Scilab Textbook Companion for
Engineering Thermodynamics: A Computer Approach (SI Units Version)
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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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List of Scilab Codes

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Chapter 2

Basic Concepts Of Thermodynamics

Scilab code Exa 2.1 1

```
1  clc
2  rho_Hg=13596;  //kg/m^3
3  g=9.806;  //m/s^2
4  h=0.76;  //m
5
6  P=rho_Hg*g*h/1000;  //kPa
7
8  disp("(i) Pressure of 80 cm of Hg")
9  h1=0.80;  //m
10 P1=h1/h*P;
11 disp(P1)
12 disp("kPa")
13
14 disp("(ii) 30 cm Hg vacuum")
15 H2=0.30;  //cm Hg vacuum
16 h2=h-H2;  //cm of Hg absolute
17 disp("Pressure due to 46 cm of Hg")
18 P2=h2/h*P;
19 disp(P2)
```

```
20 disp("kPa")
21
22 disp(" (iii) Pressure due to 1.35 m H2O gauge")
23 rho_H2O=1000; //kg/m^3
24 h3=1.35; //m
25 P3=rho_H2O*g*h3/1000;
26 disp(P3)
27 disp("kPa")
28
29 disp(" (iv) 4.2 bar")
30 P4=4.2*10^2;
31 disp(P4)
32 disp("kPa")
```

Scilab code Exa 2.2 2

```
1 clc
2 d=0.1; //m
3 F=1000; //N
4 A=%pi/4*d^2; //m^2
5 P=F/A/10^3;
6 disp("Pressure on the piston=")
7 disp(P)
8 disp("kN/m^2")
```

Scilab code Exa 2.3 3

```
1 clc
2 SG=0.9;
3 h=1.2; //m
4 g=9.81; //m/s^2
5 rho_w=1000; //kg/m^3
6 rho=SG*rho_w; //kg/m^3
```

```
7  P=rho*g*h/10^3;
8  disp("Gauge pressure P=")
9  disp(P)
10 disp("kN/m^2")
```

Scilab code Exa 2.4 4

```
1  clc
2  Vacuum_recorded=740; //mm of Hg
3  Barometric_reading=760; //mm of Hg
4
5  Absolute_pressure=(Barometric_reading-
      Vacuum_recorded)*133.4;
6  disp("Absolute pressure in the condenser=")
7  disp(Absolute_pressure)
8  disp("Pa")
```

Scilab code Exa 2.5 5

```
1  clc
2  d=0.5; //m
3  h=0.75; //m
4  m=4; //kg
5  Manometer_reading=620; //mm of Hg above atmosphere
6  Barometer_reading=760; //mm of Hg
7  V=%pi/4*d^2*h; //m^3
8  disp("(i) Total pressure in the vessel")
9
10 P=(Barometer_reading+Manometer_reading)*133.4/10^5;
      //bar
11 disp("P=")
12 disp(P)
13 disp("bar")
```

```
14  disp("(ii) Specific volume and density")
15  SV=V/m;
16  disp("Specific volume=")
17  disp(SV)
18  disp("m^3/kg")
19  D=m/V;
20  disp("Density=")
21  disp(D)
22  disp("kg/m^3")
```

Scilab code Exa 2.6 6

```
1  clc
2  h0=.761; //m
3  h=.55; //m
4  g=9.79; //m/s^2
5  rho=13640; //kg/m^3
6  P=rho*g*(h0+h); //N/m^2
7  disp("Gas pressure=")
8  disp(P/10^5)
9  disp("bar")
```

Scilab code Exa 2.7 7

```
1  clc
2  h_H2O=34; //mm of Hg
3  g=9.81; //m/s^2
4  rho=13600; //kg/m^3
5  P_Hg=97.5; //mm of Hg
6  P_atm=760; //mm of Hg
7  P_H2O=h_H2O/13.6; //mm of Hg
8  Pabs=rho*g*(P_Hg+P_atm-P_H2O)/10^8; //bar
9  disp("absolute pressure =")
```

```
10  disp(Pabs)
11  disp("bar")
```

Scilab code Exa 2.8 8

```
 1  clc
 2  SG=0.8;
 3  rho_H2O=1000; //kg/m^3
 4  g=9.81; //ms^2
 5  h=0.17; //m
 6  Patm=1.01325; //bar
 7  rho=SG*rho_H2O; //kg/m^3
 8  P_liq=rho*g*h/10^5; //bar
 9  P_gas=Patm - P_liq;
10  disp("gas pressure= ")
11  disp(P_gas)
12  disp("bar")
```

Scilab code Exa 2.9 9

```
 1  clc
 2  d=0.2; //m
 3  g=9.81; //m/s^2
 4  h=0.117; //m
 5  rho=13600; //kg/m^3
 6  p=rho*g*h;
 7  m=(p*%pi/4*d^2)/g;
 8  disp("mass=")
 9  disp(m)
10  disp("kg")
```

Scilab code Exa 2.10 10

```
1  clc
2  v=800;  //m/s
3  g=9;  //m/s^2
4  F=3600;  //N
5  m=F/g;
6  KE=1/2*m*v^2/10^6;
7  disp("Kinetic Energy=")
8  disp(KE)
9  disp("MJ")
```

Scilab code Exa 2.11 11

```
1  clc
2  m=6;  //kg
3  T1=25;  //0C
4  T2=125;  //0C
5
6  disp("(i) Heat transferred")
7  Q=integrate('m*(0.4+0.004*T)','T',T1,T2);
8  disp("heat tranferred=")
9  disp(Q)
10 disp("kJ")
11
12 disp("(ii) Mean specific heat of the gas")
13 c_n=Q/m/(T2-T1);
14 disp("Mean specific heat=")
15 disp(c_n)
16 disp("kJ/kg.0C")
```

Scilab code Exa 2.12 12

```
1  clc
2  Ice_point =0;
3  Steam_point =100;
4  //  t=a*log(p)+b
5  //  from  given  conditions  equations  formed  are
6  //  a*log(1.5)+b=0
7  //  a*log(7.5)+b=100
8  //  solving  equations
9  P=[log(1.5),1;log(7.5),1];
10 Q=[0;100];
11 X=inv(P)*Q;
12 a=X(1,1);
13 b=X(2,1);
14 p=3.5;
15 t=a*log(p)+b;
16 disp("The value of temperature is given by")
17 disp(t)
18 disp("  C ")
```

Scilab code Exa 2.13 13

```
1  clc
2  deff("[e]=func(t)","e=0.20*t-5*10^(-4)*t^2")
3  t1=0;  //0C
4  e1=func(t1);
5  t2=100;  //0C
6  e2=func(t2);
7  t3=70;  //0C
8  e3=func(t3);
9  t=e3*(t2-t1)/e2-e1;
10 disp("thermocouple will read")
11 disp(t)
12 disp("  C ")
```

Scilab code Exa 2.15 15

```
1 clc
2 p=101.325; //kPa
3 V2=0.6; //m^3
4 V1=0; //m^3
5 W=p*(V2-V1);
6 disp("work done by atmosphere=")
7 disp(-W)
8 disp("kJ")
```

Scilab code Exa 2.16 16

```
1 clc
2 p=1.013*10^5; //N/m^2
3 V1=1.5; //m^3
4 V2=0; //m^3
5 W=p*(V2-V1);
6 disp("W=")
7 disp(W/10^3)
8 disp("kJ")
```

Scilab code Exa 2.17 17

```
1 clc
2 T=1.25; //N.m
3 N=9500;
4 W1=2*%pi*N*T/1000; //kJ
5 p=101.3; //kPa
```

```
 6  d =0.65;  //m
 7  A=%pi/4*d^2;  //m^2
 8  L=0.6;  //m
 9  W2=p*A*L;  //kJ
10  Wnet=(-W1)+W2;
11  disp("The net work transfer for the system=")
12  disp(Wnet)
13  disp("kJ")
```

Scilab code Exa 2.18 18

```
 1  clc
 2  A=45*10^(-4);  //m^2
 3  P=0.9*10^5;  //N/m^2
 4  Patm=1.013*10^5;  //N/m^2
 5  L=0.05;  //m
 6  dV=300*10^(-6);  //m^3
 7  W=P*A*L-Patm*dV;
 8  disp("net work done =")
 9  disp(W)
10  disp("J")
```

Scilab code Exa 2.19 19

```
 1  clc
 2  p1=1.5;  //bar
 3  p2=7.5;  //bar
 4  V1=3/p1;
 5  V2=3/p2;
 6  W=integrate('3/V*10^2', 'V', V1, V2);
 7  disp("Work done=")
 8  disp(W)
 9  disp("kJ")
```

Scilab code Exa 2.20 20

```scilab
1  clc
2  W=150; //kJ
3  V1=0.6; //m^3
4
5  // p=8-4*V
6  // W=integration of p*dV from V1 to V2
7  // Solving above equation we get
8
9  V2=0.354; //m^3
10 disp("Final volume =")
11 disp(V2)
12 disp("m^3")
13
14 p2=8-4*V2;
15 disp("Final pressure =")
16 disp(p2)
17 disp("bar")
```

Scilab code Exa 2.21 21

```scilab
1  clc
2  p1=3*10^5; //Pa
3  v1=0.18; //m^3/kg
4  C=p1*v1^2;
5  p2=0.6*10^5; //Pa
6  v2=sqrt(C/p2);
7  W=integrate('C/v^2', 'v', v1,v2);
8  disp("Work done=")
9  disp(W)
10 disp("Nm/kg")
```

Scilab code Exa 2.22 22

```
1  clc
2  m=1; //kg
3  p1=20*10^5; //Pa
4  V1=0.05; //m^3
5  V2=2*V1;
6  p2=p1*(V1/V2)^2;
7  C=p1*V1^2;
8  V3=V1;
9  W_12=integrate('C/V^2', 'V', V1,V2);
10
11 W_23=p2*(V2-V3);
12
13 W_net=W_12-W_23;
14 disp("Net work done = ")
15 disp(W_net)
16 disp("Nm")
```

Chapter 3

Properties Of Pure Substances

Scilab code Exa 3.1 1

```
1 clc
2 m_s=50;  //kg
3 m_w=1.5;  //kg
4 x=m_s/(m_s+m_w);
5 disp("dryness fraction=")
6 disp(x)
```

Scilab code Exa 3.2 2

```
1 clc
2 V=0.6;  //m^3
3 m=3.0;  //kg
4 p=5;  //bar
5 v=V/m;
6 // At 5 bar: From steam tables
7 v_g=0.375;  //m^3/kg
8 v_f=0.00109;  //m^3/kg
9 v_fg=v_g - v_f;
```

```
10  x=1-((v_g - v)/v_fg);
11
12  disp(")(i) Mass and volume of liquid")
13  m_liq=m*(1-x);
14  disp("mass of liquid=")
15  disp(m_liq)
16  disp("kg")
17  V_liq=m_liq*v_f;
18  disp("volume of liquid=")
19  disp(V_liq)
20  disp("m^3")
21
22  disp("(ii) Mass and volume of vapour")
23  m_vap=m*x;
24  disp("mass of vapour=")
25  disp(m_vap)
26  disp("kg")
27  V_vap=m_vap*v_g;
28  disp("volume of vapour=")
29  disp(V_vap)
30  disp("m^3")
```

Scilab code Exa 3.3 3

```
1   clc
2   V=0.05; //m^3
3   m_f=10; //kg
4   // From steam tables corresponding to 245 0C
5   p_sat=36.5; //bar
6   v_f=0.001239; //m^3/kg
7   v_g=0.0546; //m^3/kg
8   h_f=1061.4; //kJ/kg
9   h_fg=1740.2; //kJ/kg
10  s_f=2.7474; //kJ/kg.K
11  s_fg=3.3585; //kJ/kg.K
```

```
12
13  disp("(i) The pressure=")
14  disp(p_sat)
15  disp("bar")
16
17  disp("(ii) The mass")
18  V_f=m_f*v_f;
19  V_g=V - V_f;
20  m_g=V_g/v_g;
21  m=m_f+m_g;
22  disp("The total mass of mixture=")
23  disp(m)
24  disp("kg")
25
26  disp("(iii) The specific volume")
27  v_fg=v_g-v_f;
28  x= m_g/(m_g+ m_f);
29  v=v_f+x*v_fg;
30  disp("specific volume=")
31  disp(v)
32  disp("m^3/kg")
33
34  disp("(iv)The specific enthalpy")
35  h=h_f+x*h_fg;
36  disp("specific enthalpy=")
37  disp(h)
38  disp("kJ/kg")
39
40  disp("(v)The specific entropy")
41  s=s_f+x*s_fg;
42  disp("specific entropy =")
43  disp(s)
44  disp("kJ/kg.K")
45
46  disp("(vi)The specific internal enegy")
47  u=h-(p_sat*v*10^2);  //kJ/kg
48  disp("specific internal energy=")
49  disp(u)
```

```
50  disp("kJ/kg")
```

Scilab code Exa 3.4 4

```
1  clc
2  m_w=2;  //kg
3  t_w=25;  //0C
4  p=5;  //bar
5  x=0.9;
6  c_pw=4.18;
7  // at 5 bar; from steam tables
8  h_f=640.1;  //kJ/kg
9  h_fg=2107.4;  //kJ/kg
10  h=h_f+x*h_fg;
11  disp("Sensible heat associated with 1kg of water, Qw
       =")
12  Qw=c_pw*(t_w-0);
13  disp(Qw)
14  disp("kJ")
15  disp("Net quantity of heat to be supplies per kg of
       water, Q=")
16  Q=h-Qw;
17  disp(Q)
18  disp("kJ")
19
20  disp("Total amount of heat supplied, Q_total=")
21  Q_total=m_w*Q;
22  disp(Q_total)
23  disp("kJ")
```

Scilab code Exa 3.5 5

```
1  clc
```

```
 2  m =4.4;  // kg
 3  p=6;  // bar
 4  t_sup =250;  //0C
 5  t_w= 30;  //0C
 6  c_ps =2.2;  // kJ/kg
 7  c_pw =4.18;
 8  // At 6 bar , 250 0C; From steam tables
 9  t_s =158.8;  //0C
10  h_f =670.4;  // kJ/kg
11  h_fg =2085;  // kJ/kg
12  h_sup=h_f+h_fg+ c_ps *( t_sup -t_s );
13
14  disp ("Amount of heat added per kg of water , Qw=")
15  Qw=c_pw *( t_w -0);
16  disp (Qw)
17
18  disp ("Net amount of heat required to be supplied per
        kg , Q=")
19  Q=h_sup -Qw ;
20  disp (Q)
21
22  disp ("Total amount of heat required , Q_total=")
23  Q_total=m*Q;
24  disp ( Q_total)
25  disp ("kJ")
```

Scilab code Exa 3.6 6

```
1  clc
2  v =0.15;  //m^3
3  p=4;  // bar
4  x =0.8;
5  // At 4 bar : From steam tables
6  v_g =0.462;  //m^3/kg
7  h_f= 604.7;  // kJ/kg
```

32

```
 8  h_fg =2133; //kJ/kg
 9  density =1/x/v_g;
10  disp(" mass of 0.15 m^3 steam , m=")
11  m=v*density;
12  disp(m)
13  disp("kg")
14
15  disp(" Total heat of 1 m3 of steam which has a mass
        of 2.7056 kg, Q=")
16  Q=density*(h_f+x*h_fg);
17  disp(Q)
18  disp("kJ")
```

Scilab code Exa 3.7 7

```
 1  clc
 2  m=1000; //kJ/kg.K
 3  p=16; //bar
 4  x=0.9;
 5  T_sup =653; //K
 6  T_w=30; //0C
 7  c_ps=2.2; //kJ/kg
 8  c_pw=4.18;
 9  // At 16 bar:From steam tables
10  T_s=474.4; //K
11  h_f=858.6; //kJ/kg
12  h_fg=1933.2; //kJ/kg
13
14  disp("(i) Heat supplied to feed water per hour to
        produce wet steam is given by")
15  H=m*[(h_f+x*h_fg)-c_pw*(T_w-0)];
16  disp(H)
17  disp("kJ")
18
19  disp("(ii) Heat absorbed by superheater per hour, Q=
```

```
    ")
20 Q=m*[(1-x)*h_fg+c_ps*(T_sup-T_s)];
21 disp(Q)
22 disp("kJ")
```

