

Scilab Textbook Companion for
Fundamental of Thermodynamics
by Moran and Shapiro¹

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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.

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Chapter 2

Energy and the First Law of Thermodynamics

Scilab code Exa 2.1 Example 1

```
1 // Given:-
2 p1 = 3*(10**5) //
   initial pressure of gas in pascal
3 v1 = 0.1 //
   initial volume of gas in meter^3
4 v2 = 0.2 //
   final volume of gas in meter^3
5
6 // calculations
7 // Part (a) i.e. n=1.5
8 //constant = p1*(v1**n) // p
   *(v^n) = constant
9 constant1 = p1*(v1**1.5)
10 constant2 = p1*(v1**1)
11 constant3 = p1*(v1**0)
12 // function p
13 function v = p1(v)
14     v = constant1/(v^1.5)
15 endfunction
```

```

16
17 function v = p2(v)
18     v = constant2/(v^1)
19 endfunction
20
21 function v = p3(v)
22     v = constant3/(v^0)
23 endfunction
24
25 work1 = intg(v1,v2,p1) //
    integrating pdv from initial to final volume
26 w1 = work1(1)/1000 //
    divided by 1000 to convert to KJ
27 printf( 'The work done for n=1.5 in KJ is %.2f',w1)
28
29 //part(b) i.e. n = 1
30 work2 = intg(v1,v2,p2)
31 w2 = work2(1)/1000
32 printf( 'The work done for n=1 in KJ is %.2f',w2)
33
34 //part(c) i.e. n=0
35 work3 = intg(v1,v2,p3)
36 w3 = work3(1)/1000
37 printf( 'The work done for n=0 in KJ is %.2f',w3)

```

Scilab code Exa 2.2 Example

```

1 // Given:-
2 p1 = 3*(10**5) //
    initial pressure in pascal
3 v1 = 0.1 //
    initial volume in m3
4 v2 = 0.2 //
    final volume
5 m = 4.0 //

```

```

        mass of the gas in kg
6  deltau = -4.6 //
        change in specific internal energy in KJ/Kg //
7
8  // Calculations
9
10 constant = p1*(v1**1.5) //
        p*(v^n) = constant //
11
12 function v = p(v)
13     v = constant/(v**1.5) // expressing
        pressure as function of volume
14 endfunction
15
16 work = intg(v1,v2,p) //
        integrating pdv from initial to final volume
17 w=work(1)/1000 //
        divided by 1000 to convert to KJ
18
19 deltaU = m*deltau //
        change in internal energy in KJ
20 Q = deltaU + w //
        neglecting kinetic and potential energy changes
21
22 // Result
23 printf( 'net heat transfer for the process in KJ %.2
        f ',Q)

```

Scilab code Exa 2.3 Example

```

1 // Given:-
2 clc;
3 patm = 10**5 //
        atmospheric pressure in pascal.

```

```

4 mp = 45.0 // mass
    of piston in Kg
5 A = 0.09 // face
    area of piston in m2
6 deltaV = 0.045 //
    increment of the volume of air in m3
7 m = 0.27 // mass
    of air in kg
8 deltau = 42.0 //
    specific internal energy increase of air in kJ/kg
9 g = 9.81 // local
    acceleration of gravity
10
11
12 // Part (a) i.e. air is system
13 // Calculations
14 p = (mp*g)/A + patm //
    constant pressure of air obtained from
    equilibrium of piston
15 w = (p*deltaV)/1000 // work
    done in KJ
16 deltaU = m*deltau //
    internal energy change of air in KJ
17 Q = w + deltaU //
    applying first with air as system
18 // Result
19 printf( '\nheat transfer from resistor to air in KJ
    for air alone as system is: %.2f',Q)
20
21 // The answer given in book is incorrect. deltaU is
    incorrect in book.
22
23 // Part(b) i.e. (air+piston) is system
24 // Calculations
25 wd = (patm*deltaV)/1000 // work
    done in KJ
26 deltaz = (deltaV)/A //
    change in elevation of piston

```

```

27 deltaPE = (mp*g*deltaz)/1000 //
    change in potential energy of piston in KJ
28 Qt = wd + deltaPE + deltaU //
    applying first law with air plus piston as system
29 // Result
30 printf( '\nheat transfer from resistor to air in KJ
    for air + piston as system is: %.2f',Qt)
31
32 // note : The answer given in book is incorrect.They
    have miscalculated deltaU.

```

Scilab code Exa 2.4 Example

```

1 // Given:-
2 w1dot = -60.0 // input work rate in
    KW
3 h = 0.171 // heat transfer
    coefficient ,unit in KW/m2 .K
4 A = 1.0 // outer surface area
    of gearbox , unit in m2
5 Tb = 300.0 // outer surface
    temperature in kelvin
6 Tf = 293.0 // temperature of the
    sorrounding
7
8 // Calculations
9 Qdot = -h*A*(Tb-Tf); // rate of energy
    transfer by heat
10 wdot = Qdot; // steady state energy
    equation
11 w2dot = wdot-w1dot;
12
13 // Results
14 printf( 'The heat transfer rate in KW is:\n\tQdot =
    %f',Qdot)

```

```
15 printf( 'The power delivered through output shaft in
    KW is: = %f',w2dot);
```

Scilab code Exa 2.5 Example

```
1 // Given:-
2 s=5*(10**-3) // measurement on
    a side in meter
3 wdot = -0.225 // power input
    in watt
4 Tf = 293.0 // coolant
    temprature in kelvin
5 h = 150.0 // heat
    transfer coefficient in w/m2 k
6 A = s**2 // surface area
7
8 // Calculation
9 Tb = ((-wdot/(h*A)) + Tf - 273) // surface
    temperature in degree
10
11 // Result
12 printf( 'The surface temperature of the chip in
    degree celcius is: %f ',Tb);
```

Scilab code Exa 2.6 Example

```
1 // Given:-
2 omega = 100.0 //motor rotation
    speed in rad/s
3 tau = 18.0 //torque applied
    by shaft in N.m
4 Welecdot = -2.0 //electric power
    input in KW
```

```

5
6 Wshaftdot = (tau*omega)/1000 //shaft work rate
   in KW
7 Wdot = Welecdot + Wshaftdot //net work rate in
   KW
8
9 //function [Qdot]=f(t)
10 //Qdot = (-0.2)* [1-2**(-0.05*t)]
11
12
13 //function [Edot]=f1(t) //function for
   rate of change of energy
14 //Edot = (-0.2)*[1-2**(-0.05*t)] - Wdot
15
16 //function [deltaE] =f2(t) //function for
   change in energy
17
18 t = linspace(0,120,100);
19 for i = 1:100
20     Qd(i) = i
21     Wd(i) = i
22     dltAE(i) = i
23     Qd(i) = (-0.2*(1-%e^(-0.05*t(i))))
24     Wd(i) = Wdot
25     dltAE(i) = 4*(1 - %e^(-0.05*t(i)))
26 end
27
28 subplot(2,2,1)
29 plot(t,Qd)
30 xlabel("Time (s)")
31 ylabel("Qdot (KW)")
32
33 subplot(2,2,2)
34 plot(t,Wd)
35 xlabel("Time (s)")
36 ylabel("Wdot (KW)")
37
38 subplot(2,2,3)

```

```
39 plot(t,deltaE)
40 xlabel("Time (s)")
41 ylabel("deltaE (KJ)")
```

Chapter 3

Evaluating Properties

Scilab code Exa 3.1 Example

```
1 // Given:-
2 // Those with 1 are of state 1 and 2 are with state
  2
3
4 // State 1
5 p1 = 10**5 // initial pressure
  in pascal
6 x1 = 0.5 // initial quality
7
8 T1 = 99.63 // temperature in
  degree celcius , from table A-3
9 v = 0.5 // volume of
  container in m3
10 vf1 = 1.0432*(10**(-3)) // specific volume of
  fluid in state 1 in m3/Kg(from table A-3)
11 vg1 = 1.694 // specific volume of
  gas in state 1 in m3/kg(from table A-3)
12
13 // State 2
14 p2 = 1.5*(10**5) // pressure after
  heating in pascal
```

```

15
16 T2 = 111.4 // temperature in
    degree celcius in state 2, from A-3
17 vf2 = 1.0582*(10**(-3)) // specific volume of
    fluid in state 2 in m3/Kg, from A-3
18 vg2 = 1.159 // specific volume of
    gas in state 2 in m3/Kg, from A-3
19
20 // Calculations
21
22 v1 = vf1 + x1*(vg1-vf1) // specific volume in
    state 1 in m3/Kg
23 v2 = v1 // specific volume in
    state 2 in m3/Kg
24 m = v/v1 // total mass in Kg
25 mg1 = x1*m // mass of vapour in
    state 1 in Kg
26
27 x2 = (v1-vf2)/(vg2-vf2) // quality in state 2
28 mg2 = x2*m // mass of vapor in
    state 2 in Kg
29
30 // State 3
31 p3 = 2.11 // pressure in state
    3 from table A-3
32
33 // Results
34 printf( ' The temperature in state 1 is %f degree
    celcius.',T1)
35 printf( ' The temperature in state 2 is %f degree
    celcius.',T2)
36 printf( ' The mass of vapour in state 1 is %.2f kg.'
    ,mg1)
37 printf( ' The mass of vapour in state 2 is %.2f kg.'
    ,mg2)
38 printf( ' The pressure corresponding to state 3 is %
    .2f bar ',p3)

```

Scilab code Exa 3.2 Example

```
1 // Given:-
2 m = 0.05 // mass of ammonia in
   kg
3 p1 = 1.5*(10**5) // initial pressure
   of ammonia in pascal
4 v1 = 0.7787 // specific volume in
   state 1 in m3/kg from table A-14
5 v2 = 0.9553 // specific volume in
   state 2 in m3/kg from table A-15
6 T2 = 25.0 // final temperature
   in degree celcius
7
8 // Calculations
9
10 V1 = m*v1 // volume occupied by
   ammonia in state 1 in m3
11 V2 = m*v2 // volume occupied by
   ammonia in state 2 in m3
12 w = (p1*(V2-V1))/1000 // work in KJ
13
14 // Results
15 printf( ' The volume occupied by ammonia in state 1
   is %.2f m^3. ',V1)
16 printf( ' The volume occupied by ammonia in state 2
   is %.2f m^3 ',V2)
17 printf( ' The work done for the process is %.2f KJ',
   w)
```

Scilab code Exa 3.3 Example

```

1 // Given:-
2 V = 0.25 // volume of tank in m3
3 v = 1.673 // specific volume in m3/kg
   obtained using table A-2
4
5 // State 1
6 T1 = 100.0 // initial temperature in
   degree celcius
7 u1 = 2506.5 // specific internal energy in
   state 1 in KJ/Kg obtained from table A-2
8
9 // State 2
10 p2 = 1.5 // final pressure in bars
11 T2 = 273.0 // temperature in state 2 in
   degree celcius obtained from table A-4
12 u2 = 2767.8 // specific internal energy in
   state 2 in KJ/Kg obtained from table A-4
13
14 // Calculations
15 m = V/v // mass of the system in kg
16 DeltaU = m*(u2-u1) // change in internal energy
   in KJ
17 W = - DeltaU // from energy balance
18
19 // Results
20 printf( ' The temperature at the final state in is %
   .2f degree celcius.',T2)
21 printf( ' The work during the process is %f KJ.',W);

```

Scilab code Exa 3.4 Example

```

1 // Given:-
2 // State
3 P1 = 10*(10**5) // initial
   pressure in pascal

```

```

4 T1 = 400.0 // initial
  temperature in degree celcius
5 v1 = 0.3066 // specific
  volume in state 1 in m3/kg obtained from table A
  -4
6 u1 = 2957.3 // specific
  internal energy in state 1 in KJ/Kg obtained from
  table A-4
7
8 // State 2
9
10 v2 = 0.1944 // specific
  volume in state 2 in m3/kg obtained from table A
  -3
11 w2to3 = 0 // work in
  process 2-3
12
13
14 // State 3
15 v3 = v2
16 vf3 = 1.0905*(10**(-3)) // specific
  volume of fluid in state 3 from table A-2
17 vg3 = 0.3928 // specific
  volume of gas in state 3 from table A-2
18 uf3 = 631.68 // specific
  internal energy for fluid in state 3 from table A
  -2
19 ug3 = 2559.5 // specific
  internal energy for gas in state 3 from table A-2
20
21 // Calculations
22 w1to2 = (P1*(v2-v1))/1000 // work in KJ
  /Kg in process 1-2
23 W = w1to2 + w2to3 // net work
  in KJ/kg
24 x3 = (v3-vf3)/(vg3-vf3)
25 u3 = uf3+x3*(ug3-uf3) // specific
  internal energy in state 3 in Kj/Kg

```

```

26 q = (u3-u1) + W // heat
    transfer in Kj/Kg
27
28 // Results
29 printf( ' The work done in the overall process is %f
    KJ/kg. ',W);
30 printf( ' The heat transfer in the overall process
    is %f KJ/kg. ',q);

```

Scilab code Exa 3.6 Example

```

1 // Given:-
2 // State 1
3 p1 = 20.0 // initial pressure
    in MPa
4 T1 = 520.0 // initial
    temperature in degree celcius
5 Z1 = 0.83 // compressibility
    factor
6 R = 8.314 // universal gas
    constant in SI unit
7 n = 1000.0/18.02 // number of moles in
    a kg of water
8
9 // State 2
10 T2 = 400.0 // final temperature
    in degree celcius
11
12 // From table A-1
13 Tc = 647.3 // critical
    temperature in kelvin
14 pc = 22.09 // critical pressure
    in MPa
15
16 // Calculations

```

```

17 Tr = (T1+273)/Tc // reduced
    temperature
18 Pr = p1/pc // reduced pressure
19 v1 = (Z1*n*R*(T1+273))/(p1*(10**6))
20 vr = v1*(pc*(10**6))/(n*R*Tc)
21 Tr2 = (T2+273)/Tc
22 PR = 0.69 // at above vr and
    Tr2
23 P2 = pc*PR
24
25 // Results
26 printf( ' The specific volume in state1 is %f m3/kg
    and the corresponding value obtained from table A
    -4 is .01551 m^3/Kg',v1)
27 printf( ' The pressure in MPa in the final state is
    %f MPa and the corresponding value from the table
    is 15.16Mpa',P2);

```

Scilab code Exa 3.7 Example

```

1 // Given:-
2 T1 = 300.00 //
    temperature in state 1 in kelvin
3 P1 = 1.00 //
    pressure in state 1 in bar
4 P2 = 2.00 //
    pressure in state 2 in bar
5 R = 287.00 //gas
    constant of air in SI units
6
7 // Calculations
8 v1 = (R*T1)/(P1*10**5) //specific
    volume in state 1
9 P = linspace(1,2,50)
10 for i = 1:50

```

```

11     v(i) = v1
12 end
13
14
15 T2 = (P2*10**5*v1)/R
16 v3 = (R*T2)/(P1*10**5)
17 vv = linspace(v1,v3,50)
18 for i = 1:50
19     Pa(i) = P1
20 end
21
22 //function[out]= f(inp)
23 //out = (R*T2)/(inp
24
25 VV = linspace(v1,v3,50)
26 for j = 1:50
27     pp(j) = (R*T2)/VV(j)/(10**5)
28 end
29 vcommon = cat(1,v,VV')
30 pcommon = [P pp']
31 size(vcommon)
32 size(pcommon)
33 //subplot(211)
34 plot(vcommon,pcommon)
35 xlabel('v')
36 ylabel('p(bar)')
37
38 //subplot(212)
39 plot(vv,Pa)
40 xlabel('v')
41 ylabel('p(bar)')
42
43 //The two steps are shown in one graph and the other
44     on is shown in the other graph""
45 printf('The temperature in kelvin in state 2 is T2
46     = %f',T2)
46 printf('The specific volume in state 3 in m^3/kg is

```



```
v = %f',v3)
```

Scilab code Exa 3.8 Example

```
1 // Given:-
2 // State 1
3 m = 0.9 // mass of air
   in kg
4 T1 = 300.0 // initial
   temperature in kelvin
5 P1 = 1.0 // initial
   pressure in bar
6
7 // State 2
8 T2 = 470.0 // final
   temperature in kelvin
9 P2 = 6.0 // final
   pressure in bar
10 Q = -20.0 // heat
   transfer in kj
11
12 // From table A-22
13 u1 = 214.07 // in KJ/kg
14 u2 = 337.32 // in KJ/Kg
15
16 // Calculations
17 deltaU = m*(u2-u1) // change in
   internal energy in kj
18 W = Q - deltaU // in KJ/kg
19
20 // Results
21
22 printf( ' The work during the process is %f KJ.',W);
```

Scilab code Exa 3.9 Example

```
1 // Given:-
2 // State 1
3 m1 = 2.0 // initial mass of
   gas in tank 1 in kg
4 T1 = 350.0 // initial
   temperature in kelvin in tank1
5 p1 = 0.7 // initial
   pressure in bar in tank 1
6
7 // State 2
8 m2 = 8.0 // initial mass of
   gas in tank 2 in kg
9 T2 = 300.0 // initial
   temperature in kelvin in tank 2
10 p2 = 1.2 // initial
   pressure in bar in tank 2
11 Tf = 315.0 // final
   equilibrium temperature in kelvin
12
13 // From table A-20
14 Cv = 0.745 // in KJ/Kg.k
15
16 // Calculations
17 pf = ((m1+m2)*Tf)/((m1*T1/p1)+(m2*T2/p2))
18 Ui = (m1*Cv*T1)+(m2*Cv*T2)
19 Uf = (m1+m2)*Cv*Tf
20 deltaU = Uf-Ui
21 Q = deltaU
22
23 // Results
24 printf( ' The final equilibrium pressure is %f bar.'
   ,pf);
```

```
25 printf( ' The heat transfer for the process is %f KJ
    . ',Q);
```

Scilab code Exa 3.11 Example

```
1 // Given:-
2 p1 = 1.0 // initial
    pressure in bar
3 T1 = 295.0 // initial
    temperature in kelvin
4 p2 = 5.0 // final
    pressure in bar
5 n = 1.3 // polytropic
    constant
6 R = 8314/28.97 // gas
    constant for air in SI units
7
8 // From table A-22
9 u2 = 306.53
10 u1 = 210.49
11
12 // Calculations
13 T2 = T1*(p2/p1)**((n-1)/n)
14 w = R*(T2-T1)/(1-n)
15 Q = u2-u1+w/1000
16
17 // Results
18 printf( ' The work done per unit mass is %f KJ/kg.',
    w/1000)
19 printf( ' The heat transfer per unit mass is %f KJ/
    kg.',Q);
```

Chapter 4

Control Volume Analysis Using Energy

Scilab code Exa 4.1 Example

```
1 // Given:-
2 // At inlet 1:-
3 p1= 7.0 //
   pressure in bar
4 T2= 200.0 //
   temperature in degree celcius
5 m1dot= 40.0 //
   mass flow rate in kg/s
6
7 // At inlet 2:-
8 p2= 7.0 //
   pressure in bar
9 T2= 40.0 //
   temperature in degree celcius
10 A2= 25.0 //
   area in cm^2
11
12 // At exit:-
13 p3= 7.0 //
```

```

    pressure in bar
14 AV3= 0.06 //
    Volumetric flow rate through wxir in m^3/s
15
16 // From table A-3
17 v3 = (1.108)*(10**(-3)) //
    specific volume at the exit in m^3/kg
18
19 // from table A-2
20 v2= (1.0078)*(10**(-3)) //
    specific volume in state 2 in m^3/kg
21
22 // Calculation:-
23 m3dot= AV3/v3 //
    mass flow rate at exit
24 m2dot = m3dot-m1dot //
    mass flow rate at inlet 2
25 V2= (m2dot*v2)/(A2*(10**(-4)))
26
27 // Results:-
28 printf( ' The mass flow rate at the inlet 2 is %.2f
    kg/s.',m2dot)
29 printf( ' The mass flow rate at the exit is %.2f kg/
    s.',m3dot)
30 printf( ' The velocity at the inlet is %.2f m/s.',
    V2)

```

Scilab code Exa 4.3 Example

```

1 // Given:-
2 p1= 40.0 //
    pressure in bar
3 T1= 400.0 //
    temperature in degree celcius
4 V1= 10.0 //

```

```

        velocity m/s
5
6 // At exit:-
7 p2= 10.0 //
        pressure in bar
8 V2= 665.0 //
        velocity in m/s
9 mdot= 2.0 // mass
        flow rate in kg/s
10
11 // From table A-4
12 h1= 3213.6 //
        snpecific enthalpy in kJ/kg
13 v2 = 0.1627 //
        specific volume at the exit in m^3/kg
14
15 // Calculation:-
16 h2 = h1 + ((V1**2-V2**2)/2)/1000 //
        snpecific enthalpy in kJ/kg
17 A2=(mdot*v2)/V2 // Exit
        area
18
19 // Results:-
20 printf( ' The exit Area of the nozzle is %.4f m^2',
        A2)

```

Scilab code Exa 4.4 Example

```

1 // Given:-
2 m1dot = 4600.0 //
        mass flow rate in kg/h
3 Wcvdot= 1000.0 //
        turbine power output in kv
4 p1= 60.0 //
        pressure in bar

```

```

5 T1=400.0 //
   temperature in degree celc
6 V1= 10.0 //
   velocity in m/s
7
8 // At exit:-
9 p2= 0.10 //
   pressure in bar
10 q2= 0.90 //
   quality
11 V2= 50.0 //
   velocity in m/s
12
13 // From table A-2 and A-3:-
14 h1= 3177.2 //
   specific enthalpy at inlet in kJ/kg
15 hf2= 191.83
16 hg2= 2584.63
17
18 // Calculation:-
19 h2 = hf2+q2*(hg2-hf2) //
   specific enthalpy at exit in kJ/kg
20 Qcvdot = Wcvdot + m1dot*((h2-h1)+(V2**2- V1**2)
   /(2*1000))/3600
21
22 // Results:-
23 printf( ' The rate of heat transfer between the
   turbine and surroundings is %.2f kW',Qcvdot)

```

Scilab code Exa 4.5 Example

```

1 // Given:-
2 p1=1.00 //
   pressure in bar
3 t1= 290.00 //

```

```

        temperature in kelvin
4  A1= 0.1 //
    area in m^2
5  V1= 6.00 //
    velocity in m/s
6
7  // At exit:-
8
9  p2=7.00 //
    pressure in bar
10 t2= 450.00 //
    temperature in kelvin
11 V2= 2.00 //
    velocity in m/s
12 Qcvdot= -180.0 //
    heat transfer rate in kJ/min
13 R= 8.314 //
    universal gas constant in SI units
14
15 // from table A-22
16
17 h1= 290.16 //
    specific enthalpy in kJ/kg
18 h2= 451.8 //
    specific enthalpy in kJ/kg
19
20 // Calculations:-
21
22 v1 = (R*1000*t1)/(28.97*p1*10**5) //
    specific volume
23 mdot=(A1*V1)/v1 //
    mass flow rate
24 Wcvdot = Qcvdot/60 + mdot*((h1-h2)+(V1**2-V2**2)
    /(2*1000))
25
26 // Results:-
27
28 printf( ' The power input to the compressor is %.2f

```


kw', Wcvdot)

Scilab code Exa 4.6 Example

```
1 // Given:-
2 // At Entry:=
3 t1=20.0 //
   Temperatue in deg celcius
4 p1=1.0 //
   pressure in atm
5 AV1= 0.1 //
   volumetric flow rate in litre/s
6 D1=2.5 //
   Diameter of th hose in cm
7
8 // At Exit:=
9 t2=23.0 //
   temperatuer in deg celcius
10 p2=1.0 //
   pressure in atm
11 V2=50.0 //
   Velocity in m/s
12 Z2=5.0 //
   elevation in m
13 g= 9.8 //
   acceleration due to gravity in m/s^2
14
15 // from table A-2 and A-19:-
16
17 v= (1.0018)*((10.0)**(-3)) //
   specific volume in m^3/kg
18 c= 4.18
19
20 // Calculation:-
21 mdot = (AV1/1000)/v //
```

```

    mass flow rate in kg/s
22 V1= (AV1/1000)/(3.14*(D1/(2*100))**2) //
    Entry velocity in m/s
23 deltah = c*(t2-t1)+v*(p2-p1)
24 Wcvdot= ((mdot*10)/9)*(-deltah+(V1**2-V2**2)
    /(2*1000)+g*(0-Z2)/1000)
25
26 // Results:-
27 printf( ' The power input to the motor is %.2f kw',
    Wcvdot)

```

Scilab code Exa 4.7 Example

```

1 // Given:-
2 // Entering:-
3 p1=0.1 //
    pressure in bar
4 x1= 0.95 //
    Quality
5 p2= 0.1 //
    pressure in bar
6 t2= 45.0 //
    temperature in deg celcius
7 t3=20.0 //
    temperature of cooling entry in deg cel
8 t4=35.0 //
    temperature of cooling exit
9
10 // From table A-3
11 hf= 191.53 //
    Enthalpy in KJ/kg
12 hg= 2584.7 //
    Enthalpy in KJ/kg
13 h2=188.45 //
    Assumption at states 2,3 and 4, h is approx equal

```

```

    to hf(T), in kJ/kg
14 deltah4_3= 62.7 //
    Assumption 4, in kJ/kg
15
16
17 // Calculations:-
18 h1= hf + x1*(hg-hf)
19 ratio= (h1-h2)/(deltah4_3)
20 QRate= (h2-h1) //
    Part B
21
22 // Results:-
23 printf('The rate of the mass flow rate of the
    cooling water to the mass flow rate of the
    condensating stream is (m3dot/m1dot) %.2f ',ratio
    )
24 printf('The rate of energy transfer from the
    condensing steam to the cooling water of the
    steam passing through the condenser is %.2f kJ/
    kg.',QRate)

```

Scilab code Exa 4.8 Example

```

1 // Given:-
2 T1 = 293.0 // In
    kelvin
3 P1= 1.01325 * (10**5) // In pascal
4 V1max= 1.3 //
    maximum velocity of entering air in m/s
5 T2max= 305.0 //
    maximum temperature at the exit in kelvin

