// kPa
w_net=1000;// kJ/kg
c_p=1.00;// kJ/kg.K
c_v=0.717;// kJ/kg.K
R=0.287;// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
v_1=(R*T_1)/P_1;// m^3/kg
v_2=v_1/r;// m^3/kg
```

```
T_2=T_1*(r)^(k-1);// K
P_2=P_1*(r)^(k);// kPa
function[X]=temperature(y)
              X(1)=w_net-((c_p*(y(1)-T_2))+(c_v*(T_1-y(2))));
              v_4=v_1;// m^3/kg
              X(2)=y(2)-(y(1)*(y(3)/v_4)^(k-1));
              X(3)=(y(1)/y(3))-(T_2/v_2);
endfunction
y=[1000 1000 0.01];
z=fsolve(y,temperature);
T_3=z(1);// K
T_4=z(2);// K
v_3=z(3);// m^3/kg
r_c=v_3/v_2;// The cut off ratio
n=(1-((1/(r^(k-1)))*(((r_c^k)-1)/(k*(r_c-1)))));// The thermal efficiency
MEP=w_net/(v_1-v_2);// kPa
r_otto=v_1/v_3;// The compression ratio for otto cycle
n_otto=(1-(1/(r^(k-1))));// The thermal efficiency for otto cycle
printf("\nThe thermal efficiency,n=%0.3f or %2.1f percentage.\nMEP=%3.0f kPa. \nThe thermal efficiency of an otto cycle operating with the same maximum pressure,n_otto=%0.3f or %2.1f percentage.",n,n*100,MEP,n_otto,n_otto*100);
// The answer provided in the text book is wrong
```

Scilab code Exa 9.6 The thermal efficiency and the heat input

```
// Example 9_6
clc;funcprot(0);
// Given data
r=16;// The compression ratio
```

```
T_1=200+273;// K
P_1=200;// kPa
r_c=2;// The cut off ratio
r_p=1.3;// The pressure ratio
c_p=1.00;// kJ/kg.K
c_v=0.717;// kJ/kg.K
R=0.287;// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
n=1-((1/(r^(k-1)))*(((r_p*r_c^k)-1)/((k*r_p*(r_c-1))+(r_p-1))));// The thermal efficiency
T_2=T_1*(r)^(k-1);// K
T_3=T_2*r_p;// K
T_4=T_3*r_c;// K
q_in=(c_v*(T_3-T_2))+(c_p*(T_4-T_3));// kJ/kg
w_out=n*q_in;// kJ/kg
v_1=(R*T_1)/P_1;// m^3/kg
MEP=w_out/(v_1*(1-(1/r)));// kPa
printf("\nThe thermal efficiency,n=%0.3f or %2.1f percentage. \nThe heat input,q_in=%4.0f kJ/kg. \nThe work output,w_out=%4.0f kJ/kg. \nThe MEP=%4.0f kPa",n,n*100,q_in,w_out,MEP);
```

Scilab code Exa 9.7 The work output and the heat input

```
// Example 9_7
clc;funcprot(0);
// Given data
r=10;// The compression ratio
P_1=30;// psia
T_1=200+460;// R
T_3=1000+460;// R
R=53;// Btu/lbm R

```

```
// Calculation
w_34=R*T_3*log(r);// ft-lbf/lbm
w_12=R*T_1*log(1/r);// ft-lbf/lbm
w_out=w_34+w_12;// The work output in ft-lbf/lbm
n=1-(T_1/T_3);// The thermal efficiency
q_in=(w_out/778)/n;// The heat input in Btu/lbm
printf("\nThe work output,w_out=%5.0f ft-lbf/lbm \nThe heat input,q_in=%3.0f Btu/lbm",w_out,q_in);
```

Scilab code Exa 9.8 `The work output and the heat input`

```
// Example 9_8
clc;funcprot(0);
// Given data
r=10;// The compression ratio
P_1=200;// kPa
T_1=100+273;// K
T_3=600+273;// K
R=0.287;// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
v_1=(R*T_1)/P_1;// m^3/kg
T_4=T_3;// K
v_4=(T_4/T_1)*v_1;// m^3/kg
v_2=v_4/r;// m^3/kg
T_2=T_1;// K
P_2=(R*T_2)/v_2;// kPa
P_3=P_2;// kPa
v_3=(R*T_3)/P_3;// m^3/kg
w_out=(R*T_1*log(v_2/v_1))+(P_2*(v_3-v_2))+(R*T_3*log(v_4/v_3))+(P_1*(v_1-v_4));// The work output in kJ/kg
T_L=T_1;// K
T_H=T_3;// K
```

```
n=1-(T_L/T_H);// The thermal efficiency
q_in=w_out/n;// The heat input in kJ/kg
printf("\nThe work output,w_out=%3.0f kJ/kg \nThe
   heat input,q_in=%3.0f kJ/kg",w_out,q_in);
```

Scilab code Exa 9.9 The back work ratio and the thermal efficiency

```
// Example 9_9
clc;funcprot(0);
// Given data
P_1=100;// kPa
T_1=25+273;// K
r_p=5;// The pressure ratio
T_3=850+273;// The maximum temperature in K
k=1.4;// The specific heat ratio

// Calculation
T_2=T_1*(r_p)^((k-1)/k);// K
T_4=T_3*(1/r_p)^((k-1)/k);// K
w_r=(T_2-T_1)/(T_3-T_4);// The back work ratio
n=1-(r_p)^((1-k)/k);// The thermal efficiency
printf("\nThe back work ratio,w_comp/w_turb=%0.3f or
    %2.0f percentage. \nThe thermal efficiency,n=%0
   .3f(%2.1f percentage)",w_r,w_r*100,n,n*100);
```

Scilab code Exa 9.10 The back work ratio and the thermal efficiency of the cycle

```
// Example 9_10
clc;funcprot(0);
// Given data
P_1=100;// kPa
T_1=25+273;// K
T_2a=472.0;// K
```

```
r_p=5;// The pressure ratio
T_3=850+273;// The maximum temperature in K
T_4a=709.1;// K
k=1.4;// The specific heat ratio
c_p=1.00;// kJ/kg.K
n_comp=0.80;// The isentropic efficiency of the
   compressor
n_turb=0.80;// The isentropic efficiency of the
   turbine

// Calculation
w_comp=(c_p/n_comp)*(T_2a-T_1);// kJ/kg
w_turb=n_turb*c_p*(T_3-T_4a);// kJ/kg
w_r=w_comp/w_turb;// The back work ratio
T_2=(w_comp/c_p)+T_1;// K
w_net=w_turb-w_comp;// kJ/kg
q_in=c_p*(T_3-T_2);// kJ/kg
n=w_net/q_in;// The thermal efficiency of the cycle
printf("\nThe back work ratio=%0.3f or %2.1f
   percentage. \nThe thermal efficiency of the cycle
   ,n=%0.3f or %2.1f percentage.",w_r,w_r*100,n,n
   *100);
```

Scilab code Exa 9.11 The thermal efficiency and the back work ratio