Scilab code Exa 3.8 8

```
1 clc
2
3 disp("(i) at 0.75 bar, between 100 C and 150 C")
4 // At 100   C
5 T1=100; // C
6 h_sup1=2679.4; //kJ/kg
7 // At 150   C
8 T2=150; // C
9 h_sup2=2778.2; //kJ/kg
10
11 c_ps=(h_sup2-h_sup1)/(T2-T1);
12 disp("mean specific heat=")
13 disp(c_ps)
14
15 disp("(ii) at 0.5 bar, between 300 C and 400 C")
16 T1=300; // C
17 h_sup1=3075.5; //kJ/kg
18 T2=400; // C
19 h_sup2=3278.9; //kJ/kg
20
21 c_ps=(h_sup2-h_sup1)/(T2-T1);
22 disp("mean specific heat c_ps=")
23 disp(c_ps)
```

Scilab code Exa 3.9 9

```
 1  clc
 2  m=1.5; //kg
 3  p=5; //bar
 4  x1=1;
 5  x2=0.6;
 6  p1=5*10^5; //N/m
 7  // At 5 bar: From steam tables
 8  t_s=151.8; //0C
 9  h_f=640.1; //kJ/kg
10  h_fg=2107.4; //kJ/kg
11  v_g=0.375; //m^3/kg
12  v_g1=0.375*10^(-3);
13  h1=h_f+h_fg;
14  V=m*v_g;
15  u1=h1-p1*v_g1;
16  v_g2=V/m/x2; //m^3/kg
17
18  // From steam table corresponding to 0.625 m^3/kg
19  p2=2.9; //bar
20  disp("Pressure at new state =")
21  disp(p2)
22  disp("bar")
23
24  t_s=132.4; //0C
25  disp("Temperature at new state =")
26  disp(t_s)
27  disp(" C ")
28  h_f2=556.5; //kJ/kg
29  h_fg2=2166.6; //kJ/kg
30  u2=(h_f2+x2*h_fg2)-p2*x2*v_g2*10^2;
31
32  Q=u2-u1; //heat transferred at constant volume per
         kg
33
34  disp("Total heat transfered,Q_total=")
35  Q_total=m*Q;
36  disp(Q_total)
37  disp("kJ")
```

Scilab code Exa 3.10 10

```scilab
1  clc
2  V=0.9; //m^3
3  p1=8; //bar
4  x1=0.9;
5  p2=4; //bar
6  p3=3; //bar
7  v_g1=0.24; //m^3/kg
8
9  disp("(i) The mass of steam blown off :")
10 m1=V/x1/v_g1;
11 h_f1=720.9; //kJ/kg
12 h_fg1=2046.5; //kJ/kg
13 h_f2=604.7; //kJ/kg
14 h_fg2=2133; //kJ/kg
15 v_g2=0.462; //m^3/kg
16
17 h1=h_f1+x1*h_fg1; //The enthalpy of steam before
        blowing off
18
19 h2=h1;
20 x2=(h1-h_f2)/h_fg2;
21 m2=x1/(x2*v_g2);
22
23 disp("Mass of steam blown off =")
24 m=m1-m2;
25 disp(m)
26 disp("kg")
27
28 disp("(ii) Dryness fraction of steam in the vessel
        after cooling")
29 v_g3=0.606; //m^3/kg
30 x3=x2*v_g2/v_g3;
```

```
31  disp("dryness  fraction  =")
32  disp(x3)
33
34
35  disp("(iii) Heat  lost  during  cooling")
36  h_f3=561.4;  //kJ/kg
37  h_fg3=2163.2;  //kJ/kg
38  h3=h_f3+x3*h_fg3;
39  u2=h2-p2*x2*v_g2*10^2;  //kJ/kg
40  u3=h3-p3*x3*v_g3*10^2;  //kJ/kg
41  Q=m*(u3-u2);
42  disp("Heat  lost  during  cooling=")
43  disp(-Q)
44  disp("kJ")
```

Scilab code Exa 3.11 11

```
 1  clc
 2  p=8*10^5;  //Pa
 3  x=0.8;
 4
 5  v_g=0.240;  //m^3/kg
 6  h_fg=2046.5;  //kJ/kg
 7
 8  disp("(i) External  work  done  during  evaporation")
 9  W=p*x*v_g/10^3;  //kJ
10  disp("W=")
11  disp(W)
12  disp("kJ")
13
14  disp("(ii) Internal  latent  heat")
15  Q=x*h_fg-W;
16  disp("Q=")
17  disp(Q)
18  disp("kJ")
```

Scilab code Exa 3.12 12

```
1  clc
2  p1=10;  //bar
3  p2=10;  //bar
4  x1=0.85;
5  V1=0.15;  //m^3
6  t_sup2=300;  //0C
7  t_sup1=179.9;  //0C
8  c_ps=2.2;  //kJ/kg.K
9  v_g1=0.194;  //m^3/kg
10 m=V1/(x1*v_g1);
11 h_fg1=2013.6;  //kJ/kg
12 Q=(1-x1)*h_fg1+c_ps*(t_sup2-t_sup1);
13 Q_total=m*Q;
14
15 disp("Total heat supplied=")
16 disp(Q_total)
17 disp("kJ")
18
19 v_sup2=v_g1*(t_sup2+273)/(t_sup1+273)
20 W=p1*(v_sup2 - (x1*v_g1))*10^2;
21 Percentage=W/Q*100;
22
23 disp("Percentage of total heat supplied=")
24 disp(Percentage)
25 disp("%")
```

Scilab code Exa 3.13 13

```
1  clc
```

```scilab
2  p=18;  //bar
3  x=0.85;
4  h_f=884.6;  //kJ/kg
5  h_fg=1910.3;  //kJ/kg
6  v_g=0.110;  //m^3/kg
7  u_f=883;  //kJ/kg
8  u_g=2598;  //kJ/kg
9  v=x*v_g;
10 disp("Specific volume of wet steam=")
11 disp(v)
12 disp("m^3/kg")
13
14 h=h_f+x*h_fg;
15 disp("Specific enthalpy of wet steam=")
16 disp(h)
17 disp("kJ/kg")
18 u=(1-x)*u_f+ x*u_g;
19 disp("Specific internal energy of wet steam =")
20 disp(u)
21 disp("kJ/kg")
```

Scilab code Exa 3.14 14

```scilab
1  clc
2  p=7;  //bar
3  h=2550;  //kJ/kg
4  h_f=697.1;  //kJ/kg
5  h_fg=2064.9;  //kJ/kg
6  v_g=0.273;  //m^3/kg
7  u_f=696;  //kJ/kg
8  u_g=2573;  //kJ/kg
9  x=(h-h_f)/h_fg;
10 disp("(i) Dryness fraction=")
11 disp(x)
12
```

```
13  v=x*v_g;
14  disp("(ii) Specific volume of wet steam =")
15  disp(v)
16  disp("m^3/kg")
17
18  u=(1-x)*u_f+ x*u_g;
19  disp("(iii) Specific internal energy of wet steam=")
20  disp(u)
21  disp("kJ/kg")
```

Scilab code Exa 3.15 15

```
1   clc
2   p=120;  //bar
3   v=0.01721;  //m^3/kg
4
5   T=350;  // C
6   disp("Temperature=")
7   disp(T)
8   disp(" C ")
9
10  h=2847.7;  //kJ/kg
11  disp("specific enthalpy=")
12  disp(h)
13  disp("kJ/kg")
14
15  u=h-p*v*10^2;  //kJ/kg
16  disp("Internal energy=")
17  disp(u)
18  disp("kJ/kg")
```

Scilab code Exa 3.16 16

```
1  clc
2  p=140; //bar
3  h=3001.9; //kJ/kg
4
5  T=400; //0C
6  disp("Temperature=")
7  disp(T)
8  disp(" C ")
9
10 v=0.01722; //m^3/kg
11 disp("The specific volume")
12 disp(v)
13 disp("m^3/kg")
14
15 u=h-p*v*10^2;
16 disp("specific internal energy=")
17 disp(u)
18 disp("kJ/kg")
```

Scilab code Exa 3.17 17

```
1  clc
2  // At 10 bar: From steam table for superheated steam
3  h_sup=3051.2; //kJ/kg
4  T_sup=573; //K
5  T_s=452.9; //K
6  v_g=0.194; //m^3/kg
7  v_sup=v_g*T_sup/T_s;
8  p=10; //bar
9
10 u1=h_sup-p*v_sup*10^2; //kJ/kg
11 disp("Internal energy of superheated steam at 10 bar
     = ")
12 disp(u1)
13 disp("kJ/kg")
```

```
14
15  // At 1.4 bar: From steam tables
16  p=1.4; //bar
17  h_f=458.4; //kJ/kg
18  h_fg=2231.9; //kJ/kg
19  v_g=1.236; //m^3/kg
20  x=0.8;
21  h=h_f+x*h_fg;
22  u2=h-p*x*v_g*10^2; //kJ
23  du=u2-u1;
24  disp("Change in internal energy=")
25  disp(du)
26  disp("kJ")
```

Scilab code Exa 3.18 18

```
1  clc
2  m=1; //kg
3  p=20; //bar
4  T_sup=400; //0C
5  x=0.9;
6  c_ps=2.3; //kJ/kg.K
7
8  disp("(i) Internal energy of 1 kg of superheated
       steam")
9  // At 20 bar: From steam tables
10 T_s=212.4; //0C
11 h_f=908.6; //kJ/kg
12 h_fg=1888.6; //kJ/kg
13 v_g=0.0995; //m^3/kg
14 h_sup = h_f+h_fg+c_ps*(T_sup-T_s);
15 v_sup=v_g*(T_sup+273)/(T_s+273);
16 u=h_sup-p*v_sup*10^2;
17 disp("Internal energy=")
18 disp(u)
```

```
19  disp("kJ/kg")
20
21  disp("(ii) Internal energy of 1 kg of wet steam")
22  h=h_f+x*h_fg;
23  u=h-p*x*v_g*10^2;
24  disp("Internal energy=")
25  disp(u)
26  disp("kJ/kg")
```

Scilab code Exa 3.19 19

```
1   clc
2   h_g1=2797.2;  //kJ/kg
3   c_ps= 2.25;
4   T_sup=350;  //0C
5   T_s=212.4;  //0C
6   h1=h_g1+c_ps*(T_sup-T_s);
7   h_f2=908.6;  //kJ/kg
8   h_fg2=1888.6;  //kJ/kg
9
10  // Main:20 bar, 250 0C
11  T_sup=250;  //0C
12  Q=2*[h_g1+c_ps*(T_sup-T_s)];
13  x2=(Q-h1-h_f2)/h_fg2;
14  disp("Quality of steam")
15  disp(x2)
```

Scilab code Exa 3.20 20

```
1   clc
2   m=1;  //kg
3   p=6;  //bar
4   x=0.8;
```

```
 5  T_s=473; //K
 6  h_fg=2085; //kJ/kg
 7  c_pw=4.18;
 8  s_wet=c_pw*log(T_s/273)+x*h_fg/T_s;
 9  disp("Entropy of wet steam=")
10  disp(s_wet)
11  disp("kJ/kg.K")
```

Scilab code Exa 3.21 21

```
 1  clc
 2  p1=10; //bar
 3  t_sup=400; //0C
 4  p2=0.2; //bar
 5  x2=0.9;
 6  h_sup=3263.9; //kJ/kg
 7  s_sup=7.465; //kJ/kg
 8  h1=3263.9; //kJ/kg
 9  s1=s_sup;
10  h_f2=251.5; //kJ/kg
11  h_fg2=2358.4; //kJ/kg
12  s_f2=0.8321; //kJ/kg.K
13  s_g2=7.9094; //kJ/kg.K
14  s_fg2=s_g2-s_f2;
15  h2=h_f2+x2*h_fg2;
16  s2=s_f2+x2*s_fg2;
17
18  disp("(i) Drop in enthalpy")
19  dh=h1-h2;
20  disp("Drop in enthalpy = ")
21  disp(dh)
22  disp("kJ/kg")
23
24
25  disp("(ii) Change in entropy")
```

```
26  ds=s1-s2;
27  disp("Change in entropy = ")
28  disp(ds)
29  disp("kJ/kg.K")
```

Scilab code Exa 3.22 22

```
1   clc
2   m=1;  //kg
3   p=12;  //bar
4   T_sup=523;  //K
5   c_ps=2.1;  //kJ/kg.K
6   T_s=461;  //K
7   h_fg=1984.3;  //kJ/kg
8   c_pw=4.18;
9   s_sup=c_pw*log(T_s/273)+h_fg/T_s+c_ps*log(T_sup/T_s)
       ;
10  disp("Entropy =")
11  disp(s_sup)
12  disp("kJ/kg.K")
```

Scilab code Exa 3.23 23

```
1   clc
2   m=3;  //kg
3   v1=0.75;  //m^3/kg
4   v2=1.2363;  //m^3/kg
5   x=v1/v2;
6   h_f=458.4;  //kJ/kg
7   h_fg=2231.9;  //kJ/kg
8   h_s=m*[h_f+x*h_fg];  //kJ
9   v_sup=1.55;  //m^3/kg
10  p=2;  //bar
```

```
11  t_s=120.2;  //0C
12  t_sup=400;  //0C
13  h=3276.6;  //kJ/kg
14  U=1708;  //kJ/kg
15  Degree=t_sup-t_s;
16  h_sup=m*h;
17
18  Q_added=h_sup - h_s;
19  disp("Heat added =")
20  disp(Q_added)
21  disp("kJ")
22
23  U_s=m*U;
24  U_sup=m*(h-p*v_sup*10^2);
25  dU= U_sup - U_s;
26  W=Q_added - dU;
27  disp("work done = ")
28  disp(W)
29  disp("kJ")
```

Scilab code Exa 3.24 24

```
 1  clc
 2  p=5;  //bar
 3  m=50;  //kg
 4  T1=20;  //0C
 5  m_s=3;  //kg
 6  T2=40;  //0C
 7  m_eq=1.5;  //kg
 8  h_f=640.1;  //kJ/kg
 9  h_fg=2107.4;  //kJ/kg
10  c_pw=4.18;
11  m_w=m+m_eq;
12  x=[(m_w*c_pw*(T2-T1))/m_s + c_pw*T2 - h_f]/h_fg;
13  disp("Dryness fraction of steam")
```

```
14  disp(x)
```

Scilab code Exa 3.25 25

```
1   clc
2   p=1.1;  //bar
3   x=0.95;
4   c_pw=4.18;
5   m1=90;  //kg
6   m2=5.25;  //kg
7   T1=25;  //0C
8   T2=40;  //0C
9   m=m1+m2;
10  h_f=428.8;  //kJ/kg
11  h_fg= 2250.8;  //kJ/kg
12  m_s= [m*c_pw*(T2-T1)]/[(h_f + x*h_fg) - c_pw*T2];
13  disp("Mass of steam condensed=")
14  disp(m_s)
15  disp("kg")
```

Scilab code Exa 3.26 26

```
1   clc
2   p1=8;  //bar
3   p2=1;  //bar
4   T_sup2=115;  //0C
5   T_s2=99.6;  //0C
6   h_f1=720.9;  //kJ/kg
7   h_fg1=2046.5;  //kJ/kg
8   h_f2=417.5;  //kJ/kg
9   h_fg2=2257.9;  //kJ/kg
10  c_ps=2.1;
11  x1=[h_f2+h_fg2+c_ps*(T_sup2-T_s2)-h_f1]/h_fg1;
```

```
12 disp("Dryness  fraction  of  the  steam  in  the  main  =  ")
13 disp(x1)
```

Scilab code Exa 3.27 27

```
1  clc
2  m_w=2;  //kg
3  m_s=20.5;  //kg
4  t_sup=110;  //0C
5  p1=12;  //bar
6  p3=1;  //bar
7  p2=p1;
8  h_f2=798.4;  //kJ/kg
9  h_fg2=1984.3;  //kJ/kg
10 T_s=99.6;  //0C
11 h_f3=417.5;  //kJ/kg
12 h_fg3=2257.9;  //kJ/kg
13 T_sup=110;  //0C
14 c_ps=2;  //kJ/kg.K
15 x2=[h_f3+h_fg3 + c_ps*(T_sup-T_s) - h_f2]/h_fg2;
16 x1=x2*m_s/(m_w+m_s);
17 disp("Quality  of  steam  supplied  =  ")
18 disp(x1)
```