```

```

6 pec= -80.0
//
// power received by electronic components in watt
7 Pf= -18.0
//
// Power received by fan in watt
8 R= 8.314
//
// Universal gas constant
9 M= 28.97*(10**(-3))
// Molar mass
// of air in kg
10 Qcvdot=0
//
// Heat transfer from the outer surface of the
// electronics enclosure to the surroundings is
// negligible.
11 Cp= 1.005*(10**3)
// in j/kg*k
12
13
14 // Calculations:-
15
16 Wcvdot = pec +Pf
// total
// electric power provided to electronic components
// and fan in watt
17 mdotmin= (-Wcvdot)/(Cp*(T2max-T1))
// minimum mass flow rate
18 v1= ((R/M)*T1)/P1
// specific
// volume
19 A1min = (mdotmin*v1)/V1max
20 D1min = (4*A1min/(%pi))**(0.5)
21
22 // Results:-
23 printf( ' The smallest fan inlet diameter is %.2f cm
',D1min*100)

```

Scilab code Exa 4.9 Example

```
1 // Given:-
2 P1 = 20.0 // pressure in
   supply line in bars
3 P2 = 1.0 // exhaust
   pressure in bar
4 T2 = 120.0 // exhaust
   temperature in degree celcius
5
6 // from table A-3 at 20 bars
7 hf1 = 908.79 // Enthalpy in
   kj/kg
8 hg1 = 2799.5 // Enthalpy in
   kj/kg
9
10 // from table A-4, at 1 bar and 120 degree celcius
11 h2 = 2766.6 // in kj/kg
12 h1 = h2 // from
   throttling process assumption
13
14
15 // Calculations:-
16 x1 = (h1-hf1)/(hg1-hf1)
17
18 // Results:-
19 printf( ' The quality of the steam in the supply
   line is %.2f',x1)
20
21
22 // Note : rounding off error. please check manually.
```

Scilab code Exa 4.10 Example

```
1 // Given:-
2 P1 = 1.0 // pressure of
   industrial discharge in bar
3 T1 = 478.0 // temperature of
   industrial discharge in kelvin
4 m1dot = 69.78 // mass flow rate of
   industrial discharge in kg/s
5 T2 = 400.0 // temperature of exit
   products from steam generator in kelvin
6 P2 = 1.0 // pressure of exit
   products from steam generator in bar
7 P3 = 0.275 // pressure of water
   stream entering the generator in Mpa
8 T3 = 38.9 // temperature of
   water stream entering the generator in degree
   celcius
9 m3dot = 2.079 // mass flow rate of
   water stream entering in kg/s
10 P5 = 0.07 // exit pressure of
   the turbine in bars
11 x5 = 0.93 // quality of turbine
   exit
12
13 // Part (a)
14 m2dot = m1dot // since gas and water
   streams do not mix
15 m5dot = m3dot // --DO
16
17 // from table A-22, A-2 and A-3:-
18 h1 = 480.3 // in kj/kg
19 h2 = 400.98 // in Kj/kg
20 h3 = 162.9 // assumption: h3 = hf
   (T3), units in Kj/kg
21 hf5 = 161.0 // in kj/kg
22 hg5 = 2571.72 // in kj/kg
23
```

```

24 // Part (b)
25 P4 = P3 // from the assumption
    that there is no pressure drop for water flowing
    through the steam generator
26 T4 = 180 // in degree celcius
27
28 // Calculations:-
29 h5 = hf5 + x5*(hg5-hf5)
30 Wcvdot = m1dot*h1 + m3dot*h3 - m2dot*h2 - m5dot*h5
31 h4 = h3 + (m1dot/m3dot)*(h1 -h2) // from steady
    state energy rate balance
32 // interpolating
    in table A
    -4, with
    these P4 and
    h4
33 // Results:-
34 printf( ' The power developed by the turbine is %.2f
    kJ/s.',Wcvdot)
35 printf( ' Turbine inlet temperature is %.2f degree
    celcius.',T4)

```

Scilab code Exa 4.11 Example

```

1 // Given:-
2 V = 0.85 // volume of
    tank in m^3
3 T1 = 260.0 // initial
    temperature of the tank in degree celcius
4 X1 = 0.7 // initial
    quality
5
6 // from table A-2
7 uf1 = 1128.4 // in kg/kg
8 ug1 = 2599.0 // in kg/kg

```

```

9
10 vf1 = 1.2755e-3 // in m^3/kg
11 vg1 = 0.04221 // in m^3/kg
12
13
14
15 // for final state , from table A-2,
16 u2 = 2599.0 // units in
    KJ/kg
17 v2 = 42.21e-3 // units in
    m^3/Kg
18 he = 2796.6 // units in
    KJ/kg
19
20 // Calculations:-
21 u1 = uf1 + X1*(ug1-uf1) // in kj/kg
22 v1 = vf1 + X1*(vg1-vf1) // in m^3/kg
23 m1 = V/v1 // initial
    mass in kg
24 m2 = V/v2 // final
    mass in kg
25 U2 = m2*u2 // final
    internal energy in KJ
26 U1 = m1*u1 // initial
    internal energy in KJ
27 Qcv = (U2-U1) - he*(m2-m1)
28
29 // Results:-
30 printf( ' The amount of heat transfer is %.2f KJ.',
    Qcv)

```

Scilab code Exa 4.12 Example

```

1 // Given:-
2 Pv = 15.0

```



```

//
3   pressure in the vessel in bar
Tv = 320.0
//
4   temperature in the vessel in degree celcius
Vt = 0.6
//
5   volume of a tank in m^3
Tt = 400.0
//
6   temperature in the tank in degree celcius when
    the tank is full
7   // Since the tank is initially empty:-
8   m1 = 0
9   u1 = 0
10
11  // From table A-4, at 15bar and 400 degree celcius:-
12  v2 = 0.203
//
13  m2 = Vt/v2
// mass
    within the tank at the end of the process in kg
14  hi = 3081.9
// in kj
    /kg
15  u2 = 2951.3
// in kj
    /kg
16
17  // Calculations:-
18  deltaUcv = m2*u2-m1*u1
19  Wcv = hi*(m2-m1)-deltaUcv
20
21  // Results:-
22  printf( ' The amount of work developed by the
    turbine is %.2f kJ.',Wcv)

```


Chapter 5

The Second Law of Thermodynamics

Scilab code Exa 5.1 Example

```
1 // Given :-
2 W = 410.00 // net work
   output in kj claimed
3 Q = 1000.00 // energy
   input by heat transfer in kj
4 Tc = 300.00 //
   temperature of cold reservoir in kelvin
5 TH = 500.00 //
   temperature of hot reservoir in kelvin
6
7 // Calculations
8 eta = W/Q // thermal
   efficiency
9 etamax = 1-(Tc/TH)
10
11 // Results
12 printf( ' Eta = %.4f ',eta)
13 printf( ' Etamax = %.4f ',etamax)
14 printf( ' Since eta is more than etamax, the claim
```

is not authentic')

Scilab code Exa 5.2 Example

```
1 // Given :-
2 Qcdot = 8000.00 // in
   kj/h
3 Wcycledot = 3200.00 // in
   kj/h
4 Tc = 268.00 //
   temperature of compartment in kelvin
5 TH = 295.00 //
   temperature of the surrounding air in kelvin
6
7 // Calculations
8 beta = Qcdot/Wcycledot //
   coefficient of performance
9 betamax = Tc/(TH-Tc) //
   reversible coefficient of performance
10
11 // Results
12 printf( ' Coefficient of performance is %.3f',beta)
13 printf( ' Coefficient of performance of a reversible
   cycle is %.3f',betamax)
```

Scilab code Exa 5.3 Example

```
1 // Given :-
2 Tc = 283.0 // in kelvin
3 TH = 295.0 // in kelvin
4 QH = 5*(10**5) // in kj per day
5
6 // Calculations
```

```
7 Wcyclemin = (1-(Tc/TH))*QH
8
9 // Results
10 printf( ' Minimum theoretical work input for one day
    of operation in kJ is: %.2f',Wcyclemin)
```

Chapter 6

Using Entropy

Scilab code Exa 6.1 Example

```
1 // Given:-
2 T = 373.15 //
   temperature in kelvin
3
4 // From table A-2
5
6 p = 1.014*(10**5) //
   pressure in pascal
7 vg = 1.673
8 vf = 1.0435e-3
9 sg = 7.3549
10 sf = 1.3069
11
12 // Calculations
13 w = p*(vg-vf)*(10**(-3))
14 Q = T*(sg-sf)
15
16 // Results
17 printf( ' The work per unit mass is %.3f KJ/Kg',w)
18 printf( ' The heat transfer per unit mass is %.2f kj
   /kg',Q)
```

Scilab code Exa 6.2 Example

```
1 // Given:-
2 // Assumptions:
3
4 // From table A-2 at 100 degree celcius
5 ug = 2506.5 // in
   kj/kg
6 uf = 418.94 // in
   kj/kg
7 sg = 7.3549
8 sf = 1.3069
9
10
11 // Calculations:-
12 // From energy balance
13 W = -(ug-uf)
14 // From entropy balance
15 sigmabym = (sg-sf)
16
17 // Results
18 printf( ' The net work per unit mass is %.2f KJ/kg.
   ',W)
19 printf( ' The amount of entropy produced per unit
   mass is %.2f KJ/kg.',sigmabym)
```

Scilab code Exa 6.3 Example

```
1 // Given:-
2 T1 = 273.0 // initial
   temperature of saturated vapor in kelvin
```

```

3 P2 = 0.7*(10**6) // final
   pressure in pascal
4
5 // From table A-10,
6 u1 = 227.06 // in kj/
   kg
7
8 // minimum theoretical work corresponds to state of
   isentropic compression
9 // From table A-12,
10 u2s = 244.32 // in kj/
   kg
11
12 // Calculations
13 Wmin = u2s-u1
14
15 // Results
16 printf( ' The minimum theoretical work input
   required per unit mass of refrigerant is: %.2f kJ
   /kg ',Wmin)

```

Scilab code Exa 6.4 Example

```

1 // Given :-
2 Qdot = -1.2 // in kilo watt
3 Tb = 300.0 // in kelvin
4 Tf = 293.0 // in kelvin
5 // Calculations
6
7 // Part (a)
8 // From entropy balance
9 sigmadot = -Qdot/Tb
10
11 // Part(b)
12 // From entropy balance

```



```

13 sigmadt = -Qdot/Tf
14
15 // Results
16 printf( ' The rate of entropy production with
    gearbox as system is %f kw/k',sigmadot)
17 printf( ' The rate of entropy production with
    gearbox + sorrounding as system is %f kw/k',
    sigmadt)

```

Scilab code Exa 6.5 Example

```

1 // GIVen:-
2 Tmi = 1200.0 //
    initial temperature of metal in kelvin
3 cm = 0.42 //
    specific heat of metal in KJ/kg.k
4 mm = 0.3 //
    mass of metal in kg
5 Twi = 300.0 //
    initial temperature of water in kelvin
6 cw = 4.2 //
    specific heat of water in KJ/Kg.k
7 mw = 9.0 //
    mass of water in kg
8
9 // Calculations
10 // Part(a)
11 // Solving energy balance equation yields
12 Tf = (mw*(cw/cm)*Twi+mm*Tmi)/(mw*(cw/cm)+mm)
13
14 // Part (b)
15 // Solving entropy balance equation yields
16 sigma = mw*cw*log(Tf/Twi)+mm*cm*log(Tf/Tmi)
17
18 // Results

```

```

19 printf( ' The final equilibrium temperature of the
    metal bar and the water is %.2f kelvin.',Tf)
20 printf( ' The amount of entropy produced is: %.2f kJ
    /k.',sigma)

```

Scilab code Exa 6.6 Example

```

1 // Given:-
2 P1 = 30.0
    //
    pressure of steam entering the turbine in bar
3 T1 = 400.0
    //
    temperature of steam entering the turbine in
    degree celcius
4 V1 = 160.0
    //
    velocity of steam entering the turbine in m/s
5 T2 = 100.0
    //
    temperature of steam exiting in degree celcius
6 V2 = 100.0
    //
    velocity of steam exiting in m/s
7 Wcvdot = 540.0
    // work
    produced by turbine in kJ/kg of steam
8 Tb = 350.0
    //
    temperature of the boundary in kelvin
9
10 // From table A-4 and table A-2
11 h1 = 3230.9
    //
    specific enthalpy at entry in Kj/kg

```

```

12 h2 = 2676.1 //
    specific enthalpy at exit in kJ/kg //
13
14 // Calculations
15
16 // Reduction in mass and energy balance equations
    results in
17 Qcvdot = Wcvdot + (h2 - h1) + (V2**2 - V1**2)
    /(2*(10**3)) // heat transfer rate
18
19 // From table A-2
20 s2 = 7.3549 // in
    kJ/kg.k
21 // From table A-4
22 s1 = 6.9212 // in
    kJ/kg.k
23
24 // From entropy and mass balance equations
25 sigmadot = -(Qcvdot/Tb) + (s2-s1)
26
27 // Results
28 printf( 'The rate at which entropy is produced
    within the turbine per kg of steam flowing is %
    .2f kJ/kg.k', sigmadot)

```

Scilab code Exa 6.7 Example

```

1 // Given:-
2 T1 = 294.0 // entry
    temperature of air in kelvin
3 P1 = 5.1 // entry
    pressure of air in bars

```

```

4 T2 = 352.0 // exit
  temperature of hot stream in kelvin
5 P2 = 1.0 // exit
  pressure of hot stream in bars
6 T3 = 255.0 // exit
  temperature of cold stream in kelvin
7 P3 = 1.0 // exit
  pressure of cold stream in bars
8 cp = 1.0 // in kj/kg.k
9
10 // Calculations
11 R = 8.314/28.97
12 se = 0.4*(cp*log((T2)/(T1))-R*log(P2/P1)) + 0.6*(cp*
  log((T3)/(T1))-R*log(P3/P1))
13 // specific
  entropy in
  kj/kg.k
14
15
16 // Results
17 printf( ' Specific entropy in kj/kg.k = %.3f KJ/kg.
  ',se)
18 printf( ' Since se > 0, the claim of the writer is
  true');

```

Scilab code Exa 6.8 Example

```

1 // Given:-
2 P1 = 3.5 //
  pressure of refrigerant entering the compressor
  in bars
3 T1 = 268.0 //
  temperature of refrigerant entering the
  compressor in kelvin
4 P2 = 14.0 //

```

```

    pressure of refrigerant entering the condenser
    in bars
5 T2 = 348.0 //
    temperature of refrigerant entering the
    condenser in kelvin
6 P3 = 14.0 //
    pressure of refrigerant exiting the condenser in
    bars
7 T3 = 301.0 //
    temperature of refrigerant exiting the condenser
    in kelvin
8 P4 = 3.5 //
    pressure of refrigerant after passing through
    expansion valve in bars
9 P5 = 1.0 //
    pressure of indoor return air entering the
    condenser in bars
10 T5 = 293.0 //
    temperature of indoor return air entering the
    condenser in kelvin
11 AV5 = 0.42 //
    volumetric flow rate of indoor return air
    entering the condenser in m^3/s
12 P6 = 1.0 //
    pressure of return air exiting the condenser in
    bar
13 T6 = 323.0 //
    temperature of return air exiting the condenser
    in kelvin
14
15 // Part(a)
16
17 // From table A-9
18 s1 = 0.9572 //
    in kj/kg.k
19 // Interpolating in table A-9
20 s2 = 0.98225 //
    in kj/kg.k

```

```

21 h2 = 294.17 //
    in kj/kg
22 // From table A-7
23 s3 = 0.2936 //
    in kj/kg.k
24 h3 = 79.05 //
    in kj/kg
25
26 h4 = h3 //
    since expansion through valve is throttling
    process
27
28 // From table A-8
29 hf4 = 33.09 //
    in kj/kg
30 hg4 = 246.00 //
    in kj/kg
31 sf4 = 0.1328 //
    in kj/kg.k
32 sg4 = 0.9431 //
    in kj/kg.k
33 cp = 1.005 //
    in kj/kg.k
34
35 // Calculations
36
37 x4 = (h4-hf4)/(hg4-hf4) //
    quality at state 4
38 s4 = sf4 + x4*(sg4-sf4) //
    specific entropy at state 4
39
40 // CONDENSER!!
41 v5 = ((8314/28.97)*T5)/(P5*(10**5)) //
    specific volume at state 5
42 mairdot = AV5/v5
43 h6 = cp*T6
44 h5 = cp*T5
45 mrefdot = mairdot*(h6-h5)/(h2-h3)

```

```

46 deltaS65 = cp*log(T6/T5) - (8.314/28.97)*log(P6/P5) //
    change in specific entropy
47 sigmacond = (mrefdot*(s3-s2)) + (mairdot*(deltaS65))
48
49 // COMPRESSOR!!
50 sigmacomp = mrefdot*(s2-s1)
51
52 // VALVE!!
53 sigmavalve = mrefdot *(s4-s3)
54
55 // Results
56 printf( ' The rates of entropy production for
    control volume enclosing the condenser is %f kw/
    k',sigmacond);
57 printf( ' The rates of entropy production for
    control volume enclosing the compressor is %f kW
    /K.',sigmacomp);
58 printf( ' The rates of entropy production for
    control volume enclosing the expansion valve is
    %f kW/K ',sigmavalve)

```

Scilab code Exa 6.9 Example

```

1 // Given:-
2 P1 = 1.00 //
    initial pressure in bar
3 T1 = 300.00 //
    initial temperature in kelvin
4 T2 = 650.00 //
    final temperature in kelvin
5
6 // Part(a)
7 // From table A-22
8 pr2 = 21.86
9 pr1 = 1.3860

```

```

10 k = 1.39                                     // From
    table A-20
11
12 // Calculations
13 p2 = P1*(pr2/pr1)
14 p2a = P1*((T2/T1)**(k/(k-1)))
15
16 // Results
17 printf( ' P2 = %f bar.',p2)
18 printf( ' Part(b) IT software problem ');
19 printf( ' P2a = %f bar',p2a);

```

Scilab code Exa 6.10 Example

```

1 // Given:-
2 m1 = 5.00
    // initial mass in kg
3 P1 = 5.00
    // initial pressure in bar
4 T1 = 500.00
    // initial temperature in kelvin
5 P2 = 1.00
    // final pressure in bar
6
7 // From table A-22
8 pr1 = 8.411
9
10
11
12 // Using this value of pr2 and interpolation in
    table A-22
13 T2 = 317.00
    // in kelvin
14
15 // Calculations

```



```

16 pr2 = (P2/P1)*pr1
17 m2 = (P2/P1)*(T1/T2)*m1
18
19 // Results
20 printf('The amount of mass remaining in the tank is
        %f kg',m2)
21 printf('and its temperature is %f kelvin.',T2);

```

Scilab code Exa 6.11 Example

```

1 // Given:-
2 P1 = 1.00
        inlet pressure in bar //
3 T1 = 593.00
        inlet temperature in kelvin //
4 P2 = 1.00
        exit pressure in bar //
5 eta =0.75
        turbine efficiency //
6
7 // From table A-4
8 h1 = 3105.6
        Kj/kg // in
9 s1 = 7.5308
        kj/kg.k // in
10 // From table A-4 at 1 bar
11 h2s = 2743.00
        // in kj
        /kg

```

```

12
13 // Calculations
14 w = eta*(h1 - h2s)
15
16 // Result
17 printf( ' The work developed per unit mass of steam
    flowing through is %f kJ/kg.',w);

```

Scilab code Exa 6.12 Example

```

1 // Given:-
2 P1 = 3.00 //
    pressure of air entering in bar
3 T1 = 390.00 //
    temperature of air entering in kelvin
4 P2 = 1.00 //
    pressure of exit air
5 Wcvdot = 74.00 // work
    developed in kJ/kg
6
7 // From table A-22,at 390k
8 h1 = 390.88 // in kJ/
    kg
9 pr1 = 3.481
10
11 // From interpolation table A-22
12 h2s = 285.27 // in kJ/
    kg
13
14 // calculations
15 pr2 = (P2/P1)*pr1
16 Wcvdots = h1 - h2s
17 eta = Wcvdot/Wcvdots
18
19 // Result

```

```
20 printf( ' The turbine efficiency is %.4f ',eta)
```

Scilab code Exa 6.13 Example

```
1 // Given:–
2 P1 = 1.00 //
   pressure of entering steam in Mpa
3 T1 = 593.00 //
   temperature of entering steam in kelvin
4 V1 = 30.00 //
   velocity of entering steam in m/s
5 P2 = 0.3 //
   pressure of exit steam in Mpa
6 T2 = 453.00 //
   temperature of exit steam in kelvin
7
8 // From table A–4, at T1 = 593 kelvin and P1 = 1 Mpa
   ;
9 // and at T2 = 453 kelvin and P2 = .3 Mpa
10 h1 = 3093.9 //
   in kj/kg
11 s1 = 7.1962 //
   in kj/kg.k
12 h2 = 2823.9 //
   in kj/kg
13
14
15 // Interpolating in table A–4
16 h2s = 2813.3 //
   in kj/kg
17
18 // Calculations
19 V2squareby2 = h1 - h2 + (V1**2)/2000
20 V2squareby2s = h1 - h2s + (V1**2)/2000
21 eta = V2squareby2/V2squareby2s
```

```

22
23 // Results
24 printf( ' The nozzle efficiency is %.4f',eta)

```

Scilab code Exa 6.14 Example

```

1 // Given:-
2 // From table A-9
3 h1 = 249.75 // in
    kj/kg
4 h2 = 294.17 // in
    kj/kg
5 mdot = 0.07 // in
    kg/s
6
7 // From table A-9
8 s1 = 0.9572 // in
    Kj/Kg.k
9 h2s = 285.58 // in
    kj/kg
10
11 // Calculations
12 wcvdot = -(mdot*(h2-h1))
13 eta = (h2s-h1)/(h2-h1)
14
15 // Results
16 printf( ' The power in is %f kw',wcvdot);
17 printf( ' The isentropic efficiency is %.3f',eta)

```

Scilab code Exa 6.15 Example

```
1 // Given:-
2 P1 = 1.00 // pressure
   of entering air in bar
3 T1 = 293.00 //
   temperature of entering air in kelvin
4 P2 = 5.00 // pressure
   of exit air in bar
5 n = 1.3
6 R = 8.314/28.97
7
8 // From table A-22
9 h1 = 293.17 // in kj/kg
10 h2 = 426.35 // in kj/kg
11
12 // Calculations
13 T2 = T1*((P2/P1)**((n-1)/n)) // in
   kelvin
14 wcvdot=((n*R)/(n-1))*(T1-T2) // in kj/kg
15 Qcvdot= wcvdot + (h2-h1) // in kj/kg
16
17 // Results
18 printf( ' The work per unit mass passing through the
   device is %.2f kJ/kg',wcvdot)
19 printf( ' The heat transfer per unit mass is %.2f kJ
   /kg. ',Qcvdot)
```

Chapter 7

Exergy Analysis

Scilab code Exa 7.1 Example

```
1 // Given:-
2 v = 2450.00 //
   volume of gaseous products in cm^3
3 P = 7.00 //
   pressure of gaseous product in bar
4 T = 867.00 //
   temperature of gaseous product in degree celcius
5 T0 = 300.00 // in
   kelvin
6 P0 = 1.013 // in
   bar
7
8 // From table A-22
9 u = 880.35 // in
   kj/kg
10 u0 = 214.07 // in
   kj/kg
11 s0T = 3.11883 // in
   kj/kg.k
12 s0T0 = 1.70203 // in
   kj/kg.k
```

```

13
14 // Calculations
15
16 e = (u-u0) + (P0*(8.314/28.97)*(((T+273)/P)-(T0/P0))
      ) - T0*(s0T-s0T0-(8.314/28.97)*log(P/P0)) // kj/
      kg
17
18 // Results
19 printf( ' The specific exergy of the gas is %.3f kJ/
      kg. ',e)

```

Scilab code Exa 7.2 Example

```

1 // Given:-
2 mR = 1.11 // mass of
      the refrigerant in kg
3 T1 = -28.00 // initial
      temperature of the saturated vapor in degree
      celcius
4 P2 = 1.4 // final
      pressure of the refrigerant in bar
5 T0 = 293.00 // in kelvin
6 P0 = 1.00 // in bar
7
8 // Part (a)
9 // From table A-10
10 u1 = 211.29 // in kj/kg
11 v1 = 0.2052 // in m^3/kg
12 s1 = 0.9411 // in kj/kg.
      k
13 // From table A-12
14 u0 = 246.67 // in kj/kg
15 v0 = 0.23349 // in m^3/kg
16 s0 = 1.0829 // in kj/kg.
      k

```

```

17
18 // From table A-12
19 u2 = 300.16 // in kj/kg
20 s2 = 1.2369 // in kj/kg.
    k
21 v2 = v1
22
23 // Calculations
24 E1 = mR*((u1-u0) + P0*(10**5)*(v1-v0)*(10**(-3))-T0
    *(s1-s0))
25 E2 = mR*((u2-u0) + P0*(10**5)*(v2-v0)*(10**(-3))-T0
    *(s2-s0))
26
27 // Results for Part A
28 printf( ' Part(a) The initial exergy is %.2f kJ.',E1
    )
29 printf( ' The final exergy is %.2f kJ.',E2)
30 printf( ' The change in exergy of the refrigerant is
    %.2f kj',E2-E1)
31
32
33 // Part (b)
34 // Calculations
35 deltaU = mR*(u2-u1)
36 // From energy balance
37 deltaPE = -deltaU
38 // With the assumption::The only significant changes
    of state are experienced by the refrigerant and
    the suspended mass. For the refrigerant ,
39 // there is no change in kinetic or potential energy
    . For the suspended mass, there is no change in
    kinetic or internal energy. Elevation is
40 // the only intensive property of the suspended mass
    that changes
41 deltaE = deltaPE
42
43 // Results for part b
44 printf( ' Part(b)The change in exergy of the

```



```

    suspended mass is %.3f kJ',deltaE)
45
46
47 // Part(c)
48 // Calculations
49 deltaEiso = (E2-E1) + deltaE
50
51 // Results
52 printf( ' Part(c)The change in exergy of an isolated
    system of the vessel and pulley mass assembly
    is %.2f kJ',deltaEiso)