```
// Example 9_11
clc;funcprot(0);
// Given data
// From example 9.9
P_1=100;// kPa
T_1=25+273;// K
r_p=5;// The pressure ratio
T_4=850+273;// The maximum temperature in K
k=1.4;// The specific heat ratio

```

```
// Calculation
n=1-((T_1/T_4)*(r_p)^((k-1)/k));// The thermal efficiency
w_r=0.420;// The back work ratio
printf("\nThe thermal efficiency,n=%0.3f or %2.1f percentage \nThe back work ratio,w_comp/w_turb=%0.3f",n,n*100,w_r);
```

Scilab code Exa 9.12 `The thermal efficiency of the cycle`

```
// Example 9_12
clc;funcprot(0);
// Given data
// From example 9.9
P_1=100;// kPa
P_4=500;// kPa
T_1=25+273;// K
T_6=850+273;// The maximum temperature in K
c_p=1.00// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
P_2=sqrt(P_1*P_4);// The intermediate pressure in kPa
T_2=T_1*(P_2/P_1)^((k-1)/k);// K
T_8=T_6;// K
P_7=P_2;// kPa
P_6=P_4;// kPa
T_7=T_6*(P_7/P_6)^((k-1)/k);// K
T_9=T_7;// K
T_5=T_7;// K
T_4=T_2;// K
T_3=T_1;// K
w_turb=(c_p*(T_6-T_7))+(c_p*(T_8-T_9));// kJ/kg
w_comp=(c_p*(T_2-T_1))+(c_p*(T_4-T_3));// kJ/kg
```

```
w_out=w_turb-w_comp;// kJ/kg
q_C=c_p*(T_6-T_5);// kJ/kg
q_R=c_p*(T_8-T_7);// kJ/kg
q_in=q_C+q_R;// kJ/kg
n=w_out/q_in;// The thermal efficiency of the cycle
printf("\nThe thermal efficiency of the cycle,n=%0.3f or %2.1f percentage",n,n*100);
```

Scilab code Exa 9.13 `The thrust developed by the engine`

```
// Example 9_13
clc;funcprot(0);
// Given data
m=100;// lbm/sec
P_1=5;// psia
P_2=50;// psia
T_1=-50+460;//  R
T_3=2000+460;//  R
V_1=600;// ft/sec
c_p=0.24// Btu/lbm- R
k=1.4;// The specific heat ratio

// Calculation
T_2=T_1*(P_2/P_1)^((k-1)/k);//  R
T_4=T_3-(T_2-T_1);//  R
P_3=P_2;// psia
P_5=P_1;// psia
P_4=P_3*(T_4/T_3)^(k/(k-1));// psia
T_5=T_4*(P_5/P_4)^((k-1)/k);//  R
V_5=[2*c_p*778*32.2*(T_4-T_5)]^(1/2);// ft/sec
T=(m/32.2)*(V_5-V_1);// lbf
hp=(T*V_1)/550;// hp
printf("\nThe thrust developed by the engine,T=%4.0f lbf \nThe horse power developed by the engine,hp=%4.0f hp",T,hp);
```

Scilab code Exa 9.14 The efficiency of the combined Brayton Rankine cycle

```
// Example 9_14
clc;funcprot(0);
// Given data
P_1=10;// kPa
P_3=4;// MPa
P_5=100;// kPa
W_ST=100;// The power output from the turbine in MW
T_5=25+273;// K
r_p=5;// The pressure ratio
T_7=850+273;// K
T_9=350;// K
c_p=1.00// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
h_1=192;// kJ/kg
h_2=h_1;// kJ/kg
// At 400 C and 4 MPa
h_3=3214;// kJ/kg
s_3=6.7698;// kJ/kg.K
s_4=s_3;// kJ/kg.K
s_f4=0.6491;// kJ/kg.K
s_fg4=7.5019;// kJ/kg.K
x=(s_4-s_f4)/s_fg4;// The quality of steam
h_f4=192;// kJ/kg
h_fg4=2393;// kJ/kg
h_4=h_f4+(x*h_fg4);// kJ/kg
h_3=3214;// kJ/kg
m_s=(W_ST*10^3)/(h_3-h_4);// kg/s
T_6=T_5*(r_p)^((k-1)/k);// K
T_8=T_7*(1/r_p)^((k-1)/k);// K
h_2=192;// kJ/kg
```

```
m_a=(m_s*(h_3-h_2))/(c_p*(T_8-T_9));// kg/s
W_turb=m_a*c_p*(T_7-T_8);// kJ/kg
W_comp=m_a*c_p*(T_6-T_5);// kJ/kg
W_GT=(W_turb-W_comp)/10^3;// The net gas turbine output in MW
Q_in=(m_a*c_p*(T_7-T_6))/10^3;// MW
n=(W_ST+W_GT)/Q_in;// The combined cycle efficiency
printf("\nThe efficiency of the combined Brayton-Rankine cycle,n=%0.3f or %2.1f percentage.",n,n*100);
```

Scilab code Exa 9.15 The minimum cycle temperature

```
// Example 9_15
clc;funcprot(0);
// Given data
T_2=-10+273;// K
T_4=30+273;// K
r=10;// The compression ratio
c_p=1.00// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
T_3=T_2*(r)^((k-1)/k);// K
T_1=T_4*(1/r)^((k-1)/k);// K
T_1C=T_1-273;// The minimum cycle temperature in  C
q_in=c_p*(T_2-T_1);// kJ/kg
w_comp=c_p*(T_3-T_2);// kJ/kg
w_turb=c_p*(T_4-T_1);// kJ/kg
COP=q_in/(w_comp-w_turb);// The coefficient of performance
printf("\nThe minimum cycle temperature,T_1=%3.0f C\nThe coefficient of performance,COP=%1.2f",T_1C,COP);
```

Scilab code Exa 9.16 `The minimum cycle temperature`

```
// Example 9_16
clc;funcprot(0);
// Given data
T_3=-10+273;// K
T_2=-40+273;// K
r=10;// The compression ratio
c_p=1.00// kJ/kg.K
k=1.4;// The specific heat ratio

// Calculation
T_4=T_3*(r)^((k-1)/k);// K
T_5=T_3;// K
T_6=T_2;// K
T_1=T_6*(1/r)^((k-1)/k);// K
T_1C=T_1-273;// The minimum cycle temperature in  C
q_in=c_p*(T_2-T_1);// kJ/kg
w_comp=c_p*(T_4-T_3);// kJ/kg
w_turb=c_p*(T_6-T_1);// kJ/kg
COP=q_in/(w_comp-w_turb);// The coefficient of performance
printf("\nThe minimum cycle temperature,T_1=%3.0f C \nThe coefficient of performance,COP=%0.3f",T_1C,COP);
```

Chapter 10

THERMODYNAMIC RELATIONS

Scilab code Exa 10.1 `The change in the specific volume of air`

```
// Example 10_1
clc;funcprot(0);
// Given data
T_1=25+273;// The initial temperature in K
P_1=122;// The initial pressure in kPa
T_2=29+273;// The final temperature in K
P_2=120;// The final pressure in kPa
R=0.287;// kJ/kg.K