Scilab code Exa 3.28 28

```
1  clc
2  p1=15;  //bar
3  p2=p1;
4  p3=1;  //bar
5  t_sup3=150;  //0C
6  m_w=0.5;  //kg/min
7  m_s=10;  //kg/min
```

```
 8  h_f2 =844.7;  //kJ/kg
 9  h_fg2 =1945.2;  //kJ/kg
10  h_sup3 =2776.4;  //kJ/kg
11  x2 =( h_sup3 - h_f2 )/ h_fg2 ;
12  x1 =x2*m_s /( m_s + m_w );
13  disp (" Quality  of  steam  supplied  = ")
14  disp (x1)
```

Chapter 4

First Law of Thermodynamics

Scilab code Exa 4.1 1

```
1 clc
2 Q=-50; //kJ/kg
3 W=-100; //kJ/kg
4 dU=Q-W;
5 disp("gain in internal energy = ")
6 disp(dU)
7 disp("kJ/kg")
```

Scilab code Exa 4.2 2

```
1 clc
2 u1=450; //kJ/kg
3 u2=220; //kJ/kg
4 W=120; //kJ/kg
5 Q=(u2-u1) + W;
6 disp("Heat rejected by air =")
7 disp(-Q)
8 disp("kJ/kg")
```

Scilab code Exa 4.3 3

```
1  clc
2  m=0.3;  //kg
3  cv=0.75;  //kJ/kg.K
4  T1=313;  //K
5  T2=433;  //K
6  W=-30;  //kJ
7  dU=m*cv*(T2-T1);
8  Q=dU + W;
9  disp("Heat rejected during the process=")
10 disp(-Q)
11 disp("kJ")
```

Scilab code Exa 4.4 4

```
1  clc
2  p1=105;  //kPa
3  V1=0.4;   //m^3
4  p2=p1;
5  V2=0.20;  //m^3
6  Q=-42.5;  //kJ
7  W=p1*(V2-V1);
8  dU=Q-W;
9  disp("change in internal energy = ")
10 disp(dU)
11 disp("kJ")
```

Scilab code Exa 4.6 6

```
 1  clc
 2  p=1.1;  //bar
 3  x=0.95;
 4  c_pw=4.18;
 5  m1=90;  //kg
 6  m2=5.25;  //kg
 7  T1=25;  //0C
 8  T2=40;  //0C
 9  m=m1+m2;
10  h_f=428.8;  //kJ/kg
11  h_fg= 2250.8;  //kJ/kg
12  m_s= [m*c_pw*(T2-T1)]/[(h_f + x*h_fg) - c_pw*T2];
13  disp("Mass of steam condensed=")
14  disp(m_s)
15  disp("kg")
```

Scilab code Exa 4.7 7

```
 1  clc
 2  W_12=-82;  //kJ
 3  Q_12=-45;  //kJ
 4  dU_12=Q_12 - W_12;
 5  W_21=100;  //kJ
 6  dU_21=-dU_12;
 7  Q_21=dU_21 + W_21;
 8  disp("Heat added to the system = ")
 9  disp(Q_21)
10  disp("kJ")
```

Scilab code Exa 4.8 8

```
 1  clc
 2  Q2=9000;  //kJ
```

```
 3  Q1=3000;  //kJ
 4  Q=Q1-Q2;
 5  W=0;
 6  dU=W-Q;
 7  disp("Work done = ")
 8  disp(W)
 9
10  disp("Change in internal energy = ")
11  disp(dU)
12  disp("kJ")
```

Scilab code Exa 4.9 9

```
 1  m=20;  //kg
 2  g=9.81;  //m/s^2
 3  z2=0;
 4  z1=15;
 5
 6  disp("(i) When the stone is about to enter the water
        ")
 7  Q=0
 8  W=0
 9  dU=0
10  PE=m*g*(z2-z1)
11  KE=-PE
12
13  disp("(ii) When the stone dips into the tank and
        comes to rest")
14  Q=0
15  W=0
16  KE=0
17  PE=m*g*(z2-z1)
18  dU=-PE
19
20  disp("(iii) When the water and stone come to their
```

```
      initial  temperature")
21  W=0
22  KE=0
23  Q=-dU
```

Scilab code Exa 4.10 10

```
 1  clc
 2  Q_lqm=168;  //kJ
 3  W_lqm=64;  //kJ
 4  dU_lm=Q_lqm - W_lqm;
 5  W_lnm=21;  //kJ
 6  W_ml=-42;  //kJ
 7
 8  Q_lnm=dU_lm + W_lnm;
 9  disp(" (i) Q_lnm=")
10  disp(Q_lnm)
11  disp("kJ")
12
13
14  Q_ml=W_ml - dU_lm;
15  disp(" (ii) Q_ml = ")
16  disp(Q_ml)
17  disp("kJ")
18
19
20  W_ln=21;  //kJ
21  dU_ln=84;  //kJ
22  Q_ln=dU_ln + W_ln;
23  Q_nm=Q_lnm-Q_ln;
24  disp("Q_nm = ")
25  disp(Q_nm)
26  disp("kJ")
```

Scilab code Exa 4.11 11

```
1  clc
2  T1=55; //0C
3  T2=95; //0C
4  W=integrate('200', 'T', T1, T2);
5  Q=integrate('160', 'T', T1, T2);
6  dU=Q-W;
7  disp("change in internal energy=")
8  disp(dU/10^3)
9  disp("kJ")
```

Scilab code Exa 4.12 12

```
1  clc
2  Q=-340; //kJ
3  n=200; //cycles/min
4
5  //For Process 1-2
6
7  W_12=4340; //kJ/min
8  Q_12=0;
9
10 dE_12=Q_12-W_12;
11 disp("dE_12 =")
12 disp(dE_12)
13 disp("kJ/min")
14
15 //For process 2-3
16
17 Q_23=42000; //kJ/min
18 W_23=0;
```

```
19
20  dE_23=Q_23-W_23;
21  disp("dE_23 =")
22  disp(dE_23)
23  disp("kJ/min")
24
25  //For process 3-4
26
27  Q_34=-4200;  //kJ/min
28  dE_34=-73200;  //kJ/min
29
30  W_34=Q_34-dE_34;
31  disp("W_34 =")
32  disp(W_34)
33  disp("kJ/min")
34
35  //For process 4-1
36  Q_41=Q*n-Q_12-Q_23-Q_34;
37  disp("Q_41 =")
38  disp(Q_41)
39  disp("kJ/min")
40
41  dE_41=0-dE_12-dE_23-dE_34;
42  disp("dE_41 =")
43  disp(dE_41)
44  disp("kJ/min")
45
46  W_41=Q_41-dE_41;
47  disp("W_41 =")
48  disp(W_41)
49  disp("kJ/min")
```

Scilab code Exa 4.13 13

```
1  clc
```

```
2 P=1200; //kW
3 Qin=3360; //kJ/kg
4 Qout=2520; //kJ/kg
5 F=6; //kW
6 dQ=Qin - Qout;
7 dW=P-F; //kJ/s
8 m = dW/dQ;
9 disp("Steam flow round the cycle")
10 disp(m)
11 disp("kg/s")
```

Scilab code Exa 4.14 14

```
1 clc
2 dT=25; //0C
3 Q=30; //kJ
4 cv=1.2; //kJ/kg.0C
5 m=2.5; //kg
6 dU=m*cv*dT;
7
8
9 disp("change in internal energy = ")
10 disp(dU)
11 disp("kJ")
12
13 W=Q - dU;
14 disp("Work done = ")
15 disp(W)
16 disp("kJ")
```

Scilab code Exa 4.15 15

```
1 clc
```

```
2  Q=50;  //kJ
3  dV=0.14;  //m^3
4  p=1.2*10^5;  //N/m^2
5  m=90;  //kg
6  d=5.5;  //m
7  g=9.8;  //m/s^2
8  W_adb = -110;  //kJ
9  Wnet=m*g*d/1000;  //kJ
10
11
12  disp(" (i)Change  in  internal  energy")
13  W=p*dV/1000 + Wnet;  //kJ
14  dE=Q-W;
15  disp("dE=")
16  disp(dE)
17  disp("kJ")
18
19  disp(" (ii)  Adiabatic  process")
20  Q=0;
21  dE=-W_adb;
22  disp("dE=")
23  disp(dE)
24  disp("kJ")
25
26  disp(" (iii)Change  in  internal  energy")
27  Q=50;  //kJ
28  dE=Q - [W_adb+W];
29  disp("dE=")
30  disp(dE)
31  disp("kJ")
```

Scilab code Exa 4.16 16

```
1  clc
2  V1=0.15;  //m^3
```

```
 3  V2=0.05;  //mˆ3
 4  Q=-45;  //kJ
 5  p1=(5/V1+1.5)*10^5;  //N/mˆ2
 6  p2=(5/V2+1.5)*10^5;  //N/mˆ2
 7  W=integrate('(5/V+1.5)*10^2', 'V', V1, V2);
 8
 9
10  disp("(i)Change in internal energy = ")
11  dU=Q-W;
12  disp("dU=")
13  disp(dU)
14  disp("kJ")
15
16
17  disp("(ii) Change in enthalpy")
18  dH=(dU*10^3+(p2*V2-p1*V1))/10^3;
19  disp("dH=")
20  disp(dH)
21  disp("kJ")
```

Scilab code Exa 4.17 17

```
 1  clc
 2  V1=0.25;  //mˆ3
 3  p1=500;  //kPa
 4  p2=100;  //kPa
 5  V2=V1*(p1/p2)^(1/1.25)
 6  n=1.25
 7  dU=3.64*(p2*V2 - p1*V1)
 8
 9
10  disp("(i) If the expansion is quasi-static")
11  W=(p1*V1-p2*V2)/(n-1);
12  Q=dU+W
13  disp("Heat transfered=")
```

```
14  disp(Q)
15  disp("kJ")
16
17
18  disp("(ii) In another process")
19  Q=32; //kJ
20  W=Q-dU;
21  disp("Work done=")
22  disp(W)
23  disp("kJ")
24
25
26  disp("(iii)The difference")
27  disp("(iii) The work in (ii) is not equal to       p
       dV since the process is not quasi−static.")
```

Scilab code Exa 4.18 18

```
1  clc
2  v1=0.3; //m^3/kg
3  T1=20; //0C
4  v2=0.55; //m^3/kg
5  T2=260; //0C
6  p=1.6*10^5; //Pa
7
8  disp("(i)Heat added per kg = ")
9  Q=integrate('1.5 + 75/(T+45)', 'T', T1,T2);
10 disp("Q=")
11 disp(Q)
12 disp("kJ/kg")
13
14
15 disp("(ii)The work done per kg of fluid")
16 W=p*(v2-v1)/1000; //kJ/kg
17 disp("W=")
```

```
18  disp(W)
19  disp("kJ/kg")
20
21
22  disp("(iii)Change in internal energy")
23  dU=Q-W;
24  disp("dU=")
25  disp(dU)
26  disp("kJ/kg")
27
28
29  disp("(iv)Change in enthalpy")
30  dH=Q;
31  disp("dH=")
32  disp(dH)
33  disp("kJ/kg")
```

Scilab code Exa 4.19 19

```
1  clc
2  m=1;  //kg
3  du=-42000;  //J
4  cp=840;  //J/kg.0C
5  cv=600;  //J/kg.0C
6  dT=du/m/cv;
7  Q=m*cp*dT;
8  W=(Q-du)/10^3;
9  disp("Work done=")
10  disp(W)
11  disp("kJ")
```

Scilab code Exa 4.20 20

```
1  clc
2  p1=190; //kPa
3  V1=0.035; //m^3
4  p2=420; //kPa
5  V2=0.07; //m^3
6  dU=3.6*(p2*V2-p1*V1);
7  // p=a+b*v
8  // a+0.035*b=190
9  // a+0.07*b=420
10 // solving the two equations
11 p=[1,0.035;1,0.07];
12 q=[190;420];
13 X=inv(p)*q;
14 a=X(1,1);
15 b=X(2,1);
16 W=integrate('a+b*V', 'V', V1, V2);
17 disp("Work done by the system = ")
18 disp(W)
19 disp("kJ")
20
21
22 Q=dU+W;
23 disp("Heat transfer into the system = ")
24 disp(Q)
25 disp("kJ")
```

Scilab code Exa 4.21 21

```
1  clc
2  Qv=90; //kJ
3  Qp=-95; //kJ
4  W=-18; //kJ
5  U_l=105; //kJ
6  W_lm=0;
7  Q_lm=90;
```

```
8   U_m=U_l+90;
9   dU_mn=Qp-W;
10  U_n=U_m+dU_mn;
11  dQ=Qv+Qp;
12  dW=dQ;
13  W_nl=dW-W;
14  disp("W_nl(in kJ)=")
15  disp(W_nl)
16  disp("U_l in kJ =")
17  disp(U_l)
18  disp("U_m in kJ =")
19  disp(U_m)
20  disp("U_n in kJ")
21  disp(U_n)
```

Scilab code Exa 4.23 23

```
1   clc
2   V1=0.2; //m^3
3   p1=4*10^5; //N/m^2
4   T1=403; //K
5   p2=1.02*10^5; //N/m^2
6   dH=72.5; //kJ
7   Q_23=dH;
8   cp=1; //kJ/kg
9   cv=0.714; //kJ/kg
10  y=1.4;
11  V2=V1*(p1/p2)^(1/y);
12  T2=T1*((p2/p1)^((y-1)/y));
13  R=(cp-cv)*1000; //J/kg.K
14  m=p1*V1/R/T1;
15  T3=Q_23/(m*cp) +T2;
16  V3=V2*T3/T2;
17  W_12=(p1*V1 - p2*V2)/(y-1);
18  W_23=p2*(V3-V2);
```

```
19  W_123=W_12+W_23;
20  disp("Total work done = ")
21  disp(W_123)
22  disp("J")
23
24
25  disp("(ii) Index of expansion, n")
26  p3=p2;
27  n=(p1*V1-p3*V3)/W_123 + 1;
28  disp("value of index = ")
29  disp(n)
```

Scilab code Exa 4.25 25

```
1  clc
2  d=0.15; //m
3  T=303; //K
4  p=3*10^5; //N/m^2
5  l=0.085; //m
6  Q=-4000; //J
7
8  disp("(i) Workdone by the system")
9  dv=%pi/4*d^2*l;
10 W=p*dv;
11 disp("W=")
12 disp(W/10^3)
13 disp("kJ")
14
15
16 disp("(ii) Decrease in internal energy of the system
    ")
17 dU=(Q-W)/10^3;
18 disp("Decrease in internal energy = ")
19 disp(-dU)
20 disp("kJ")
```

Scilab code Exa 4.27 27

```
1  clc
2  y=1.4
3  R=294.2;  //J/kg.0C
4  p1=1*10^5;  //N/m^2
5  T1=353;  //K
6  V1=0.45;  //m^3
7  V2=0.13;  //m^3
8  p2=5*10^5;  //N/m^2
9  cv=R/(y-1);
10
11 disp(" (i) The mass of gas")
12 m=p1*V1/R/T1;
13 disp("m=")
14 disp(m)
15 disp("kg")
16
17
18 disp(" (ii) The value of index   n    for
         compression")
19 n=log(p2/p1)/log(V1/V2);
20 disp("n=")
21 disp(n)
22
23
24 disp(" (iii) The increase in internal energy of the
         gas")
25 T2=T1*(V1/V2)^(n-1);
26 dU=m*cv*(T2-T1)/10^3;
27 disp("dU=")
28 disp(dU)
29 disp("kJ")
30
```

```
31
32 disp(" ( iv ) The heat received or rejected by the gas
      during compression .")
33 W=m*R*(T1-T2)/(n-1)/10^3;
34 Q=dU+W;
35 disp("Q=")
36 disp(Q)
37 disp("kJ")
```

Scilab code Exa 4.28 28

```
1 clc
2 p1=1.02*10^5;  //Pa
3 T1=295;  //K
4 V1=0.015;  //m^3
5 p2=6.8*10^5;  //Pa
6 y=1.4;
7
8
9 disp(" ( i ) Final temperature")
10 T2=T1*(p2/p1)^((y-1)/y);
11 t2=T2-273;
12 disp("t2=")
13 disp(t2)
14 disp("  C ")
15
16
17 disp(" ( ii ) Final volume :")
18 V2=V1*(p1/p2)^(1/y);
19 disp("V2=")
20 disp(V2)
21 disp("m^3")
22
23
24 disp(" ( iii )Work done")
```

```
25  R =287;
26  m = p1 * V1 / R / T1 ;
27  W = m * R * ( T1 - T2 ) / ( y -1) /10^3;
28  disp (" W=" )
29  disp ( W )
30  disp (" kJ" )
```