```

Scilab code Exa 7.3 Example

```

1 // Given :-
2 T = 373.15
    //
    initial temperature of saturated liquid in kelvin
3 T0 = 293.15
    // in
    kelvin
4 P0 = 1.014
    //
    in bar
5
6 // Part(a)
7 // From table A-2
8 ug = 2506.5
    // in
    kj/kg
9 uf = 418.94
    // in
    kj/kg
10 vg = 1.673
    //

```

```

    in m^3/kg
11 vf = 1.0435*(10**(-3))
                                           // in m^3/kg
12 sg = 7.3549
                                           // in
    kj/kg.k
13 sf = 1.3069
                                           // in
    kj/kg.k
14
15
16 // Calculations
17 // Energy transfer accompanying work
18 etaw = 0
                                           //
    since p = p0
19 // Exergy transfer accompanying heat
20 Q = 2257
                                           //
    in kj/kg, obtained from example 6.1
21 etah = (1-(T0/T))*Q
22
23 // Exergy destruction
24 ed = 0
    // since the process is accomplished without any
    irreversibilities
25 deltae = ug-uf + P0*(10**5)*(vg-vf)/(10**3)-T0*(sg-
    sf)
26
27 // Results
28 printf( ' Part(a)the change in exergy is %.2f kJ/kg.
    ',deltae)
29 printf( ' The exergy transfer accompanying work is %
    .2f kJ/kg. ',etaw)
30 printf( ' The exergy transfer accompanying heat is %
    .2f kJ/kg',etah)
31 printf( ' The exergy destruction is %.2f kJ/kg.',ed)

```

```

32
33
34 // Part(b)
35 Deltae = deltae
// since
    the end states are same
36 Etah = 0
// since process is adiabatic
37 // Exergy transfer along work
38 W = -2087.56
// in
    kJ/kg from example 6.2
39 Etaw = W- P0*(10**5)*(vg-vf)/(10**3)
40 // Exergy destruction
41 Ed = -(Deltae+Etaw)
42
43 // Results
44 printf( ' Part(b)the change in exergy is %.2f kJ/kg.
    ',Deltae)
45 printf( ' The exergy transfer accompanying work is %
    .2f kJ/kg. ',Etaw)
46 printf( ' The exergy transfer accompanying heat is %
    .2f kJ/kg. ',Etah)
47 printf( ' The exergy destruction is %.2f kJ/kg. ',Ed)

```

Scilab code Exa 7.4 Example

```

1 // Given:-
2 T0 = 293.00
    // in kelvin
3 Qdot = -1.2
    // in KW, from example 6.4a
4 Tb = 300.00
    // temperature at the outer surface of the

```

```

    gearbox in kelvin from example 6.4a
5  sigmadot = 0.004
    // rate of entropy production in KW/k from
    example 6.4a
6
7  // Calculations
8  R = -(1-T0/Tb)*Qdot
                                     // time rate of
    exergy transfer accompanying heat
9  Eddot = T0*sigmadot
    // rate of exergy destruction
10
11 // Results
12 printf( ' Balance sheet');
13 printf( '\n Rate of exergy in high speed shaft 60Kw'
    )
14 printf( '\n Disposition of the exergy: Rate of
    exergy out low-speed shaft %.1f Kw',58.8 )
15 printf( '\n Heat transfer is %.3f kw.',R)
16 printf( '\n Rate of exergy destruction is %.3f kw',
    Eddot)

```

Scilab code Exa 7.5 Example

```

1 // Given:-
2 p1 = 3.0
                                     //
    entry pressure in Mpa
3 p2 = 0.5
                                     //
    exit pressure in Mpa
4 T1 = 320.0
                                     //
    entry temperature in degree celcius
5 T0 = 25.0

```

```

// in
        degree celcius
6  p0 = 1.0
//
        in atm
7
8  // From table A-4
9  h1 = 3043.4
// in
        kj/kg
10 s1 = 6.6245
// in
        kj/kg.k
11 h2 = h1
//
        from reduction of the steady-state mass and
        energy rate balances
12 s2 = 7.4223
//
        Interpolating at a pressure of 0.5 MPa with h2 =
        h1, units in kj/kg.k
13
14 // From table A-2
15 h0 = 104.89
// in
        kj/kg
16 s0 = 0.3674
// in
        kj/kg.k
17
18 // Calculations
19 ef1 = h1-h0-(T0+273)*(s1-s0)
// flow exergy at the
        inlet
20 ef2 = h2-h0-(T0+273)*(s2-s0)
// flow exergy at the
        exit
21 // From the steady-state form of the exergy rate

```

```

    balance
22 Ed = ef1-ef2
                                     // the
    exergy destruction per unit of mass flowing is
23
24 // Results
25 printf( ' The specific flow exergy at the inlet is %
    .2f kJ/kg. ',ef1)
26 printf( ' The specific flow exergy at the exit is %
    .2f kJ/kg. ',ef2)
27 printf( ' The exergy destruction per unit of mass
    flowing is %.2f kJ/kg. ',Ed)

```

Scilab code Exa 7.6 Example

```

1 // Given:-
2 T1 = 610.0
                                     //
    temperature of the air entering heat exchanger
    in kelvin
3 p1 = 10.0
                                     //
    pressure of the air entering heat exchanger in
    bar
4 T2 = 860.0
                                     //
    temperature of the air exiting the heat
    exchanger in kelvin
5 p2 = 9.70
                                     //
    pressure of the air exiting the heat exchanger
    in bar
6 T3 = 1020.0
                                     //
    temperature of entering hot combustion gas in

```

```

kelvin
7 p3 = 1.10

    // pressure of entering hot combustion gas in
    bar
8 p4 = 1.0

    // pressure of exiting hot combustion gas in bar
9 mdot = 90.0
                                                    //
    mass flow rate in kg/s
10 T0 = 300.0
                                                    //
    in kelvin
11 p0 = 1.0

    // in bar
12
13 // Part (a)
14 // From table A-22
15 h1 = 617.53
                                                    //
    in kj/kg
16 h2 = 888.27
                                                    //
    in kj/kg
17 h3 = 1068.89
                                                    //
    in kj/kg
18
19 // Calculations
20 h4 = h3+h1-h2
21
22 // Using interpolation in table A-22 gives
23 T4 = 778

    // in kelvin
24

```

```

25 // Results
26 printf( ' The exit temperature of the combustion gas
        is %f kelvin. ',T4);
27
28 // Part(b)
29 // From table A-22
30 s2 = 2.79783
                                     //
        in kj/kg.k
31 s1 = 2.42644
                                     //
        in kj/kg.k
32 s4 = 2.68769
                                     //
        in kj/kg.k
33 s3 = 2.99034
                                     //
        in kj/kg.k
34
35 // Calculations for part b
36
37 deltaR = (mdot*((h2-h1)-T0*(s2-s1-(8.314/28.97)*log(
        p2/p1))))/1000
38 deltc = mdot*((h4-h3)-T0*(s4-s3-(8.314/28.97)*log(
        p4/p3)))/1000
39
40 // Results for part b
41 printf( ' The net change in the flow exergy rate
        from inlet to exit of compressed gas   is %.3f MW
        . ',deltaR)
42 printf( ' The net change in the flow exergy rate
        from inlet to exit of hot combustion gas   is %.3
        f MW. ',deltc)
43
44 // Part(c)
45 //From an exergy rate balance
46 Eddot = -deltaR-deltc
47

```



```

48 // Results
49 printf( ' The rate exergy destroyed , is %.3f MW.'
, Eddot)

```

Scilab code Exa 7.7 Example

```

1 // Given:-
2 p1 = 30.0
           //
           pressure of entering steam in bar
3 t1 = 400.0
           //
           temperature of entering steam in degree celcius
4 v1 = 160.0
           //
           velocity of entering steam in m/s
5 t2 = 100.0
           //
           temperature of exiting saturated vapor in degree
           celcius
6 v2 = 100.0
           //
           velocity of exiting saturated vapor in m/s
7 W = 540.0
           //
           rate of work developed in kj per kg of steam
8 Tb = 350.0
           // the
           temperature on the boundary where heat transfer
           occurs in kelvin
9 T0 = 25.0
           // in
           degree celcius
10 p0 = 1.0
           //

```

```

    in atm
11
12 // From table A-4
13 h1 = 3230.9 // in
    kj/kg
14 s1 = 6.9212 // in
    kj/kg.k
15 // From table A-2
16 h2 = 2676.1 // in
    kj/kg
17 s2 = 7.3549 // in
    kj/kg.k
18 // From example 6.6
19 Q = -22.6 // in
    kj/kg
20
21 // Calculations
22 DELTAef = (h1-h2)-(T0+273)*(s1-s2)+(v1**2-v2**2)
    /(2*1000)
23 // The net exergy carried in per unit mass of steam
    flowing in kj/kg
24 Eq = (1-(T0+273)/Tb)*(Q) // exergy transfer
    accompanying heat in kj/kg
25 Ed = ((1-(T0+273)/Tb)*(Q))-W+(DELTAef)
    // The exergy destruction
    determined by rearranging the steady-state form
    of the exergy
26 //
    rate
    balance

```

```

27
28 // Results
29 printf( ' Balance sheet ')
30 printf( ' Net rate of exergy %f kJ/kg, ', DELTAef)
31 printf( ' Disposition of the exergy: ')
32 printf( '* Rate of exergy out ')
33 printf( ' Work %f kJ/kg. ', W)
34 printf( ' Heat transfer %f', -Eq)
35 printf( '      Rate of exergy destruction %f kJ/kg. ',
      Ed)

```

Scilab code Exa 7.8 Example

```

1 // Given:—
2 clc;
3 mldot = 69.78 // in
      kg/s
4 p1 = 1.0
      // in bar
5 T1 = 478.0 //
      in kelvin
6 T2 = 400.0 //
      in kelvin
7 p2 = 1.0
      // in bar
8 p3 = 0.275 //
      in Mpa
9 T3 = 38.9

```

```

10      // in degree celcius
m3dot = 2.08
//
      in kg/s
11 T4 = 180.0
//
      in degree celcius
12 p4 = 0.275
//
      in Mpa
13 p5 = 0.07
//
      // in bar
14 x5 = 0.93
15 Wcvdot = 876.8
// in
      kW
16 T0 = 298.0
//
      in kelvin
17
18
19 // Part(a)
20 // From table A-22
21 h1 = 480.35
//
      in kj/kg
22 h2 = 400.97
//
      in kj/kg
23 s1 = 2.173
//
      in kj/kg
24 s2 = 1.992
//
      in kj/kg
25

```

```

26 // From table A-2E
27 h3 = 162.82
//
// in kj/kg
28 s3 = 0.5598
//
// in kj/kg.k
29 // Using saturation data at 0.07 bars from Table A-3
30 h5 = 2403.27
//
// in kj/kg
31 s5 = 7.739
//
// in kj/kg.k
32 //The net rate exergy carried out by the water
// stream
33
34 // From table A-4
35 h4 = 2825.0
//
// in kj/kg
36 s4 = 7.2196
//
// in kj/kg.k
37 // Calculations
38 netRE = m1dot*(h1-h2-T0*(s1-s2-(8.314/28.97)*log(p1/
// p2))) // the net rate exergy carried into the
// control volume
39 netREout = m3dot*(h5-h3-T0*(s5-s3))
40 // From an exergy rate balance applied to a control
// volume enclosing the steam generator
41 Eddot = netRE + m3dot*(h3-h4-T0*(s3-s4))
// the rate exergy is destroyed
// in the heat-recovery steam generator
42
43 // From an exergy rate balance applied to a control
// volume enclosing the turbine
44 Eddot = -Wcvdot + m3dot*(h4-h5-T0*(s4-s5))

```

```

// the rate exergy is destroyed in
the tpurbine
45
46 // Results
47 printf( '\n balance sheet ')
48 printf( '\n- Net rate of exergy in: %f kJ/kg.',netRE
)
49 printf( '\n Disposition of the exergy:')
50 printf( '\n Rate of exergy out')
51 printf( '\n power developed %f kJ/kg.',netRE-
netREout-Eddot-EdDot)
52 printf( '\n water stream %f',netREout)
53 printf( '\n Rate of exergy destruction')
54 printf( '\n heat-recovery steam generator %f kJ/kg',
Eddot)
55 printf( '\n turbine %f',EdDot)
56
57 // note : answer is slightly different because of
rounding off error.

```

Scilab code Exa 7.9 Example

```

1 // Given:-
2 T0 = 273.00

// in kelvin
3 pricerate = 0.08 //
exergy value at $0.08 per kw.h

4
5 // From example 6.8
6 sigmadotComp = 17.5e-4 // in kw/k
7 sigmadotValve = 9.94e-4 // in kw/k

```

```

8 sigmadotcond = 7.95e-4
                                                    // in kw/k
9
10 // Calculations
11 // The rates of exergy destruction
12 EddotComp = T0*sigmadotComp
                                                    // in kw
13 EddotValve = T0*sigmadotValve
                                                    // in kw
14 Eddotcond = T0*sigmadotcond
                                                    // in kw
15
16 mCP = 3.11
    // From the solution to Example 6.14, the
    // magnitude of the compressor power in kW
17
18 // Results
19 printf( ' Daily cost in dollars of exergy
    destruction due to compressor irreversibilities =
    %.3f ',EddotComp*pricerate*24)
20 printf( ' Daily cost in dollars of exergy
    destruction due to irreversibilities in the
    throttling valve = %.3f ',EddotValve*pricerate*24)
21 printf( ' Daily cost in dollars of exergy
    destruction due to irreversibilities in the
    condenser = %.3f ',Eddotcond*pricerate*24)
22 printf( ' Daily cost in dollars of electricity to
    operate compressor = %.3f ',mCP*pricerate*24)

```

Scilab code Exa 7.10 Example

```

1 // Given:-
2 EfFdot = 100.00
                                                    //

```

```

    exergy rate of fuel entering the boiler in MW
3  cF = 1.44

    // unit cost of fuel in cents per kw.h
4  Zbdot = 1080.00

    //
    the cost of owning and operating boiler in
    dollars per hour
5  Ef1dot = 35.00

    //
    exergy rate of exiting steam from the boiler in
    MW
6  p1 = 50.00

    // pressure of exiting steam from the boiler in
    bar
7  T1 = 466.00

    // temperature of exiting steam from the boiler
    in degree celcius
8  Ztdot = 92.00

    //
    the cost of owning and operating turbine in
    dollars per hour
9  p2 = 5.00

    // pressure of exiting steam from the turbine in
    bars
10 T2 = 205.00

    // temperature of exiting steam from the turbine
    in degree celcius
11 m2dot = 26.15

    //
    mass flow rate of exiting steam from the turbine
    in kg/s
12 T0 = 298.00

```



```

    // in kelvin
13
14
15 // Part(a)
16 // From table A-4,
17 h1 = 3353.54
                                     //
    // in kj/kg
18 h2 = 2865.96
                                     //
    // in kj/kg
19 s1 = 6.8773
                                     //
    // in kj/kg.k
20 s2 = 7.0806
                                     //
    // in kj/kg.k
21
22 // Calculations
23 // From assumption ,For each control volume ,Qcvdot =
    // 0 and kinetic and potential energy effects are
    // negligible ,the mass and energy rate
24 // balances for a control volume enclosing the
    // turbine reduce at steady state to give
25 Wedot = m2dot *(h1-h2)/1000
                                     // power in MW
26 Ef2dot = Ef1dot+m2dot*(h2-h1-T0*(s2-s1))/1000
    // the rate exergy exits with the
    // steam in MW
27
28 // Results
29 printf( ' For the turbine ,the power is %.2f MW. ',
    Wedot)
30 printf( ' For the turbine ,the rate exergy exits with
    the steam is %.2f MW. ',Ef2dot)
31
32 // Part(b)
33 // Calculations

```

```

34 c1 = cF*(EfFdot/Ef1dot) + ((Zbdot/Ef1dot)/10**3)*100
      // unit cost of exiting steam from
      boiler in cents/Kw.h
35 c2 = c1

      // Assigning the same unit cost to the steam
      entering and exiting the turbine
36 ce = c1*((Ef1dot-Ef2dot)/Wedot) + ((Ztdot/Wedot)
      /10**3)*100 // unit cost of power in cents/kw.h
37
38 // Results
39 printf('The unit costs of the steam exiting the
      boiler of exergy is: %.2f cents per kw.h.',c1)
40 printf('The unit costs of the steam exiting the
      turbine of exergy is: %.2f cents per kw.h.',c2)
41 printf('Unit cost of power is: %f cents per kw.h.',
      ce)
42
43 // Part(c)
44 C2dot = (c2*Ef2dot*10**3)/100
      // cost rate for
      low-pressure steam in dollars per hour
45 Cedot = (ce*Wedot*10**3)/100
      // cost rate for
      power in dollars per hour
46
47 // Results
48 printf( ' The cost rate of the steam exiting the
      turbine is: %.2f dollars per hour.',C2dot)
49 printf( ' The cost rate of the power is: %.2f
      dollars per hour.',Cedot)

```

Chapter 8

Vapor Power Systems

Scilab code Exa 8.1 Example

```
1 // Given:-
2 p1 = 8.0
   // pressure of saturated vapor entering the
   turbine in MPa
3 p3 = 0.008
   // pressure of saturated liquid exiting the
   condenser in MPa
4 Wcycledot = 100.00
   // the net power output of the cycle in MW
5
6 // Analysis
7 // From table A-3
8 h1 = 2758.0
   // in kJ/kg
9 s1 = 5.7432
   // in kJ/kg.k
10 s2 = s1
11 sf = 0.5926
   // in kJ/kg.k
12 sg = 8.2287
   // in kJ/kg.k
```

```

13 hf = 173.88
    // in kj/kg
14 hfg = 2403.1
    // in kj/kg
15 v3 = 1.0084e-3
    // in m^3/kg
16
17 // State 3 is saturated liquid at 0.008 MPa, so
18 h3 = 173.88
    // in kj/kg
19
20 // Calculations
21 x2 = (s2-sf)/(sg-sf)
    // quality at state 2
22 h2 = hf + x2*hfg
23 p4 = p1
24 h4 = h3 + v3*(p4-p3)*10**6*10**-3
    // in kj/kg
25
26 // Part(a)
27 //Mass and energy rate balances for control volumes
    around the turbine and pump give, respectively
28 wtdot = h1 - h2
29 wpdot = h4-h3
30
31 // The rate of heat transfer to the working fluid as
    it passes through the boiler is determined using
    mass and energy rate balances as
32 qindot = h1-h4
33
34 eta = (wtdot-wpdot)/qindot
    // thermal efficiency)
35
36 // Result for part a
37 printf( ' The thermal efficiency for the cycle is %
    .2f',eta)
38
39 // Part(b)

```

```

40 bwr = wpdot/wtdot
                                        // back work
    ratio
41
42 // Result
43 printf( ' The back work ratio is %f',bwr)
44
45 // Part(c)
46 mdot = (Wcycledot*10**3*3600)/((h1-h2)-(h4-h3))
    // mass flow rate in kg/h
47
48 // Result
49 printf( ' The mass flow rate of the steam is %.2f kg
    /h . ',mdot)
50
51 // Part(d)
52 Qindot = mdot*qindot/(3600*10**3)
    // in MW
53
54 // Results
55 printf('The rate of heat transfer ,Qindot , into the
    working fluid as it passes through the boiler , is
    %.2f MW. ',Qindot)
56
57 // Part(e)
58 Qoutdot = mdot*(h2-h3)/(3600*10**3)
    // in MW
59
60 // Results
61 printf( ' The rate of heat transfer ,Qoutdot from the
    condensing steam as it passes through the
    condenser , is %.2f MW. ',Qoutdot)
62
63 // Part(f)
64 // From table A-2
65 hcwout= 146.68
                                        // in kj/kg
66 hcwin= 62.99

```

```

// in kj/
kg
67 mcwdot= (Qoutdot*10**3*3600)/(hcwout-hcwin)
// in kg/h
68
69 // Results
70 printf( ' The mass flow rate of the condenser
cooling water is %.2f kg/ h. ',mcwdot)

```

Scilab code Exa 8.2 Example

```

1 // Given:-
2 etat= .85 // given
that the turbine and the pump each have an
isentropic efficiency of 85%
3 // Analysis
4 // State 1 is the same as in Example 8.1, so
5 h1 = 2758.0 // in kj
/kg
6 s1 = 5.7432 // in kj
/kg.k
7 // From example 8.1
8 h1 = 2758.0 // in kj
/kg
9 h2s = 1794.8 // in kj
/kg
10 // State 3 is the same as in Example 8.1, so
11 h3 = 173.88 // in kj
/kg
12
13 // Calculations
14 h2 = h1 - etat*(h1-h2s) // in kj
/kg
15 wpdot = 8.06/etat // where
the value 8.06 is obtained from example 8.1

```

```

16
17 h4 = h3 + wpdot
18
19 // Part(a)
20 eta = ((h1-h2)-(h4-h3))/(h1-h4) //
    thermal efficiency
21
22 // Result for part (a)
23 printf( ' Thermal efficiency is: %.3f',eta)
24
25 // Part(b)
26 Wcycledot = 100 // given
    ,a net power output of 100 MW
27 // Calculations
28 mdot = (Wcycledot*(10**3)*3600)/((h1-h2)-(h4-h3))
29 // Result for part (b)
30 printf( ' The mass flow rate of steam, in kg/h, for
    a net power output of 100 MW is %.3f kg/h. ',
    mdot)
31
32 // Part(c)
33 Qindot = mdot*(h1-h4)/(3600 * 10**3)
34 // Result
35 printf( ' The rate of heat transfer Qindot into the
    working fluid as it passes through the boiler , is
    %.3f MW. ',Qindot)
36
37 // Part(d)
38 Qoutdot = mdot*(h2-h3)/(3600*10**3)
39 // Result
40 printf( ' The rate of heat transfer Qoutdotfrom the
    condensing steam as it passes through the
    condenser , is %.3f MW. ',Qoutdot)
41
42 // Part(e)
43 // From table A-2
44 hcwout = 146.68 // in kj
    /kg

```

```

45 hcwin = 62.99 // in kj
    /kg
46 mcwdot = (Qoutdot*10**3*3600)/(hcwout-hcwin)
47 // Result
48 printf( ' The mass flow rate of the condenser
    cooling water , is: %.3f kg/h. ',mcwdot)

```

Scilab code Exa 8.3 Example

```

1 // Given:-
2 clc;
3 T1 = 480.0 // temperature of
    steam entering the first stage turbine in degree
    celcius
4 p1 = 8.0 // pressure of
    steam entering the first stage turbine in MPa
5 p2 = 0.7 // pressure of
    steam exiting the first stage turbine in MPa
6 T3 = 440.0 // temperature of
    steam before entering the second stage turbine
7 Pcond = 0.008 // condenser
    pressure in MPa
8 Wcycledot = 100.0 // the net power
    output in MW
9
10 // Analysis
11 // From table A-4
12 h1 = 3348.4 // in kj/kg
13 s1 = 6.6586 // in kj/kg.k
14 s2 = s1 // isentropic
    expansion through the first-stage turbine
15 // From table A-3
16 sf = 1.9922 // in kj/kg.k
17 sg = 6.708 // in kj/kg.k
18 hf = 697.22 // in kj/kg

```



```

19 hfg = 2066.3 // in kj/kg
20
21 // Calculations
22 x2 = (s2-sf)/(sg-sf)
23 h2 = hf + x2*hfg
24 // State 3 is superheated vapor with p3 = 0.7 MPa
    and T3= 440C, so from Table A-4
25 h3 = 3353.3 // in kj/kg
26 s3 = 7.7571 // in kj/kg.k
27 s4 = s3 // isentropic
    expansion through the second-stage turbine
28 // For determing quality at state 4,from table A-3
29 sf = 0.5926 // in kj/kg.k
30 sg = 8.2287 // in kj/kg.k
31 hf = 173.88 // in kj/kg
32 hfg = 2403.1 // in kj/kg
33
34 // Calculations
35 x4 = (s4-sf)/(sg-sf)
36 h4 = hf + x4*hfg
37
38 // State 5 is saturated liquid at 0.008 MPa, so
39 h5 = 173.88
40 // The state at the pump exit is the same as in
    Example 8.1, so
41 h6 = 181.94
42
43 // Part(a)
44 eta = ((h1-h2)+(h3-h4)-(h6-h5))/((h1-h6)+(h3-h2))
45 // Result
46 printf( '\n The thermal efficiency of the cycle is:
    %.2f ',eta)
47
48 // Part(b)
49 mdot = (Wcycledot*3600*10**3)/((h1-h2)+(h3-h4)-(h6-
    h5))
50 printf( '\n The mass flow rate of steam, is: %.2f kg
    /h. ',mdot)

```

```

51
52 // Part(c)
53 Qoutdot = (mdot*(h4-h5))/(3600*10**3)
54 printf('\nThe rate of heat transfer Qoutdot from the
        condensing steam as it passes through the
        condenser , is %.2f MW',Qoutdot)

```

Scilab code Exa 8.4 Example

```

1 // Given :-
2 // Part (a)
3 etat = 0.85

    // given efficiency
4 // From the solution to Example 8.3, the following
    specific enthalpy values are known, in kJ/kg
5 h1 = 3348.4
6 h2s = 2741.8
7 h3 = 3353.3
8 h4s = 2428.5
9 h5 = 173.88
10 h6 = 181.94
11
12
13 // Calculations
14 h2 = h1 - etat*(h1 - h2s)

    // The specific enthalpy at the exit of the first
    -stage turbine in kJ/kg
15 h4 = h3 - etat*(h3-h4s)

    // The specific enthalpy at the exit of the
    second-stage turbine in kJ/kg
16 eta = ((h1-h2)+(h3-h4)-(h6-h5))/((h1-h6)+(h3-h2))
17

```

```

18 // Result
19 printf( ' The thermal efficiency is:  %f',eta)
20
21 // Part (b)
22 x = linspace(0.85,1,50)
23 for i =1:50
24     h2(i) = h1 - x(i)*(h1 - h2s)
                                     // The
                                     specific enthalpy at the exit of the first-
                                     stage turbine in kj/kg
25     h4(i) = h3 - x(i)*(h3-h4s)
                                     // The
                                     specific enthalpy at the exit of the second-
                                     stage turbine in kj/kg
26     y(i)  = ((h1-h2(i))+(h3-h4(i))-(h6-h5))/((h1-h6)
                                     +(h3-h2(i)))
27 end
28
29 plot(x,y)
30 xlabel('isentropic turbine efficiency')
31 ylabel('cycle thermal efficiency')