// Calculation
dv=((R*T_2)/P_2)-((R*T_1)/P_1);// The change in the
   specific volume of air in m^3/kg
printf("\nThe change in the specific volume of air,
   dv=%0.5f m^3/kg",dv);
```

Scilab code Exa 10.2 `Verify one of the relationships using the steam tables`

```
// Example 10_2
clc;funcprot(0);
// Given data
T=400;//   C
P=4;// MPa

// Calculation
// From steam tables
dh=3330-3092;// kJ/kg
ds=6.937-6.583;// kJ/kg.K
dhbyds=dh/ds;// K
printf("\n(dh/ds)_P=%3.0f K or %3.0f C",dhbyds,
    dhbyds-273);
```

Scilab code Exa 10.3 `The percent error`

```
// Example 10_3
clc;funcprot(0);
// Given data
T=200;//   C
P=1554;// kPa
R=0.462;// kJ/kg.K

// Calculation
v_g=(R*(T+273))/P;// m^3/kg
rho=1000;// kg/m^3
v_f=0.001;// m^3/kg
dPbydT=(1906-1254)/(210-190);// kN/m^2.K
h_fg=(T+273)*(v_g-v_f)*dPbydT;// kJ/kg
h_fga=1941;// kJ/kg (From steam tables)
error=((h_fg-h_fga)/h_fga)*100;// The percentage
    error
printf("\nThe percent error=%2.1f percentage",error)
    ;
```

Scilab code Exa 10.4 The temperature at the state 2

```
// Example 10_4
clc;funcprot(0);
// Given data
P_1=2;// kPa
T_1=17.5+273;// K
P_2=1;// kPa
h_fg=2480;// kJ/kg
R=0.462;// kJ/kg.K

// Calculation
T_2=1/((1/T_1)-((R/h_fg)*log(P_2/P_1)));// K
printf("\nT_2=%3.0f K or %1.0f C",T_2,T_2-273);
```

Scilab code Exa 10.8 The entropy change

```
// Example 10_8
clc;funcprot(0);
// Given data
m=10;// kg
P_1=100;// The initial pressure in kPa
P_2=50;// The final pressure in MPa
beta=5*10^-5;// K^-1
rho=8770;// kg/m^3

// Calculation
// ds=s_2-s_1;
ds=-(1/rho)*beta*[(P_2-(P_1/10^3))*10^6];// J/kg.K
printf("\nThe entropy change,s_2-s_1=%0.3f J/kg.K",
   ds);
```

Scilab code Exa 10.9 The Joule thomson coefficient

```
// Example 10_9
clc;funcprot(0);
// Given data
T=400;// C
P=1;// MPa
v=0.3066;// m^3/kg

// Calculation
ds=7.619-7.302;// kJ/kg.K
dT=450-350;// K
c_p=(T+273)*(ds/dT);// kJ/kg.K
dv=0.3304-0.2825;// m^3/kg
mu_j=(1/(c_p*10^3))*[((T+273)*(dv/dT))-v];// K/Pa
printf("\nThe Joule thomson coefficient,mu_j=%1.2e K/Pa",mu_j);
dT=403.7-396.2;// K
dP=(1.5-0.5)*10^6;// Pa
mu_j=dT/dP;// K/Pa
printf("\nThe Joule thomson coefficient,mu_j=%1.2e K/Pa",mu_j);
```

Scilab code Exa 10.10 The enthalpy change and the change in internal energy of nit

```
// Example 10_10
clc;funcprot(0);
// Given data
T_1=-50;// C
P_1=2;// MPa
T_2=40;// C
P_2=6;// MPa
```

```
c_p=1.042;// kJ/kg.K
c_v=0.745;// kJ/kg.K
R=0.297;// kJ/kg.K
M=28;// The molecular weight of nitrogen in kg/kmol

// Calculation
// (a)
dh=c_p*(T_2-T_1);// The enthalpy change in kJ/kg
du=c_v*(T_2-T_1);// The change in internal energy in kJ/kg
ds=(c_p*log((T_2+273)/(T_1+273)))-(R*log(P_2/P_1));// The entropy change in kJ/kg.K
printf("\n(a)The enthalpy change,dh=%2.1f kJ/kg \n The change in internal energy,du=%2.0f kJ/kg \n The entropy change,ds=%0.2f kJ/kg.K",dh,du,ds);
// (b)
// Interpolating in the ideal gas table (Table F-2) gives
h_1=6479;// kJ/kmol
h_2=9102;// kJ/kmol
dh=(h_2-h_1)/M;// The enthalpy change in kJ/kg
u_1=4625;// kJ/kmol
u_2=6499;// kJ/kmol
du=(u_2-u_1)/M;// The change in internal energy in kJ/kg
phi_1=183.0;// kJ/kmol.K
phi_2=192.9;// kJ/kmol.K
ds=((phi_2-phi_1)/M)-(R*log(P_2/P_1));// The entropy change in kJ/kg.K
printf("\n(b)The enthalpy change,dh=%2.1f kJ/kg \n The change in internal energy,du=%2.0f kJ/kg \n The entropy change,ds=%0.2f kJ/kg.K",dh,du,ds);
// (c)
// Using (10.69) and the enthalpy departure chart in Appendix I we find
T_c=126.2;// K
```

```
T_R1=(T_1+273)/T_c;// The reduced temperature at state 1
T_R2=(T_2+273)/T_c;// The reduced temperature at state 2
P_c=3.39;// MPa
P_R1=P_1/P_c;// The reduced pressure at state 1
P_R2=P_2/P_c;// The reduced pressure at state 2
// The enthalpy departure chart(Appendix I) provides us with
// Assume dh_s1=(hbar*_1-hbar_1)/T_c,dh_s2=(hbar*_2-hbar_2)/T_c,dh_1=h*_1-h_1,dh_2=h*_2-h_2,
dh_s1=1.6;// kJ/kmol.K
dh_s2=2.5;// kJ/kmol.K
dh_1=(dh_s1*T_c)/M;// kJ/kg
dh_2=(dh_s2*T_c)/M;// kJ/kg
dh=-dh_1+dh_2+[c_p*(T_2-T_1)];// The enthalpy change in kJ/kg
// Using Compressibility chart,
Z_1=0.99;// The Compressibility factor at state 1
Z_2=0.985;// The Compressibility factor at state 2
du=dh-[R*((Z_2*(T_2+273))-(Z_1*(T_1+273)))];// The change in internal energy in kJ/kg
// Assume ds_s1=(sbar*_1-sbar_1),ds_s2=(sbar*_2-sbar_2),ds_1=s*_1-s_1,ds_2=s*_2-s_2,
ds_s1=1.0;// kJ/kmol.K
ds_s2=1.2;// kJ/kmol.K
ds_1=ds_s1/M;// kJ/kg.K
ds_2=ds_s2/M;// kJ/kg.K
ds=-ds_1+ds_2+((c_p*log((T_2+273)/(T_1+273)))-(R*log(P_2/P_1)));// The entropy change in kJ/kg.K
printf("\n(c)The enthalpy change,dh=%2.1f kJ/kg \n The change in internal energy,du=%2.0f kJ/kg \n The entropy change,ds=%0.2f kJ/kg.K",dh,du,ds);
```

Chapter 11

MIXTURES AND SOLUTIONS

Scilab code Exa 11.1 `The molecular weight of the mixture`