Scilab code Exa 4.29 29

```
1  clc
2  m =0.44;  // kg
3  T1 =453;  // K
4  ratio =3;  // ratio=V2/V1
5  T2 =288;  // K
6  W_12 =52.5;  // kJ
7  y = log ( T2 / T1 )/ log (1/ ratio ) + 1;
8  R = W_12 * ( y -1) / m / ( T1 - T2 );
9  // We have got two equations
10  // cp−cv=R
11  // cp−y*cv=0
12  M =[1 , -1;1 , - y ];
13  N =[ R ;0];
14  X = inv ( M ) * N ;
15  cp = X (1 ,1);
16  cv = X (2 ,1);
17  disp (" cp=" )
18  disp ( cp )
19  disp (" kJ / kg . K" )
20
21
22  disp (" cv=" )
23  disp ( cv )
24  disp (" kJ / kg . K" )
```

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Scilab code Exa 4.30 30

```
1  clc
2  n=1.3;
3  m=1;  //kg
4  p1=1.1;  //bar
5  T1=300;  //K
6  p2=6.6;  //bar
7  R0=8314;
8  M=30;
9  cp=1.75;  //kJ/kg.K
10 R=R0/M/1000;  //kJ/kg.K
11 cv=cp - R;
12 y=cp/cv;
13 T2=T1 *(p2/p1)^((n-1)/n);
14 W=R*(T1-T2)/(n-1);
15 Q=((y-n)/(y-1))*W;
16 disp("Heat  supplied  = ")
17 disp(Q)
18 disp("kJ/kg")
```

Scilab code Exa 4.31 31

```
1  clc
2  cp=14.3;  //kJ/kg.K
3  cv=10.2;  //kJ/kg.K
4  V1=0.1;  //m^3
5  T1=300;  //K
6  p1=1;  //bar
7  p2=8;  //bar
8  y=cp/cv;
9  R=cp-cv;
```

```
10  V2=V1*(p1/p2)^(1/y);
11  V3=V2;
12  T2=T1*(p2/p1)^((y-1)/y);
13  p3=p1*V1/V3;
14  T3=300;  //K
15
16
17  disp(" (i) Pressure at the end of constant volume
        cooling = ")
18  disp(p3)
19  disp("bar")
20
21
22  disp(" (ii) Change in internal energy during constant
        volume process")
23  m=p1*V1/R/T1*10^2;  //kg
24
25  dU_23=m*cv*(T3-T2);
26  disp("dU_23 = ")
27  disp(dU_23)
28  disp("kJ")
29
30
31  disp(" (iii) Net work done and heat transferred
        during the cycle")
32  W_12=m*R*(T1-T2)/(y-1);
33  W_23=0;
34  W_31=p3*V3*log(V1/V3)*10^2;  //kJ
35  disp("Net work done=")
36  Wnet=W_12+W_23+W_31;
37  disp(Wnet)
38  disp("kJ")
39  Qnet=Wnet;
40  disp("Heat transferred during the complete cycle = "
        )
41  disp(Qnet)
42  disp("kJ")
```

Scilab code Exa 4.32 32

```
1  clc
2  V1=0.15; //m^3
3  p1=15; //bar
4  T1=550; //K
5  T2=T1;
6  r=4; //r=V2/V1
7  V2=r*V1;
8  T3=290; //K
9  p2=p1*V1/V2;
10 W_12=p1*V1*log(V2/V1)*10^2; //kJ
11 V3=V2;
12 p3=p2*T3/T2;
13 W_23=0;
14 n=log(p1/p3)/log(V3/V1);
15 W_31=(p3*V3-p1*V1)/(n-1)*10^2; //kJ
16
17 disp("net work done = ")
18 Wnet=W_12+W_23+W_31
19 disp("kJ")
20
21 Qnet=Wnet;
22 disp("Heat transferred during the cycle = ")
23 disp(Qnet)
24 disp("kJ")
```

Scilab code Exa 4.33 33

```
1  clc
2  m=1; //kg
3  p1=5; //bar
```

```
 4  V1 =0.02;  // m^3
 5  V2 =0.08;  // m^3
 6  p2 =1.5;  // bar
 7
 8  function p=f(V)
 9      p=a+b*V;
10  endfunction
11
12  //  5=a+0.02*b
13  //  1.5=a+0.08*b
14  //  Solving  above  two  equations
15
16  A =[1 ,0.02;1 ,0.08];
17  B =[5;1.5];
18  X = inv(A)*B;
19  a=X(1 ,1);
20  b=X(2 ,1);
21
22  disp("(i) p-V diagram")
23
24  V =0.02:0.001:0.08;
25  p=a+b*V;
26  plot(V,p,'b')
27
28  V =[0.0667 0.08];
29  p =[1.5 1.5];
30  plot(V,p,'g')
31
32  V =0.02:0.001:0.0667;
33  function p=fa(V)
34      p =0.1/V;
35  endfunction
36
37  plot(V,fa,'r')
38
39  V =[0.0667 0.0667];
40  p =[1.5 0];
41  plot(V,p,'--')
```

```
42
43  xtitle("p-V diagram", "V(m^3)", "p(bar)");
44  legend("p=a+b*V","p=constant","pv=constant")
45
46
47  disp("(ii) Work done and heat transfer")
48
49  W_12=integrate('(a+b*V)*10^2','V',V1,V2);
50  disp("Work done by the system =")
51  disp(W_12)
52  disp("kJ")
53
54  p3=p2;
55  V3=p1*V1/p3;
56  W_23=p2*(V3-V2)*10^2;  //kJ
57
58  W_31=p3*V3*log(V1/V3)*10^2;  //kJ
59  disp("Work done on the system =")
60  disp(W_31)
61  disp("kJ")
62
63  W_net=W_12+W_23+W_31;
64  disp("Net work done =")
65  disp(W_net)
66  disp("kJ")
67
68  Q_net=W_net;
69  disp("Heat transferred during the complete cycle =")
70  disp(Q_net)
71  disp("kJ")
```

Scilab code Exa 4.34 34

```
1  clc
2  cv=0.71;  //kJ/kg.K
```

```
3  R=0.287;  //kJ/kg.K
4  d=8;  //cm
5  l=3.5;  //cm
6  S=150;  //N/cm
7  p1=30;  //N/cm
8  V1=45;  //cm^3
9  T1=293;  //K
10 cv=0.71;  //kJ/kg.K
11 R=0.287;  //kJ/kg.K
12 A=%pi/4*d^2;
13 C=p1-S/A^2*V1;
14 dV=l*A;
15 V2=V1+dV;
16 p2=S/A^2*V2 + C;
17 W=integrate('A^2/S*p/100', 'p', p1, p2);
18 T2=p2*V2*T1/p1/V1;
19 m=p1*V1/R/T1/10^5;  //kg
20 dU=m*cv*(T2-T1);
21 Q_12=dU + W*10^(-3);
22 disp("Amount of heat added to the system = ")
23 disp(Q_12)
24 disp("kJ")
```

Scilab code Exa 4.35 35

```
1  clc
2  r=10;  //kg/min
3  p1=1.5*10^5;  //N/m^2
4  rho1=26;  //kg/m^3
5  C1=110;  //m/s
6  u1=910;  //kJ/kg
7  p2=5.5*10^5;  //N/m^2
8  rho2=5.5;  //kg/m^3
9  C2=190;  //m/s
10 u2=710;  //kJ/kg
```

```
11  Q=55;  //kJ/s
12  h=55;  //m
13  g=9.81;  //m/s^2
14  v2=1/rho2;
15  v1=1/rho1;
16
17  disp(" (i) Change in enthalpy")
18  dh=u2-u1+ (p2*v2-p1*v1)/10^3;
19  disp(dh)
20  disp("kJ/kg")
21
22  disp(" (ii) Work done during the process (W).")
23
24  Q=330;  //kJ/kg
25  KE=(C2^2-C1^2)/2/10^3;  //kJ
26  PE=g*h/10^3;  //kJ
27  W=-Q-KE-PE-dh;
28  disp("Work done = ")
29  disp(W)
30  disp("kJ")
31
32
33  disp("Work done per second = ")
34  P=W*10/60;
35  disp(P)
36  disp("kW")
```

Scilab code Exa 4.36 36

```
1  clc
2  m=15;  //kg/s
3  v=0.45;  //m^3/kg
4  P=12000;  //kW
5  W=P/m;  //kJ/kg
6  h1=1260;  //kJ/kg
```

```
 7  h2 =400;  //kJ/kg
 8  C1 =50;  //m/s
 9  C2 =110;  //m/s
10
11  disp (" ( i )  Heat  rejected  =  ")
12  Q=h2 - h1 +( C2 ^2 - C1 ^2) /2/10^3 +W;
13  Qnet =m*Q;
14  disp (" Qnet =")
15  disp (-Qnet)
16  disp ("kW")
17
18  disp (" ( ii )  Inlet  area ")
19  A=v*m/C1 ;
20  disp ("A=")
21  disp (A)
22  disp ("m ^2")
```

Scilab code Exa 4.37 37

```
 1  clc
 2  m=0.5;  //kg/s
 3  C1 =6;  //m/s
 4  C2 =5;  //m/s
 5  p1 =1;  //bar
 6  p2 =7;  //bar
 7  v1 =0.85;  //m^3/kg
 8  v2 =0.16;  //m^3/kg
 9  du =90;  //kJ/kg
10  Q= -120;  //kJ/kg
11
12
13  disp (" ( i )  Power  required  to  drive  the  compressor ")
14  W= -du +( C1 ^2 - C2 ^2) /2/1000 + (p1*v1 - p2*v2) *10^2 + Q;
15  Power =m*W;
16  disp (" Power =")
```

```
17  disp(-Power)
18  disp("kW")
19
20
21  disp("(ii) Inlet and outlet pipe cross-sectional
        areas")
22  A1=m*v1/C1;
23  A2=m*v2/C2;
24  disp("Inlet crosssectional area = ")
25  disp(A1)
26  disp("m^2")
27
28  disp("Outlet crossectional area=")
29  disp(A2)
30  disp("m^2")
```

Scilab code Exa 4.38 38

```
1   clc
2   h1=800;  //kJ/kg
3   C1=5;  //m/s
4   h2=2520;  //kJ/kg
5   C2=50;  //m/s
6   dZ=4;  //m
7   g=9.81;  //m/s^2
8   Q=2180;  //kJ/kg
9   W=h1-h2+(C1^2 - C2^2)/2/1000 +dZ*g/1000+Q;
10  disp("Power developed = ")
11  disp(W)
12  disp("kW")
```

Scilab code Exa 4.39 39

```
1  clc
2  g=9.8;  //m/s^2
3  m=4500/3600;  //kg/s
4  C1=2800/60;  //m/s
5  Z1=5.5;  //m
6  h1=2800;  //kJ/g
7  C2=5600/60;  //m/s
8  Z2=1.5;  //m
9  h2=2300;  //kJ/kg
10 Q=-16000/3600;  //kJ/s
11 W=Q-m*[(h1-h2) + (C2^2 - C1^2)/2/1000 + (Z2-Z1)*g
      /1000];
12 disp("Power output of the turbine = ")
13 disp(-W)
14 disp("kW")
```

Scilab code Exa 4.40 40

```
1  clc
2  p1=6.87;  //bar
3  C1=50;  //m/s
4  p2=1.37;  //bar
5  C2=500;  //m/s
6  disp("From steam table corresponding to p1")
7  h1=2850;  //kJ/kg
8  h2=h1 - (C2^2-C1^2)/2/1000;
9  disp("Final enthalpy of steam = ")
10 disp(h2)
11 disp("kJ")
```

Scilab code Exa 4.41 41

```
1  clc
```

```
 2  m=220/60;  //kg/s
 3  C1=320;  //m/s
 4  p1=6*10^5;  //N/m^2
 5  u1=2000*10^3;  //J/kg
 6  v1=0.36;  //m^3/kg
 7  C2=140;  //m/s
 8  p2=1.2*10^5;  //N/m^2
 9  u2=1400*10^3;  //J/kg
10  v2=1.3;  //m^3/kg
11  Q=100*10^3;  //J/s
12  W=(m*[(u1-u2)+ (p1*v1 - p2*v2) + (C1^2-C2^2)/2] -Q)
       /10^6;
13  disp("power capacity of the system = ")
14  disp(W)
15  disp("MW")
```

Scilab code Exa 4.42 42

```
 1  clc
 2  p1=7.5*10^5;  //N/m^2
 3  C1=140;  //m/s
 4  h1=950*10^3;  //J/kg
 5  p2=2*10^5;  //N/m^2
 6  C2=280;  //m/s
 7  h2=650*10^3;  //J/kg
 8  m=5;  //kg/s
 9  W=(h1-h2)+(C1^2-C2^2)/2
10  Power=m*W/1000;
11  disp("Power capacity of turbine = ")
12  disp(Power)
13  disp("kW")
```

Scilab code Exa 4.43 43

```
1  clc
2  C1=12;  //m/s
3  p1=1*10^5;  //N/m^2
4  v1=0.5;  //m^3/kg
5  C2=90;  //m/s
6  p2=8*10^5;  //N/m^2
7  v2=0.14;  //m^3/kg
8  dh=150;  //kJ/kg
9  Q=-11.67;  //kJ/s
10  m=0.2;  //kg/s
11
12  disp("(i) Motor power required to drive the
        compressor")
13  W=m*[-dh + (C1^2-C2^2)/2/1000] +Q;
14  disp("Power=")
15  disp(-W)
16  disp("kW")
17
18
19  disp("(ii)Ratio of inlet to outlet pipi diameter")
20  ratio=sqrt(C2/C1*v1/v2);
21  disp("ratio=")
22  disp(ratio)
```

Scilab code Exa 4.44 44

```
1  clc
2  W=-175;  //kJ/kg
3  dh=70;  //kJ/kg
4  Q_water=-92;  //kJ/kg
5  Q=dh+W;
6  Q_atm=Q-Q_water;
7  disp("Heat transferred to the atmosphere = ")
8  disp(-Q_atm)
9  disp("kJ/kg")
```

Scilab code Exa 4.45 45

```
1  clc
2  h1=2800*10^3; //J/kg
3  C1=50; //m/s
4  A1=900*10^(-4); //m^2
5  v1=0.187; //m^3/kg
6  h2=2600*10^3; //J/kg
7  v2=0.498; //m^3/kJ
8  disp("(i) Velocity at exit of the nozzle")
9  C2=sqrt(2*[(h1-h2) + C1^2/2]);
10
11 disp("C2=")
12 disp(C2)
13 disp("m/s")
14
15
16 disp("(ii) Mass flow rate")
17 m=A1*C1/v1;
18 disp("m=")
19 disp(m)
20 disp("kg/s")
21
22
23 disp("(iii) Area at the exit")
24 A2=m*v2/C2*10^4;
25 disp("A2=")
26 disp(A2)
27 disp("cm^2")
```

Scilab code Exa 4.46 46

```
1  clc
2  h1 =240;  //kJ/kg
3  h2 =192;  //kJ/kg
4  dZ =20;  //m
5  g =9.81;  //m/s^2
6  Q=(h2-h1)+dZ*g/1000;
7
8  disp("heat transfer = ")
9  disp(-Q)
10 disp("kJ/kg")
```

Scilab code Exa 4.47 47

```
1  clc
2  p1 =2;  //bar
3  C1 =300;  //m/s
4  Q=0;
5  h1 =915*10^3;  //J/kg
6  h2 =800*10^3;  //J/kg
7  C2 =sqrt(2*[h1-h2 + C1^2/2]);
8  disp("Relative velocity of gas leaving the pipe=")
9  disp(C2)
10 disp("m/s")
```

Scilab code Exa 4.48 48

```
1  clc
2  mw =50;  //kg/s
3  p1 =10^5;  //N/m^2
4  p2 =4.2*10^5;  //N/m^2
5  h =10.7;  //m
6  d1 =0.2;  //m
7  d2 =0.1;  //m
```

```
8  v1=1/1000;
9  v2=1/1000;
10 g=9.81; //m/s^2
11
12 C1=mw*4/%pi/d1^2*v1;
13 C2=mw*4/%pi/d2^2*v2;
14 W=mw*[(p1*v1-p2*v2) + (g*(0-h))+(C1^2-C2^2)/2]/10^3;
15 disp("Capacity of electric motor")
16 disp(-W)
17 disp("kW")
```