```

Scilab code Exa 8.5 Example

```

1 // Given:-
2 T1 = 480.0

    // temperature of steam entering the turbine in
    degree celcius
3 p1 = 8.0

    // pressure of steam entering the turbine in MPa
4 Pcond = 0.008

    // condenser pressure in MPa

```

```

5  etat = 0.85

    // turbine efficiency
6  Wcycledot = 100.0

    // net power output of the cycle
7
8
9  // Analysis
10 // With the help of steam tables
11 h1 = 3348.4

    // in kj/kg
12 h2 = 2832.8

    // in kj/kg
13 s2 = 6.8606

    // in kj/kg.k
14 h4 = 173.88

    // in kj/kg
15 // With s3s = s2, the quality at state 3s is x3s=
    0.8208; using this, we get
16 h3s = 2146.3

    // in kj/kg
17
18 // Calculations
19 // The specific enthalpy at state 3 can be
    determined using the efficiency of the second-
    stage turbine
20 h3 = h2 - etat*(h2-h3s)
21
22 // State 6 is saturated liquid at 0.7 MPa. Thus,
23 h6 = 697.22

    // in kj/kg

```

```

24 // For determining specific enthalpies at states 5
    and 7 ,we have
25 p5 = 0.7

    // in MPa
26 p4 = 0.008

    // in MPa
27 p7 = 8.0

    // in MPa
28 p6 = 0.7

    // in MPa
29 v4 = 1.0084e-3

    // units in m^3/kg,obtained from steam tables
30 v6 = 1.1080e-3

    // units in m^3/kg,obtained from steam tables
31
32 // Calculations
33 h5 = h4 + v4*(p5-p4)*10**6*10**-3

    // in kj/kg
34 h7 = h6 + v6*(p7-p6)*10**3

    // in kj/kg
35
36 // Applying mass and energy rate balances to a
    control volume enclosing the open heater , we find
    the fraction y of the flow extracted at state 2
    from
37 y = (h6-h5)/(h2-h5)
38
39 // Part(a)
40 wtdot = (h1-h2) + (1-y)*(h2-h3)

```

```

    // the total turbine work output, units in KJ/Kg
41 wpdot = (h7-h6) + (1-y)*(h5-h4)

    // The total pump work per unit of mass passing
    // through the first-stage turbine, in KJ/kg
42 qindot = h1 - h7

    // in kj/kg
43 eta = (wtdot-wpdot)/qindot
44
45 // Results
46 printf( ' The thermal efficiency is: %.2f',eta)
47
48 // Part(b)
49 mldot = (Wcycledot*3600*10**3)/(wtdot-wpdot)
50
51 // Results
52 printf( ' The mass flow rate of steam entering the
    first turbine stage, is: %.2f kg/h.',mldot)

```

Scilab code Exa 8.6 Example

```

1
2 // Given:-
3 // Analysis
4 // State 1 is the same as in Example 8.3, so
5 h1 = 3348.4

    // in kj/kg
6 s1 = 6.6586

    // in kj/kg.k
7 // State 2 is fixed by p2 2.0 MPa and the specific
    entropy s2, which is the same as that of state 1.
    Interpolating in Table A-4, we get

```

```

8 h2 = 2963.5
   // in kj/kg
9 // The state at the exit of the first turbine is the
   same as at the exit of the first turbine of
   Example 8.3, so
10 h3 = 2741.8
   // in kj/kg
11 // State 4 is superheated vapor at 0.7 MPa, 440C.
   From Table A-4,
12 h4 = 3353.3
   // in kj/kg
13 s4 = 7.7571
   // in kj/kg.k
14 // Interpolating in table A-4 at p5 = .3MPa and s5 =
   s4, the enthalpy at state 5 is
15 h5 = 3101.5
   // in kj/kg
16 // Using s6 = s4, the quality at state 6 is found to
   be
17 x6 = 0.9382
18 // Using steam tables , for state 6
19 hf = 173.88
   // in kj/kg
20 hfg = 2403.1
   // in kj/kg
21
22 h6 = hf + x6*hfg
23
24 // At the condenser exit , we have
25 h7 = 173.88

```

```

26   // in kj/kg
    v7 = 1.0084e-3

27   // in m^3/kg
    p8 = 0.3

28   // in MPa
    p7 = 0.008

29   // in MPa
30   h8 = h7 + v7*(p8-p7)*10**6*10**-3

    //
    The specific enthalpy at the exit of the first
    pump in kj/kg
31 // The liquid leaving the open feedwater heater at
    state 9 is saturated liquid at 0.3 MPa. The
    specific enthalpy is
32 h9 = 561.47

    // in kj/kg
33
34 // For the exit of the second pump,
35 v9 = 1.0732e-3

    // in m^3/kg
36 p10 = 8.0

    // in MPa
37 p9 = 0.3

    // in MPa
38 h10 = h9 + v9*(p10-p9)*10**6*10**-3

    //
    The specific enthalpy at the exit of the second
    pump in kj/kg
39 // The condensate leaving the closed heater is
    saturated at 2 MPa. From Table A-3,

```



```

40 h12 = 908.79

    // in kj/kg
41 h13 = h12

    // since The fluid passing through the trap
    // undergoes a throttling process
42 // For the feedwater exiting the closed heater
43 hf = 875.1

    // in kj/kg
44 vf = 1.1646e-3

    // in m^3/kg
45 p11 = 8.0

    // in MPa
46 psat = 1.73

    // in MPa
47 h11 = hf + vf*(p11-psat)*10**6*10**-3           // in
    kj/kg

48
49 ydash = (h11-h10)/(h2-h12)

    // the fraction of the total flow diverted to the
    // closed heater
50 ydashdash = ((1-ydash)*h8+ydash*h13-h9)/(h8-h5)
    // the fraction
    // of the total flow diverted to the open heater
51
52 // Part(a)
53 wt1dot = (h1-h2) + (1-ydash)*(h2-h3)           // The
    work developed by the first turbine per unit of
    mass entering in kj/kg
54 wt2dot = (1-ydash)*(h4-h5) + (1-ydash-ydashdash)*(h5

```

```

        -h6)                                // The work developed
        by the second turbine per unit of mass in kj/kg
55  wp1dot = (1-ydash-ydashdash)*(h8-h7)
                                           // The
        work for the first pump per unit of mass in kj/
        kg
56  wp2dot = h10-h9

        // The work for the second pump per unit of mass
        in kj/kg
57  qindot = (h1-h11) + (1-ydash)*(h4-h3)
                                           // The
        total heat added expressed on the basis of a unit
        of mass entering the first
58

59  eta = (wt1dot+wt2dot-wp1dot-wp2dot)/qindot
                                           // thermal
        efficiency
60
61  // Result
62  printf( ' The thermal efficiency is:  %.2f',eta)
63
64  // Part(b)
65  Wcycledot = 100.0

        // the net power output of the cycle in MW
66  m1dot = (Wcycledot*3600*10**3)/(wt1dot+wt2dot-wp1dot
        -wp2dot)
67
68  // Result
69  printf( ' The mass flow rate of the steam entering
        the first turbine , in kg/h is:  %.2f',m1dot)

```

Scilab code Exa 8.7 Example

```
1
2 // Given:-
3 // Analysis
4 // The solution to Example 8.2 gives
5 h1 = 2758

    // in kj/kg
6 h4 = 183.36

    // in kj/kg
7 // From table A-22
8 hi = 1491.44

    // in kj/kg
9 he = 843.98

    // in kj/kg
10 // Using the conservation of mass principle and
    energy rate balance, the ratio of mass flow rates
    of air and water is
11 madotbymdot = (h1-h4)/(hi-he)
12 // From example 8.2
13 mdot = 4.449e5

    // in kg/h
14 madot = madotbymdot*mdot

    // in kg/h
15
16 // Part(a)
17 T0 = 295
```

```

    // in kelvin
18 // From table A-22
19 si = 3.34474

    // in kj/kg.k
20 se = 2.74504

    // in MW
21 // Calculation
22 Rin = madot*(hi-he-T0*(si-se))/(3600*10**3)
                                     // The net rate
    at which exergy is carried into the heat
    exchanger
23

24 // Result
25 printf('The net rate at which exergy is carried into
    the heat exchanger unit by the gas stream, is :
    %.2f MW ',Rin)
26
27 // Part(b)
28 // From table A-3
29 s1 = 5.7432

    // in kj/kg.k
30 // From interpolation in table A-5 gives
31 s4 = 0.5957

```

```

    // in kj/kg.k
32 // Calculation
33 Rout = mdot*(h1-h4-T0*(s1-s4))/(3600*10**3)
                                     // in MW
34 // Result
35 printf( ' The net rate at which exergy is carried
    from the heat exchanger by the water stream, is :
    %.2f MW .',Rout)
36
37 // Part(c)
38 Eddot = Rin-Rout

    // in MW
39 // Result
40 printf( ' The rate of exergy destruction , in MW is :
    %.2f ',Eddot)
41
42 // Part(d)
43 epsilon = Rout/Rin
44 // Result
45 printf( ' The exergetic efficiency is: %.2f',
    epsilon)

```

Scilab code Exa 8.8 Example

```

1
2 // Given:-
3 T0 = 295.00

    // in kelvin
4 P0 = 1.00

    // in atm
5
6 // Analysis

```

```

7 // From table A-3
8 s1 = 5.7432

    // in kj/kg.k
9 s3 =0.5926

    // in kj/kg.k
10
11 // Using h2 = 1939.3 kJ/kg from the solution to
    Example 8.2, the value of s2 can be determined
    from Table A-3 as
12 s2 = 6.2021

    // in kj/kg.k
13 s4 = 0.5957

    // in kj/kg.k
14 mdot = 4.449e5

    // in kg/h
15
16 // Calculations
17 Eddot = mdot*T0*(s2-s1)/(3600*10**3)
    // the
    rate of exergy destruction for the turbine in MW
18 EddotP = mdot*T0*(s4-s3)/(3600*10**3)
    // the
    exergy destruction rate for the pump
19
20 // Results
21 printf( ' The rate of exergy destruction for the
    turbine is: %.2f MW.',Eddot)
22 // From the solution to Example 8.7, the net rate at
    which exergy is supplied by the cooling
    combustion gases is 231.28 MW
23 printf( ' The turbine rate of exergy destruction
    expressed as a percentage is: %.f',(Eddot
    /231.28)*100)

```

```

24 // However, since only 69% of the entering fuel
    exergy remains after the stack loss and
    combustion exergy destruction are accounted for ,
25 // it can be concluded that
26 printf( ' Percentage of the exergy entering the
    plant with the fuel destroyed within the turbine
    is : %.2f ',0.69*(Eddot/231.28)*100)
27 printf( ' The exergy destruction rate for the pump
    in MW is : %.2f ',EddotP)
28 printf( 'and expressing this as a percentage of the
    exergy entering the plant as calculated above, we
    have %.2f ',(EddotP/231.28)*69)
29 printf( ' The net power output of the vapor power
    plant of Example 8.2 is 100 MW. Expressing this
    as a percentage of the rate at which exergy is ')
30 printf( 'carried into the plant with the fuel, %.2f'
    ,(100/231.28)*69)

```

Scilab code Exa 8.9 Example

```

1
2 // Given:-
3 T0 = 295

    // in kelvin
4 // Analysis
5 // From solution to Example 8.2.
6 mcwdot = 9.39e6

    // mass flow rate of the cooling water in kg/h
7
8 // Part(a)
9 // With saturated liquid values for specific
    enthalpy and entropy from Table A-2
10 he = 146.68

```

```

11     // in kj/kg
hi = 62.99

12     // in kj/kg
se = 0.5053

13     // in kj/kg.k
si = 0.2245

14     // in kj/kg.k
// Calculations
15 Rout = mcwdot*(he-hi-T0*(se-si))/(3600*10**3)
// The net rate at
which exergy is carried out of the condenser in
MW
16 // Results
17 printf( ' The net rate at which exergy is carried
from the condenser by the cooling water, is: %.2f
MW. ',Rout)
18 printf( ' Expressing this as a percentage of the
exergy entering the plant with the fuel , we get %
.2f percent ',(Rout/231.28)*69)
19
20 // Part(b)
21 // From table
22 s3 = 0.5926

// in kj/kg.k
23 s2 = 6.2021

// in kg/kg.k
24 mdot = 4.449e5

// in kg/h
25 // Calculations
26 Eddot = T0*(mdot*(s3-s2)+mcwdot*(se-si))
// the rate of

```



```
    exergy destruction for the condenser in MW
27 // Results
28 printf( ' The rate of exergy destruction for the
    condenser is: %.2f MW.',Eddot)
29 printf( ' Expressing this as a percentage of the
    exergy entering the plant with the fuel , we get ,
    %.2f percent ',(Eddot/231.28)*69)
```

Chapter 9

Gas Power Systems

Scilab code Exa 9.1 Example

```
1 // Given:–
2 T1 = 300.00

    // The temperature at the beginning of the
    // compression process in kelvin
3 p1 = 1.00

    // the pressure at the beginning of the
    // compression process in bar
4 r = 8.00

    // compression ratio
5 V1 = 560.00

    // the volume at the beginning of the compression
    // process in cm^3
6 T3 = 2000.00

    // maximum temperature during the cycle in kelvin
7
8 // Part(a)
```

```

9 // At T1 = 300k, table A-22 gives
10 u1 = 214.07

    // in kj/kg
11 vr1 = 621.2
12 // Interpolating with vr2 in Table A-22, we get
13 T2 = 673.00

    // in kelvin
14 u2 = 491.2

    // in kj/kg
15 // At T3 = 2000 K, Table A-22 gives
16 u3 = 1678.7

    // in kj/kg
17 vr3 = 2.776
18 // Interpolating in Table A-22 with vr4 gives
19 T4 = 1043

    // in kelvin
20 u4 = 795.8

    // in kj/kg
21
22 // Calculations
23 // For the isentropic compression Process 1 2
24 vr2 = vr1/r
25 // With the ideal gas equation of state
26 p2 = p1*(T2/T1)*(r)

    // in bars
27 // Since Process 2 3 occurs at constant volume,
    the ideal gas equation of state gives
28 p3 = p2*(T3/T2)

    // in bars
29 // For the isentropic expansion process 3 4

```

```

30 vr4 = vr3*(r)
31 // The ideal gas equation of state applied at states
    1 and 4 gives
32 p4 = p1*(T4/T1)

    // in bars
33
34 // Results
35 printf( ' At state1 , the pressure is: %f bar.',p1)
36 printf( ' At state1 , the temperature is %f kelvin.',
    T1)
37 printf( ' At state2 , the pressure is : %.3f bar.',p2
    )
38 printf( ' At state2 , the temperature is %f kelvin.',
    T2)
39 printf( ' At state3 , the pressure is : %.3f bar.',p3
    )
40 printf( ' At state3 , the temperature is %f kelvin.',
    T3)
41 printf( ' At state4 , the pressure is : %.4f bar.',p4
    )
42 printf( ' At state4 , the temperature is %f kelvin.',
    T4)
43
44 // Part(b)
45 eta = 1-(u4-u1)/(u3-u2)

    // thermal efficiency
46 // Result
47 printf( ' The thermal efficiency is : %.2f ',eta)
48
49 // Part(c)
50 R = 8.314

    // universal gas constant , in SI units
51 M = 28.97

    // molar mass of air in grams

```

```

52 // Calculations
53 m = ((p1*V1)/((R/M)*T1))*10**-6*10**5*10**-3
                                         // mass of the air
      in kg
54 Wcycle = m*((u3-u4)-(u2-u1))
                                         //
      the net work per cycle in KJ
55 mep = (Wcycle/(V1*(1-1/r)))*10**6*10**3*10**-5
                                         // in bars
56
57 // Result
58 printf( ' The mean effective pressure , is : %.4f atm
      . ',mep)

```

Scilab code Exa 9.2 Example

```

1
2 // Given :-
3 clc;
4 r = 18.00
      // compression ratio
5 T1 = 300.00
      // temperature at the beginning of the
      compression process in kelvin
6 p1 = 0.1
      // pressure at the beginning of the compression
      process in MPa
7 rc = 2.00
      // cutoff ratio
8
9 // Part(a)

```

```

10 // With T1 = 300 K, Table A-22 gives
11 u1 = 214.07

    // in kj/kg
12 vr1 = 621.2
13 // Interpolating in Table A-22, we get
14 T2 = 898.3

    // in kelvin
15 h2 = 930.98

    // in kj/kg
16 // From Table A-22,
17 h3 = 1999.1

    // in kj/kg
18 vr3 = 3.97
19
20 // Interpolating in Table A-22 with vr4, we get
21 u4 = 664.3

    // in kj/kg
22 T4 = 887.7

    // in kelvin
23
24 // Calculations
25 // Since Process 2 3 occurs at constant pressure ,
    the ideal gas equation of state gives
26 T3 = rc*T2

    // in kelvin
27 // With the ideal gas equation of state
28 p2 = p1*(T2/T1)*(r)

    // in MPa
29 p3 = p2
30 // For the isentropic compression process 1 2

```

```

31 vr2 = vr1/r
32 // For the isentropic expansion process 3 4
33 vr4 = (r/rc)*vr3
34 // The ideal gas equation of state applied at states
    1 and 4 gives
35 p4 = p1*(T4/T1)

    // in MPa
36
37 // Results
38 printf( '\n At state1 , the pressure is : %.2f bar.',
    p1)
39 printf( '\n At state1 , the temperature is %.2f
    kelvin.' ,T1)
40 printf( '\n At state2 , the pressure in bar is : %.2f
    bar.' ,p2)
41 printf( '\n At state2 , the temperature is %.2f
    kelvin.' ,T2)
42 printf( '\n At state3 , the pressure in bar is : %.2f
    bar.' ,p3)
43 printf( '\n At state3 , the temperature is %.2f
    kelvin.' ,T3)
44 printf( '\n At state4 , the pressure is: %.2f MPa.' ,
    p4)
45 printf( '\n At state4 , the temperature is %.2f
    kelvin.' ,T4)
46
47 // Part(b)
48 eta = 1- (u4-u1)/(h3-h2)
49 printf( '\n The thermal efficiency is : %.2f ',eta)
50
51 // Part(c)
52 R = 8.314

    // universal gas constant , in SI units
53 M = 28.97

    // molar mass of air in grams

```

```

54
55 // Calculations
56 wcycle = (h3-h2)-(u4-u1)

    // The net work of the cycle in kj/kg
57 v1 = ((R/M)*T1/p1)/10**3

    // The specific volume at state 1 in m^3/kg
58 mep = (wcycle/(v1*(1-1/r)))*10**3*10**-6 // in MPa

59
60 // Results
61 printf( '\n The mean effective pressure, is : %.2f
    MPa. ',mep)

```

Scilab code Exa 9.3 Example

```

1 // Given :-
2 T1 = 300.00

    // beginning temperature in kelvin
3 p1 = 0.1

    // beginning pressure in MPa
4 r = 18.00

    // compression ratio
5 pr = 1.5

    // The pressure ratio for the constant volume
    part of the heating process
6 vr = 1.2

    // The volume ratio for the constant pressure
    part of the heating process

```



```

7
8 // Analysis
9 // States 1 and 2 are the same as in Example 9.2, so
10 u1 = 214.07

    // in kj/kg
11 T2 = 898.3

    // in kelvin
12 u2 = 673.2

    // in kj/kg
13
14 // Interpolating in Table A-22, we get
15 h3 = 1452.6

    // in kj/kg
16 u3 = 1065.8

    // in kj/kg
17
18 // From Table A-22,
19 h4 = 1778.3

    // in kj/kg
20 vr4 = 5.609
21
22 // Interpolating in Table A-22, we get
23 u5 = 475.96

    // in kj/kg
24
25 // Calculations
26 // Since Process 2 3 occurs at constant volume,
    the ideal gas equation of state reduces to give
27 T3 = pr*T2

    // in kelvin

```

```

28 // Since Process 3 4 occurs at constant pressure ,
    the ideal gas equation of state reduces to give
29 T4 = vr*T3

    // in kelvin
30 // Process 4 5 is an isentropic expansion , so
31 vr5 = vr4*r/vr
32
33 // Part(a)
34 eta = 1-(u5-u1)/((u3-u2)+(h4-h3))
35 // Result
36 printf( ' The thermal efficiency is : %.2f',eta)
37
38 // Part(b)
39 // The specific volume at state 1 is evaluated in
    Example 9.2 as
40 v1 = 0.861

    // in m^3/kg
41 mep = (((u3-u2)+(h4-h3)-(u5-u1))/(v1*(1-1/r)))
    *10**3*10**-6 // in MPa
42
43 // Result
44 printf( ' The mean effective pressure , is : %.2f MPa
    .',mep)

```

Scilab code Exa 9.4 Example

```

1 // Given:-
2 T1 = 300.00

    // in kelvin
3 AV = 5.00

    // volumetric flow rate in m^3/s

```

```

4 p1 = 100.00
    // in kpa
5 pr = 10.00
    // compressor pressure ratio
6 T3 = 1400.00
    // turbine inlet temperature in kelvin
7
8 // Analysis
9 // At state 1, the temperature is 300 K. From Table
    A-22,
10 h1 = 300.19
    // in kj/kg
11 pr1 = 1.386
12
13
14 // Interpolating in Table A-22,
15 h2 = 579.9
    // in kj/kg
16 // From Table A-22
17 h3 = 1515.4
    // in kj/kg
18 pr3 = 450.5
19
20 // Interpolating in Table A-22, we get
21 h4 = 808.5
    // in kj/kg
22
23 // calculations
24 pr2 = pr*pr1
25 pr4 = pr3*1/pr
26

```

```

27
28 // Part(a)
29 eta = ((h3-h4)-(h2-h1))/(h3-h2)

        // thermal efficiency
30 // Result
31 printf( ' The thermal efficiency is : %.4f ',eta)
32
33 // Part(b)
34 bwr = (h2-h1)/(h3-h4)

        // back work ratio
35 // Result
36 printf( ' The back work ratio is : %.4f',bwr)
37
38 // Part(c)
39 R = 8.314

        // universal gas constant , in SI units
40 M = 28.97

        // molar mass of air in grams
41 // Calculations
42 mdot = AV*p1/((R/M)*T1)

        // mass flow rate in kg/s
43 Wcycledot = mdot*((h3-h4)-(h2-h1))

        //
        The net power developed
44 // Result
45 printf( ' The net power developed , is : %.2f kW .',
        Wcycledot)

```

Scilab code Exa 9.6 Example

```

1 // Given:-
2 T1 = 300.00

    // in kelvin
3 AV = 5.00

    // volumetric flow rate in m^3/s
4 p1 = 100.00

    // in kpa
5 pr = 10.00

    // compressor pressure ratio
6 T3 = 1400.00

    // turbine inlet temperature in kelvin
7 Wt_ms = 706.9

    // kJ/kg
8 Wc_m = 279.7
9 // Analysis
10 // At state 1, the temperature is 300 K. From Table
    A-22,
11 h1 = 300.19

    // in kj/kg
12 pr1 = 1.386
13
14
15 // Interpolating in Table A-22,
16 h2 = 579.9

    // in kj/kg
17 // From Table A-22
18 h3 = 1515.4

    // in kj/kg
19 pr3 = 450.5

```

```

20
21 // Interpolating in Table A-22, we get
22 h4 = 808.5

    // in kJ/kg
23
24 // calculations
25 Wtbym = 0.8*Wt_ms
26 Wcbym = Wc_m/0.8
27 h2 = 300.19 + Wcbym
28
29 //pr2 = pr*pr1
30 //pr4 = pr3*1/pr
31
32
33 // Part(a)
34 //eta = ((h3-h4)-(h2-h1))/(h3-h2)

    // thermal efficiency
35 Qinbym = h3 - h2
36 n = (Wtbym-Wcbym)/Qinbym
37 // Result
38 printf( '\n The thermal efficiency is : %.3f ',n)
39
40 // Part(b)
41 //bwr = (h2-h1)/(h3-h4)

    // back work ratio
42 bwr = Wcbym/Wtbym
43 // Result
44 printf( '\n The back work ratio is : %.3f',bwr)
45
46 // Part(c)
47 R = 8.314

    // universal gas constant, in SI units
48 M = 28.97

```

```

    // molar mass of air in grams
49 // Calculations
50 //mdot = AV*p1/((R/M)*T1)

    // mass flow rate in kg/s
51 Wcycledot = 5.807*(Wcbym-Wtbym)

    //
    The net power developed
52 // Result
53 printf( '\n The net power developed , is : %.f kW .'
    , -Wcycledot)

```

Scilab code Exa 9.7 Example

```

1 // Given:-
2 // Part(a)
3 etareg = 0.8

    // regenerator effectiveness of 80%.
4 // From example 9.4
5 h1 = 300.19

    // in kj/kg
6 h2 = 579.9

    // in kj/kg
7 h3 = 1515.4

    // in kj/kg
8 h4 = 808.5

    // in kj/kg
9
10 // Calculations
11 hx = etareg*(h4-h2)+h2

```

```

    // in kj/kg
12 eta = ((h3-h4)- (h2-h1))/(h3-hx)

    // thermal efficiency
13 // Result
14 printf('The thermal efficiency is:  %.2f',eta)
15
16 // Part(b)
17
18 etareg = linspace(0,0.8,50)
19 for i = 1:50
20     x(i) = (etareg(i)*(h4-h2))+h2
21     eta(i) = ((h3-h4)- (h2-h1))/(h3-x(i))
22 end
23
24 plot(etareg,eta)
25 xlabel('Regenerator effectiveness')
26 ylabel('Thermal efficiency')

```

Scilab code Exa 9.8 Example

```

1 // Given:-
2 // Analysis
3 // States 1, 2, and 3 are the same as in Example
  9.4:
4 h1 = 300.19

    // in kj/kg
5 h2 = 579.9

    // in kj/kg
6 h3 = 1515.4

    // in kj/kg