```
// Example 11_1
clc;funcprot(0);
// Given data
N_1=78;// The number of moles for nitrogen in mol
N_2=22;// The number of moles for oxygen in mol
M_1=28;// The molecular weight of nirogen in kg/kmol
M_2=32;// The molecular weight of oxygen in kg/kmol
Rbar=8.314;// The universal gas constant kJ/kmol.K

// Calculation
// (a)
N=N_1+N_2;// The total number of moles in mol
y_1=N_1/N;// The mole fraction for nitrogen
y_2=N_2/N;// The mole fraction for oxygen
// (b)
m_1=N_1*M_1;// The mass of nitrogen in kg
m_2=N_2*M_2;// The mass of oxygen in kg
m=m_1+m_2;// The total mass of the mixture in kg
mf_1=m_1/m;// The mass fraction for nitrogen
```

```
mf_2=m_2/m;// The mass fraction for oxygen
// (c)
M=m/N;// The molecular weight of the mixture in kg/k.mol
// (d)
R=Rbar/M;// The gas constant for air in kJ/kg.K
printf("\n(a)The mole fraction for nitrogen,y_1=%0.2f \n   The mole fraction for oxygen,y_2=%0.2f \n(b)The mass fraction for nitrogen,mf_1=%0.3f \n The mass fraction for oxygen,mf_2=%0.3f \n(c)The molecular weight of the mixture,M=%2.1f kg/k.mol \n(d)The gas constant for air,R=%0.3f kJ/kg.K",y_1,y_2,mf_1,mf_2,M,R);
```

Scilab code Exa 11.2 `The gas constant of the mixture`

```
// Example 11_2
clc;funcprot(0);
// Given data
T=25;//  C
P=2;// MPa
m_1=2;// The mass of nitrogen in kg
m_2=4;// The mass of CO_2 in kg
M_1=28;// The molecular weight of the nitrogen in kg/k.mol
M_2=44;// The molecular weight of the CO_2 in kg/k.mol
Rbar=8.314;// The universal gas constant kJ/kmol.K

// Calculation
N_1=m_1/M_1;// The number of moles for nitrogen in mol
N_2=m_2/M_2;// The number of moles for CO_2 in mol
N=N_1+N_2;// The total number of moles in mol
y_1=N_1/N;// The mole fraction for nitrogen
```

```
y_2=N_2/N;// The mole fraction for CO_2
P_1=y_1*P;// The partial pressure for nitrogen in MPa
P_2=y_2*P;// The partial pressure for CO_2 in MPa
M=(M_1*y_1)+(M_2*y_2);// The molecular weight of the mixture in kg/k.mol
R=Rbar/M;// The gas constant of the mixture in kJ/kg.K
printf("\nThe partial pressure for nitrogen,P_1=%0.2f MPa \nThe partial pressure for CO_2,P_2=%1.2f MPa \nThe gas constant of the mixture,R=%0.3f kJ/kg.K",P_1,P_2,R);
```

Scilab code Exa 11.3 `The heat transfer`

```
// Example 11_3
clc;funcprot(0);
// Given data
m=20;// The mass of the mixture in lbm
T_1=80;//  F
T_2=300;//  F
c_v1=0.177;// Btu/lbm- R
c_v2=0.158;// Btu/lbm- R
c_v3=0.157;// Btu/lbm- R
mf_1=20/100;// The mole fraction for nitrogen
mf_2=40/100;// The mole fraction for CO_2
mf_3=40/100;// The mole fraction for oxygen

// Calculation
c_v=(mf_1*c_v1)+(mf_2*c_v2)+(mf_3*c_v3);// // Btu/lbm- R
delT=T_2-T_1;//  F
Q=m*c_v*delT;// The heat transfer in Btu
printf("\nThe heat transfer,Q=%3.0f Btu",Q);
```

Scilab code Exa 11.4 `The change in entropy`

```
// Example 11_4
clc;funcprot(0);
// Given data
N_1=2;// The number of moles for CO_2 in mol
N_2=4;// The number of moles for nitrogen in mol
M_1=44;// The molecular weight of the CO_2 in kg/k.
   mol
M_2=28;// The molecular weight of nirogen in kg/kmol
P_1=100;// kPa
T_1=20+273;// K
P_2=2000;// kPa
c_v1=0.653;// kJ/kg.K
c_v2=0.745;// kJ/kg.K
c_p1=0.842;// kJ/kg.K
c_p2=1.042;// kJ/kg.K
Rbar=8.314;// The universal gas constant kJ/kgmol.K

// Calculation
// (a)
N=N_1+N_2;// The total number of moles in mol
m_1=N_1*M_1;// The mass of CO_2 in kg
m_2=N_2*M_2;// The mass of nitrogen in kg
m=m_1+m_2;// The mass of the mixture in kg
m_f1=m_1/m;// The mole fraction for CO_2
m_f2=m_2/m;// The mole fraction for nitrogen
c_v=(m_f1*c_v1)+(m_f2*c_v2);// kJ/kg.K
c_p=(m_f1*c_p1)+(m_f2*c_p2);// kJ/kg.K
k=c_p/c_v;// The ratio of specific heats
T_2=T_1*(P_2/P_1)^((k-1)/(k));// K
// (b)
W=(-m*c_v*(T_2-T_1))/10^3;// MJ
// (c)
```

```
dels=(c_p*log(T_2/T_1))-((Rbar/(((N_1/N)*M_1)+((N_2/N)*M_2)))*log(P_2/P_1));// The entropy change in kJ/kg.K
printf("\n(a)The final temperature,T_2=%3.0f K or %3.0f C \n(b)The work required,W=%2.1f MJ \n(c)The change in entropy,dels=%0.5f kJ/kg.K",T_2,T_2-273,W,dels);
```

Scilab code Exa 11.5 `The mole fraction of the water vapor`

```
// Example 11_5
clc;funcprot(0);
// Given data
T=25;//  C
P=100;// kPa
V=150;// m^3
phi=60/100;// The relative humidity at state 1
P_g=3.169;// kPa
M_v=18;// kg/k.mol
M_a=28.97;// kg/k.mol
R_a=0.287;// kJ/kg.K

// Calculation
// (a)
P_v=P_g*phi;// kPa
P_a=P-P_v;// The partial pressure of air in kPa
w=0.622*(P_v/P_a);// The humidity ratio in kg H2O/kg dry air
// (b)
// From psychrometric chart
T_dp=16.6;// The dew point temperature in  C
// (c)
m_v=w*((P_a*V)/(R_a*(T+273)));// The mass of water vapor in kg
// (d)
```

```
N_v=m_v/M_v;// mol
N_a=((P_a*V)/(R_a*(T+273)))/M_a;// mol
y_v=N_v/(N_a+N_v);// The mole fraction of the water vapor
printf("\n(a)The humidity ratio ,w=%0.5f kg H2O/kg dry air \n(b)The dew point temperature ,T_dp=%2.1f C \n(c)The mass of water vapor ,m_v=%1.2f kg \n(d)The mole fraction of the water vapor ,y=%0.4f",w,T_dp,m_v,y_v);
```

Scilab code Exa 11.6 The amount of water vapor that will condense