Scilab code Exa 4.49 49

```
1  clc
2  Ca=250; //m/s
3  t=-14; //0C
4  ha=250; //kJ/kg
5  hg=900; //kJ/kg
6  ratio=0.0180;
7  Ef=45*10^3; //kJ/kg
8  Q=-21; //kJ/kg
9  ma=1; //kg
10 mg=1.018; //kg
11 mf=0.018; //kg
12 Eg=0.06*mf/mg*Ef;
13 Cg=sqrt(2000*([ma*(ha+Ca^2/2/1000) + mf*Ef + Q]/mg -
      hg-Eg));
14 disp("velocity of exhaust gas jet = ")
15 disp(Cg)
16 disp("m/s")
```

Scilab code Exa 4.50 50

```
1  clc
2  t1=20;  //0C
3  C1=40;  //m/s
4  t2=820;  //0C
5  C2=40;  //m/s
6  t3=620;  //0C
7  C3=55;  //m/s
8  t4=510;  //0C
9  m=2.5;  //kg/s
10 cp=1.005;  //kJ/kg.0C
11
12
13 disp("(i) Heat exchanger")
14 Q_12=m*cp*(t2-t1);
15 disp("rate of heat transfer=")
16 disp(Q_12)
17 disp("kJ/s")
18
19
20 disp("(ii) Turbine")
21 W_23=m*[(cp*(t2-t3))+(C2^2-C3^2)/2/1000];
22 disp("Power output of turbine=")
23 disp(W_23)
24 disp("kW")
25
26
27 disp("(iii) Nozzle")
28 C4=sqrt(2*1000*(cp*(t3-t4)+C3^2/2/1000));
29 disp("Velocity at exit from the nozzle= ")
30 disp(C4)
31 disp("m/s")
```

Scilab code Exa 4.51 51

```
1  clc
```

```
 2 V=0.028; //m^3
 3 p1=80; //bar
 4 t=350; //0C
 5 p2=50; //bar
 6 v1=0.02995; //m^3/kg
 7 h1=2987.3; //kJ/kg
 8 v2=0.02995; //m^3/kg
 9 vg2=0.0394; //m^3/kg
10 uf2=1149; //kJ/kg
11 ug2=2597; //kJ/kg
12
13 m=V/v1;
14 u1=h1 - (p1*v1*10^2); //kJ/kg
15
16
17 disp(" (i) State of steam after cooling")
18 x2=v2/vg2;
19 disp(" dryness fraction = ")
20 disp(x2)
21
22
23 disp(" (ii) Heat rejected by the steam")
24 u2=(1-x2)*uf2 + x2*ug2;
25 Q=m*(u2-u1);
26 disp(" Heat rejected = ")
27 disp(-Q)
28 disp("kJ")
```

Scilab code Exa 4.52 52

```
1 clc
2 m=0.08; //kg
3 p=2*10^5; //Pa
4 V=0.10528; //m^3
5 h1=2706.3; //kJ/kg
```

```
6  h2 =3071.8;  //kJ/kg
7  v1 =0.885;  //m^3/kg
8  v2=V/m;  //m^3/kg
9

10
11 disp("(i) Heat supplied")
12 Q=m*(h2-h1);
13 disp("Q=")
14 disp(Q)
15 disp("kJ")
16
17 disp("(ii) Work done")
18 W=p*(v2-v1);
19 W_total=m*W/10^3;
20 disp("Total work done = ")
21 disp(W_total)
22 disp("kJ")
```

Scilab code Exa 4.53 53

```
1  clc
2  m=1;  //kg
3  p=8;  //bar
4  s1 =6.55;  //kJ/kg.K
5  T=200;  //0C
6  s_f1 =2.0457;  //kJ/kg.K
7  s_fg1 =4.6139;  //kJ/kg.K
8  h_f1 =720.9;  //kJ/kg
9  h_fg1 =2046.5;  //kJ/kg
10 h2 =2839.3;  //kJ/kg
11
12 x1=(s1-s_f1)/s_fg1;
13 h1=h_f1+x1*h_fg1;
14 Q=h2-h1;
15 disp("Heat supplied=")
```

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```
16  disp(Q)
17  disp("kJ/kg")
18
19  // For T-s diagram
20
21  s=0:0.01:10;
22  T=(-(s-5)^2+298);
23  plot(s,T)
24
25  T=[295.44 295.44];
26  s=[6.6 3.45];
27  plot(s,T,'g')
28
29  s=[6.6 7];
30  T=[295.44 300];
31  plot(s,T,'g')
32
33  s=[6.55 6.55];
34  T=[270 295.44];
35  plot(s,T,'r')
36
37  s=[6.6 6.6];
38  T=[270 295.44];
39  plot(s,T,'--r')
40
41  s=[6.66 6.66];
42  T=[270 295.44];
43  plot(s,T,'r')
44
45  xtitle("T-s diagram", "s(kJ/kg K)", "T(K)")
46  //The area in red represents the heat flow and it
        goes upto x-axis
```

Scilab code Exa 4.54 54

```scilab
1  clc
2  p1=7*10^5;  //Pa
3  p2=1.5*10^5;  //Pa
4  Q=420;  //kJ/kg
5  uf=696;  //kJ/kg
6  x=0.95;
7  ug=2573;  //kJ/kg
8  u_f2=2580;  //kJ/kg
9  u_g2=2856;  //kJ/kg
10 x2=15/50;
11 h_f1=697.1;  //kJ/kg
12 h_fg1=2064.9;  //kJ.kg
13 h_f2=2772.6;  //kJ/kg
14 h_g2=2872.9;  //kJ/kg
15
16
17 disp("(i) Change of internal energy")
18 u1=(1-x)*uf + x*ug;
19 u2=2602.8;  //kJ/kg
20 du=u2-u1;
21 disp("du=")
22 disp(du)
23 disp("kJ/kg")
24
25
26 disp("(ii) Change in enthalpy")
27 h1=h_f1+x*h_fg1;
28 h2=h_f2+x2*(h_g2-h_f2);
29 dh=h2-h1;
30 disp("dh=")
31 disp(dh)
32 disp("kJ/kg")
33
34
35 disp("(iii) Work done = ")
36 W=Q-du;
37 disp("W=")
38 disp(W)
```

```
39  disp("kJ/kg")
```

Scilab code Exa 4.55 55

```
 1  clc
 2  p1=5.5*10^5; //Pa
 3  x1=1;
 4  p2=0.75*10^5; //Pa
 5  v1=0.3427; //m^3/kg
 6  v2=p1*v1/p2;
 7  // Since v2 > vg (at 0.75 bar), therefore, the steam
        is superheated at state 2.
 8  u2=2567.25; //kJ/kg
 9  u1=2565; //kJ/kg
10  du=u2-u1; //kJ/kg
11  C=p1*v1;
12
13  disp("Work done = ")
14  W=integrate('C/v', 'v', v1,v2)
15  disp("N-m/kg")
16
17
18  disp("Heat supplied = ")
19  Q=du+W/10^3;
20  disp(Q)
21  disp("kJ/kg")
```

Scilab code Exa 4.56 56

```
 1  p1=100; //bar
 2  p2=10; //bar
 3  s1=5.619; //kJ/kg.K
 4  T=584; //K
```

```
 5  s2 =7.163;  //kJ/kg.K
 6  u1 =2545;  //kJ/kg
 7  u2 =2811.8;  //kJ/kg
 8
 9
10  disp ("(i)Heat supplied ")
11  Q=T*(s2-s1);
12  disp ("Q=")
13  disp (Q)
14  disp ("kJ/kg")
15
16
17  disp ("(ii) Work done")
18  W=Q-(u2-u1);
19  disp ("W=")
20  disp (W)
21  disp ("kJ/kg")
```

Scilab code Exa 4.57 57

```
 1  clc
 2  m=1;  //kg
 3  p1 =120*10^5;  //N/m^2
 4  t1 =400;  //0C
 5  p2 =38;  //bar
 6  h1 =3051.3;  //kJ/kg
 7  v1 =0.02108;  //m^3/kg
 8  u1=h1-p1*v1/10^3;  //kJ/kg
 9  u2 =2602;  //kJ/kg
10  disp ("WOrk done = ")
11  W=u1-u2;
12  disp (W)
13  disp ("kJ/kg")
```

Scilab code Exa 4.58 58

```scilab
1  clc
2  p1=7*10^5;  //N/m^2
3  x1=0.98;
4  p2=0.34*10^5;  //N/m^2
5  vg=0.273;  //m^3/kg
6  n=1.1;
7  v_g2=4.65;  //m^3/kg
8  u_f1=696;  //kJ/kg
9  u_g1=2573;  //kJ/kg
10 u_f2=302;  //kJ/kg
11 u_g2=2472;  //kJ/kg
12
13
14 v1=x1*vg;
15 v2=v1*(p1/p2)^(1/n);
16 x2=v2/v_g2;
17
18
19 disp("(i) Work done by the steam during the process"
       )
20 W=(p1*v1-p2*v2)/(n-1)/10^3;  //kJ/kg
21 disp("W=")
22 disp(W)
23 disp("kJ/kg")
24
25
26 disp("(ii) Heat transferred")
27 u1=(1-x1)*u_f1+x1*u_g1;
28 u2=(1-x2)*u_f2+x2*u_g2;
29 Q=u2-u1 + W;
30 disp("Q=")
31 disp(Q)
```

```
32  disp ("kJ/kg")
```

Scilab code Exa 4.59 59

```
 1  clc
 2  p1=15;  //bar
 3  t1=350;  //0C
 4  C1=60;  //m/s
 5  p2=1.2;  //bar
 6  C2=180;  //m/s
 7  s1=7.102;  //kJ/kg
 8  s_f2=1.3609;  //kJ/kg
 9  s_g2=7.2884;  //kJ/kg
10  h_f2=439.4;  //kJ/kg
11  h_fg2=2241.1;  //kJ/kg
12  h1=3147.5;  //kJ/kg
13
14
15  x2=(s1 - s_f2)/(s_g2-s_f2);
16  h2=h_f2+x2*h_fg2;
17
18  W=(h1-h2) + (C1^2 - C2^2)/2/1000;
19  disp("Work done = ")
20  disp(W)
21  disp("kJ/kg")
```

Scilab code Exa 4.60 60

```
 1  clc
 2  p1=10;  //bar
 3  t1=200;  //0C
 4  C1=60;  //m/s^2
 5  c2=650;  //m/s
```

```
6  p2=1.5; //bar
7  h1=2827.9; //kJ/kg
8  h_f2=467.1; //kJ/kg
9  h2=2618.45; //kJ/kg
10 h_g2=2693.4; //kJ/kg
11 x2=(h2-h_f2)/(h_g2-h_f2);
12 disp("quality of steam leaving the nozzle=")
13 disp(x2)
```

Scilab code Exa 4.61 61

```
1  clc
2  h1=2776.4; //kJ/kg
3  h2=h1;
4  h_f1=884.6; //kJ/kg
5  h_fg1=1910.3; //kJ/kg
6  x1=(h1-h_f1)/h_fg1;
7  disp("Initial dryness fraction = ")
8  disp(x1)
```

Scilab code Exa 4.62 62

```
1  p1=10; //bar
2  x1=0.9; //bar
3  p2=2; //bar
4
5
6  // Using Mollier chart, we get
7  x2=0.94;
8  disp("x2 =")
9  disp(x2)
```

Scilab code Exa 4.63 63

```
1  clc
2
3  disp("(a)From steam tables")
4
5  p1=15*10^5; //Pa
6  p2=7.5*10^5; //Pa
7  h_f1=844.7; //kJ/kg
8  ts1=198.3; //0C
9  s_f1=2.3145; //kJ/kg.K
10 s_g1=6.4406; //kJ/kg.K
11 v_g1=0.132; //m^3/kg
12 h_fg1=1945.2; //kJ/kg
13 x1=0.95;
14 h_f2=709.3; //kJ/kg
15 h_fg2=2055.55; //kJ/kg
16 s_f2=2.0195; //kJ/kg
17 s_g2=6.6816; //kJ/kg.K
18 v_g2=0.255; //m^3/kg
19 x2=0.9;
20 x3=1;
21 s_f3=0.521; //kJ/kg K
22 s_g3=8.330; //kJ/kg K
23
24 h2=h_f2+x2*h_fg2;
25 h1=h_f1 + x1*h_fg1;
26 s1=s_f1 + x1*(s_g1-s_f1);
27 s2=s1;
28 ds_12=s2-s1;
29
30 s3=s_f3+x3*(s_g3-s_f3);
31 ds_23=s3-s2;
32
```

```
33  ds=ds_12+ds_23;
34  disp(")(i) Change in entropy =")
35  disp(ds)
36  disp("kJ/kg K")
37
38  h3=h2;
39
40  disp("(ii) Change in enthalpy")
41  dh=h2-h1;
42  disp(dh)
43  disp("kJ/kg")
44
45
46  disp("(iii) Change in internal energy")
47  u1=h1-p1*x1*v_g1/10^3;
48  u2=h2-p2*x2*v_g2/10^3;
49  du=u2-u1;
50  disp("du=")
51  disp(du)
52  disp("kJ/kg")
53
54
55  // Only the expansion of steam from point 1 to 2 (i.
        e., isentropic expansion) is reversible because
        of unresisted flow whereas the expansion from
        point 2 to point 3 (i.e., throttling expansion)
        is irreversible because of frictional resistance
        to flow. Increase of entropy also shows that
        expansion from point 2 to point 3 is irreversible
        .
56
57
58  disp("(b) Using Mollier chart")
59  h1=2692;  //kJ/kg
60  h2=2560;  //kJ/kg
61  s1=6.23;  //kJ/kg K
62  s2=s1;
63  s3=8.3;  //kJ/kg K
```

```
64
65  disp("(i) Change in entropy =")
66  ds=s3-s1;
67  disp(ds)
68  disp("kJ/kg K")
69
70
71  disp("(ii) Change in enthalpy =")
72  dh=h2-h1;
73  disp(dh)
74  disp("kJ/kg")
```

Scilab code Exa 4.64 64

```
1  clc
2  V1=5.5;  //m^3
3  p1=16*10^5;  //Pa
4  T1=315;  //K
5  V2=V1;
6  p2=12*10^5;  //Pa
7  R=0.287*10^3;
8  y=1.4;
9
10  m1=p1*V1/R/T1;
11  T2=T1*(p2/p1)^((y-1)/y);
12
13  m2=p2*V2/R/T2;
14  disp("Mass of air which left the receiver=")
15  m=m1-m2;
16  disp(m)
17  disp("kg")
```

Scilab code Exa 4.65 65

```
1  clc
2  cp=1; //kJ/kg.K
3  cv=0.711; //kJ/kg.K
4  V1=1.6; //m^3
5  V2=V1;
6  p1=5*10^5; //Pa
7  T1=373; //K
8  p2=1*10^5; //Pa
9  R=287;
10 y=1.4;
11
12 m1=p1*V1/R/T1;
13 T2=T1*(p2/p1)^((y-1)/y);
14 m2=p2*V2/R/T2;
15 KE=(m1*cv*T1)-(m2*cv*T2)-(m1-m2)*cp*T2;
16 disp("Kinetic energy of discharge air =")
17 disp(KE)
18 disp("kJ")
19
20 disp("This is the exact answer when using proper
       value of cv")
```

Scilab code Exa 4.66 66

```
1  clc
2  //For oxygen
3  cpa=0.88; //kJ/kg K
4  Ra=0.24; //kJ/kg K
5  V1a=0.035; //m^3
6  p1a=4.5; //bar
7  T1a=333; //K
8  V2a=0.07; //m^3
9
10 //For methane
11 V1b=0.07; //m^3
```

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```
12  V2b =0.035;  //m^3
13  p1b =4.5;  //bar
14  T1b =261;  //K
15  cpb =1.92;  //kJ/kg K
16  Rb =0.496;  //kJ/kg K
17
18  yb=cpb/(cpb-Rb);  //for methane
19  cva=cpa-Ra;  //for oxygen
20
21  disp(" (i) Final state condition")
22
23  p2b=p1b*(V1b/V2b)^yb;
24  disp("p2 for methane =")
25  disp(p2b)
26  disp("bar")
27
28  T2b=p2b*V2b*T1b/p1b/V1b;
29  disp("T2 for methane =")
30  disp(T2b)
31  disp("K")
32
33  p2a=p2b;
34
35  T2a=p2a*V2a/p1a/V1a*T1a;
36  disp("T2 for oxygen =")
37  disp(T2a)
38  disp("K")
39
40  Wb=(p1b*V1b - p2b*V2b)/(yb-1)*100;  //kJ
41
42  disp(" (ii) Work done by the piston ")
43  disp("The piston will be in virtual equilibrium and
        hence zero work is effected by the piston .")
44
45  Wa=-Wb;
46
47  ma=p1a*V1a/Ra/T1a*10^2;
48
```