```



```

7 // The temperature at state b is the same as at
  state 3, so
8 hb = h3
9
10 pa = 300.00

    // in kpa
11 p3 = 1000.00

    // in kpa
12 // From table A-22
13 pr3 = 450.5
14
15 // Interpolating in Table A-22, we get
16 ha = 1095.9

    // in kj/kg
17 p4 = 100.00

    // in kpa
18 pb = 300.00

    // in kpa
19 // Interpolating in Table A-22, we obtain
20 h4 = 1127.6

    // in kj/kg
21
22 // Calculions
23 pra = pr3*(pa/p3)
24 prb = pra
25 pr4 = prb*(p4/pb)
26 // Since the regenerator effectiveness is 100%,
27 hx = h4
28 eta = ((h3-ha)+(hb-h4)-(h2-h1))/((h3-hx)+(hb-ha))
    // thermal
    efficiency
29

```

```
30 // Result
31 printf( ' The thermal efficiency is : %.2f ', eta)
```

Scilab code Exa 9.9 Example

```
1 // Given:-
2 T1 = 300.00

    // in kelvin
3 p1 = 100.00

    // in kpa
4 p2 = 1000.00

    // in kpa
5 p3 = p2
6 pc = 300.00

    // in kpa
7 pd = 300.00

    // in kpa
8 Td = 300.00

    // in kelvin
9
10
11 // Part(a)
12 // From table A-22
13 prd = 1.386
14 // Interpolating in Table A-22, we get
15 T2 = 422

    // in kelvin
16 h2 = 423.8
```

```

    // in kj/kg
17 // Calculations
18 pr2 = prd*(p2/pd)
19 // Result
20 printf( ' The temperature at the exit of the second
    compressor stage is : %.2f kelvin.',T2)
21
22 // Part(b)
23 // From Table A-22 at T1 = 300
24 h1 = 300.19

    // in kj/kg
25 // Since Td = T1,
26 hd = 300.19

    // in kj/kg
27 // with pr data from Table A-22 together
28 pr1 = 1.386
29 // Interpolating in Table A-22, we obtain
30 hc = 411.3

    // in kj/kg
31 // Calculations
32 prc = pr1*(pc/p1)
33 wcdot = (hc-h1)+(h2-hd)

    // The total compressor work per unit of mass in
    kj/kg
34 // Result
35 printf( ' The total compressor work input per unit
    of mass flow is : %.2f kJ/kg',wcdot)
36
37 // Part(c)
38 // Interpolating in Table A-22, we get
39 T3 = 574

    // in kelvin

```

```

40 h3 = 579.9

    // in kj/kg
41 // Calculations
42 pr3 = pr1*(p3/p1)
43 wcdot = h3-h1

    // The work input for a single stage of
    // compression in kj/kg
44 // Results
45 printf( ' For a single stage of compression , the
    temperature at the exit state is : %.2f kelvin ',
    T3)
46 printf( ' For a single stage of compression , the
    work input is : %.2f kJ. ',wcdot)

```

Scilab code Exa 9.11 Example

```

1 // Given:-
2 T1 = 300.00

    // in kelvin
3 p1 = 100.00

    // in kpa
4 mdot = 5.807

    // in kg/s
5 p2 = 300.00

    // in kpa
6 p3 = p2
7 p4 = 1000.00

    // in kpa

```

```

8 p5 = p4
9 p6 = p4
10 T6 = 1400.00

    // in kelvin
11 T8 = T6
12 p7 = 300.00

    // in kpa
13 p8 = p7
14 etac = 0.8

    // isentropic efficiency of compressor
15 etat = 0.8

    // isentropic efficiency of turbine
16 etareg = 0.8

    // regenerator effectiveness
17 // Analysis
18 // From example 9.9
19 h1 = 300.19

    // in kj/kg
20 h3 = h1

    // in kj/kg
21 h2s = 411.3

    // in kj/kg
22 h4s = 423.8

    // in kj/kg
23 // From example 9.8
24 h6 = 1515.4

    // in kj/kg
25 h8 = h6

```

```

26 h7s = 1095.9

    // in kj/kg
27 h9s = 1127.6

    // in kj/kg
28
29 // Calculations
30 h4 = h3 + (h4s-h3)/etac

    // in kj/kg
31 h2 = h1 + (h2s-h1)/etac

    // in kj/kg
32 h9 = h8-etat*(h8-h9s)

    // in kj/kg
33 h7 = h6-etat*(h6-h7s)

    // in kj/kg
34 h5 = h4+etareg*(h9-h4)

    // in kj/kg
35
36 // Part(a)
37 // Calculations
38 wtdot = (h6-h7)+(h8-h9)

    // The total turbine work per unit of mass flow
    in kj/kg
39 wcdot = (h2-h1)+(h4-h3)

    // The total compressor work input per unit of
    mass flow in kj/kg
40 qindot = (h6-h5)+(h8-h7)

    // The total heat added per unit of mass flow in
    kj/kg

```

```

41 eta = (wtdot-wcdot)/qindot

    // thermal efficiency
42 // Result
43 printf( ' The thermal efficiency is:  %.2f',eta)
44
45 // Part(b)
46 bwr = wcdot/wtdot

    // back work ratio
47 // Result
48 printf( ' The back work ratio is:  %.2f',bwr)
49
50 // Part(c)
51 Wcycledot = mdot*(wtdot-wcdot)

    // net power developed in kw
52 // Result
53 printf( ' The net power developed , is:  %.2f kW.',
    Wcycledot)

```

Scilab code Exa 9.12 Example

```

1 // Given:-
2 Ta = 240.00

    // in kelvin
3 pa = 0.8

    // in bar
4 Va = 278.00

    // in m/s
5 PR = 8.00

```

```

        // pressure ratio across the compressor
6  T3 = 1200.00

        // in kelvin
7  p5 = 0.8

        // in bar
8
9  // From table A-22
10 ha = 240.02

        // in kj/kg
11 h1 = ha + ((Va**2)/2)*10**-3

        // in kj/kg
12 // Interpolating in Table A-22 gives
13 pr1 = 1.070
14 pra = .6355
15
16 // Interpolating in Table A-22, we get
17 h2 = 505.5

        // in kj/kg
18 // At state 3 the temperature is given as T3 = 1200
        K. From Table A-22
19 h3 = 1277.79

        // in kj/kg
20
21
22 // Interpolating in Table A-22 with h4, gives
23 pr4 = 116.8
24 // pr data from table A-22 gives
25 pr4 = 116.00
26 pr3 = 238.00
27 // From table A-22
28 h5 = 621.3

```



```

    // in kj/kg
29
30 // The expansion through the nozzle is isentropic to
31 p5 = .8

    // in bars
32
33 // Calculations
34 p1 = (pr1/pra)*pa

    // in bars
35 // With the help of assumption, 'The turbine work
    output equals the work required to drive the
    compressor.',
36 h4 = h3+h1-h2

    // in kj/kg
37 p2 = PR*p1

    // in bars
38 // Using assumption 'There is no pressure drop for
    flow through the combustor',
39 p3 = p2
40 p4 = p3*(pr4/pr3)

    // in bars
41 pr5 = pr4*(p5/p4)
42 V5 = ((2*(h4-h5)*10**3)**(0.5)

    // the velocity at the nozzle exit in m/s
43
44 // Results
45 printf( ' The velocity at the nozzle exit in m/s is:
    %.2f ', V5)
46 printf( ' pa in bars = %.2f ',pa)
47 printf( ' p1 in bars = %.2f ',p1)
48 printf( ' p2 in bars = %.2f ',p2)
49 printf( ' p3 in bars = %.2f ',p3)

```

```
50 printf( ' p4 in bars = %.2f ',p4)
51 printf( ' p5 in bars = %.2f ',p5)
```

Scilab code Exa 9.13 Example

```
1 // Given:-
2 Wnetdot = 45.00

   // in MW
3 T1 = 300.00

   // in kelvin
4 p1 = 100.00

   // in kpa
5 etac = 0.84

   // The isentropic efficiency of the compressor
6 T3 = 1400.00

   // in kelvin
7 p2 = 1200.00

   // in kpa
8 p3 = p2
9 etat = 0.88

   // isentropic efficiency of the turbine
10 T5 = 400.00

   // in kelvin
11 p4 = 100.00

   // in kpa
12 p5 = p4
```

```

13 T7 = 400.00

    // in degree celcius
14 p7 = 8.00

    // in MPa
15 etatw =0.9

    // isentropic efficiency of turbine of the vapor
    cycle
16 p8 = 8.00

    // in kpa
17 p9 = p8
18 etap = 0.8

    // isentropic efficiency of pump of the vapor
    cycle
19 T0 = 300.00

    // in kelvin
20 p0 = 100.00

    // -in kpa
21
22 // Analysis
23 // With procedure similar to that used in the
    examples of chapters 8 and 9,we can determine
    following property data
24 h1 = 300.19

    // in kj/kg
25 h2 = 669.79

    // in kj/kg
26 h3 = 1515.42

    // in kj/kg

```

```
27 h4 = 858.02
    // in kj/kg
28 h5 = 400.98
    // in kj/kg
29 h6 = 183.96
    // in kj/kg
30 h7 = 3138.30
    // in kj/kg
31 h8 = 2104.74
    // in kj/kg
32 h9 = 173.88
    // in kj/kg
33 s1 = 1.7020
    // in kj/kg.k
34 s2 = 2.5088
    // in kj/kg.k
35 s3 = 3.3620
    // in kj/kg.k
36 s4 = 2.7620
    // in kj/kg.k
37 s5 = 1.9919
    // in kj/kg.k
38 s6 = 0.5975
    // in kj/kg.k
39 s7 = 6.3634
```

```

    // in kj/kg.k
40 s8 = 6.7282

    // in kj/kg.k
41 s9 = 0.5926

    // in kj/kg.k
42
43 // Part(a)
44 // By applying mass and energy rate balances
45 // Calculations
46 mvdotbymgdot = (h4-h5)/(h7-h6)

    // ratio of mass flow rates of vapor and air
47 mgdot = (Wnetdot*10**3)/(((h3-h4)-(h2-h1)) +
    mvdotbymgdot*((h7-h8)-(h6-h9))) // mass
    flow rate of air in kg/s
48 mvdot = mvdotbymgdot*mgdot

    // mass flow rate of vapor in kg/s
49 Wgasdot = mgdot*((h3-h4)-(h2-h1))*10**-3 // net
    power developed by gas turbine in MW
50 Wvapdot = mvdot*((h7-h8)-(h6-h9))*10**-3 // net
    power developed by vapor cycle in MW
51
52 // Results
53 printf( ' Mass flow rate of air is: %.2f kg/s.',
    mgdot)
54 printf( ' Mass flow rate of vapor is: %.2f kg/s.',
    mvdot)
55 printf( ' Net power developed by gas turbine is: %
    .2f MW.', Wgasdot)
56 printf( ' Net power developed by vapor cycle is: %
    .2f MW.', Wvapdot)
57
58

```

```

59 // Part(b)
60
61 // The net rate of exergy increase of the air
    passing through the combustor is
62 E_dot_f32 = m_dot*(h3-h2-T0*(s3-s2))*10**-3
                                                    // in MW
63 // The net rate exergy is carried out by the exhaust
    air stream at 5 is
64 E_dot_f51 = m_dot*(h5-h1-T0*(s5-s1))/10**3
                                                    // in
    MW
65 // The net rate exergy is carried out as the water
    passes through the condenser is
66 E_dot_f89 = m_dot*(h8-h9-T0*(s8-s9))*10**-3
                                                    // in MW
67 R = 8.314
    // universal gas constant, in SI units
68 M = 28.97
    // molar mass of air in grams
69 // The rate of exergy destruction for air turbine is
70 E_dot_d = m_dot*T0*(s4-s3-(R/M)*log(p4/p3))/10**3
                                                    // in MW
71 // The rate of exergy destruction for compressor is
72 E_dot_d = m_dot*T0*(s2-s1-(R/M)*log(p2/p1))/10**3
                                                    // in MW
73 // The rate of exergy destruction for steam turbine
    is
74 E_dot_d = m_dot*T0*(s8-s7)/10**3
    // in MW
75 // The rate of exergy destruction for pump is
76 E_dot_d = m_dot*T0*(s6-s9)/10**3
    // in MW
77 // For heat exchanger
78 E_dot_d = T0*(m_dot*(s5-s4)+m_dot*(s7-s6))/10**3

```

```

79
80 // Results
81 printf( ' Balance sheet ')
82 printf( 'Net exergy increase of the gas passing ')
83 printf( ' Through the combustor: %.2f MW',Edotf32)
84 printf( 'Disposition of the exergy:')
85 printf( '      Net power developed ')
86 printf( 'gas turbine cycle %.2f MW',Wgasdot)
87 printf( 'vapor cycle %.2f MW',Wvapdot)
88 printf( '      Net exergy lost ')
89 printf( 'with exhaust gas at state 5 %.2f MW',
      Edotf51)
90 printf( 'from water passing through condenser %.2f
      MW',Edotf89)
91 printf( '      Exergy destruction ')
92 printf( 'air turbine %.2f MW',Eddott)
93 printf( 'compressor %.2f MW',Eddotc)
94 printf( 'steam turbine %.2f MW',Eddotst)
95 printf( 'pump %.2f MW',Eddotp)
96 printf( 'heat exchanger %.2f MW',EddotHE)

```

Scilab code Exa 9.14 Example

```

1
2 // Given:-
3 Tnot = 360.00

      // in kelvin
4 pnot = 1.00

      // in MPa
5 A2 = 0.001

      // in m^2

```

```

6 k = 1.4
7
8 // Calculations
9 pstarbypnot = (1+(k-1)/2)**(k/(1-k))
10 pstar = pstarbypnot*pnot
11
12 // Part(a)
13 // Since back pressure of 500 kpa is less than
    critical pressure pstar(528kpa in this case)
    found above, the nozzle is choked
14 // At the exit
15 M = 1.00
16 p2 = pstar

    // in MPa
17 T2 = Tnot/(1+((k-1)/2)*(M**2))

    // exit temperature in kelvin
18 R = 8.314

    // universal gas constant, in SI units
19 Mwt = 28.97

    // molar mass of air in grams
20 V2 = ((k*(R/Mwt)*T2*10**3)**0.5)

    // exit velocity in m/s
21 mdot = (p2/((R/Mwt)*T2))*A2*V2*10**3

    //
    mass flow rate in kg/s
22
23 // Results
24 printf( ' The exit mach number for back pressure of
    500kpa is: %.2f',M)
25 printf( ' The mass flow rate in kg/s for back
    pressure of 500kpa is: %.2f',mdot)
26
27 // Part(b)

```



```

28 // Since the back pressure of 784kpa is greater than
    critical pressure of pstar determined above, the
    flow throughout the nozzle is subsonic and the
    exit pressure equals the back pressure,
29 p2 = 784.00

    // exit pressure in kpa
30 // Calculations
31 M2 = (((2.00)/(k-1))*(((pnot*10**3)/p2)**((k-1)/k)
    -1)**0.5 // exit mach
    number
32 T2 = Tnot/(1+((k-1)/2)*(M2**2))

    // exit temperature in kelvin
33 V2 = M2*((k*(R/Mwt)*10**3*T2)**0.5) //

    exit velocity in m/s
34 mdot2 = (p2/((R/Mwt)*T2))*A2*V2

    // mass flow rate in kg/s
35 // Results
36 printf( ' The mass flow rate at the exit for back
    pressure of 784kpa is: %.2f kg/s.',mdot2)
37 printf( ' The exit mach number for back pressure of
    784 kpa is: %.2f',M2)

```

Scilab code Exa 9.15 Example

```

1 // Given:-
2 // Part(a)
3 Mt = 0.7

    // mach number at the throat
4 At = 6.25

```

```

    // throat area in cm^2
5 Ae = 15.00

    // exit area in cm^2
6
7 // The flow throughout the nozzle, including the
  exit, is subsonic. Accordingly, with this value
  for A2byAstar, Table 9.1 gives
8 M2 = 0.24
9 // For M2 = 0.24,
10 T2byTnot = 0.988
11 p2bypnot = 0.959
12 k = 1.4
13 T0 = 280.00

    // in kelvin
14 pnot = 6.8

    // in bars
15 // Calculations
16 // With Mt = 0.7, Table 9.1 gives
17 AtbyAstar = 1.09437
18 A2byAstar = (Ae/At)*AtbyAstar
19 T2 = T2byTnot*T0

    // in kelvin
20 p2 = p2bypnot*pnot

    // in bars
21 V2 = M2*((k*(8.314/28.97)*T2*10**3)**0.5)
                                                                    //
    velocity at the exit in m/s
22 mdot = (p2/((8.314/28.97)*T2))*Ae*V2*10**-2
                                                                    // mass flow
    rate in kg/s
23 // Results
24 printf( ' Part(a)  the mass flow rate in kg/s is:  %
    .2f ',mdot)

```

```

25 printf( ' The exit pressure in bars is: %.2f',p2)
26 printf( ' The exit mach number is: %.2f',M2)
27
28 // Part(b)
29 Mt = 1.00

    // mach number at the throat
30 // From table 9.1
31 M2 = 0.26
32 T2byTnot = 0.986
33 p2bypnot = 0.953
34
35 T0 = 280.00

    // in kelvin
36 pnot = 6.8

    // in bars
37 // Calculations
38 T2 = T2byTnot*T0

    // in kelvin
39 p2 = p2bypnot*pnot

    // in bars
40 k = 1.4
41 V2 = M2*((k*(8314/28.97)*T2)**0.5)

    // exit velocity in m/s
42 mdot = (p2/((8.314/28.97)*T2))*Ae*V2*10**-2
                                                    // mass flow
    rate in kg/s
43 // Results
44 printf( ' Part(b) the mass flow rate is: %.f kg/s
    .',mdot)
45 printf( ' The exit pressure is: %f bars. ',p2)
46 printf( ' The exit mach number is: %f',M2)
47

```

```

48 // Part(c)
49 // From part (b), the exit Mach number in the
    present part of the example is
50 M2 = 2.4
51 // Using this, Table 9.1 gives
52 p2bypnot = 0.0684
53 pnot = 6.8

    // in bars
54 // Calculation
55 p2 = p2bypnot*pnot

    // in bars
56 // Results
57 // Since the nozzle is choked, the mass flow rate is
    the same as found in part (b).
58 printf( ' Part(c)  the mass flow rate is:  %f kg/s.'
    ,mdot)
59 printf( ' The exit pressure is:  %f bars.',p2)
60 printf( ' The exit mach number is:  %f',M2)
61
62 // Part(d)
63 // Since a normal shock stands at the exit and the
    flow upstream of the shock is isentropic, the
    Mach number Mx and the pressure px correspond to
    the values found in part (c),
64 Mx = 2.4
65 px = 0.465

    // in bars
66 // Then, from Table 9.2
67 My = 0.52
68 //py is the exit pressure
69 pybypx = 6.5533
70 py = px*pybypx
71
72 // The pressure downstream of the shock is thus
    3.047 bars. This is the exit pressure

```

```

73 // The mass flow is the same as found in part (b).
74 // Results
75 printf( ' Part(d)  the mass flow rate is:  %f kg/s.'
        ,mdot)
76 printf( ' The exit pressure is:  %.3f bars.',py)
77 printf( ' The exit mach number is:  %f',My)
78
79 // Part(e)
80 // A shock stands in the diverging portion where the
    area is
81 Ax = 12.5

    // in cm^2
82 // Since a shock occurs , the flow is sonic at the
    throat , so
83 Axstar = 6.25

    // in cm^2
84 At = Axstar
85 // The Mach number Mx can then be found from Table
    9.1, by using AxbyAxstar as
86 Mx = 2.2
87
88 // Results
89 // With Mx = 2.2, the ratio of stagnation pressures
    is obtained from Table 9.2 as
90 pnotybypnotx = 0.62812
91
92 // Using this ratio and noting that the flow is
    subsonic after the shock, Table 9.1 gives
93 M2 = 0.43
94 // For M2 = 0.43,
95 p2bypnoty = 0.88
96 // Calculations
97 A2byAystar = (Ae/Axstar)*pnotybypnotx
98 p2 = p2bypnoty*pnotybypnotx*pnot

    //
    in bars

```

```
99
100 // Results
101 // Since the flow is choked, the mass flow rate is
    the same as that found in part (b).
102 printf( ' part(e)  the mass flow rate is: %f kg/s.',
    mdot)
103 printf( ' the exit pressure is: %f bars',p2)
104 printf( ' the exit mach number is: %f',M2)
```

Chapter 10

Refrigeration and Heat Pump Systems

Scilab code Exa 10.1 Example

```
1 // Given:–
2 Tc = 273.00

    // temperature of cold region in kelvin
3 Th = 299.00

    // temperature of hot region in kelvin
4 mdot = 0.08

    // mass flow rate in kg/s
5
6 // Analysis
7 // At the inlet to the compressor, the refrigerant
  is a saturated vapor at 0C, so from Table A–10
8 h1 = 247.23

    // in kj/kg
9 s1 = 0.9190
```

```

    // in kj/kg.k
10
11 // The pressure at state 2s is the saturation
    pressure corresponding to 26C, or
12 p2 = 6.853

    // in bars
13 // The refrigerant at state 2s is a superheated
    vapor with
14 h2s = 264.7

    // in kj/kg
15 // State 3 is saturated liquid at 26C, so
16 h3 = 85.75

    // in kj/kg
17 h4 = h3

    // since The expansion through the valve is a
    throttling process
18
19 // Part(a)
20 Wcdot = mdot*(h2s-h1)

    // The compressor work input in KW
21 printf( ' The compressor power, in kW, is: %.2f ',
    Wcdot)
22
23 // Part(b)
24 Qindot = mdot*(h1-h4)*60/211

    // refrigeration capacity in ton
25 printf( ' The refrigeration capacity in tons is: %
    .2f ',Qindot)
26
27 // Part(c)
28 beta1 = (h1-h4)/(h2s-h1)
29 printf( ' The coefficient of performance is: %.2f ',

```



```

    beta1)
30
31 // Part(d)
32 betamax = Tc/(Th-Tc)
33 printf( ' The coefficient of performance of a Carnot
    refrigeration cycle operating between warm and
    cold regions at 26 and 0C, respectively is: %.2f
    ',betamax);

```

Scilab code Exa 10.2 Example

```

1 // Given:-
2 mdot = 0.08

    // mass flow rate in kg/s
3 // Analysis
4 // At the inlet to the compressor, the refrigerant
    is a saturated vapor at 10C, so from Table A-10,
5 h1 = 241.35

    // in kj/kg
6 s1 = .9253

    // in kj/kg.k
7 // Interpolating in Table A-12 gives
8 h2s = 272.39

    // in kj/kg.k
9 // State 3 is a saturated liquid at 9 bar, so
10 h3 = 99.56

    // in kj/kg
11 h4 = h3

    // since The expansion through the valve is a

```

```

        throttling process
12
13 // Part(a)
14 Wcdot = mdot*(h2s-h1)

        // The compressor power input in KW
15 // Result
16 printf( ' \nThe compressor power in kw is:  %.2f ',
        Wcdot)
17
18 // Part(b)
19 Qindot = mdot*(h1-h4)*60/211

        // refrigeration capacity in tons
20 // Result
21 printf( ' \nThe refrigeration capacity in tons is:
        %.2f ',Qindot)
22
23 // Part(c)
24 beta1 = (h1-h4)/(h2s-h1)
25 // Result
26 printf( ' \nThe coefficient of performance is:  %.2f
        ',beta1)

```

Scilab code Exa 10.3 Example

```

1 // Given:-
2 Tnot = 299

        //in kelvin
3 etac = .8

        //compressor efficiency of 80 percent
4 mdot = .08

```

```

    //mass flow rate in kg/s
5 //analysis
6 //State 1 is the same as in Example 10.2, so
7 h1 = 241.35

    //in kj/kg
8 s1 = .9253

    //in kj/kg.k
9 //from example 10.2
10 h2s = 272.39

    //in kj/kg
11 h2 =(h2s-h1)/etac + h1

    //in
    kj/kg
12 //Interpolating in Table A-12,
13 s2 = .9497

    //in kj/kg.k
14 h3 = 91.49

    //in kj/kg
15 s3 = .3396
16 h4 = h3

    //since The expansion through the valve is a
    throttling process
17 //from data table
18 hf4 = 36.97

    //in kj/kg
19 hg4 = 241.36

    //in kj/kg
20 sf4 = .1486

    //in kj/kg.k

```

```

21 sg4 = .9253

    //in kj/kg.k
22 x4 = (h4-hf4)/(hg4-hf4) //
    quality at state 4
23 s4 = sf4 + x4*(sg4-sf4) //
    specific entropy at state 4 in kj/kg.k
24
25 //part(a)
26 Wcdot = mdot*(h2-h1) //
    compressor power in kw
27 printf( 'The compressor power in kw is: %.2f kW',
    Wcdot)
28
29 //part(b)
30 Qindot = mdot*(h1-h4)*60/211 //
    refrigeration capacity in ton
31 printf( 'The refrigeration capacity in ton is: %.2f
    ton ',Qindot)
32
33 //part(c)
34 beta = (h1-h4)/(h2-h1) //
    coefficient of performance
35 printf( 'The coefficient of performance is: %.2f',
    beta)
36
37 //part(d)
38 Eddotc = mdot*Tnot*(s2-s1) //in kw
39 Eddotv = mdot*Tnot*(s4-s3) //in kw
40 printf( 'The rate of exergy destruction within the
    compressor is: %.2f kW',Eddotc)

```

```
41 printf( 'The rate of exergy destruction within the
    valve is: %.2f kw',Eddotv)
```