```
// Example 11_6
clc;funcprot(0);
// Given data
T=25;//  C
T_dp=10;// The dew point temperature in  C
P=100;// kPa
V=150;// m^3
P_g=3.169;// kPa
M_v=18;// kg/k.mol
M_a=28.97;// kg/k.mol
R_a=0.287;// kJ/kg.K

// Calculation
// (a)
P_v=1.228;// kPa
P_a=P-P_v;// The partial pressure of air in kPa
w_1=0.622*(P_v/P_a);// The humidity ratio in kg H2O/kg dry air
w_2=0.01205;// kg H2O/kg dry air
dw=w_2-w_1;// The difference in humidity ratio in kg H2O/kg dry air
dm_v=dw*((P_a*V)/(R_a*(T+273)));// kg H2O
// (b)
```

```
phi=1.608*((w_1*P_a)/(P_g));// The relative humidity in %
printf("\n(a)The amount of water vapor that will condense,delm_v=%0.3f kg H2O \n(b)The relative humidity,phi=%0.3f or %2.1f percentage.",dm_v,phi,phi*100);
```

Scilab code Exa 11.7 `The specific enthalpy of the air`

```
// Example 11_7
clc;funcprot(0);
// Given data
T_1=100;//  F
T_2=80;//  F
P=14.7;// psia
P_g1=0.9503;// psia
P_g2=0.5073;// psia
c_p=0.24;// Btu/lbm- R
h_fg2=1048;// Btu/lbm
h_g1=1105;// Btu/lbm
h_f2=48.09;// Btu/lbm

// Calculation
// (a)
w_2=0.622*(P_g2/(P-P_g2));// lbm H2O/lbm dry air
w_1=((w_2*h_fg2)+(c_p*(T_2-T_1)))/(h_g1-h_f2);// lbm H2O/lbm dry air
// (b)
P_v1=(w_1*P)/(0.622*(1+(w_1)));// psia
phi=P_v1/P_g1;// The relative humidity in %
// (c)
h=(c_p*T_1)+(w_1*h_g1);// Btu/lbm dry air
printf("\n(a)The humidity ratio,w_1=%0.5f lbm H2O/lbm dry air \n(b)The relative humidity,phi=%0.3f or %2.1f percentage. \n(c)The specific enthalpy
```

```
of the air,h=%2.1f Btu/lbm dry air",w_1,phi,phi*100,h);
```

Scilab code Exa 11.9 The rate of heat transfer

```
// Example 11_9
clc;funcprot(0);
// Given data
T_1=5;//  C
T_2=25;//  C
phi_1=70/100;// The relative humidity at state 1
V=50;// m^3/min
P=100;// kPa
P_g1=0.872;// kPa
R_a=0.287;// kJ/kg.K

// Calculation
P_a1=P-(phi_1*P_g1);// kPa
rho_a1=P_a1/(R_a*(T_1+273));// kg/m^3
mdot_a=(V/60)*rho_a1;// The mass flux of dry air in kg/s
// Using psychrometric chart
h_1=14;// kJ/kg air
h_2=35;// kJ/kg air
Q=mdot_a*(h_2-h_1);// The rate of heat transfer in kJ/s
// From the chart
phi_2=19;// The relative humidity at state 2
printf("\nThe rate of heat transfer,Q=%2.1f kJ/s \nThe final relative humidity,phi_2=%2.0f percentage.",Q,phi_2);
// The answer provided in the textbook is wrong
```

Scilab code Exa 11.10 The state of the steam introduced

```
// Example 11_10
clc;funcprot(0);
// Given data
T_1=5;// C
T_2=25;// C
phi_1=40/100;// The relative humidity at state 1
phi_2=40/100;// The relative humidity at state 2
V=60;// m^3/min
P=100;// kPa
P_g1=0.872;// kPa
R_a=0.287;// kJ/kg.K

// Calculation
// (a)
P_a1=P-(phi_1*P_g1);// kPa
rho_a1=P_a1/(R_a*(T_1+273));// kg/m^3
mdot_a=(V/60)*rho_a1;// The mass flux of dry air in kg/s
// Using psychrometric chart
h_1=10;// kJ/kg air
h_2=31;// kJ/kg air
Q=mdot_a*(h_2-h_1);// The rate of heat transfer in kJ/s
// (b)
w_2=0.0021;// kgH2O/kg dry air
w_3=0.008;// kgH2O/kg dry air
mdot_s=(w_3-w_2)*mdot_a;// The rate of steam supplied in kg/s
// (c)
h_2=31;// kJ/kg
h_3=45;// kJ/kg
h_s=(mdot_a/mdot_s)*(h_3-h_2);// kJ/kg
h_fs=604.7;// kJ/kg
h_fgs=2133.8;// kJ/kg
x_s=(h_s-h_fs)/h_fgs;// The state of the steam introduced
```

```
printf("\n(a)The rate of heat transfer,Q=%2.1f kJ/s \n(b)The rate of steam supplied,mdot_s=%0.4f kg/s \n(c)The state of the steam introduced,x_s=%0.2f",Q,mdot_s,x_s);
```

Scilab code Exa 11.11 `The amount of moisture removed`

```
// Example 11_11
clc;funcprot(0);
// Given data
T_1=80;//   F
phi_1=90;// The relative humidity at state 1
T_2=75;//   F
phi_2=40;// The relative humidity at state 2

// Calculation
// (a)
// From psychrometric chart
w_2=0.0177;// lbm H2O/lbm dry air
w_3=0.0075;// lbm H2O/lbm dry air
dw=w_3-w_2;// The amount of moisture removed in lbm H2O/lbm dry air
// (b)
h_3=20;// Btu/lbm dry air
h_1=39.5;// Btu/lbm dry air
q=h_3-h_1;// The heat removed in Btu/lbm dry air
// (c)
h_3=20;// Btu/lbm dry air
h_4=26.5;// Btu/lbm dry air
q_c=h_4-h_3;// The necessary added heat in Btu/lbm dry air
printf("\n(a)The amount of moisture removed,dw=%0.3f lbm H2O/lbm dry air \n(b)The heat removed,q=%2.1f Btu/lbm dry air \n(c)The necessary added heat,q=%1.1f Btu/lbm dry air",dw,q,q_c);
```

Scilab code Exa 11.12 `The amount of water added`

```
// Example 11_12
clc;funcprot(0);
// Given data
w_1=0.0046;// kg H2O/kg dry air
w_2=0.010;// kg H2O/kg dry air

// Calculation
// (b)
dw=w_2-w_1;// The amount of water added in kg H2O/kg dry air
printf("\n(b)The amount of water added,w_2-w_1=%0.4f kg H2O/kg dry air",dw);
```

Scilab code Exa 11.14 `The volume flow rate of air into the cooling tower`