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```
49  Q=ma*cva*(T2a-T1a) + Wa;
50  disp("(iii) Heat transferred to oxygen =")
51  disp(Q)
52  disp("kJ")
```

Chapter 5

Second Law of Thermodynamics and Entropy

Scilab code Exa 5.1 1

```
1  clc
2  Q1 =1500/60;  //kJ/s
3  W =8.2;  //kW
4
5  disp("(i) Thermal efficiency")
6  n=W/Q1;
7  disp("n=")
8  disp(n)
9
10
11 disp("(ii) Rate of heat rejection")
12 Q2=Q1-W;
13 disp("Q2=")
14 disp(Q2)
15 disp("kW")
```

Scilab code Exa 5.2 2

```
1 clc
2 Q_12=30; //kJ
3 W_12=60; //kJ
4 dU_12=Q_12-W_12;
5 Q_21=0;
6 W_21=Q_21+dU_12;
7 disp("W_21 =")
8 disp(W_21)
9 disp("Thus 30 kJ work has to be done on the system
      to restore it to original state, by adiabatic
      process.")
```

Scilab code Exa 5.3 3

```
1  clc
2  Q2=12000; //kJ/h
3  W=0.75*60*60; //kJ/h
4  COP=Q2/W;
5  disp("Coefficient of performance")
6  disp(COP)
7
8  Q1=Q2+W;
9  disp("heat transfer rate=")
10 disp(Q1)
11 disp("kJ/h")
```

Scilab code Exa 5.4 4

```
1 clc
2 T2=261; //K
3 T1=308; //K
```

```
4 Q2=2; //kJ/s
5 Q1=Q2*(T1/T2);
6 W=Q1-Q2;
7
8 disp("Least power required to pump the heat
      continuosly")
9 disp(W)
10 disp("kW")
```

Scilab code Exa 5.5 5

```
1 clc
2
3 disp("(i) Heat abstracted from outside=")
4 Q1=2*10^5; //kJ/h
5 W=3*10^4; //kJ/h
6 Q2=Q1-W;
7 disp("Heat abstracted from outside=")
8 disp(Q2)
9 disp("kJ/h")
10
11
12 disp("(ii) Co-efficient of performance")
13 COP_hp=Q1/(Q1-Q2);
14 disp("Co-efficient of performance=")
15 disp(COP_hp)
```

Scilab code Exa 5.6 6

```
1 clc
2 T1=2373; //K
3 T2=288; //K
4 n_max=1-T2/T1;
```

```
5  disp("Highest possible theoritical efficiency=")
6  disp(n_max*100)
7  disp("%")
```

Scilab code Exa 5.7 7

```
1  clc
2  T1=523;  //K
3  T2=258;  //K
4  Q1=90;  //kJ
5
6  n=1-T2/T1;
7  disp("(i) Efficiency of the system")
8  disp(n*100)
9  disp("%")
10
11
12 disp("(ii) The net work transfer")
13 W=n*Q1;
14 disp("W=")
15 disp(W)
16 disp("kJ")
17
18
19 disp("(iii) Heat rejected to the sink")
20 Q2=Q1-W;
21 disp("Q2=")
22 disp(Q2)
23 disp("kJ")
```

Scilab code Exa 5.8 8

```
1  clc
```

```
2  T1=1023;  //K
3  T2=298;  //K
4  n_carnot=1-T2/T1;
5  W=75*1000*60*60;
6  Q=3.9*74500*1000;
7  n_thermal=W/Q;
8  disp("n_carnot =")
9  disp(n_carnot)
10
11 disp("n_thermal =")
12 disp(n_thermal)
13
14 disp("Since  thermal >  carnot , therefore claim of
        the inventor is not valid (or possible")
```

Scilab code Exa 5.9 9

```
1  clc
2  T1=1273;  //K
3  T2=313;  //K
4  n_max=1-T2/T1;
5  Wnet=1;
6  Q1=Wnet/n_max;
7  Q2=Q1-Wnet;
8  disp("the least rate of heat rejection = ")
9  disp(Q2)
10 disp("kW")
```

Scilab code Exa 5.10 10

```
1  clc
2  one_ton_of_refrigeration=210;  //kJ/min
```

```
 3 Cooling_required =40*( one_ton_of_refrigeration ); //kJ
     /min
 4 T1 =303; //K
 5 T2 =238; //K
 6 COP_refrigerator=T2/(T1-T2);
 7 COP_actual =0.20* COP_refrigerator;
 8 W=Cooling_required/COP_actual /60;
 9 disp ("power  required  = ")
10 disp (W)
11 disp ("kW")
```

Scilab code Exa 5.11 11

```
 1 clc
 2 E=12000; //kJ/min
 3
 4 T2 =308; //K
 5
 6 // Source  1
 7 T1 =593; //K
 8 n1 =1- T2/T1 ;
 9
10 // Source  2
11 T1 =343; //K
12 n2 =1- T2/T1 ;
13
14 W1=E*n1 ;
15 disp ("W1 =")
16 disp (W1)
17
18 W2=E*n2 ;
19 disp ("W2 =")
20 disp (W2)
21
22 disp ("Thus ,  choose  source  2.")
```

```
23  disp("The source 2 is selected even though
       efficiency in this case is lower, because the
       criterion for selection is the larger output.")
```

Scilab code Exa 5.12 12

```
1  clc
2  T1=973; //K
3  T2=323; //K
4  T3=248; //K
5
6  Q1=2500; //kJ
7  W=400; //kJ
8
9  disp("(i)Heat rejection to the 50 C reservoir")
10 n_max=1-T2/T1;
11 W1=n_max*Q1;
12 COP_max=T3/(T2-T3);
13 W2=W1-W;
14 Q4=COP_max*W2;
15 COP1=Q4/W2;
16 Q3=Q4+W2;
17 Q2=Q1-W1;
18 disp("Heat rejection to the 50 C reservoir=")
19 disp(Q2+Q3)
20 disp("kJ")
21
22
23 disp("(ii)Heat rejected to 50 C reservoir ")
24 n=0.45*n_max;
25 W1=n*Q1;
26 W2=W1-W;
27 COP2=0.45*COP1;
28 Q4=W2*COP2;
29 Q3=Q4+W2;
```

```
30  Q2=Q1-W1;
31
32  disp("Heat  rejected  to  50  C  reservoir=")
33  disp(Q2+Q3)
34  disp("kJ")
```

Scilab code Exa 5.13 13

```
1  clc
2  T1=298; //K
3  T2=273; //K
4  Q1=24; //kJ/s
5  T3=653; //K
6  COP=T1/(T1-T2);
7  disp("(i) determine COP and work input required")
8
9  disp("Coefficient of performance = ")
10  disp(COP)
11
12  COP_ref=T2/(T1-T2);
13  W=Q1/COP_ref;
14  disp("Work input required = ")
15  disp(W)
16  disp("kW")
17
18
19  disp("(ii)Determine overall COP of the system ")
20  Q4=T1*W/(T3-T1);
21  Q3=Q4+W;
22  Q2=Q1+W;
23  COP=Q1/Q3;
24  disp("COP=")
25  disp(COP)
26
27  COP_overall=(Q2+Q4)/Q3;
```

```
28  disp("Overall COP=")
29  disp(COP_overall)
```

Scilab code Exa 5.14 14

```
1   clc
2   T_e1=493; //K
3   T_e2=298; //K
4   T_p1=298; //K
5   T_p2=273; //K
6   Amt=15; //tonnes produced per day
7   h=334.5; //kJ/kg
8   Q_abs=44500; //kJ/kg
9   Q_p2=Amt*10^3*h/24/60;
10  COP_hp=T_p2/(T_p1-T_p2);
11  W=Q_p2/COP_hp/60;
12  disp("(i)Power developed by the engine = ")
13  disp(W)
14  disp("kW")
15
16
17  disp("(ii) Fuel consumed per hour")
18  n_carnot=1-(T_e2/T_e1);
19  Q_e1=W/n_carnot*3600; //kJ/h
20  fuel_consumed=Q_e1/Q_abs;
21  disp("Quantity of fuel consumed/hour = ")
22  disp(fuel_consumed)
23  disp("kg/h")
```

Scilab code Exa 5.15 15

```
1   clc
2   T1=550; //K
```

```
3  T3=350; //K
4  // W=Q2*((T1-T2)/T2)
5  // W=Q2((T2-T3)/T2)
6  // From this we get following expression
7  T2=(T1+T3)/2;
8  disp("Intermediate temperature =")
9  disp(T2)
10 disp("K")
```

Scilab code Exa 5.16 16

```
1  clc
2  T1=600; //K
3  T2=300; //K
4
5
6  disp("(i) When Q1=Q2")
7  T3=2*T1/(T1/T2+1);
8  disp("T3=")
9  disp(T3)
10 disp("K")
11
12
13 disp("(ii) Efficiency of Carnot engine and COP of
       carnot refrigerator")
14 n=(T1-T3)/T1; //carnot engine
15 COP=T2/(T3-T2); //refrigerator
16
17 disp("Efficiency of carnot engine = ")
18 disp(n)
19
20 disp("COP of carnot refrigerator = ")
21 disp(COP)
```

Scilab code Exa 5.17 17

```
1  clc
2  T3=278;  //K
3  T2=350;  //K
4  T4=T2;
5  T1=1350;  //K
6
7  Q1=100/[((T4/T1)*(T1-T2)/(T4-T3))+T2/T1];  //Q4+Q2
     =100; Q4=Q1*((T4/T1)*(T1-T2)/(T4-T3)); Q2=T2/T1*
     Q1;
8
9  disp("Q1=")
10 disp(Q1)
11 disp("kJ")
```

Scilab code Exa 5.18 18

```
1  clc
2  Q1=300;  //kJ/s
3  T1=290;  //0C
4  T2=8.5;  //0C
5  disp("let   dQ/T = A")
6
7  disp("(i) 215 kJ/s are rejected")
8  Q2=215;  //kJ/s
9  A= Q1/(T1+273) - Q2/(T2+273)
10 disp("Since, A<0, Cycle is irreversible.")
11
12
13 disp("(ii) 150 kJ/s are rejected")
14 Q2=150;  //kJ/s
```

```
15  A= Q1/(T1+273) - Q2/(T2+273)
16  disp(" Since A=0, cycle is reversible ")
17
18
19  disp("(iii) 75 kJ/s are rejected .")
20  Q2=75;  //kJ/s
21  A= Q1/(T1+273) - Q2/(T2+273)
22  disp(" Since A>0, cycle is impossible ")
```

Scilab code Exa 5.19 19

```
1  clc
2  P1=0.124*10^5;  //N/m^2
3  T1=433;  //K
4  T2=323;  //K
5  h_f1=687;  //kJ/kg
6  h2=2760;  //kJ/kg
7  h3=2160;  //kJ/kg
8  h_f4=209;  //kJ/kg
9  Q1=h2-h_f1;
10  Q2=h_f4-h3;
11  disp(" Let A= dQ/T")
12  A=Q1/T1+Q2/T2;
13  disp(A)
14  disp("A<0. Hence classius inequality is verified ")
```

Scilab code Exa 5.20 20

```
1  clc
2  T1=437;  //K
3  T2=324;  //K
4  h2=2760;  //kJ/kg
5  h1=690;  //kJ/kg
```

110

```
6 h3 =2360;  // kJ / kg
7 h4 =450;  // kJkg
8
9 Q1=h2 - h1 ;
10 Q2=h4 - h3 ;
11
12 disp (" Let  A= dQ /T")
13 A=Q1/T1 + Q2/T2 ;
14 disp (A)
15 disp (" Since  A<0, Classius  inequality  is  verified ")
```

Scilab code Exa 5.21 21

```
1 clc
2 T0 =273;  // K
3 T1 =673;  // K
4 T2 =298;  // K
5 m_w =10;  // kg
6 T3 =323;  // K
7 c_pw =4186;  // kJ / kg .K
8 disp (" Let  C=mi∗ cpi ")
9 C=m_w ∗ c_pw ∗(T3 - T2 ) /(T1 - T3 ) ;
10
11 S_iT1=C∗ log (T1/T0 ) ;  // Entropy  of  iron  at  673  K
12 S_wT2=m_w ∗ c_pw ∗ log (T2/T0 ) ;  // Entropy  of  water  at  298
       K
13 S_iT3=C∗ log (T3/T0 ) ;  // Entropy  of  iron  at  323  K
14 S_wT3=m_w ∗ c_pw ∗ log (T3/T0 ) ;  // Entropy  of  water  at  323
       K
15
16 dS_i=S_iT3 - S_iT1 ;
17 dS_w=S_wT3 - S_wT2 ;
18 dS_net=dS_i + dS_w
19
20 disp (" Since  dS>0, process  is  irreversible ")
```

Scilab code Exa 5.23 23

```
 1 clc
 2 T1=293; //K
 3 V1=0.025; //m^3
 4 V3=V1;
 5 p1=1.05*10^5; //N/m^2
 6 p2=4.5*10^5; //N/m^2
 7 R=0.287*10^3;
 8 cv=0.718;
 9 cp=1.005;
10 T3=293; //K
11
12 disp(")(i)Net heat flow")
13 m=p1*V1/R/T1;
14 T2=p2/p1*T1;
15 Q_12=m*cv*(T2-T1);
16 Q_23=m*cp*(T3-T2)
17
18 disp("Net heat flow = ")
19 Q_net=Q_12+Q_23;
20 disp(Q_net)
21 disp("kJ")
22
23
24 disp("(ii) Net entropy change")
25 dS_32=m*cp*log(T2/T1);
26 dS_12=m*cv*log(T2/T1);
27 dS_31=dS_32 - dS_12;
28 disp("Decrease in entropy = ")
29 disp(dS_31)
30 disp("kJ/K")
```

Scilab code Exa 5.24 24

```
1  clc
2  p1 =1.05*10^5; //N/m^2
3  V1 =0.04; //m^3
4  T1 =288; //K
5  p2 =4.8*10^5;
6  T2 =T1;
7  R0 =8314;
8  M=28;
9
10
11 disp(" ( i )  The  change  of  entropy  =")
12 R=R0/M;
13 m=p1*V1/R/T1;
14 dS=m*R*log(p1/p2)
15 disp(" Decrease  in  entropy  =")
16 disp(-dS)
17 disp(" J/K")
18
19
20 disp(" ( i i ) Heat  rejected  =  ")
21 Q=T1*(-dS);
22 disp("Q=")
23 disp(Q)
24 disp(" J")
25
26
27 W=Q;
28 disp(" Work  done  =  ")
29 disp(W)
30 disp(" J")
31
32 V2 =p1*V1/p2;
```

```
33  v1=V1/m; //specific volume
34  v2=V2/m; //specific volume
35
36  v=v2:0.01:v1;
37  function p=f(v)
38       p=p1*v1/v
39  endfunction
40
41  plot(v,f)
42
43  p=p1
44  plot(v,p,'--')
45
46  p=[0 p2]
47  v=[v2 v2]
48  plot(v,p,'--')
49
50  p=[0 p1]
51  v=[v1 v1]
52  plot(v,p,'--')
53
54  xtitle("p-v diagram", "v(m^3/kg)", "p(N/m^2)")
55
56  xset('window', 1)
57
58  T=[288 288]
59  s=[10 (10-dS)]
60  plot(s,T)
61
62  s=[10 10]
63  T=[0 288]
64  plot(s,T,'--')
65
66  s=[(10-dS) (10-dS)]
67  T=[0 288]
68  plot(s,T,'--')
69
70  xtitle("T-s diagram", "s(kJ/kg K)", "T(K)")
```

Scilab code Exa 5.25 25

```
1  clc
2  R=287;  //kJ/kg.K
3  dU=0;
4  W=0;
5  Q=dU+W;
6
7  dS=R*log(2);  //v2/v1=2
8
9  disp("Change in entropy = ")
10 disp(dS)
11 disp("kJ/kg.K")
```

Scilab code Exa 5.26 26