Scilab code Exa 10.4 Example

```
1 // Given:-
2 p1 = 1.00

    // in bar
3 T1 = 270.00

    // in kelvin
4 AV = 1.4

    // in m^3/s
5 r = 3.00

    // compressor pressure ratio
6 T3 = 300.00

    // turbine inlet temperature in kelvin
7
8 // Analysis
9 // From Table A-22,
10 h1 = 270.11

    // in kj/kg
11 pr1 = 0.9590
12 // Interpolating in Table A-22,
13 h2s = 370.1

    // in kj/kg
14 // From Table A-22,
15 h3 = 300.19
```

```

    // in kj/kg
16 pr3 = 1.3860
17 // Interpolating in Table A-22, we obtain
18 h4s = 219.00

    // in kj/kg
19 // Calculations
20 pr2 = r*pr1
21 pr4 = pr3/r
22
23 // Part(a)
24 R = 8.314

    // universal gas constant, in SI units
25 M = 28.97

    // molar mass of air in grams
26
27 // Results
28 mdot = (AV*p1)/((R/M)*T1)*10**2

    // mass flow rate in kg/s
29 Wcycledot = mdot*((h2s-h1)-(h3-h4s))
30 printf( ' The net power input in kw is: %.2f',
    Wcycledot)
31
32 // Part(b)
33 Qindot = mdot*(h1-h4s)

    // refrigeration capacity in kw
34 printf( ' The refregeration capacity in kw is: %.2f
    ',Qindot)
35
36 // Part(c)
37 beta = Qindot/Wcycledot

    // coefficient of performance
38 printf( 'The coefficient of performance is: %.2f',

```

beta)

Scilab code Exa 10.5 Example

```
1 // Given:-
2 // Part(a)
3 wcdots = 99.99

    // work per unit mass for the isentropic
    // compression determined with data from the
    // solution in Example 10.4 in kj/kg
4 mdot = 1.807

    // mass flow rate in kg/s from 10.4
5 etac = 0.8

    // isentropic efficiency of compressor
6 Wcdot = (mdot*wcdots)/etac

    // The power input to the compressor in kw
7
8 // Using data form the solution to Example 10.4
   // gives
9 wtdots =81.19

    // in kj/kg
10 etat = 0.8

    // isentropic efficiency of turbine
11 // Calculations
12 Wtdot = mdot*etat*wtdots

    // actual turbine work in kw
13 Wdotcycle = Wcdot-Wtdot
```

```

    // The net power input to the cycle in kw
14 // Result
15 printf( ' The net power input in kw is:  %.2f',
    Wdotcycle)
16
17 // Part(b)
18 h3 = 300.19

    // in kj/kg
19 // From table A-22
20 h1 = 270.11

    // in kj/kg
21 // Calculations
22 h4 = h3 -Wdot/mdot
23 Qindot = mdot*(h1-h4)

    // refrigeration capacity in kw
24 // Result
25 printf( ' The refrigeration capacity in kw is:  %.2f
    ',Qindot)
26
27 // Part(c)
28 beta = Qindot/Wdotcycle

    // coefficient of performance
29 // Result
30 printf( ' The coefficient of performance is:  %.2f',
    beta)

```

Chapter 11

Thermodynamic Relations

Scilab code Exa 11.1 Example

```
1 // Given:-
2 m = 4.00

    // mass of carbon monoxide in kg
3 T = 223.00

    // temperature of carbon monoxide in kelvin
4 D = 0.2

    // inner diameter of cylinder in meter
5 L = 1.00

    // length of the cylinder in meter
6 pi=3.14
7 // Analysis
8 M = 28.00

    // molar mass in kg/kmol
9
10 // Calculations
11 V = (pi*D**2.00/4.00)*L
```

```

    // volume occupied by the gas in m^3
12 vbar = M*(V/m)

    // The molar specific volume in m^3/kmol
13
14 // Part(a)
15 // From Table A-1 for CO
16 Tc = 133

    // in kelvin
17 Pc = 35

    // in bar
18 Tr = T/Tc

    // reduced temperature
19 Rbar = 8314

    // universal gas constant in N.m/kmol.K
20 Z = 0.9
21 // Calculations
22 vrdash = (vbar*Pc*10**5)/(Rbar*Tc)

    //
    pseudoreduced specific volume
23 p = (Z*Rbar*T/vbar)*10**-5

    // in bar
24 // Result
25 printf( '\n part(a)the pressure in bar is: %.2f bar
    ',p)
26
27 // Part(b)
28 // The ideal gas equation of state gives
29 // Calculations
30 p = (Rbar*T/vbar)/10**5

    // in bar

```

```

31 // Result
32 printf( '\n Part(b)the pressure in bar is: %.2f bar'
    ,p)
33
34 // Part(c)
35 // For carbon monoxide, the van der Waals constants
    a and b can be read directly from Table A-24
36 a = 1.474
    // in (m^3/kmol)^2
37 b = 0.0395
    // in m^3/kmol
38 // Calculations
39 p = (Rbar*T/(vbar-b))/10**5 - a/vbar**2
40 // Result
41 printf( '\n Part(c)the pressure in bars is: %.2f
    bar',p)
42
43 // Part(d)
44 // For carbon monoxide, the Redlich Kwong
    constants can be read directly from Table A-24
45 a = 17.22
    // in m^6*K^.5/kmol^2
46 b = 0.02737
    // in m^3/kmol
47 // Calculations
48 p = (Rbar*T/(vbar-b))/10**5 - a/(vbar*(vbar+b)*T
    **.5)
49 // Result
50 printf( '\n Part(d)the pressure in bar is: %.2f bar
    ', p)

```

Scilab code Exa 11.3 Example

```
1 // Given:-
2 // Part(a)
3 v = 0.4646

    // specific volume in in m^3/kg
4 M = 18.02

    // molar mass of water in kg/kmol
5 // At the specified state, the temperature is 513 K
    and the specific volume on a molar basis is
6 vbar = v*M

    // in m^3/kmol
7 // From Table A-24
8 a = 142.59

    // (m^3/kmol)^2 * K^0.5
9 b = 0.0211

    // in m^3/kmol
10
11 Rbar = 8314.0

    // universal gas constant in N.m/kmol.K
12 T = 513.0

    // in kelvin
13 delpbydelT = (Rbar/(vbar-b) + a/(2*vbar*(vbar+b)*T
    **1.5)*10**5)/10**3 // in kj/(m^3*K)
14
15 // By The Maxwell relation
16 delsbydelv = delpbydelT
17 // Result
18 printf( ' The value of delpbydelT in kj/(m^3*K) is :
    %.2f ',delpbydelT);
19
```

```

20 // Part(b)
21 // A value for (dels/delv)T can be estimated using a
    graphical approach with steam table data, as
    follows: At 240C, Table A-4 provides the values
    for specific entropy s and specific volume v
    tabulated below
22 T = 240.0

    // in degree celcius
23 // At p =1, 1.5, 3, 5, 7, 10 bar respectively
24 y = [7.994, 7.805, 7.477, 7.230, 7.064, 6.882]
25 x = [2.359, 1.570, 0.781, 0.4646, 0.3292, 0.2275]
26 plot(x,y)
27 xlabel(" Specific volume")
28 ylabel(" Specific entropy")
29
30 // The pressure at the desired state is 5 bar.The
    corresponding slope is
31 delsbydelv = 1

    // in kj/m^3.K
32 printf( ' From the data of the table ,delsbydelv = %
    .2f ',delsbydelv);

```

Scilab code Exa 11.4 Example

```

1 // Given:-
2 // Analysis
3 // For comparison, Table A-2 gives at 100C,
4 hgf =2257.00

    // in kj/kg
5 ugf = 2087.6

    // in kj/kg

```

```

6  sgf = 6.048

    // in kj/kg.K
7  // Values
8  printf( ' From table , hg-hf = %.2 f ', hgf);
9  printf( ' From table , ug-uf = %.2 f ', ugf);
10 printf( ' From table , sg-sf = %.2 f ', sgf);
11
12 // Part(a)
13 T = 373.15

    // in kelvin
14 // If we plot a graph between temperature and
    saturation pressure using saturation
    pressure temperature data from the steam tables
    , the desired slope is:
15 delpbydelT = 3570.00

    // in N/(m^2.K)
16 vg = 1.673

    // in m^3/kg
17 vf = 1.0435e-3

    // in m^3/kg
18 // Calculations
19 // From the Clapeyron equation
20 hgf = T*(vg-vf)*delpbydelT*10**-3

    //

    in kj/kg
21 // Result
22 printf( '\n Part(a) using Clapeyron equation , hg-hf =
    %.2 f KJ/kg ', hgf);
23
24 // Part(b)
25 psat = 1.014e5

    // in N/m^2

```

```

26 hgf = 2256.00

    // can be obtained using IT software in kj/kg
27 // Calculations
28 ugf = hgf - psat*(vg-vf)/10**3

    // in kj/kg
29 // Result
30 printf( '\n Part(b)ug-uf = %.2 f KJ/kg ',ugf)
31 // Part(c)
32 // Calculation
33 sgf =hgf/T

    // in kj/kg.K
34 // Result
35 printf( '\n Part(c)sg-sf = %.2 f KJ/kg. k ',sgf)

```

Scilab code Exa 11.6 Example

```

1 // Given:-
2 // Part(a)
3 v = 1.00/998.21

    // specific volume of water in m^3/kg
4 T = 293.00

    // given temperature in kelvin
5 beta = 206.6e-6

    // volume expansivity in /K
6 k = 45.90e-6

    // isothermal compressibility in /bar
7 // Interpolating in Table A-19
8 cp = 4.188

```

```

9 // in kj/kg.k
9 // Calculations
10 cpv = (v*T*beta**2.00/k)*10**2 //
    in kj/kg.k
11 cv = cp-cpv

    // in kj/kg.k
12 errorPercentage = 100*(cp-cv)/cv
13 // Result
14 printf( ' The percentage error is:  %.2f',
    errorPercentage)
15
16 // Part(b)
17 // Calculations
18 K = cp/cv

    // specific heat ratio
19 c = ((K*v/k)*10**5)**0.5

    // velocity of sound in m/s
20 // Result
21 printf( ' The velocity of sound is:  %.2f m/s',c)

```

Scilab code Exa 11.8 Example

```

1 // Given:-
2 p1 = 100.00

    // in bar
3 T1 = 300.00

    // in kelvin
4 p2 = 40.00

```



```

5      // in bar
T2 = 245.00

      // in kelvin
6
7
8 // From table A-23
9 h1starbar = 8723.00

      // in kj/kmol
10 h2starbar = 7121.00

      // in kj/kmol
11 // From Tables A-1
12 Tc = 126.00

      // critical temperature in kelvin
13 pc = 33.9

      // critical pressure in bar
14 M = 28.00

      // molar mass in kg/kmol
15 Rbar = 8.314

      // universal gas constant in kj/(kmol.K)
16 Term1 = 0.5
17 Term2 = 0.31
18
19 // Calculations
20 TR1 = T1/Tc

      // reduced temperature at the inlet
21 PR1 = p1/pc

      // reduced pressure at the inlet
22 TR2 = T2/Tc

```

```

    // reduced temperature at the exit
23 PR2 = p2/pc

    // reduced pressure at the exit
24 wcvdot = (1.00/M)*(h1starbar-h2starbar-Rbar*Tc*(
    Term1-Term2)) // in kj/kg
25
26 // Result
27 printf( ' The work developed , in kJ per kg of
    nitrogen flowing is : %.2f ',wcvdot)

```

Scilab code Exa 11.9 Example

```

1
2 // Given:-
3 // Part(a)
4 // With values from Table A-23
5 sT2bar = 185.775

    // in kj/(kmol.K)
6 sT1bar = 191.682

    // in kj/(kmol.K)
7 Rbar = 8.314

    // universal gas constant
8 M = 28.00

    // molar mass in kg/kmol
9 p2 = 40.00

    // in bar
10 p1 = 100.00

```

```

    // in bar
11 Term1 = 0.21
12 Term2 = 0.14
13
14 // Calculations
15
16 S2StarBarMinusS1StarBar = sT2bar-sT1bar-Rbar*log(p2/
    p1) // The change in specific
    entropy in kj/(kmol.K)
17 sigmacvdot = (1.00/M)*(S2StarBarMinusS1StarBar-Rbar
    *(Term2-Term1))
18 // Result
19 printf( ' the rate of entropy production in kj/kg.K
    is: %.2f', sigmacvdot)
20
21 // Part(b)
22 // From Table A-23,
23 h2starbar = 6654.00

    // in kj/kmol
24 h1starbar = 8723.00

    // in kj/kmol
25 Tc = 126.00

    // critical temperature in kelvin
26 Term2 = 0.36
27 Term1 = 0.5
28 wcvdot = 50.1

    // from example 11.8
29
30 // Calculations
31 wcvdots = (1.00/M)*(h1starbar-h2starbar-Rbar*Tc*(
    Term1-Term2)) // isentropic work
    in kj/kg
32 etat = wcvdot/wcvdots

```

```

    // turbine efficiency
33
34 // Result
35 printf( ' The isentropic turbine efficiency is: %.2f
    ', etat)

```

Scilab code Exa 11.10 Example

```

1
2 // Given:-
3 // Analysis
4 V = 0.241

    // volume of the mixture in m^3
5 T = 511.00

    // temperature of the mixture in kelvin
6 n1 = 0.18

    // number of moles of methane in kmol
7 n2 = 0.274

    // number of moles of butane in kmol
8 Rbar = 8314

    // universal gas constant in (N.m)/(kmol.K)
9
10 // Calculations
11 n = n1 + n2

    // The total number of moles of mixture
12 y1 = n1/n

    // mole fraction of methane
13 y2 = n2/n

```

```

    // mole fraction of butane
14 vbar = V/(n)

    // The specific volume of the mixture on a molar
    // basis in m^3/kmol
15
16 // Part(a)
17 p = (Rbar*T/vbar)*10**-5

    // in bar
18 // Result
19 printf( ' The pressure in bar obtained using ideal
    // gas equation is: %.2f',p)
20
21 // Part(b)
22 // From table A-1
23 Tc1 = 191.00

    // critical temperature for methane in kelvin
24 Pc1 = 46.4

    // critical pressure for methane in bar
25 Tc2 = 425.00

    // critical temperature for butane in kelvin
26 Pc2 = 38.00

    // critical pressure for butane in bar
27 Z = 0.88
28
29
30 // Calculations
31 Tc = y1*Tc1 + y2*Tc2

    // critical temperature in kelvin
32 Pc = y1*Pc1 + y2*Pc2

```

```

    // critical pressure in bar
33 TR = T/Tc

    // reduced temperature of the mixture
34 vRdash= vbar*Pc/(Rbar*Tc)
35 p = ((Z*Rbar*T)/vbar)*10**-5

    // mixture pressure in bar
36 // Result
37 printf( ' Pressure obtained using Kay s rule
    together with the generalized compressibility
    chart , is: %.2f ',p)
38
39 // Part(c)
40 // Table A-24 gives the following van der Waals
    constants values for methane
41 a1 = 2.293

    // in (m^3/kmol)^2
42 b1 = 0.0428

    // in m^3/kmol
43 // Table A-24 gives the following van der Waals
    constants values for butane
44 a2 = 13.86

    // in (m^3/kmol)^2
45 b2 = 0.1162

    // in m^3/kmol
46
47 a = (y1*a1**.5 + y2*a2**.5)**2

    // in bar*(m^3/kmol)^2
48 b = y1*b1+y2*b2

    // in m^3/kmol
49 // From van der Waals equation

```

```

50 p = ((Rbar*T)/(vbar-b))*10**-5 - a/(vbar**2)
51 printf( ' The pressure in bar from van der Waals
    equation is:  %.2f ',p)
52
53 // Part(d)
54 // For methane
55 TR1 = T/Tc1
56 vR1dash = (.241/.18)*10**5*Pc1/(Rbar*Tc1)
57 Z1 = 1.00
58 // For butane
59 TR2 = T/Tc2
60 vR2dash = (.88*10**5*Pc2)/(Rbar*Tc2)
61 Z2 = 0.8
62 Z = y1*Z1 + y2*Z2
63 // Accordingly, the same value for pressure as
    determined in part (b) using Kay s rule results
    :
64 p = 70.4
65
66 // Result
67 printf( ' The pressure in bar obtained using the
    rule of additive pressures employing the
    generalized compressibility chart is:  %.2f ',p)

```

Chapter 12

Ideal Gas Mixtures and Psychrometrics Applications

Scilab code Exa 12.1 Example

```
1 // Given:-
2 n1 = 0.08

    // mole fraction of CO2
3 n2 = 0.11

    // mole fraction of H2O
4 n3 = 0.07

    // mole fraction of O2
5 n4 = 0.74

    // mole fraction of N2
6
7 // Part(a)
8 M1 = 44.0

    // molar mass of CO2 in kg/kmol
9 M2 = 18.0
```



```

10 // molar mass of H2O in kg/kmol
M3 = 32.0

11 // molar mass of O2 in kg/kmol
M4 = 28.0

12 // molar mass of N2 in kg/kmol
13 // Calculations
14 M = M1*n1 + M2*n2 + M3*n3 + M4*n4
//
// in kg/kmol
15 // Result
16 printf( 'The apparent molecular weight of the
mixture in kg/kmol is: %f',M)
17
18 // Part(b)
19 mf1 = (M1*n1/M)*100.0

20 // mass fraction of CO2 in percentage
mf2 = (M2*n2/M)*100.0

21 // mass fraction of H2O in percentage
mf3 = (M3*n3/M)*100.0

22 // mass fraction of O2 in percentage
mf4 = (M4*n4/M)*100.0

23 // mass fraction of N2 in percentage
24 // Results
25 printf( 'The mass fraction of CO2 in percentage is:
%f',mf1)
26 printf( 'The mass fraction of H2O in percentage is:
%f',mf2)
27 printf( 'The mass fraction of O2 in percentage is:
%f',mf3)

```

```
28 printf( 'The mass fraction of N2 in percentage is:
    %f',mf4)
```

Scilab code Exa 12.2 Example

```
1 // Given:-
2 mf1 = 0.1

    // mass fraction of H2
3 mf2 = 0.6

    // mass fraction of N2
4 mf3 = 0.3

    // mass fraction of CO2
5
6 // Part(a)
7 M1 = 2.0

    // molar mass of H2 in kg/kmol
8 M2 = 28.0

    // molar mass of N2 in kg/kmol
9 M3 = 44.0

    // molar mass of CO2 in kg/kmol
10
11 // Calculations
12 n1 = (mf1/M1)/(mf1/M1 + mf2/M2 + mf3/M3) // mole
    fraction of H2
13 n2 = (mf2/M2)/(mf1/M1 + mf2/M2 + mf3/M3) // mole
    fraction of N2
14 n3 = (mf3/M3)/(mf1/M1 + mf2/M2 + mf3/M3)
```

```

                                                                    // mole
    fraction of CO2
15
16 // Results
17 printf( 'The mole fraction of H2 in percentage is:
    %f',n1*100)
18 printf( 'The mole fraction of N2 in percentage is:
    %f',n2*100)
19 printf( 'The mole fraction of CO2 in percentage is:
    %f',n3*100)
20
21 // Part(b)
22 // Calculation
23 M = n1*M1 + n2*M2 + n3*M3

    // in kg/kmol
24 // Result
25 printf( 'The apparent molecular weight of the
    mixture in kg/kmol is: %f',M);

```

Scilab code Exa 12.3 Example

```

1 // Given:-
2 m1 = 0.3

    // mass of CO2 in kg
3 m2 = 0.2

    // mass of N2 in kg
4 p1 = 1.0

    // in bar
5 T1 = 300.0

    // in kelvin

```

```

6 p2 = 3.0

    // in bar
7 n = 1.25
8
9 // Part(a)
10 // Calculation
11 T2 = T1*(p2/p1)**((n-1)/n)

    // in kelvin
12 // Result
13 printf( 'The final temperature in Kelvin is: %f',T2
    );
14
15 // Part(b)
16 Rbar = 8.314

    // universal gas constant in SI units
17 // Calculations
18 M = (m1+m2)/(m1/44 + m2/28)

    // molar mass of mixture in kg/kmol
19 W = ((m1+m2)*(Rbar/M)*(T2-T1))/(1-n)

    // in
    kj
20 // Result
21 printf( 'The work in kj is: %f',W )
22
23 // Part(c)
24 // From table A-23
25 uC02T1 = 6939.0

    // internal energy of CO2 on molar mass basis at
    temperature T1
26 uC02T2 = 9198.0

    // internal energy of CO2 on molar mass basis at
    temperature T2

```

```

27 uN2T1 = 6229.0

    // internal energy of N2 on molar mass basis at
    // temperature T1
28 uN2T2 = 7770.0

    // internal energy of N2 on molar mass basis at
    // temperature T2
29 deltaU = (m1/44)*(uC02T2-uC02T1) + (m2/28)*(uN2T2-
    uN2T1) // internal energy
    // change of the mixture in KJ
30
31 // With assumption , The changes in kinetic and
    // potential energy between the initial and final
    // states can be ignored
32 Q = deltaU + W
33 // Result
34 printf( 'The heat transfer in kj is: %f',Q);
35
36 // Part(d)
37 // From table A-23
38 sbarT2C02 = 222.475
39 sbarT1C02 = 213.915
40 sbarT2N2 = 198.105
41 sbarT1N2 = 191.682
42 Rbar = 8.314

    // universal gas constant
43 // Calculation
44 deltaS = (m1/44)*(sbarT2C02-sbarT1C02-Rbar*log(p2/p1
    )) + (m2/28)*(sbarT2N2-sbarT1N2-Rbar*log(p2/p1))
45 // Result
46 printf( 'The change in entropy of the mixture in kj/
    k is: %f',deltaS)

```

Scilab code Exa 12.4 Example

```
1 // Given:-
2 y1 = 0.8

    // mole fraction of CO2
3 y2 = 0.2

    // mole fraction of O2
4 T1 = 700.0

    // in kelvin
5 p1 = 5.0

    // in bars
6 V1 = 3.0

    // in m/s
7 p2 = 1.0

    // in bars
8
9
10 // Part(a)
11 // From table A-23
12 sO2barT1 = 231.358
13 sCO2barT1 = 250.663
14 // Calculations
15
16 RHS = y2*sO2barT1 + y1*sCO2barT1 + 8.314*log(p2/p1)
17 // Using table A-23
18 LHSat510K = y2*221.206 + y1*235.7
19 LHSat520K = y2*221.812 + y1*236.575
20 // Using linear interpolation ,
21 T2 = 510 +((520-510)/(LHSat520K-LHSat510K))*(RHS-
    LHSat510K)
22 // Result
23 printf( 'The temperature at the nozzle exit in K is:
```

```

        %f',T2);
24
25 // Part(b)
26 // From table A-23
27 sbarO2T2 = 221.667

    // in kj/kmol.K
28 sbarO2T1 = 231.358

    // in kj/kmol.K
29 sbarCO2T2 = 236.365

    // in kj/kmol.K
30 sbarCO2T1 = 250.663

    // in kj/kmol.K
31 // Calculations
32 deltasbarO2 = sbarO2T2-sbarO2T1-8.314*log(p2/p1)
                // in kj/kmol.K
33 deltasbarCO2 = sbarCO2T2-sbarCO2T1-8.314*log(p2/p1)
                // in kj/kmol.K
34 // Results
35 printf( 'The entropy changes of the CO2 from inlet
        to exit, in KJ/Kmol.K is: %f',deltasbarCO2)
36 printf( 'The entropy change of the O2 from inlet to
        the exit in kj/kmol.k is: %f',deltasbarO2)
37
38 // Part(c)
39 // From table A-23, the molar specific enthalpies of
        O2 and CO2 are
40 h1barO2 = 21184.0
41 h2barO2 = 15320.0
42 h1barCO2 = 27125.0
43 h2barCO2 = 18468.0
44 // Calculations
45 M = y1*44.0 + y2*32.0

    // apparent molecular weight of the mixture in kg

```

```

    /kmol
46 deltax = (1.0/M)*(y2*(h1barO2-h2barO2) + y1*(
    h1barCO2-h2barCO2))
47 V2 = sqrt(V1**2+ 2*deltax*10**3)
48 // Result
49 printf( 'The exit velocity in m/s is: %f',V2)

```

Scilab code Exa 12.5 Example

```

1 // Given:-
2 nN2 = 0.79

    // initial moles of nitrogen in kmol
3 pN2 = 2.0

    // initial pressure of nitrogen in bars
4 TN2 = 250.0

    // initial temperature of nitrogen in kelvin
5 nO2 = 0.21

    // initial moles of oxygen in kmol
6 pO2 = 1.0

    // initial pressure of oxygen in bars
7 TO2 = 300.0

    // initial temperature of oxygen in kelvin
8
9 // Part(a)
10 MN2 = 28.01

    // molar mass of nitrogen in kg/kmol
11 MO2 = 32.0

```



```

    // molar mass of oxygen in kg/kmol
12 // Calculations
13 // With the help of table A-20
14 cvbarN2 = MN2*0.743

    // in kj/kmol.K
15 cvbarO2 = MO2*0.656

    // in kj/kmol.K
16 T2 = (nN2*cvbarN2*TN2+nO2*cvbarO2*T02)/(nN2*cvbarN2+
    nO2*cvbarO2)
17 // Result
18 printf( 'The final temperature of the mixture in
    kelvin is: %f',T2);
19
20 // Part(b)
21 // Calculation
22 p2 = ((nN2+nO2)*T2)/(nN2*TN2/pN2 + nO2*T02/pO2)
23 // Result
24 printf( 'The final pressure of the mixture in bar is
    : %f',p2);
25
26 // Part(c)
27 Rbar = 8.314

    // universal gas constant
28 // Calculations
29 cpbarN2 = cvbarN2 + Rbar
30 cpbarO2 = cvbarO2 + Rbar
31 yN2 = nN2/(nN2+nO2)

    // mole fraction of N2
32 yO2 = nO2/(nN2+nO2)

    // mole fraction of O2
33 sigma = nN2*(cpbarN2*log(T2/TN2)-Rbar*log(yN2*p2/pN2
    )) + nO2*(cpbarO2*log(T2/T02)-Rbar*log(yO2*p2/pO2
    ))

```

```
34 // Result
35 printf( 'The amount of entropy produced in the
    mixing process , in kJ/K is:  %f',sigma);
```