```
// Example 11_14
clc;funcprot(0);
// Given data
m_w3=10000;// kg/min
T_ain=20;// The temperature of air at inlet in  C
phi_1=50;// Humidity in %
T_aout=32;// The temperature of air at exit in  C
phi_2=98;// Humidity in %
T_win=40;// The temperature of water at inlet in  C
T_wout=25;// The temperature of water at exit in  C

// Calculation
// (a)
// From the psychrometric chart we find
```

```
h_1=37;// kJ/kg of dry air
h_2=110;// kJ/kg of dry air
w_1=0.0073;// kgH2O/kg dry air
w_2=0.0302;// kgH2O/kg dry air
// From steam tables
h_3=167.5;// kJ/kg
h_4=104.9;// kJ/kg
m_a=(m_w3*(h_4-h_3))/(h_1-h_2+((w_2-w_1)*h_4));// kg
    /min
// From the psychrometric chart we find
v_1=0.84;// m^3/ kg dry air
Vdot=m_a*v_1;// m^3/min
// (b)
m_4=m_w3-((w_2-w_1)*m_a);// kg/min
printf("\n(a)The volume flow rate of air into the
    cooling tower,Vdot=%4.0f m^3/min \n(b)The mass
    flux of water,m_4=%4.0f kg/min",Vdot,m_4);
```

Chapter 12

COMBUSTION

Scilab code Exa 12.1 `The volume percentage of Carbon dioxide in the products`

```
// Example 12_1
clc;funcprot(0);
// Given data
AF_act=20;// The air-fuel ratio
// The reaction equation for theoretical air is C_4H_10+6.5(O_2+3.76N_2)-->4CO_2+5H_2O+24.44N_2
a=6.5;// Constant
M_air=29;// kg/kmol
M_fuel=58;// kg/kmol
P_atm=100;// kPa

// Calculation
m_air=a*(4.76)*M_air;// kg air
m_fuel=1*M_fuel;// kg fuel
// (a)
AF_th=m_air/m_fuel;// The theoretical air-fuel ratio
P_ea=((AF_act-AF_th)/AF_th)*100;// % excess air
// (b)
// The reaction equation with 129.28% theoretical air is C_4H_10+(6.5)(1.2928)(O_2+3.76N_2)-->4CO_2+5H_2O+1.903O_2+31.64N_2
```

```
N_CO2=4;// mol
N=42;// mol
P_CO2=(N_CO2/N)*100;// The volume percentage of CO_2
    in the products in %
// (c)
N_H2O=5;// mol
N=42.5;// mol
y_H2O=N_H2O/N;// The mole fraction
P_v=y_H2O*P_atm;// The partial pressure of the water
    vapor in kPa
// Using Table C-2
T_dp=49;//  C
printf("\n(a)The percent excess air=%2.2f percentage
    \n(b)The volume percentage of CO_2 in the
   products=%1.2f percentage \n(c)The dew point
   temperature of the products,T_dp=%2.0f  C",P_ea,
   P_CO2,T_dp);
```

Scilab code Exa 12.2 The volume percentage of CO

```
// Example 12_2
clc;funcprot(0);
// Given data
P_ta=90;// % theoretical air
// The reaction equation for theoretical air is
   C_4H_10+(0.9)(6.5)(O_2+3.76N_2)-->4CO_2+5H_2O+22
   N_2+bCO
a_1=6.5;// The stoichiometric coefficient
M_air=29;// kg/kmol
M_fuel=58;// kg/kmol

// Calculation
function[X]=atomicbalances(y)
    X(1)=y(1)+y(2)-4;
    X(2)=(2*y(1))+5+y(2)-11.7;
```

```
endfunction
y=[1 1];
z=fsolve(y,atomicbalances);
a=z(1);// mol
b=z(2);// mol
P_CO=(b/31)*100;// % CO
m_air=(P_ta/100)*a_1*(4.76)*M_air;// lbm air
m_fuel=1*M_fuel;// lbm fuel
AF=m_air/m_fuel;// The air-fuel ratio in lbm air/lbm fuel
printf("\nThe volume percentage of CO=%1.2f percentage \nThe air-fuel ratio,AF=%2.2f lbm air/lbm fuel",P_CO,AF);
```

Scilab code Exa 12.3 The percent theoretical air

```
// Example 12_3
clc;funcprot(0);
// Given data
// The volumetric analysis of the products on dry basis
CO_2=11.0// %
CO=1.0;// %
O_2=3.5;// %
N_2=84.5;// %

// Calculation
// The chemical equation is aC_4H_10+b(O_2+3.76N_2)-->11CO_2+1CO+3.5O_2+84.5N_2+cH_2O
// Balancing each element,
a=(11+1)/4;// (C)
c=(10*a)/2;// (H)
b=(22+1+7+c)/2;// (O)
printf("\nDividing through the chemical equation by the value of a so that we hve 1 mol fuel is %1.0
```

```
fC_4H_10+%1.1f(O_2+3.76N_2)-->%1.2fCO_2+%0.2fCO+%1.2fO_2+%2.2fN_2+%1.0fH_2O",a/a,b/a,11/a,1/a,3.5/a,84.5/a,c/a);
// From example 12.1
b_1=6.5;// The stoichiometric coefficient
P_ta=((b/a)/(b_1))*100;// The percent theoretical air in %
printf("\nThe percent theoretical air=%3.1f percentage",P_ta);
```

Scilab code Exa 12.4 `The percent theoretical air`

```
// Example 12_4
clc;funcprot(0);
// Given data
// The volumetric analysis of the products on dry basis
CO_2=10.4// %
CO=1.2;// %
O_2=2.8;// %
N_2=85.6;// %

// Calculation
// The chemical equation is C_aH_b+c(O_2+3.76N_2)-->10.4CO_2+1.2CO+2.8O_2+85.6N_2+dH_2O
// Balancing each element,
a=10.4+1.2;// (C)
c=85.6/3.76;// (N)
d=(2*c)-(20.8+1.2+5.6);// (O)
b=2*d;// (H)
printf("\nThe chemical formula for the fuel is C_%2.1fH_%2.1f",a,b);
// The find the percent theoretical air from the actual chemical equation, C_11.6H_37.9+21.08(O_2+3.76N_2)-->11.6CO_2+18.95H_2O+79.26N_2
```

```
c_act=21.08;
P_ta=(c/c_act)*100;// The percent theoretical air in %
printf("\nThe percent theoretical air=%3.1f percentage",P_ta);
```

Scilab code Exa 12.5 `The enthalpy of combustion of gaseous and liquid propane`

```
// Example 12_5
clc;funcprot(0);
// Given data
T=25;//  C
P=1;// atm
// Assuming theoretical air C_3H_8+5(O_2+3.76N_2)--->3CO_2+4H_2O(l)+18.8N_2
N_CO2=3;// mol
N_H2O=4;// mol
N_N2=18.8;// mol
// From table B-7
hbar0_fp=-103850;// kJ/kmol (C_3H_8)
hbar_fgp=15060;// kJ/kmol (C_3H_8)
hbar0_fCO2=-393520;// kJ/kmol
hbar0_fH2O=-285830;// kJ/kmol