```
1  clc
2  m=0.04;  //kg
3  p1=1*10^5;  //N/m^2
4  T1=293;  //K
5  p2=9*10^5;  //N/m^2
6  V2=0.003;  //m^3
7  cp=0.88;  //kJ/kg.K
8  R0=8314;
9  M=44;
10
11 R=R0/M;
12 T2=p2*V2/m/R;
13 ds_2A=R/10^3*log(p2/p1);
14 ds_1A=cp*log(T2/T1);
15 ds_21=ds_2A - ds_1A;
```

```
16  dS_21=m*ds_21;
17  disp("Decrease in entropy=")
18  disp(dS_21)
19  disp("kJ/K")
```

Scilab code Exa 5.27 27

```
1   clc
2   p1=7*10^5;  //N/m^2
3   T1=873;  //K
4   p2=1.05*10^5;  //N/M62
5   n=1.25;
6   m=1;  //kg
7   R=0.287;
8   cp=1.005;
9   T2=T1*(p2/p1)^((n-1)/n);
10
11  // At constant temperature from 1 to A
12  ds_1A=R*log(p1/p2);
13
14  // At constant pressure from A to 2
15  ds_2A=cp*log(T1/T2);
16
17
18  ds_12=ds_1A - ds_2A;
19  disp("Increase in entropy = ")
20  disp(ds_12)
21  disp("kJ/kg.K")
```

Scilab code Exa 5.28 28

```
1   clc
2   p1=7*10^5;  //Pa
```

116

```
3  T1=733;  //K
4  p2=1.012*10^5;  //Pa
5  T2a=433;  //K
6  y=1.4;
7  cp=1.005;
8
9  disp(" (i) To prove that the process is irreversible"
      )
10 T2=T1*(p2/p1)^((y-1)/y);
11 disp(" T2 =")
12 disp(T2)
13 disp(" But the actual temperature is 433K at th
      epressure of 1.012 bar, Hence the process is
      irreversible. Proved.")
14
15
16 disp(" (ii) Change of entropy per kg of air")
17 ds=cp*log(T2a/T2);
18 disp(" Increase of entropy=")
19 disp(ds)
20 disp(" kJ/kg.K")
```

Scilab code Exa 5.29 29

```
1  clc
2  V1=0.3;  //m^3
3  p1=4*10^5;  //N/m^2
4  V2=0.08;  //m^3
5  n=1.25;
6  p2=p1*(V1/V2)^n;
7
8  disp(" (i) Change in enthalpy")
9  dH=n*(p2*V2-p1*V1)/(n-1)/10^3;
10 disp(" dH=")
11 disp(dH)
```

```
12 disp("kJ")
13
14
15 disp("(ii) Change in internal energy")
16 dU=dH-(p2*V2 - p1*V1)/10^3;
17 disp("dU=")
18 disp(dU)
19 disp("kJ")
20
21
22 disp("(iii) Change in entropy")
23 dS=0;
24 disp("dS")
25 disp(dS)
26
27
28 disp("(iv)Heat transfer")
29 Q=0;
30 disp("Q=")
31 disp(Q)
32
33
34 disp("(v) Work transfer")
35 W=Q-dU;
36 disp("W=")
37 disp(W)
38 disp("kJ")
```

Scilab code Exa 5.30 30

```
1 clc
2 m=20; //kg
3 p1=4*10^5; //Pa
4 p2=8*10^5; //Pa
5 V1=4; //m^3
```

```
6  V2=V1;
7  cp=1.04; //kJ/kg.K
8  cv=0.7432; //kJ/kg.K
9  R=cp-cv;
10 T1=p1*V1/R/1000; //kg.K;   T=mass*temperature
11 T2=p2*V2/R/1000; //kg.K
12
13
14 disp(" (i) Change in internal energy")
15 dU=cv*(T2-T1);
16 disp("dU=")
17 disp(dU)
18 disp("kJ")
19
20
21 disp(" (ii) Work done")
22 Q=0;
23 W=Q-dU;
24 disp("W")
25 disp(W)
26 disp("kJ")
27
28
29 disp(" (iii) Heat transferred = ")
30 disp(Q)
31
32
33 disp(" (iv) Change in entropy =")
34 dS=m*cv*log(T2/T1);
35 disp(dS)
36 disp("kJ/K")
```

Scilab code Exa 5.31 31

```
1 clc
```

```
2  V1=5;  //m^3
3  p1=2*10^5;  //Pa
4  T1=300;  //K
5  p2=6*10^5;  //Pa
6  p3=2*10^5;  //Pa
7  R=287;
8  n=1.3;
9  y=1.4;
10
11 m=p1*V1/R/T1;
12 T2=T1*(p2/p1)^((n-1)/n);
13 T3=T2*(p3/p2)^((y-1)/y);
14 W_12=m*R*(T1-T2)/(n-1)/1000;  //polytropic
       compression
15 W_23=m*R*(T2-T3)/(y-1)/1000;  //Adiabatic  expansion
16
17 W_net=W_12+W_23;
18 disp("Net  work  done  on  the  air  =  ")
19 disp(-W_net)
20
21 T=[T1 310 320 330 340 350 360 370 380 T2];
22 function  s=f(T)
23     s=(y-n)/(y-1)/(1-n)*R/10^3*log(T);
24 endfunction
25 s=[f(T1) f(310) f(320) f(330) f(340) f(350) f(360) f
       (370) f(380) f(T2)]
26 plot(s,T)
27
28 T=[T2 T3];
29 s=[f(T2) f(T2)];
30 plot(s,T,'r')
31
32 xtitle("T-s  diagram",  "s(kJ/kg  K)",  "T(K)")
33 legend("p*v^1.3=constant",  "p*v^y=constant")
```

Scilab code Exa 5.32 32

```
1  clc
2  V1 =0.004;  //m^3
3  p1 =1*10^5;  //Pa
4  T1 =300;  //K
5  T2 =400;  //K
6  y =1.4;
7  M =28;
8  R0 =8.314;
9  R =R0/M;
10
11
12  disp ("( i )  The  heat  supplied")
13  m =p1*V1/R/1000/T1;  //kg
14  cv =R/(y-1);
15  Q =m*cv*(T2 -T1);
16  disp ("Q")
17  disp (Q)
18  disp ("kJ")
19
20
21  disp ("( ii )  The  entropy  change")
22  dS =m*cv*log (T2/T1);
23  disp ("dS=")
24  disp (dS)
25  disp ("kJ/kg.K")
```

Scilab code Exa 5.33 33

```
1  clc
2  V1 =0.05;  //m^3
3  p1 =1*10^5;  //Pa
4  T1 =280;  //K
5  p2 =5*10^5;  //Pa
```

```
6
7  disp(" ( i )  Change  in  entropy")
8  R0=8.314;
9  M=28;
10 R=R0/M;
11 m=p1*V1/R/T1/1000;
12
13
14 dS=m*R*log(p1/p2);
15 disp("dS=")
16 disp(dS)
17 disp("kJ/K")
18
19 disp(" ( i i )Work  done")
20 Q=T1*dS;
21 disp("Q=")
22 disp(Q)
23 disp("kJ")
```

Scilab code Exa 5.34 34

```
1  clc
2  R=0.287;  //kJ/kg.K
3  m=1;  //kg
4  p1=8*10^5;  //Pa
5  p2=1.6*10^5;  //Pa
6  T1=380;  //K
7  n=1.2;
8  y=1.4;
9
10
11 disp(" ( i )  Final  specific  volume  and  temperature")
12 v1=R*T1/p1*10^3;  //m^3/kg
13 v2=v1*(p1/p2)^(1/n);
14 T2=T1*(p2/p1)^((n-1)/n);
```

```
15  disp("v2=")
16  disp(v2)
17  disp("m^3/kg")
18  disp("T2=")
19  disp(T2)
20
21
22  disp("(ii) Change of internal energy, work done and
        heat interaction")
23  dU=R/(y-1)*(T2-T1);
24  disp("dU=")
25  disp(dU)
26  disp("kJ/kg")
27
28  W=R*(T1-T2)/(n-1);
29  disp("W=")
30  disp(W)
31  disp("kJ/kg")
32
33  Q=dU + W;
34  disp("Q=")
35  disp(Q)
36  disp("kJ/kg")
37
38
39  disp("(iii) Change in entropy")
40  dS=R/(y-1)*log(T2/T1) + R*log(v2/v1)
41  disp("dS=")
42  disp(dS)
43  disp("kJ/kg.K")
```

Scilab code Exa 5.35 35

```
1  clc
2  y=1.4;
```

```
 3  cv=0.718;  //kJ/kg.K
 4  m=1;  //kg
 5  T1=290;  //K
 6  n=1.3;
 7  r=16;
 8  y=1.4;
 9
10  T2=T1*(r)^(n-1);
11
12  disp("(a)")
13
14  T=[T1 300 310 320 330 340 350 360 370 380 390 400
        410 420 430 440 450 460 470 480 490 500 510 520
        530 540 550 560 570 580 590 600 610 620 630 640
        650 660 T2];
15  function s=f(T)
16      s=(y-n)*cv/(1-n)/10^3*log(T);
17  endfunction
18  s=[f(T1) f(300) f(310) f(320) f(330) f(340) f(350) f
        (360) f(370) f(380) f(390) f(400) f(410) f(420) f
        (430) f(440) f(450) f(460) f(470) f(480) f(490) f
        (500) f(510) f(520) f(530) f(540) f(550) f(560) f
        (570) f(580) f(590) f(600) f(610) f(620) f(630) f
        (640) f(650) f(660) f(T2)];
19  plot(s,T)
20
21  T=[0 T2];
22  s=[f(T2) f(T2)];
23  plot(s,T,'r--')
24
25  T=[0 T1];
26  s=[f(T1) f(T1)];
27  plot(s,T,'r--')
28
29  T=[T1 T2];
30  s=[f(T1) f(T2)];
31  plot(s,T,'r--')
32
```

```
33 xtitle("T-s diagram", "s", "T")
34 legend("p*v^n=c")
35
36 //Heat transferred = Area of trapezium = Base*mean
      ordinate
37
38 //Heat transferred=dS*(T1+T2)/2
39 //Hence we get
40 disp("Entropy change=Heat transferred/Mean absolute
      temperature")
41
42 disp("(b)Entropy change")
43 dS=cv*((n-y)/(n-1))*log(T2/T1);
44 disp("dS=")
45 disp(dS)
46 disp("kJ/kg.K")
47 disp("There is decrease in entropy")
48
49 Q=cv*((y-n)/(n-1))*(T1-T2);
50 Tmean = (T1+T2)/2;
51 dS_app=Q/Tmean;
52
53 %error=((-dS) - (-dS_app))/(-dS) * 100;
54 disp("%age error =")
55 disp(%error)
56 disp("%")
```

Scilab code Exa 5.36 36

```
1 clc
2 cp=1.005; //kJ/kg.K
3 R=0.287; //kJ/kg.K
4 V1=1.2; //m^3
5 p1=1*10^5; //Pa
6 p2=p1;
```

```
 7  T1=300;  //K
 8  T2=600;  //K
 9  T3=T1;
10  p1=1*10^5;  //Pa
11  cv=cp-R;
12
13  disp(" (i) The net heat flow")
14  m=p1*V1/R/1000/T1;  //kg
15  Q=m*R*(T2-T1);
16  disp("Q=")
17  disp(Q)
18  disp("kJ")
19
20
21  disp(" (ii) The overall change in entropy")
22  dS_12=m*cp*log(T2/T1);
23  dS_23=m*(cp-R)*log(T3/T2);  //cv=cp-R
24  dS_overall=dS_12+dS_23;
25  disp("Overall change in entropy=")
26  disp(dS_overall)
27  disp("kJ/K")
28
29
30  s=sqrt(300):0.1:sqrt(600);
31  T=s^2;
32  plot(s,T)
33
34  s=22.18:0.1:sqrt(600);
35  T=10*(s-16.725)^2;
36  plot(s,T,'r')
37
38  s=[17 25];
39  T=[600 600];
40  plot(s,T,'--')
41
42  s=[17 25];
43  T=[300 300];
44  plot(s,T,'--')
```

```
45
46  xtitle("T-s diagram", "S", "T")
47  legend("p=C", "V=C")
```

Scilab code Exa 5.37 37

```
 1  clc
 2  cv=0.718; //kJ/kg.K
 3  R=0.287; //kJ/kg.K
 4  p1=1*10^5; //Pa
 5  T1=300; //K
 6  V1=0.018; //m^3
 7  p2=5*10^5; //Pa
 8  T3=T1;
 9  cp=cv+R;
10  p3=p2;
11
12  m=p1*V1/R/T1/1000; //kg
13  T2=T1*p2/p1;
14
15  disp("(i) constant volume process")
16  disp("dS=")
17  dS_12=m*cv*log(T2/T1);
18  disp(dS_12)
19  disp("kJ/K")
20
21  disp("(ii) Constant prssure process ")
22  disp("dS=")
23  dS_23=m*cp*log(T3/T2);
24  disp(dS_23)
25  disp("kJ/K")
26
27  disp("(iii) Isothermal process")
28  disp("dS=")
29  dS_31=m*R*log(p3/p1);
```

```
30  disp(dS_31)
31  disp("kJ/K")
32
33  disp("T-s  diagram")
34  s=sqrt(300):0.1:sqrt(600);
35  T=s^2;
36  plot(s,T)
37
38  s=22.18:0.1:sqrt(600);
39  T=10*(s-16.725)^2;
40  plot(s,T,'r')
41
42  s=[sqrt(300)  22.18];
43  T=[300  300];
44  plot(s,T,'g')
45
46  xtitle("T-s  diagram",  "S",  "T")
47  legend("p=C",  "V=C",  "T=C")
48
49  disp("p-V  diagram")
50  xset('window',1)
51
52  V=[0.018  0.018];
53  p=[1  5];
54  plot(V,p)
55
56  p=[5  5];
57  V=[0.0036  0.018];
58  plot(V,p,'r')
59
60  V=0.0036:0.0001:0.018;
61  function p=f(V)
62      p=1*0.018/V;
63  endfunction
64
65  plot(V,f,'g')
66
67  xtitle("p-V  diagram",  "V",  "p")
```

```
68  legend("V=C","p=C","T=C")
```

Scilab code Exa 5.39 39

```
1  clc
2  m=4;  //kg
3  T1=400;  //K
4  T2=500;  //K
5
6  dS=integrate('m*(0.48+0.0096*T)/T', 'T', T1,T2);
7  disp("dS=")
8  disp(dS)
9  disp("kJ")
```

Scilab code Exa 5.40 40

```
1  clc
2  p1=1*10^5;  //Pa
3  T1=273;   //K
4  p2=25*10^5;  //Pa
5  T2=750;  //K
6  R=0.29;  //kJ/kg.K ; cp=0.85+0.00025*T; cv
      =0.56+0.00025*T; R=cp-cv;
7  v2=R*T2/p2;
8  v1=R*T1/p1;
9  ds=integrate('(0.56+0.00025*T)/T', 'T', T1, T2) +
      integrate('R/v', 'v', v1, v2);
10
11  disp("ds=")
12  disp(ds)
13  disp("kJ/kg K")
```

Scilab code Exa 5.41 41

```scilab
1  clc
2  cv=0.715; //kJ/kg K
3  R=0.287; //kJ/kg K
4  V_A=0.25; //m^3
5  p_Ai=1.4; //bar
6  T_Ai=290; //K
7  V_B=0.25; //m^3
8  p_Bi=4.2; //bar
9  T_Bi=440; //K
10
11 disp("(i) Final equilibrium temperature")
12 m_A=p_Ai * 10^5 * V_A / R / 1000/ T_Ai; //kg
13 m_B=p_Bi * 10^5 * V_B / R / 1000/ T_Bi; //kg
14
15 T_f=(m_B * T_Bi + m_A * T_Ai)/(m_A + m_B);
16 disp("T_f = ")
17 disp(T_f)
18 disp("K")
19
20
21 disp("(ii) Final pressure on each side of the
         diaphragm")
22 p_Af=p_Ai*T_f/T_Ai;
23 disp("p_Af=")
24 disp(p_Af)
25 disp("bar")
26
27 p_Bf=p_Bi*T_f/T_Bi;
28 disp("p_Bf=")
29 disp(p_Bf)
30 disp("bar")
31
```

```
32
33  disp(" ( iii ) Entropy change of the system")
34  dS_A=m_A*cv*log(T_f/T_Ai);
35  dS_B=m_B*cv*log(T_f/T_Bi);
36  dS_net=dS_A+dS_B;
37  disp(" Net change of entropy=")
38  disp(dS_net)
39  disp(" kJ/K")
```

Scilab code Exa 5.42 42