Scilab code Exa 12.6 Example

```
1 // Given:-
2 T1 = 32.0

    // temperature of dry air in degree celcius
3 p1 = 1.0

    // pressure of dry air in bar
4 AV1 = 100.0

    // volume rate of dry air in m^3/min
5 T2 = 127.0

    // temperature of oxygen stream in degree celcius
6 p2 = 1.0

    // pressure of oxygen stream in bar
7 T3 = 47.0

    // temperature of mixed stream in degree celcius
8 p3 = 1.0

    // pressure of mixed stream in bar
9
10 // Part(a)
11 Rbar = 8314.0

    // universal gas constant
12 Ma = 28.97
```

```

    // molar mass of air
13 Mo = 32.0

    // molar mass of oxygen
14 // From table A-22 and A-23
15 haT3 = 320.29

    // in kj/kg
16 haT1 = 305.22

    // in kj/kg
17 hnotT2 = 11711.0

    // in kj/kmol
18 hnotT1 = 9325.0

    // in kj/kmol
19
20 // Calculations
21 va1 = (Rbar/Ma)*(T1+273.0)/(p1*10**5)
    //
    specific volume of air in m^3/kg
22 ma1dot = AV1/va1

    // mass flow rate of dry air in kg/min
23 modot = ma1dot*(haT3-haT1)/((1/Mo)*(hnotT2-hnotT1))
    // in kg/min
24 // Results
25 printf( 'The mass flow rate of dry air in kg/min is:
    %f',ma1dot);
26 printf( 'The mass flow rate of oxygen in kg/min is:
    %f',modot);
27
28 // Part(b)
29 nadot = ma1dot/Ma

    // molar flow rate of air in kmol/min
30 nodot = modot/Mo

```

```

// molar flow rate of oxygen in kmol/min
31 ya = nadot/(nadot+nodot)

// mole fraction of air
32 yo = nodot/(nadot+nodot)

// mole fraction of oxygen
33 // Results
34 printf( 'The mole fraction of dry air in the exiting
mixture is: %f',ya)
35 printf( 'The mole fraction of dry oxygen in the
exiting mixture is: %f',yo)
36
37 // Part(c)
38 // With the help of tables A-22 and A-23
39 sanotT3 = 1.7669

// in kj/kg.K
40 sanotT1 = 1.71865

// in kj/kg.K
41 sbarT3 = 207.112

// in kj/kmol.K
42 sbarT2 = 213.765

// in kj/kmol.K
43 // Calculations
44 sigmadot = maldot*(sanotT3-sanotT1-(8.314/Ma)*log(ya
))+(modot/Mo)*(sbarT3-sbarT2-8.314*log(yo))
45 // Result
46 printf( 'The time rate of entropy production , in kJ/
K . min is: %f',sigmadot)

```

Scilab code Exa 12.7 Example

```
1 // Given:-
2 m =1.0

    // mass of sample in kg
3 T1 = 21.0

    // initial temperature in degree celcius
4 psi1 = 0.7

    // initial relative humidity
5 T2 = 5.0

    // final temperature in degree celcius
6
7 // Part(a)
8 // From table A-2
9 pg = 0.02487

    // in bar
10 // Calculations
11 pv1 = psi1*pg

    // partial pressure of water vapor in bar
12 omega1 = 0.622*(0.2542)/(14.7-0.2542)
13 // Result
14 printf( 'the initial humidity ratio is: %f',omega1)
15
16 // Part(b)
17 // The dew point temperature is the saturation
    temperature corresponding to the partial pressure
    , pv1. Interpolation in Table A-2 gives
18 T = 15.3

    // the dew point temperature in degree celcius
19 // Result
20 printf( 'The dew point temperature in degree celcius
```

```

        is: %f',T)
21
22 // Part(c)
23 // The partial pressure of the water vapor remaining
    in the system at the final state is the
    saturation pressure corresponding to 5C:
24 // Calculations
25 mv1 = 1/((1/omega1)+1)

    // initial amount of water vapor in the sample in
    kg
26 ma = m-mv1

    // mass of dry air present in kg
27 pg = 0.00872

    // in bar
28 omega2 = 0.622*(pg)/(1.01325-pg)

    // humidity ratio after cooling
29 mv2 = omega2*ma

    // The mass of the water vapor present at the
    final state
30 mw = mv1-mv2
31
32 // Result
33 printf( 'The amount of water vapor that condenses ,
    in kg. is: %f',mw)

```

Scilab code Exa 12.8 Example

```

1
2 // Given:-
3 V = 35.0

```

```

4     // volume of the vessel in m^3
p1 = 1.5

     // in bar
5 T1 = 120.0

     // in degree celcius
6 psi1 = 0.1
7 T2 = 22.0

     // in degree celcius
8
9 // Part(a)
10 // The dew point temperature at the initial state is
    the saturation temperature corresponding to the
    partial pressure pv1. With the given relative
    humidity and the saturation pressure at 120C from
    Table A-2
11 pg1 = 1.985
12 // Interpolating in Table A-2 gives the dew point
    temperature as
13 T = 60.0

     // in degree celcius
14 // Calculation
15 pv1 = psi1*pg1

     // partial pressure in bar
16 // Result
17 printf( 'The dew point temperature corresponding to
    the initial state , in degee celcius is: %f',T)
18
19 // Part(b)
20 Rbar = 8314.0

     // universal gas constant
21 Mv = 18.0

```

```

    // molar mass of vapor in kj/kmol
22 // Interpolation in Table A-2
23 Tdash = 56.0

    // in degrees
24 vv1 = ((Rbar/Mv)*(T1+273))/(pv1*10**5)

    //
    the specific volume of the vapor at state 1 in m
    ^3/kg
25 // Result
26 printf( 'The temperature at which condensation
    actually begins in degree celcius is: %f',Tdash)
27
28 // Part(c)
29 // From table
30 vf2 = 1.0022e-3
31 vg2 = 51.447
32 vv2 = vv1

    // specific volume at final state
33 // Calculations
34 mv1 = V/vv1

    // initial amount of water vapor present in kg
35 x2 = (vv2-vf2)/(vg2-vf2)

    // quality
36 mv2 = x2*mv1

    // the mass of the water vapor contained in the
    system at the final state
37 mw2 = mv1-mv2
38 // Result
39 printf( 'The amount of water condense in kg is: %f'
    ,mw2)

```

Scilab code Exa 12.9 Example

```
1
2 // Given:-
3 V = 35.0

    // volume of vessel in m^3
4 p1 = 1.5

    // initial pressure in bar
5 T1 = 120.0

    // initial temperature in degree celcius
6 psi = 0.1
7 T2 = 22.0

    // in degree celcius
8 Rbar = 8314.0

    // universal gas constant
9 Ma = 28.97

    // molar mass of air
10 pv1 = 0.1985

    // in bar, from example 12.8
11 mv2 = 0.681

    // in kg, from examples 12.8
12 mv1 = 3.827

    // in kg, from example 12.8
13 mw2 = 3.146
```

```

    // in kg, from example 12.8
14 // evaluating internal energies of dry air and water
    from Tables A-22 and A-2, respectively
15 ua2 = 210.49

    // in kj/kg
16 ua1 = 281.1

    // in kj/kg
17 ug2 = 2405.7

    // in kj/kg
18 uf2 = 92.32

    // in kj/kg
19 ug1 = 2529.3

    // in kj/kg
20
21 // Calculations
22 ma = ( ((p1-pv1)*10**5)*V)/((Rbar/Ma)*(T1+273))
    // mass of dry
    air in kg
23 Q = ma*(ua2-ua1) + mv2*ug2 + mw2*uf2 - mv1*ug1
24
25 // Result
26 printf( 'The heat transfer during the process , in kJ
    is:  %f',Q)

```

Scilab code Exa 12.10 Example

```

1
2 // Given :-
3 AV1 = 150.0

```

```

    // entry volumetric flow rate in m^3/min
4 T1 = 10.0

    // entry temperature in degree celcius
5 psi1 = 0.8
6 T2 = 30.0

    // exit temperature in degree celcius
7 p = 1.0

    // in bar
8
9 // Part(a)
10 Rbar = 8314.0

    // universal gas constant
11 Ma = 28.97

    // molar mass of air
12 // The specific enthalpies of the dry air are
    // obtained from Table A-22 at the inlet and exit
    // temperatures T1 and T2, respectively:
13 ha1 = 283.1

    // in kj/kg
14 ha2 = 303.2

    // in kj/kg
15 // The specific enthalpies of the water vapor are
    // found using hv hg and data from Table A-2 at T1
    // and T2, respectively:
16 hv1 = 2519.8

    // in kj/kg
17 hv2 = 2556.3

    // in kj/kg
18 // From table A-2

```

```

19 pg1 = 0.01228

    // in bar
20 // Calculations
21 pv1 = psi1*pg1

    // the partial pressure of the water vapor in bar
22 pa1 = p-pv1
23 va1 = (Rbar/Ma)*(T1+273)/(pa1*10**5) //

    specific volume of the dry air in m^3/kg
24 madot = AV1/va1

    // mass flow rate of the dry air in kg/min
25 omega = 0.622*(pv1/(p-pv1))

    // humidity ratio
26 Qcvdot = madot*((ha2-ha1)+omega*(hv2-hv1)) // in kj/

    min
27 // Result
28 printf( 'Rate of heat transfer , in kJ/min is: %.2f'
    ,Qcvdot);
29
30 // Part(b)
31 // From Table A-2 at 30C
32 pg2 = 0.04246

    // in bar
33 // Calculations
34 pv2 = pv1
35 psi2 = pv2/pg2

    // relative humidity at the exit
36 // Result
37 printf( 'The relative humidity at the exit is: %.2f
    ',psi2);

```

Scilab code Exa 12.11 Example

```
1
2 // Given:-
3 T1 = 30.0
4
5 // in degree celcius
6 AV1 = 280.0
7
8 // in m^3/min
9 psi1 = 0.5
10
11 // relative humidity at the inlet
12 T2 = 10.0
13
14 // in degree celcius
15 p = 1.013
16
17 // pressure in bar
18
19 8
20 // Part(a)
21 // From table A-2
22 pg1 = 0.04246
23
24 // in bar
25 Rbar = 8314
26
27 // universal gas constant
28 Ma = 28.97
29
30 // molar mass of air
31 // Calculations
32 pv1 = psi1*pg1
```

```

    // in bar
16 pa1 = p-pv1

    // partial pressure of the dry air in bar
17 madot = AV1/((Rbar/Ma)*((T1+273)/(pa1*10**5)))
    // common mass
    flow rate of the dry air in kg/min
18 // Result
19 printf( '\n The mass flow rate of the dry air in kg/
    min is: %.2f',madot);
20
21 // Part(b)
22 // From table A-2
23 pv2 = 0.01228

    // in bar
24 // Calculations
25 omega1 = 0.622*(pv1/(p-pv1))
26 omega2 = 0.622*(pv2/(p-pv2))
27 mwdotbymadot = omega1-omega2
28 // Result
29 printf( '\n The rate at which water is condensed, in
    kg per kg of dry air flowing through the control
    volume is: %.4f',mwdotbymadot);
30
31 // Part(c)
32 // From table A-2 and A-22
33 ha2 = 283.1

    // in kg/kj
34 ha1 = 303.2

    // in kg/kj
35 hg1 = 2556.3

    // in kg/kj
36 hg2 = 2519.8

```

```

    // in kg/kj
37 hf2 = 42.01

    // in kg/kj
38 // Calculations
39 Qcvdot = madot*((ha2-ha1)-omega1*hg1+omega2*hg2+(
    omega1-omega2)*hf2) // in kj/min
40 // Result
41 printf( '\n The required refrigerating capacity, in
    tons is: %.2f ',Qcvdot/211);

```

Scilab code Exa 12.12 Example

```

1
2 // Given:-
3 T1 = 22.0

    // entry temperature of moist air in degree
    celcius
4 Twb = 9.0

    // wet-bulb temperature of entering moist air in
    degree celcius
5 madot = 90.0

    // mass flow rate of dry air in kg/min
6 Tst = 110.0

    // temperature of injected saturated water vapor
    in degree celcius
7 mstdot = 52.0

    // mass flow rate of injected saturated water
    vapor in kg/h
8 p = 1.0

```

```

    // pressure in bar
9
10 // Part(a)
11 // By inspection of the psychrometric chart
12 omega1 = 0.002
13 // Calculation
14 omega2 = omega1 + mstdot/(madot*60)
15 // Result
16 printf( 'The humidity ratio at the exit is: %.2f',
    omega2);
17
18 // Part(b)
19 // The steady-state form of the energy rate balance
    can be rearranged as
20 //  $(h_a + \omega \cdot h_g)_2 = (h_a + \omega \cdot h_g)_1 + (\omega_2 - \omega_1) \cdot h_{g3}$ 
21 // On putting values in the above equation from
    tables and figures , temperature at the exit can
    then be read directly from the chart
22 T2 = 23.5

    // in degree celcius
23 // Result
24 printf( 'The temperature at the exit in degree
    celcius is: %.2f',T2)

```

Scilab code Exa 12.13 Example

```

1
2 // Given:-
3 T1 = 38.0

    // temperature of entering air in degree celcius
4 psi1 = 0.1

```



```

// relative humidity of entering air
5 AV1 = 140.0

// volumetric flow rate of entering air in m^3/
min
6 Tw = 21.0

// temperature of added water in degree celcius
7 T2 = 21.0

// temperature of exiting moist air in degree
celcius
8 p = 1.0

// pressure in atm
9
10 // Part(a)
11 // From table A-2
12 pg1 = 0.066

// in bar
13 // The specific volume of the dry air can be
evaluated from the ideal gas equation of state.
The result is
14 va1 = .887

// in m^3/kg
15 cpa = 1.005
16 // From table A-2
17 hf = 88.14
18 hg1 = 2570.7
19 hg2 = 2539.94
20 // Calculations
21 pv1 = psi1*pg1

// the partial pressure of the moist air entering
the control volume in bar

```

```

22 omega1 = 0.622*(pv1/(p*1.01325-pv1))
23 omega2 = (cpa*(T1-T2)+omega1*(hg1-hf))/(hg2-hf)
24 madot = AV1/va1

    // mass flow rate of the dry air in kg/min
25 mwdot = madot*60*(omega2-omega1)

    // in kg/h
26 // Result
27 printf( '\n The mass flow rate of the water to the
    soaked pad in is: %.2f kg(water)/h',mwdot);
28
29 // Part(b)
30 pv2 = (omega2*p*1.01325)/(omega2+0.622) // in
    bars
31 // At 21C, the saturation pressure is
32 pg2 = 0.02487
33 psi2 = pv2/pg2
34 // Result
35 printf( '\n The relative humidity of the moist air
    at the exit to the evaporative cooler is: %.2f',
    psi2)

```

Scilab code Exa 12.14 Example

```

1
2 // Given:-
3 AV1 = 142.0

    // in m^3/min
4 T1 = 5.0

    // in degree celcius
5 omega1 = 0.002

```

```

6 AV2 = 425.0

    // in m^3/min
7 T2 = 24.0

    // in degree celcius
8 psi2 = 0.5
9 p = 1.0

    // in bar
10
11
12 // Part(a)
13 // From the psychrometric chart , Fig. A-9.
14 va1 = 0.79

    // in m^3/kg
15 va2 = 0.855

    // in m^3/kg
16 omega2 = 0.0094
17 // Calculations
18 ma1dot = AV1/va1

    // in kg/min
19 ma2dot = AV2 /va2

    // in kg/min
20 omega3 = (omega1*ma1dot+omega2*ma2dot)/(ma1dot +
    ma2dot)
21 // Result
22 printf( '\n The humidity ratio is: %.4f',omega3);
23
24 // Part(b)
25 // Reduction of the energy rate balance gives
26 // (ha + omega*hv)3 = [ma1dot*(ha + omega*hv)1 +
    ma2dot*(ha + omega*hv)2]/(ma1dot+ma2dot)
27 // With (ha + omega*hv)1 = 10kj/kg and (ha + omega*

```

```

    hv)2 = 47.8kj/kg from figure A-9
28 LHS = (ma1dot*10+ma2dot*47.8)/(ma1dot + ma2dot)
29
30 // This value for the enthalpy of the moist air at
    the exit , together with the previously determined
    value for omega3, fixes the state of the exiting
    moist air. From inspection of Fig. A-9,
31 T3 = 19.0

    // in degree celcius
32 // Result
33 printf( '\n The temperature of the exiting mixed
    stream in degree celcius T3 is : %.2f',T3)

```

Scilab code Exa 12.15 Example

```

1
2 // Given:-
3 T1 = 38.0

    // in degree celcius
4 m1dot = 4.5e7

    // in kg/h
5 T2 = 30.0

    // in degree celcius
6 m2dot = 4.5e7

    // in kg/h
7 T3 = 25.0

    // in degree celcius
8 psi3 = 0.35
9 T4 = 35.0

```

```

    // in degree celcius
10 psi4 = 0.9
11 T5 = 20.0

    // in degree celcius
12
13 // Analysis
14 // The humidity ratios omega3 and omega4 can be
    determined using the partial pressure of the
    water vapor obtained with the respective relative
    humidity
15 omega3 =0.00688
16 omega4 = 0.0327
17 // From tables A-2 and A-22
18 hf1 = 159.21
19 hf2 = 125.79
20 ha4 = 308.2
21 ha3 = 298.2
22 hg4 = 2565.3
23 hg3 = 2547.2
24 hf5 = 83.96
25 // Calculations
26 madot = (m1dot*(hf1-hf2))/(ha4-ha3+omega4*hg4-omega3
    *hg3-(omega4-omega3)*hf5) // in kg/h
27 m5dot = madot*(omega4-omega3)

    // in kg/h
28 // Results
29 printf( 'The mass flow rate of dry air in kg/h is:
    %.2f',madot)
30 printf( 'The mass flow rate of makeup water in kg/h
    is: %.2f',m5dot)

```

Chapter 13

Reacting Mixtures and Combustion

Scilab code Exa 13.1 Example

```
1
2 // Given:-
3 // Part(a)
4 // The combustion equation can be written in the
   form of
5 //  $C_8H_{18} + a(O_2 + 3.76N_2) - b CO_2 + c H_2O + d N_2$ 
6 // Using conservation of mass principle
7 b = 8.00
8 c = 18.00/2.00
9 a = (2.00*b+c)/2.00
10 d = 3.76*a
11
12 // The air fuel ratio on a molar basis is
13 AFbar = a*(1+3.76)/1.00
14 Ma = 28.97
   // molar mass of air
15 MC8H18 = 114.22
```

```

    // molar mass of C8H18
16 // The air fuel ratio expressed on a mass basis is
17 AF = AFbar*(Ma/MC8H18)
18
19 // Result
20 printf( ' The air fuel ratio on a molar basis is:
    %f', AFbar);
21 printf( ' The air fuel ratio expressed on a mass
    basis is:  %.2f',AF)
22
23 // Part(b)
24 // For 150% theoretical air, the chemical equation
    for complete combustion takes the form
25 //  $c\text{C}_8\text{H}_{18} + 1.5 \times 12.5 \times (\text{O}_2 + 3.76\text{N}_2) \rightarrow b\text{CO}_2 + c\text{H}_2\text{O} + d\text{N}_2 + e\text{O}_2$ 
26 // Using conservation of mass
27 // Calculations
28 b = 8.00
29 c =18.00/2.00
30 e = (1.5*12.5*2 - c -2*b)/2.00
31 d = 1.5*12.5*3.76
32 // The air fuel ratio on a molar basis is
33 AFbar = 1.5*12.5*(1+3.76)/1
34 // The air fuel ratio expressed on a mass basis is
35 AF = AFbar*(Ma/MC8H18)
36
37 // Results
38 printf( ' The air fuel ratio on a molar basis is:
    %f', AFbar)
39 printf( ' The air fuel ratio expressed on a mass
    basis is:  %.2f',AF)

```

Scilab code Exa 13.2 Example

```

2 // Given:-
3 // Part(a)
4 // The chemical equation
5 // a CH4 + b*(O2 + 3.76N2)  --  9.7CO2 + .5CO + 2.95
   O2 + 86.85N2 + cH2O
6 // Calculations
7 // Applying conservation of mass
8 a = 9.7 + 0.5
9 c = 2.0*a
10 b = ((9.7)*(2.0)+(0.5)+((2.0)*(2.95))+c)/2.00
11 Ma = 28.97

   // molar mass of air
12 MCH4 = 16.04

   // molar mass of methane
13 // On a molar basis , the air fuel ratio is
14 AFbar = (b*(1+3.76))/a
15 // On a mass basis
16 AF = AFbar*(Ma/MCH4)
17
18 // Results
19 printf( ' The air-fuel ratio on a molar basis is :
   %f',AFbar)
20 printf( ' The air-fuel ratio on a mass basis is: %
   .2f',AF)
21
22 // Part(b)
23 // The balanced chemical equation for the complete
   combustion of methane with the theoretical amount
   of air is
24 // CH4 + 2(O2 + 3.76N2)  --  CO2 + 2H2O + 7.52N2
25 // The theoretical air fuel ratio on a molar basis
   is
26 // Calculations
27 AFbartheo = 2.00*(1+3.76)/1.0
28 // The percent theoretical air is
29 Ta = AFbar/AFbartheo

```



```

30 // Result
31 printf( ' The percent theoretical air is: %.2f',Ta
        *100)
32
33 // Ppart(c)
34 // The mole fraction of the water vapor is
35 yv = 20.4/(100+20.4)
36 pv = yv*1
37 // Interpolating in Table A-2,
38 T = 57

        // in degree celcius
39 // Result
40 printf( ' The dew point temperature of the products,
        in C, if the mixture were cooled at 1 atm is:
        %f',T);

```

Scilab code Exa 13.3 Example

```

1
2 // Given:-
3 // Part(a)
4 // The chemical equation
5 // (.8062CH4 + .0541C2H6 + .0187C3H8 + .0160C4H10 +
        .1050N2) + a(O2 + 3.76N2) --- b(.078CO2 + .002
        CO + .07O2 + .85N2) + c H2O
6 // Calculations
7 // Using mass conservation
8 b = (0.8062 + 2*.0541 + 3*.0187 + 4*.0160)/(0.078 +
        .002)
9 c = (4*.8062 + 6*.0541 + 8*.0187 + 10*.0160)/2
10 a = (b*(2*.078+.002+2*.07) + c)/2
11 // The air fuel ratio on a molar basis is
12 AFbar = a*(1+3.76)/1
13 // Result

```

```

14 printf( ' The air-fuel ratio on a molar mass basis
      is:  %.2f ',AFbar)
15
16 // Part(b)
17 p = 1.0

      // in bar
18 V = 100.0

      // in m^3
19 Rbar = 8314.0

      // in N.m/kmol.K
20 T = 300.0

      // in kelvin
21 // Calculations
22 // The amount of fuel in kmol
23 nF = (p*10**5*V)/(Rbar*T)
24 // The amount of product mixture that would be
      formed from 100 m3 of fuel mixture is
25 n = nF*(b+c)
26 // Result
27 printf( ' The amount of products in kmol that would
      be formed from 100 m3 of fuel mixture at 300 K
      and 1 bar is:  %.2f ',n)
28
29 // Part(c)
30 // The balanced chemical equation for the complete
      combustion of the fuel mixture with the
      theoretical amount of air is
31 // (10.8062CH4 + 0.0541C2H6 + 0.0187C3H8 + 0.0160
      C4H10 + 0.1050N2) + 2(O2 + 3.76N2)  --- 1.0345
      CO2 + 1.93H2O + 7.625N2
32 // Calculations
33 // The theoretical air fuel ratio on a molar basis
      is
34 AFbartheo = 2*(1+3.76)/1

```

```

35 // The percent theoretical air is
36 Ta = AFbar/AFbartheo
37 // Result
38 printf( ' The percent of theoretical air is: %.2f ',
        Ta*100)

```

Scilab code Exa 13.4 Example

```

1
2 // Given:-
3 // The balanced chemical equation for complete
  combustion with the theoretical amount of air is
  obtained from the solution to Example 13.1 as
4 // C8H18 +12.5O2 + 47N2 ----- 8CO2 + 9H2O + 47N2
5 // From tabel A-25
6 hRbar = -249910

  // in kj/kmol
7 mfdot = 1.8e-3

  // mass flow rate of liquid octane in kg/s
8 M = 114.22

  // molar mass of octane
9 Wcvdot = 37

  // power output of the engine in kw
10
11 // Calculations
12 // With enthalpy of formation values for CO2 and H2O
  (g) from Table A-25, and enthalpy values for N2,
  H2O, and CO2 from Table A-23
13 hpbar = 8*(-393520 + (36876 - 9364)) + 9*(-241820 +
  (31429 - 9904)) + 47*((26568 - 8669))
14 nFdot = mfdot/M

```

```

    // molar flow rate of the fuel in kmol/s
15 Qcvdot = Wcvdot + nFdot*(hpbar-hRbar)
    // in
    kw
16
17 // Result
18 printf( ' The rate of heat transfer from the engine ,
    in kW is:  %.2f ',Qcvdot)

```

Scilab code Exa 13.5 Example

```

1
2 // Given:-
3 // When expressed on a per mole of fuel basis , the
    balanced chemical equation obtained in the
    solution to Example 13.2  takes the form
4 // CH4 + 2.265O2 + 8.515N2  -----  .951CO2 + .049CO
    + .289O2 + 8.515N2 + 2H2O
5 cpbar = 38.00

    // specific heat in KJ/kmol.K
6 // From table A-25
7 hfnotbar = -74850.00

    // enthalpy of formation for methane
8 // From table A-23
9 deltahbarO2 = 14770-8682
10 deltahbarN2 = 14581-8669
11
12 // Calculations
13 hRbar = hfnotbar + cpbar*(400-298) + 2.265*
    deltahbarO2 + 8.515*deltahbarN2    // in kj/
    kmol
14 // With enthalpy of formation values for CO2, CO,

```

```

    and H2O(g) from Table A-25 and enthalpy values
    from Table A-23
15 hpbar = .951*(-393520 + (88806 - 9364)) +
    .049*(-110530 + (58191 - 8669)) + .289*(60371 -
    8682) + 8.515*(57651 - 8669) + 2*(-241820 +
    (72513 - 9904))
16 Qcvdot = hpbar - hRbar

    // in kj/kmol
17
18 // Result
19 printf( ' The rate of heat transfer from the
    combustion chamber in kJ per kmol of fuel is: %
    .2f ',Qcvdot)

```

Scilab code Exa 13.6 Example

```

1
2 // Given:-
3 nCH4 = 1.00

    // moles of methane in kmol
4 nO2 = 2.00

    // moles of oxygen in kmol
5 T1 = 25.00

    // in degree celcius
6 p1 = 1.00

    // in atm
7 T2 = 900.00

    // in kelvin
8 Rbar = 8.314