// Calculation
Q_gp=(N_CO2*hbar0_fCO2)+(N_H2O*hbar0_fH2O)-hbar0_fp;// The enthalpy of combustion of gaseous propane in kJ/kmol fuel
Q_lp=(N_CO2*hbar0_fCO2)+(N_H2O*hbar0_fH2O)-(hbar0_fp-hbar_fgp);// The enthalpy of combustion of liquid propane in kJ/kmol fuel
printf("\nThe enthalpy of combustion of gaseous propane,Q=%7.0f kJ/kmol fuel \nThe enthalpy of combustion of liquid propane,Q=%7.0f kJ/kmol fuel",Q_gp,Q_lp);
```

Scilab code Exa 12.6 `The required heat transfer`

```
// Example 12_6
clc;funcprot(0);
// Given data
T_1=25;//   C
P=1;// atm
T_2=600;// K
// The combustion equation C_3H_8+5(O_2+3.76N_2)
    --->3CO_2+4H_2O(l)+18.8N_2
N_CO2=3;// mol
N_H2O=4;// mol
N_N2=18.8;// mol
hbar0_fp=-103850;// kJ/kmol (C_3H8)
hbar0_fCO2=-393520;// kJ/kmol
hbar_CO2=22280;// kJ/kmol
hbar0_CO2=9360;// kJ/kmol
hbar0_fH2O=-241810;// kJ/kmol
hbar_H2O=20400;// kJ/kmol
hbar0_H2O=9900;// kJ/kmol
hbar0_fN2=0;// kJ/kmol
hbar_N2=17560;// kJ/kmol
hbar0_N2=8670;// kJ/kmol

// Calculation
Q=(N_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(N_H2O*(
    hbar0_fH2O+hbar_H2O-hbar0_H2O))+(N_N2*(hbar0_fN2+
    hbar_N2-hbar0_N2))-(hbar0_fp);// The required
    heat transfer in kJ/kmol fuel
printf("\nThe required heat transfer,Q=%7.0f kJ/kmol
     fuel",Q);
```

Scilab code Exa 12.7 `The exit velocity`

```
// Example 12_7
clc;funcprot(0);
// Given data
T_o=25;//   C
P=1;// atm
T_1=600;// K
T_2=1000;// K
// The combustion equation C_8H_18(l)+12.5(O_2+3.76 N_2)--->8CO_2+9H_2O(l)+47N_2
N_CO2=8;// mol
N_H2O=9;// mol
N_N2=47;// mol
N_O2=12.5;// mol
hbar0_fO=-249910;// kJ/kmol (C_8H18)
hbar0_fCO2=-393520;// kJ/kmol
hbar_CO2=42770;// kJ/kmol
hbar0_CO2=9360;// kJ/kmol
hbar0_fH2O=-241810;// kJ/kmol
hbar_H2O=35880;// kJ/kmol
hbar0_H2O=9900;// kJ/kmol
hbar0_fN2=0;// kJ/kmol
hbar_N2=30130;// kJ/kmol
hbar0_N2=8670;// kJ/kmol
hbar0_fO2=0;// kJ/kmol
hbar_O2=17930;// kJ/kmol
hbar0_O2=8680;// kJ/kmol
M_CO2=44;// The molecular weight of carbon dioxide in kg/kmol
M_H2O=18;// The molecular weight of H2O in kg/kmol
M_N2=28;// The molecular weight of nitrogen in kg/kmol

// Calculation
H_P=(N_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(N_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(N_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the
```

```
   products of combustion in kJ/kmol fuel
// From table F_2 andF_3
hbar_N2=17560;// kJ/kmol (at 600 K for reactants)
H_R=(hbar0_f0)+(N_O2*(hbar0_fO2+hbar_O2-hbar0_O2))+(
   N_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The
   enthalpy of the reactants of combustion in kJ/
   kmol fuel
M_P=(N_CO2*M_CO2)+(N_H2O*M_H2O)+(N_N2*M_N2);// The
   mass of the products in kg/kmol fuel
V=sqrt((2/M_P)*(H_R-H_P));// The exit velocity in m/
   s
printf("\nThe exit velocity ,V=%2.0f m/s",V);
// The answer provided in the textbook is wrong
```

Scilab code Exa 12.8 `The heat transfer`

```
// Example 12_8
clc;funcprot(0);
// Given data
T_0=25;//  C
P=1;// atm
T_1=1000;// K
// The combustion equation C_8H_18(l)+12.5(O_2+3.76
   N_2)--->8CO_2+9H_2O(l)+47N_2
// For 300% excess theoretical air,the reaction is
   C_8H_18(l)+50(O_2+3.76N_2)--->8CO_2+9H_2O(l)+37.5
   O_2+188N_2
N_CO2=8;// mol
N_H2O=9;// mol
N_N2=188;// mol
N_O2=37.5;// mol
hbar0_f0=-249910;// kJ/kmol (C_8H18)
hbar0_fCO2=-393520;// kJ/kmol
hbar_CO2=42770;// kJ/kmol
hbar0_CO2=9360;// kJ/kmol
```

```
hbar0_fH2O=-241810;// kJ/kmol
hbar_H2O=35880;// kJ/kmol
hbar0_H2O=9900;// kJ/kmol
hbar0_fN2=0;// kJ/kmol
hbar_N2=30130;// kJ/kmol
hbar0_N2=8670;// kJ/kmol
hbar0_fO2=0;// kJ/kmol
hbar_O2=31390;// kJ/kmol
hbar0_O2=8680;// kJ/kmol

// Calculation
H_P=(N_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(N_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(N_O2*(hbar0_fO2+hbar_O2-hbar0_O2))+(N_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
H_R=hbar0_fO;// The enthalpy of the reactants of combustion in kJ/kmol fuel
Q=H_P-H_R;// The heat transfer in kJ/kmol fuel
printf("\nThe heat transfer,Q=%6.0f kJ/kmol fuel",Q);
```

Scilab code Exa 12.9 `The enthalpy of formation`

```
// Example 12_9
clc;funcprot(0);
// Given data
T=77;//  F
Q=-874000;// Btu/lbmol
// The chemical reaction is C_3H_8+5O_2--->3CO_2+4H_2O
N_CO2=3;// mol
N_H2O=4;// mol
N_p=1;// mol (C_3H_8-Propane)
N_O2=5;// mol
```

```
hbar0_fCO2=-169300;// Btu/lbmol
hbar0_fH2O=-104040;// Btu/lbmol
Rbar=1.987;// Btu/lbmol- R

// Calculation
N_P=N_CO2+N_H2O;// mol
N_R=N_p+N_O2;// mol
hbar0_fC3H8=(N_CO2*hbar0_fCO2)+(N_H2O*hbar0_fH2O)+((N_R-N_P)*Rbar*(T+460))-Q;// Btu/lbmol
printf("\nThe enthalpy of formation,(hbar_f)C3H8=%5.0f Btu/lbmol",hbar0_fC3H8);
```

Scilab code Exa 12.10 The adiabatic flame temperature in the steady flow combustio