```

```

    // universal gas constant
9 // The chemical reaction equation for the complete
    combustion of methane with oxygen is
10 // CH4 + 2O2  ———  CO2 + 2H2O
11
12 // Part(a)
13 // with enthalpy of formation values from table A-25
14 hfbarsC02 = -393520
15 hfbarsH20 = -241820
16 hfbarsCH4 = -74850
17 // Calculations
18 // with enthalpy values from table A-23
19 deltabarsC02 = 37405-9364
20 deltabarsH20 = 31828-9904
21 Q = ((hfbarsC02 + deltabarsC02)+2*(hfbarsH20 +
    deltabarsH20) - hfbarsCH4) + 3*Rbar*(T1+273-T2)
22 // Result
23 printf( ' The amount of heat transfer in kJ is: %.2
    f', Q)
24
25 // Part(b)
26 p2 = p1*(T2/(T1+273))

    // in atm
27 // Result
28 printf( ' The final pressure in atm is: %.2f',p2)

```

Scilab code Exa 13.7 Example

```

1
2 // Given:-
3 // The combustion equation is
4 // CH4 + 2O2 + 7.52N2  ———  CO2 + 2H2O + 7.52N2
5

```

```

6 // Part(a)
7 // With enthalpy of formation values from Table A-25
8 hfbarC02 = -393520

    // in kj/kmol
9 hfbarH20 = -285830

    // in kj/kmol
10 hfbarCH4 = -74850

    // in kj/kmol
11 M = 16.04

    // molar mass of CH4 in kg/kmol
12 // Calculations
13 hRPbar = hfbarC02 + 2*hfbarH20 - hfbarCH4
                                                // in kj/
    kmol
14 hRP = hRPbar/M

    // in kj/kg
15 // Result
16 printf( ' Part(a) the enthalpy of combustion of
    gaseous methane, fuel is: %f kJ/kg.', hRP)
17
18 // Part(b)
19 hfbarC02 = -393520

    // in kj/kmol
20 hfbarH20 = -241820

    // in kj/kmol
21 hfbarCH4 = -74850

    // in kj/kmol
22 // Calculations
23 hRPbar = hfbarC02 + 2*hfbarH20 - hfbarCH4
                                                // in kj/

```

```

    kmol
24 hRP = hRPbar/M

    // in kj/kg
25 // Result
26 printf( ' Part(b)the enthalpy of combustion of
    gaseous methane, fuel is: %f kJ/kg',hRP);
27
28 // Part(c)
29 // From table A-23
30 deltahbarO2 = 31389-8682

    // in kj/kmol
31 deltahbarH2O = 35882-9904

    // in kj/kmol
32 deltahbarCO2 = 42769-9364

    // in kj/kmol
33
34 // Using table A-21
35 // Calculations
36 // function cpbar = f(T)
37 T=298

    // in kelvin
38
39 function T = cpbar(T)
40     T = (3.826 - (3.979e-3)*T + 24.558e-6*T**2 -
        22.733e-9*T**3 + 6.963e-12*T**4)*8.314
41 endfunction
42
43 deltahbarCH4 = intg(298,1000,cpbar)
44 var = deltahbarCH4(1)
45
46 hRPbar = hRPbar + (deltahbarCO2 + 2*deltahbarH2O -
    var -2*deltahbarO2)
47 hRP = hRPbar/M

```



```

48 // in kj/kg
49 // Result
49 printf( ' Part(c)the enthalpy of combustion of
    gaseous methane, per kg of fuel is %.f kJ/kg',hRP
    );

```

Scilab code Exa 13.8 Example

```

1
2 // Given:-
3 // Part(a)
4 // For combustion of liquid octane with the
    theoretical amount of air, the chemical equation
    is
5 //  $C_8H_{18}(l) + 12.5 O_2 + 47N_2 \longrightarrow 8 CO_2 + 9 H_2O(g) + 47N_2$ 
6 // with enthalpy of formation data from Table A-25
7 hfbarc8H18 = -249910.0

    // in kj/kmol
8 hfbarcO2 = -393520.0
9 hfbarcH2O = -241820.0
10
11 // Calculations
12 RHS = hfbarc8H18 -(8*hfbarcO2 + 9*hfbarcH2O)
    // in kj/kmol
13 // at temperature 2400k
14 LHS1 = 5089337.0

    // in kj/kmol
15 // at temperature 2350 k
16 LHS2 = 4955163.0

    // in kj/kmol

```

```

17 // Interpolation between these temperatures gives
18 Tp = 2400.00 + ((2400.0-2350.0)/(LHS1-LHS2))*(RHS -
    LHS1)
19 // Result
20 printf( ' The temperature in kelvin with theoretical
    amount of air is: %.2f', Tp)
21
22 // Part(b)
23 // For complete combustion of liquid octane with 400
    % theoretical air , the chemical equation is
24 // C8H18(l) + 50O2 + 188N2 ----- 8CO2 + 9H2O +
    37.5O2 + 188N2
25
26 // Proceeding iteratively as part(a)
27 Tp = 962

    // in kelvin
28
29 // Result
30 printf( ' The temperature in kelvin using 400
    percent theoretical air is: %.2f ',Tp)

```

Scilab code Exa 13.9 Example

```

1
2 // Given:-
3
4 // Part(a)
5 Tp = 2395

    // in kelvin , from example 13.8
6 // For combustion of liquid octane with the
    theoretical amount of air , the chemical equation
    is
7 // C8H18(l) + 12.5O2 + 47N2 ---- 8CO2 + 9H2O(g) +

```

```

      47N2
8
9 // From table A-25
10 sFbar = 360.79

      // absolute entropy of liquid octane in kj/kmol.K
11
12 // From table A-23
13 // For reactant side
14 sbar02atTref = 205.03

      // in kj/kmol.K
15 sbarN2atTref = 191.5

      // in kj/kmol.K
16 Rbar = 8.314

      // universal gas constant in SI units
17 yO2 = 0.21
18 yN2 = 0.79
19 // For product side
20 yCO2 = 8.0/64.0
21 yH2O = 9.0/64.0
22 yN2p = 47.0/64.0
23
24 // Calculations
25 sbarO2 = sbar02atTref - Rbar*log(yO2)
                                     // in kj/
                                     kmol.K
26 sbarN2 = sbarN2atTref - Rbar*log(yN2)
                                     // in kj/
                                     kmol.K
27 // With the help from table A-23
28 sbarCO2 = 320.173 - Rbar*log(yCO2)
29 sbarH2O = 273.986 - Rbar*log(yH2O)
30 sbarN2p = 258.503 - Rbar*log(yN2p)
31 sigmadot = (8*sbarCO2 + 9*sbarH2O + 47*sbarN2p) -
              sFbar - (12.5*sbarO2 + 47*sbarN2)

```

```

32
33 // Result
34 printf( ' The rate of entropy production , in kJ/K
    per kmol of fuel with theoretical amount of air
    is:  %.2f ',sigmadot)
35
36 // Part(b)
37 // The complete combustion of liquid octane with 400
    % theoretical air is described by the following
    chemical equation:
38 // C8H18(l) + 50 O2 + 188N2  ----  8 CO2 + 9H2O(g) +
    37.5O2 + 188N2
39
40 // For product side
41 yCO2 = 8.0/242.5
42 yH2O = 9.0/242.5
43 yO2 = 37.5/242.5
44 yN2p = 188.0/242.5
45 // Calculations
46 // With help from table A-23
47 sbarCO2 = 267.12 - Rbar*log(yCO2)
48 sbarH2O = 231.01 - Rbar*log(yH2O)
49 sbarO2p = 242.12 - Rbar*log(yO2)
50 sbarN2p = 226.795 - Rbar*log(yN2p)
51 sigmadot = (8.0*sbarCO2 + 9.0*sbarH2O + 37.5*sbarO2p
    +188.0*sbarN2p) -sFbar - (50.0*sbarO2 + 188.0*
    sbarN2)
52
53 // Result
54 printf( ' The rate of entropy production , in kJ/K
    per kmol of fuel with 400 percent theoretical air
    is:  %.2f ', sigmadot)

```

Scilab code Exa 13.10 Example

```

1
2 // Given:-
3 Rbar = 8.314

    // universal gas constant in SI units
4 // The chemical equation for the complete combustion
    of methane with oxygen is
5 // CH4 + 2O2 ---- CO2 + 2H2O
6 yCH4 = 1.0/3.0
7 yO2 = 2.0/3.0
8 yCO2 = 1.0/3.0
9 yH2O = 2.0/3.0
10 // From table A-25
11 sbarCH4atTref = 186.16

    // in kj/kmol.K
12 sbarO2atTref = 205.03

    // in kj/kmol.K
13 p2 = 3.02

    // in atm
14 pref = 1.0

    // in atm
15
16 // Calculations
17 sbarCH4 = sbarCH4atTref - Rbar*log(yCH4)
18 sbarO2 = sbarO2atTref - Rbar*log(yO2)
19 // With help from table A-23
20 sbarCO2 = 263.559 - Rbar*log(yCO2*p2/pref)
    // in kj/kmol.K
21 sbarH2O = 228.321 - Rbar*log(yH2O*p2/pref)
    // in kj/kmol.K
22 deltaS = sbarCO2 + 2*sbarH2O - sbarCH4 -2*sbarO2
    // in kj/K
23
24 // Result

```

```
25 printf( ' The change in entropy of the system is: %  
    .2f kJ/K ',deltaS)
```

Scilab code Exa 13.11 Example

```
1  
2 // Given:-  
3 // Methane is formed from carbon and hydrogen  
    according to  
4 // C + 2H2 ----- CH4  
5  
6 // In the present case, all substances are at the  
    same temperature and pressure, 25C and 1 atm,  
    which correspond to the standard reference state  
    values  
7 hCbar = 0  
8 hH2bar = 0  
9 gRbar = 0  
10 // With enthalpy of formation and absolute entropy  
    data from Table A-25  
11 hfbarCH4 = -74850  
12 sbarCH4 = 186.16  
13 sbarC = 5.74  
14 sbarH2 = 130.57  
15 Tref = 298.15  
  
    // in kelvin  
16  
17 // Calculation  
18 gfbarCH4 = hfbarCH4 -Tref*(sbarCH4-sbarC-2*sbarH2)  
    // in kJ/kmol  
19  
20 // Result  
21 printf( ' The gibbs function of formation of methane  
    at the standard state is: %f kJ/mol',gfbarCH4)
```

Scilab code Exa 13.12 Example

```
1
2 // Given:-
3 // Complete combustion of liquid octane with O2 is
  described by
4 //  $C_8H_{18}(l) + 12.5O_2 \longrightarrow 8CO_2 + 9H_2O$ 
5
6 // Part(a)
7 Rbar = 8.314
8
9 // universal gas constant in SI units
10 Tnot = 298.15
11
12 // in kelvin
13 // From table A-25
14 gbarC8H18 = 6610.0
15 gbarO2 = 0
16 gbarCO2 = -394380
17 gbarH2O = -228590
18 yO2 = 0.2035
19 yCO2 = 0.0003
20 yH2O = 0.0312
21 M = 114.22
22
23 // molecular weight of liquid octane
24
25 // Calculations
26 ech = ((gbarC8H18 + 12.5*gbarO2 -8*gbarCO2 -9*
  gbarH2O) + Rbar*Tnot*log(yO2**12.5/(yCO2**8*yH2O
  **9
  )))/M
27
28 // Result
29 printf( ' Part(a) the chemical exergy obtained on a
  unit mass basis is: %.2f kJ/K',ech)
```

```

23
24 // Part(b)
25 // With data from Table A-25 and Model II of Table A
    -26
26 gbarH2O = -237180.0
27 ebarCO2 = 19870.0
28 ebarH2O = 900.0
29 ebarO2 = 3970.0
30
31 // Calculation
32 ech = ((gbarC8H18 + 12.5*gbarO2 -8*gbarCO2 - 9*
    gbarH2O) + 8*ebarCO2 + 9*ebarH2O - 12.5*ebarO2)/M
33 // Result
34 printf( ' Part(b) chemical exergy on a unit mass
    basis is: %.3f kJ/K',ech)

```

Scilab code Exa 13.13 Example

```

1
2 // Given:-
3 Rbar = 8.314

    // universal gas constant in SI units
4 Tnot = 298.0

    // in kelvin
5 // With data from the steam tables
6 h = 2939.9

    // in kj/kg
7 hnot = 104.9

    // in kj/kg
8 s = 7.2307

```



```

    // in kj/kg
9  snot = 0.3674

    // in kj/kg
10 // With data from Table A-25
11 gbarH2Oliq = -237180.0
12 gbarH2Ogas = -228590.0
13 yeH2O = 0.0303
14 M =18.0

    // molar mass of steam
15
16 // Calculations
17 ech = (1.0/M)*(gbarH2Oliq-gbarH2Ogas + Rbar*Tnot*log
    (1/yeH2O)) // in kj/kg
18 ef = h-hnot-Tnot*(s-snot) + ech // in
    kj/kg
19
20 // Result
21 printf( ' The flow exergy of the steam, in is: %.2f
    kJ/kg ',ef)

```

Scilab code Exa 13.14 Example

```

1
2 // Given:-
3 // For 140% theoretical air, the reaction equation
    for complete combustion of methane is
4 // CH4 + 2.8(O2 + 3.76N2) ----- CO2 + 2H2O +
    10.53N2 + .8O2
5
6 // For product side
7 yCO2p = 1.0/(1.0+2.0+10.53+.8)
8 yH2Op = 2.0/(1.0+2.0+10.53+.8)

```

```

9  yN2p = 10.53/(1.0+2.0+10.53+.8)
10 yO2p = 0.8/(1.0+2.0+10.53+.8)
11
12 Rbar = 8.314

    // universal gas constant in SI units
13 Tnot = 298.15

    // in kelvin
14
15 yeN2 = 0.7567
16 yeO2 = 0.2035
17 yeH2O = 0.0303
18 yeCO2 = 0.0003
19
20 // Calculations
21
22 ebarch = Rbar*Tnot*(log(yCO2p/yeCO2) + 2*log(yH2Op/
    yeH2O) + 10.53*log(yN2p/yeN2) + .8*log(yO2p/yeO2)
    )
23
24 // with data from tables A-23 at 480 and 1560 kelvin
    ,the thermomechanical contribution to the flow
    exergy, per mole of fuel, is
25 contri480 = 17712.0

    // kJ per kmol of fuel
26 contri1560 = 390853.0

    // kJ per kmol of fuel
27 efbarch = contri480 + ebarch

    // kJ per kmol of fuel
28 efbarch1560 = contri1560 + ebarch

    // kJ per kmol of fuel
29
30 // Results

```

```
31 printf( ' At T= 480k, the flow exergy of the
    combustion products , in kJ per kmol of fuel is:
    %.2f ',efbar480)
32 printf( ' At T = 1560K, the flow exergy of the
    combustion products , in kJ per kmol of fuel is:
    %.2f ',efbar1560)
```

Scilab code Exa 13.15 Example

```
1
2 // Given:-
3 mFdot = 1.8e-3

    // fuel mass flow rate in kg/s
4 ech = 47346.0

    // in kj/kg, from example 13.12(a)
5 Wcvdot = 37.0

    // power developed by the engine in kw
6
7 // Calculations
8 Efdot = mFdot*ech

    // rate at which exergy enters with the fuel in
    kw
9 epsilon = Wcvdot/Efdot

    // exergetic efficiency
10
11 // Result
12 printf( ' The exergetic efficiency is: %.3f ',
    epsilon)
```

Scilab code Exa 13.16 Example

```
1
2 // Given:-
3 Tnot = 298
    // in kelvin
4
5 // For the case of complete combustion with the
  theoretical amount of air
6 sigmadot = 5404.0
    // rate of entropy production from example 13.9,
  in kj/kmol.K
7 Efdot = 5407843.0
    // rate at which exergy enters with the fuel from
  example 13.12, in kj/kmol
8 // Calculations:-
9 Eddot = Tnot*sigmadot
    // in kj/kmol
10 epsilon = 1-Eddot/Efdot
11 // Result
12 printf( ' The exergetic efficiency with theoretical
  amount of air is: %.3f',epsilon)
13
14 // For the case of combustion with 400% theoretical
  air
15 sigmadot = 9754.0
    // rate of entropy production from example 13.9,
  in kj/kmol.K
16 // Calculations
```

```
17 Eddot = Tnot*sigmadot
    // in kj/kmol
18 epsilon = 1-Eddot/Efdot
19 // Result
20 printf( 'The exergetic efficiency with 400 percent
    theoretical amount of air is: %.3f ',epsilon)
```

Chapter 14

Chemical and Phase Equilibrium

Scilab code Exa 14.1 Example

```
1
2 // Given:-
3 // The reaction is CO + .5O2 ---- CO2
4 // Part(a)
5 T = 298.0

    // in kelvin
6 Rbar = 8.314

    // universal gas constant in SI units
7 // From table A-25
8
9 hfbarCO2 = -393520.0

    // in kj/kmol
10 hfbarCO = -110530.0

    // in kj/kmol
11 hfbarO2 = 0
```

```

    // in kj/kmol
12 deltahbarCO2 = 0

    // in kj/kmol
13 deltahbarCO = 0

    // in kj/kmol
14 deltahbarO2 = 0

    // in kj/kmol
15 sbarCO2 = 213.69

    // in kj/kmol.K
16 sbarCO = 197.54

    // in kj/kmol.K
17 sbarO2 = 205.03

    // in kj/kmol.K
18 // From table A-27
19 logKtable = 45.066
20 // Calculations
21 deltaG = (hfbarCO2-hfbarCO-.5*hfbarO2) + (
           deltahbarCO2-deltahbarCO-.5*deltahbarO2) - T*(
           sbarCO2-sbarCO-.5*sbarO2)
22 lnK = -deltaG/(Rbar*T)
23 logK = (1/log(10))*lnK
24 // Results
25 printf( ' Part(a) the value of equilibrium constant
           expressed as log10K is: %f',logK);
26 printf( ' The value of equilibrium constant
           expressed as log10K from table A-27 is: %f ',
           logKtable);
27
28 // Part(b)
29 T = 2000.0

```

```

    // in kelvin
30 // From table A-23
31 hfbarC02 = -393520.0

    // in kj/kmol
32 hfbarC0 = -110530.0

    // in kj/kmol
33 hfbarO2 = 0

    // in kj/kmol
34 deltahbarC02 = 100804-9364

    // in kj/kmol
35 deltahbarC0 = 65408 - 8669

    // in kj/kmol
36 deltahbarO2 = 67881 - 8682

    // in kj/kmol
37 sbarC02 = 309.210

    // in kj/kmol.K
38 sbarC0 = 258.6

    // in kj/kmol.K
39 sbarO2 = 268.655

    // in kj/kmol.K
40 // Calculations
41 deltaG = (hfbarC02-hfbarC0-.5*hfbarO2) + (
    deltahbarC02-deltahbarC0-.5*deltahbarO2) - T*(
    sbarC02-sbarC0-.5*sbarO2)
42 lnK = -deltaG/(Rbar*T)
43 logK = (1/log(10))*lnK
44 // From table A-27
45 logKtable = 2.884
46 // Results

```



```

47 printf( ' Part(b) the value of equilibrium constant
    expressed as log10K is: %f ',logK);
48 printf( ' The value of equilibrium constant
    expressed as log10K from table A-27 is: %f ',
    logKtable);

```

Scilab code Exa 14.2 Example

```

1
2 // Given:-
3 // Applying conservation of mass, the overall
    balanced chemical reaction equation is
4 //  $CO + .5O_2 \rightleftharpoons zCO + (z/2)O_2 + (1-z)CO_2$ 
5
6 // At 2500 K, Table A-27 gives
7 log10K = -1.44
8 // Part(a)
9 p = 1.0
10 // in atm
11 // Calculations
12 K = (10.0)**(log10K)
13 // equilibrium constant
14 // Solving equation  $K = (z/(1-z))*(2/(2+z))^{.5} *(p/1)^{.5}$  gives
15 z = 0.129
16 yCO = 2.0*z/(2.0 + z)
17 yO2 = z/(2.0 + z)
18 yCO2 = 2.0*(1.0 - z)/(2.0 + z)
19 // Results
20 printf( ' Part(a) mole fraction of CO is: %.3f ',yCO
    )
    printf( ' Mole fraction of O2 is: %.3f',yO2)

```

```

21 printf( ' Mole fraction of CO2 is:  %.3f ',yC02)
22
23 // Part(b)
24 p = 10.0

    // in atm
25 // Solving equation  $K = (z/(1-z))*(2/(2 + z))^{.5} *(p$ 
    // /1)^.5 gives
26 z = 0.062
27 yC0 = 2.0*z/(2.0 + z)
28 yO2 = z/(2.0 + z)
29 yC02 = 2.0*(1.0 - z)/(2.0 + z)
30
31 // Results
32 printf( ' Part(b) mole fraction of CO is:  %.3f ',yC0
    )
33 printf( ' Mole fraction of O2 is:  %.3f ',yO2)
34 printf( ' Mole fraction of CO2 is:  %.3f ',yC02)

```

Scilab code Exa 14.3 Example

```

1
2 // Given:-
3 yC0 = 0.298
4 p = 1

    // in atm
5 pref = 1

    // in atm
6 // With this value of K, table A-27 gives
7 T = 2881
8
9 // Calculations
10 // Solving  $y_{CO} = 2z/(2 + z)$ 

```

```

11 z = 2*yCO/(2 - yCO)
12 K = (z/(1-z))*(z/(2 + z))**.5*(p/pref)**.5
13
14 // Result
15 printf( ' The temperature T of the mixture in kelvin
        is:  %f',T);

```

Scilab code Exa 14.4 Example

```

1
2 // Given:-
3 // For a complete reaction of CO with the
  theoretical amount of air
4 // CO + .5 O2 + 1.88N2 ----- CO2 + 1.88N2
5 // Accordingly, the reaction of CO with the
  theoretical amount of air to form CO2, CO, O2,
  and N2 is
6 // CO + .5O2 + 1.88N2 -- zCO + z/2 O2 + (1-z)CO2 +
  1.88N2
7
8 K = 0.0363

  // equilibrium constant the solution to Example
  14.2
9 p =1.0

  // in atm
10 pref = 1.0

  // in atm
11
12 // Calculations
13 // Solving  $K = (z*z^{.5}/(1-z))*((p/pref)*2/(5.76+z))^{.5}$  gives
14 z = 0.175

```

```

15 yCO = 2.0*z/(5.76 + z)
16 yO2 = z/(5.76 + z)
17 yCO2 = 2.0*(1.0-z)/(5.76 + z)
18 yN2 = 3.76/(5.76 + z)
19
20 // Results
21 printf( ' The mole fraction of CO is: %.3f ',yCO)
22 printf( ' The mole fraction of O2 is: %.3f ',yO2)
23 printf( ' The mole fraction of CO2 is: %.3f ',yCO2)
24 printf( ' The mole fraction of N2 is: %.3f ',yN2)

```

Scilab code Exa 14.5 Example

```

1
2 // Given:-
3 // Applying the conservation of mass principle , the
  overall dissociation reaction is described by
4 //  $\text{CO}_2 \rightleftharpoons z\text{CO}_2 + (1-z)\text{CO} + ((1-z)/2)\text{O}_2$ 
5
6 p = 1.0
7
8 // in atm
9 pref = 1.0
10
11 // in atm
12 // At 3200 K, Table A-27 gives
13 log10k = -.189
14 // Solving  $k = ((1-z)/2)*((1-z)/(3-z))^{.5}$  gives
15 z = 0.422
16
17 // Calculations
18 k = 10**log10k
19 // From tables A-25 and A-23
20 hfbarsCO2 = -393520.0

```

```

    // in kj/kmol
17 deltabarCO2 = 174695-9364

    // in kj/kmol
18 hfbarCO = -110530.0

    // in kj/kmol
19 deltabarCO = 109667-8669

    // in kj/kmol
20 hfbarO2 = 0

    // in kj/kmol
21 deltabarO2 = 114809-8682

    // in kj/kmol
22 hfbarCO2r = -393520.0

    // in kj/kmol
23 deltabarCO2r = 0

    // in kj/kmol
24
25 Qcvdot = 0.422*(hfbarCO2 + deltabarCO2) + 0.578*(
    hfbarCO + deltabarCO) + 0.289*(hfbarO2 +
    deltabarO2)- (hfbarCO2r + deltabarCO2r)
26
27 // Result
28 printf( ' The heat transfer to the reactor , in kJ
    per kmol of CO2 entering is:  %f', Qcvdot);

```

Scilab code Exa 14.8 Example

```

1
2 // Given:—

```

```

3 // The ionization of cesium to form a mixture of Cs,
   Cs+, and e- is described by
4 // Cs  ----  (1-z)Cs + zCs+ + Ze-
5
6 K = 15.63
7 z = 0.95
8 pref =1

   // in atm
9 // Calculation
10 p = pref*K*((1-z**2)/z**2)
11
12 // Results
13 printf( ' The pressure if the ionization of CS is 95
   percent complete is: %f atm',p);
14
15 x = linspace(0,10,100)
16 for i = 1:100
17     y(i)= 100*((1/(1+x(i)/K))**0.5)
18 end
19
20 plot(x,y)
21 xlabel(" Pressure (atm)")
22 ylabel(" Ionization")

```

Scilab code Exa 14.10 Example

```

1
2 // Given:-
3 // With data from Table A-2 at 20C,
4 vf = 1.0018e-3

   // in m^3/kg
5 psat = 0.0239

```

```

        // in bar
6  p = 1.0

        // in bar
7  T = 293.15

        // in kelvin
8  Rbar = 8.314

        // universal gas constant in SI units
9  M = 18.02

        // molat mass of water in kg/kmol
10 e=2.715
11
12 // Calculations
13 pvbypsat = e**((vf*(p-psat)*10**5)/((1000*Rbar/M)*T))
14 percent = (pvbypsat-1)*100
15
16 // Result
17 printf( ' The departure , in percent , of the partial
        pressure of the water vapor from the saturation
        pressure of water at 20 is: %.3f ',percent)

```