```
// Example 12_10
clc;funcprot(0);
// Given data
T=25;// C
P=1;// atm
// The combustion equation C_3H_8+12.5(O_2+3.76N_2)--->3CO_2+4H_2O+7.5O_2+47N_2
N_p=1;// mol
N_CO2=3;// mol
N_H2O=4;// mol
N_N2=47;// mol
N_O2=7.5;// mol
hbar0_fp=-103850;// kJ/kmol (C_3H_8)
hbar0_fCO2=-393520;// kJ/kmol
hbar0_CO2=9360;// kJ/kmol
hbar0_fH2O=-241810;// kJ/kmol
hbar0_H2O=9900;// kJ/kmol
hbar0_fN2=0;// kJ/kmol
hbar0_N2=8670;// kJ/kmol
hbar0_fO2=0;// kJ/kmol
hbar0_O2=8680;// kJ/kmol
```

```
Q=0;// kJ/kmol
H_R=-103850;// kJ/kmol fuel

// Calculation
H_P=H_R;
hbar_p=((H_R-((N_CO2*(hbar0_fCO2))+(N_H2O*(hbar0_fH2O))))/61.5)+hbar0_N2;// kJ/kmol
// Suggests T_P=1380 K
T_P1=1380;// K
hbar_CO2=64120;// kJ/kmol
hbar_H2O=52430;// kJ/kmol
hbar_N2=42920;// kJ/kmol
hbar_O2=44920;// kJ/kmol
H_P1=(N_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(N_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(N_O2*(hbar0_fO2+hbar_O2-hbar0_O2))+(N_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
// The temperature is obiviously too high.We select aa lower value,T_p=1300 K
T_P2=1300;// K
hbar_CO2=59520;// kJ/kmol
hbar_H2O=48810;// kJ/kmol
hbar_N2=40170;// kJ/kmol
hbar_O2=44030;// kJ/kmol
H_P2=(N_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(N_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(N_O2*(hbar0_fO2+hbar_O2-hbar0_O2))+(N_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
T_P=T_P2-([(-H_P+H_P2)/(H_P1-H_P2)]*(T_P1-T_P2));// K
printf(”\nThe adiabatic flame temperature in the steady−flow combustion chamber,T_P=%4.0f K”,T_P);
```

Scilab code Exa 12.11 `The adiabatic flame temperature`

```
// Example 12_11
clc;funcprot(0);
// Given data
T=25;//   C
P=1;// atm
// The combustion equation C_3H_8+5(O_2+3.76N_2)--->3CO_2+4H_2O+18.8N_2
N_p=1;// mol
N_CO2=3;// mol
N_H2O=4;// mol
N_N2=18.8;// mol
hbar0_fp=-103850;// kJ/kmol (C_3H_8)
hbar0_fCO2=-393520;// kJ/kmol
hbar0_CO2=9360;// kJ/kmol
hbar0_fH2O=-241810;// kJ/kmol
hbar0_H2O=9900;// kJ/kmol
hbar0_fN2=0;// kJ/kmol
hbar0_N2=8670;// kJ/kmol
Q=0;// kJ/kmol
H_R=-103850;// kJ/kmol fuel

// Calculation
H_P=H_R;// kJ/kmol fuel
hbar_p=((H_R-((N_CO2*(hbar0_fCO2))+(N_H2O*(hbar0_fH2O))))/25.8)+hbar0_N2;// kJ/kmol
// Suggests T_P=1380 K
T_P1=2600;// K
hbar_CO2=137400;// kJ/kmol
hbar_H2O=114300;// kJ/kmol
hbar_N2=86600;// kJ/kmol
H_P1=(N_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(N_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(N_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
// The temperature is obiviously too high.We select aa lower value,T_p=1300 K
```

```
T_P2=2400;// K
hbar_CO2=125200;// kJ/kmol
hbar_H2O=103500;// kJ/kmol
hbar_N2=79320;// kJ/kmol
H_P2=(N_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(N_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(N_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
T_P=T_P2-([(-H_P+H_P2)/(H_P1-H_P2)]*(T_P1-T_P2));// K
printf("\nThe adiabatic flame temperature,T_P=%4.0f K",T_P);
```

Scilab code Exa 12.12 `The temperature of products of combustion`

```
// Example 12_12
clc;funcprot(0);
// Given data
A=2;// The surface area in m^2
U=0.5;// The over all heat transfer coefficient in kW/m^2.K
mdot_p=0.2;// The mass flow rate of propane in kg/s
M_p=44;// The molecular weight of the propane in kg/kmol
T_E=25+273;// K
P=1;// atm
// From example 12.11
// The combustion equation C_3H_8+5(O_2+3.76N_2)--->3CO_2+4H_2O+18.8N_2
N_CO2=3;// mol
N_H2O=4;// mol
N_N2=18.8;// mol
hbar0_fp=-103850;// kJ/kmol (C_3H_8)
hbar0_fCO2=-393520;// kJ/kmol
hbar0_CO2=9360;// kJ/kmol
```

```
hbar0_fH2O=-241810;// kJ/kmol
hbar0_H2O=9900;// kJ/kmol
hbar0_fN2=0;// kJ/kmol
hbar0_N2=8670;// kJ/kmol

// Calculation
mdot_fuel=mdot_p/M_p;// The molar influx in kg/s
M_CO2=N_CO2*mdot_fuel;// kmol/s
M_H2O=N_H2O*mdot_fuel;// kmol/s
M_N2=N_N2*mdot_fuel;// kmol/s
// LHS=Q+H_R
// RHS=H_P
// For a first guess at T_P let us assume a some what lower temperature than that of Example 12.11,since energy leaving the combustion chamber .The guesses follow
T_P1=1600;// K
LHS_1=(-U*A*(T_P1-T_E))+(mdot_fuel*hbar0_fp);// kJ/kmol fuel
hbar_CO2=76944;// kJ/kmol
hbar_H2O=62748;// kJ/kmol
hbar_N2=50571;// kJ/kmol
RHS_1=(M_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(M_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(M_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
T_P2=2000;// K
LHS_2=(-U*A*(T_P2-T_E))+(mdot_fuel*hbar0_fp);// kJ/kmol fuel
hbar_CO2=100804;// kJ/kmol
hbar_H2O=82593;// kJ/kmol
hbar_N2=64810;// kJ/kmol
RHS_2=(M_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(M_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(M_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
T_P3=1900;// K
LHS_3=(-U*A*(T_P3-T_E))+(mdot_fuel*hbar0_fp);// kJ/
```

```
kmol fuel
hbar_CO2=94793;// kJ/kmol
hbar_H2O=77517;// kJ/kmol
hbar_N2=61220;// kJ/kmol
RHS_3=(M_CO2*(hbar0_fCO2+hbar_CO2-hbar0_CO2))+(M_H2O*(hbar0_fH2O+hbar_H2O-hbar0_H2O))+(M_N2*(hbar0_fN2+hbar_N2-hbar0_N2));// The enthalpy of the products of combustion in kJ/kmol fuel
// Interpolation between the last two entries gives
T_P=1970;// K
printf("\nThe temperature of products of combustion, T_P=%4.0f K",T_P);
```