```
1   clc
2   cv=1.25; //kJ/kg.K
3   T1=530; //K
4   v1=0.0624; //m^3/kg
5   v2=0.186; //m^3/kg
6   dT_31=25; //K
7   T3=T1-dT_31; //K
8   dT_21=165; //K
9   T2=T1-dT_21; //K
10  // Path 1−2 : Reversible adiabatic process
11  ds_12=0;
12
13  // To calculate ( s3   s1 ) a reversible path has to
        be selected joining 3 and 1. This is achieved by
        selecting the reversible adiabatic path 1−2 and
        the reversible constant volume process 2−3.
14
15  // Path 1−3 : Adiabatic process
16  v3=0.186; //m^3/kg
17  v3=v2;
18  ds_13=cv*log(T3/T2);
19  disp(" Chang in entropy = ")
20  disp(ds_13)
21  disp(" kJ/kgK")
```

Scilab code Exa 5.44 44

```
1  clc
2  T1=500;  //K
3  T2=400;  //K
4  T3=300;  //K
5  Q1=1500;  //kJ/min
6  W=200;  //kJ/min
7
8  //Q1/T1 + Q2/T2 + Q3/T3=0
9  //Q1+Q2+Q3=W
10 //For solving the above two equations we use
       following method
11 //Q2-Q3=-1300
12 //Q2/400 - Q3/300 =-1500/500=-3
13
14 A=[1,-1;(1/400),(-1/300)];
15 B=[(-1300);(-3)];
16 X=inv(A)*B;
17 Q2=X(1,1);
18 disp("Q2 =")
19 disp(Q2)
20 disp("kJ/min")
21
22 Q3=X(2,1);
23 disp("Q3 =")
24 disp(Q3)
25 disp("kJ/min")
26
27 disp("(ii) Entropy change ")
28 dS1=(-Q1)/T1;
29 disp("Entropy change of source 1 =")
30 disp(dS1)
31 disp("kJ/K")
```

```
32
33  dS2=(-Q2)/T2;
34  disp("Entropy change of sink 2 =")
35  disp(dS2)
36  disp("kJ/K")
37
38  dS3=Q3/T3;
39  disp("Entropy change of source 3 =")
40  disp(dS3)
41  disp("kJ/K")
42
43
44  disp("(iii) Net change of the entropy")
45  dSnet = dS1 + dS2 + dS3;
46  disp("dSnet=")
47  disp(dSnet)
```

Scilab code Exa 5.45 45

```
1   clc
2   T1=250; //K
3   T2=125; //K
4   //cv=0.0045*T^2
5   Q1=integrate('0.045*T^2', 'T', T1, T2);
6   dS_system=integrate('0.045*T', 'T', T1, T2);
7
8   //dS_reservoir=(Q1-W)/T_resservoir
9
10  //dS_universe >= 0
11  //But for maximum work done dS_universe=0
12  dS_universe=0;
13
14  W_max=((-Q1) -T2*(dS_universe-dS_system))/1000;
15  disp("W_max=")
16  disp(W_max)
```

```
17  disp ("kJ")
```

Scilab code Exa 5.46 46

```
1  clc
2  cp=1.005;  //kJ/kg K
3  T_A=333;  //K
4  T_B=288;  //K
5  p_A=140;  //kPa
6  p_B=110;  //kPa
7  //h=cp*T
8  //v/T=0.287/p
9  ds_system=integrate('cp/T', 'T', T_A, T_B) +
      integrate('0.287/p', 'p', p_A, p_B);
10 ds_surr=0;
11 ds_universe=ds_system+ds_surr;
12 disp("change in entropy of universe = ")
13 disp(ds_universe)
14 disp("kJ/kgK")
15 disp("Since change in entropy of universe from A to
     B is -ve")
16 disp("The flow is from B to A")
```

Scilab code Exa 5.47 47

```
1  clc
2  m1=3;  //kg
3  m2=4;  //kg
4  T0=273;  //K
5  T1=80+273;  //K
6  T2=15+273;  //K
7  c_pw=4.187;  //kJ/kgK
8  tm=(m1*T1 + m2*T2)/(m1+m2);
```

```
9  Si=m1*c_pw*log(T1/T0) + m2*c_pw*log(T2/T0);
10 Sf=(m1+m2)*c_pw*log(tm/T0);
11 dS=Sf-Si;
12 disp("Net change in entropy =")
13 disp(dS)
14 disp("kJ/K")
```

Scilab code Exa 5.49 49

```
1  clc
2  m=1;  //kg
3  T1=273;  //K
4  T2=363;  //K
5  c=4.187;
6
7  disp("(a)")
8  disp("(i) Entropy of water=")
9  ds_water=m*c*log(T2/T1);
10 disp(ds_water)
11 disp("kJ/kgK")
12
13
14 disp("(ii) Entropy change of the reservoir ")
15 Q=m*c*(T2-T1);
16 ds_reservoir=-Q/T2;
17 disp("ds_reservoir=")
18 disp(ds_reservoir)
19 disp("kJ/K")
20
21
22 disp("(iii) Entropy change of universe =")
23 ds_universe=ds_water+ds_reservoir;
24 disp(ds_universe)
25 disp("kJ/K")
26
```

```
27
28 disp(")(b)")
29 T3=313; //K
30 ds_water=m*c*(log(T3/T1) + log(T2/T3));
31 ds_res1=-m*c*(T3-T1)/T3;
32 ds_res2=-m*c*(T2-T3)/T2;
33
34 ds_universe=ds_water+ds_res1+ds_res2;
35 disp("(iii) Entropy change of universe =")
36 disp(ds_universe)
37 disp("kJ/K")
38
39 disp("(c) The entropy change of universe would be
       less and less, if the water is heated in more and
        more stages, by bringing the water in contact
       successively with more and more heat reservoirs,
       each succeeding reservoir being at a higher
       temperature than the preceding one.")
40 disp("When water is heated in infinite steps, by
       bringing in contact with an infinite number of
       reservoirs in succession, so that at any instant
       the temperature difference between the water and
       the reservoir in contact is infinitesimally small
       , then the entropy change of the universe would
       be zero and the water would be reversibly heated.
       ")
```

Scilab code Exa 5.50 50

```
1 clc
2 cp=2.093; //kJ/kg0C
3 c=4.187;
4 Lf=333.33; //kJ/kg
5 m=1; //kg
6 T0=273; //K
```

```
 7  T1=268;  //K
 8  T2=298;  //K
 9  Q_s=m*cp*(T0-T1);
10  Q_f=m*Lf;
11  Q_l=m*c*(T2-T0);
12  Q=Q_s+Q_f+Q_l;
13
14  disp("(i) Entropy increase of the universe")
15  ds_atm=-Q/T2;
16  ds_sys1=m*cp*log(T0/T1);
17  ds_sys2=Lf/T0;
18  ds_sys3=m*c*log(T2/T0);
19  ds_total=ds_sys1+ds_sys2+ds_sys3;
20  ds_universe=ds_total+ds_atm;
21
22  disp("Entropy increase of universe=")
23  disp(ds_universe)
24  disp("kJ/K")
25
26
27  disp("(ii) Minimum amount of work necessary to
        convert the water back into ice at     5 C , Wmin
        .")
28  dS_refrigerator=0;
29
30  //  dS_atm=(Q+W)/T;
31  //  dS_universe >= 0
32  //  dS_system=(s1-s4)
33  //dS_universe=dS_system+dS_refrigerator+dS_atm
34
35  dS_system=-1.6263;  //kJ/kg K
36  T=298;  //K
37
38  //For minimum work
39  W_min=T*(-dS_system)-Q;
40  disp("Minimum work done =")
41  disp(W_min)
42  disp("kJ")
```

Chapter 6

Availability and Irreversibility

Scilab code Exa 6.1 1

```
1  clc
2  T0=293; //K
3  T1=300; //K
4  T2=370; //K
5  cv=0.716;
6  cp=1.005;
7  R=0.287;
8  p1=1; //bar
9  p2=6.8; //bar
10 m=1; //kg
11 Wmax=-[cv*(T2-T1) - T0*[cp*log(T2/T1)-R*log(p2/p1)
       ]];
12 n=1/(1-(log(T2/T1)/log(p2/p1)));
13 Wact=m*R*(T1-T2)/(n-1);
14
15 I=Wmax - Wact;
16 disp("Irreversibility = ")
17 disp(I)
18 disp("kJ/kg")
```

Scilab code Exa 6.2 2

```scilab
1  clc
2  T1=1000; //K
3  T2=500; //K
4  T0=300; //K
5  Q=7200; //kJ/min
6
7  disp(" ( i ) Net change of entropy :")
8  dS_source=-Q/T1;
9  dS_system=Q/T2;
10 dS_net=dS_source+dS_system;
11 disp(" dS_net=")
12 disp(dS_net)
13 disp("kJ/min.K")
14
15
16 disp(" ( ii ) Decrease in available energy :")
17 AE_source=(T1-T0)*(-dS_source); //Available energy
       with the source
18 AE_system=(T2-T0)*dS_system; //Available energy with
        the system
19 dAE=AE_source - AE_system; //Decrease in available
      energy
20 disp("dAE=")
21 disp(dAE)
22 disp("kJ")
```

Scilab code Exa 6.3 3

```scilab
1  clc
2  m=8; //kg
```

```scilab
 3  T1=650;  //K
 4  p1=5.5*10^5;  //Pa
 5  p0=1*10^5;  //Pa
 6  T0=300;  //K
 7  cp=1.005;  //kJ/kg.K
 8  cv=0.718;
 9  R=0.287;
10  //p1*v1/T1=p0*v0/T0
11  //Let  r=v1/v0=1/2.54
12  r=1/2.54;
13
14
15  disp(" (i) Change in available energy(for bringing
        the system to dead state )=")
16  ds=cv*log(T1/T0) + R*log(r);
17  dAE=m*[cv*(T1-T0) - T0*[ds]];
18  //dAE is the change in available energy in kJ
19
20  V1=m*R*10^3*T1/p1;
21  V0=V1/r;
22  disp("Loss of availability , L=")
23  L=p0*(V0 - V1)/10^3;
24  disp(L)
25  disp("kJ")
26
27
28  disp(" (ii) Available Energy and Effectiveness")
29  Q=m*cp*(T1-T0);
30  ds=m*cp*log(T1/T0);
31  Unavailable_energy=T0*ds;
32  Available_energy = Q - Unavailable_energy;
33  disp("Available energy = ")
34  disp(Available_energy)
35  disp("kJ")
36
37  Effectiveness=Available_energy/dAE;
38  disp("Effectiveness = ")
39  disp(Effectiveness)
```

Scilab code Exa 6.4 4

```
1  clc
2  c_pg =1;  //kJ/kgK
3  h_fg =1940.7;  //kJ/kg
4  Ts =473;  //K ; Temperature of saturation of steam
5  T1 =1273;  //K ; Initial temperature of gases
6  T2 =773;  //K ; Final temperature of gases
7  T0 =293;  //K ; atmospheric temperature
8
9  //Heat lost by gases=Heat gained by 1 kg saturated
       water when it is converted to steam at 200 0C
10
11 m_g=h_fg/c_pg/(T1-T2);
12 dS_g=m_g*c_pg*log(T2/T1);
13 dS_w=h_fg/Ts;
14
15 dS_net=dS_g + dS_w;
16 disp("Net change in entropy = ")
17 disp(dS_net)
18 disp("kJ/K")
19
20 E=T0*dS_net;  //Increase in unavailable energy due to
       hea transfer
21 disp("Increase in unavailable energy =")
22 disp(E)
23 disp("kJ")
```

Scilab code Exa 6.5 5

```
1  clc
```

```
2  m_g=3; //kg
3  p1=2.5; //bar
4  T1=1200; //K; Temperature of infinite source
5  T1a=400; //K; Initial temperature
6  Q=600; //kJ
7  cv=0.81; //kJ/kg.K
8  T0=290; //K; Surrounding Temperature
9  //final temperature = T2a
10
11  T2a=Q/m_g/cv + T1a;
12  AE=(T1-T0)*Q/T1; //Available energy with the source
13  dS=m_g*cv*log(T2a/T1a); //Change in entropy of the
       gas
14
15  UAE=T0*dS; //Unavailability of the gas
16  A=Q-UAE; //Available energy with the gas
17
18  loss=AE-A;
19  disp("Loss in available energy due to heat transfer
       =")
20  disp(loss)
21  disp("kJ")
```

Scilab code Exa 6.6 6

```
1  clc
2  m=60; //kg
3  T1=333; //K
4  T0=279; //K
5  p=1; //atm
6  cp=4.187;
7
8  //dW=-m*cp*(1-T0/T)dT
9  //Wmax=Available energy
10  Wmax=integrate('m*cp*(1-T0/T)', 'T', T0, T1);
```

```
11  Q1=m*cp*(T1-T0);
12
13  //Let unavailable energy=E
14  E=Q1-Wmax;
15  disp("unavailable energy = ")
16  disp(E)
17  disp("kJ")
```

Scilab code Exa 6.7 7

```
1  clc
2  m=15;  //kg
3  T1=340;  //K
4  T0=300;  //K
5  cp=4.187;  //kJ/kgK
6  //Work added during churning = Increase in enthalpy
       of water
7  W=m*cp*(T1-T0);
8  ds=cp*log(T1/T0);
9  AE=m*[cp*(T1-T0)-T0*ds];
10  AE_loss=W-AE;  //Loss in availability
11  disp("Loss in availability")
12  disp(AE_loss)
13  disp("kJ")
```

Scilab code Exa 6.8 8

```
1  clc
2  m=5;  //kg
3  T1=550;  //K
4  p1=4*10^5;  //Pa
5  T2=290;  //K
6  T0=T2;
```

```
7  p2=1*10^5;  //Pa
8  p0=p2;
9  cp=1.005;  //kJ/kg K
10 cv=0.718;  //kJ/kg K
11 R=0.287;  //kJ/kg K
12
13 disp(" (i) Availability of the system :")
14 ds=cp*log(T1/T0) - R*log(p1/p0);
15 Availability=m*[cv*(T1-T0) - T0*ds];
16 disp(" Availability of the system =")
17 disp(Availability)
18 disp("kJ")
19
20
21 disp(" (ii) Available energy and Effectiveness")
22 Q=m*cp*(T1-T0);
23 dS=m*cp*log(T1/T0);
24 E=T0*dS;  //Unavailable energy
25 AE=Q-E;
26 disp(" Available Energy = ")
27 disp(AE)
28 disp("kJ")
29
30 disp(" Effectiveness=")
31 Effectiveness=AE/Availability;
32 disp(Effectiveness)
```

Scilab code Exa 6.9 9

```
1 clc
2 R=0.287;  //kJ/kgK
3 cp=1.005;  //kJ/kgK
4 m=25/60;  //kg/s
5 p1=1;  //bar
6 p2=2;  //bar
```

```
7  T1=288; //K
8  T0=T1;
9  T2=373; //K
10
11  W_act=cp*(T2-T1); //W_actual
12  W_total= m*W_act;
13
14  disp("Total actual power required =")
15  disp(W_total)
16  disp("kW")
17
18  ds=cp*log(T2/T1) - R*log(p2/p1);
19  Wmin=cp*(T2-T1) - T0*(ds);
20
21  disp("Minimuumm work required = ")
22  W=m*Wmin;
23  disp(W)
24  disp("kW")
```

Scilab code Exa 6.10 10

```
1  clc
2  m_O2=1; //kg
3  m_H2=1; //kg
4  p=1*10^5; //Pa
5  T_O2=450; //K
6  T_H2=450; //K
7  T0=290; //K
8  R0=8.314;
9  M_O2=32;
10  M_H2=2;
11
12  R_O2=R0/M_O2;
13  v_O2=m_O2*R_O2*T_O2/p;
14
```

```
15  R_H2=R0/M_H2;
16  v_H2=m_H2*R_H2*T_H2/p;
17
18  v_f=v_O2 + v_H2;  // total volume after mixing
19
20  dS_O2=R_O2*log(v_f/v_O2);
21  dS_H2=R_H2*log(v_f/v_H2);
22
23  dS_net=dS_O2 + dS_H2;
24
25  // Let E be the loss in availability
26  E=T0*dS_net;
27  disp("Loss in availability=")
28  disp(E)
29  disp("kJ")
```

Scilab code Exa 6.11 11

```
1  clc
2  T0=283;  //K
3  cp=4.18;  //kJ/kgK
4  m1=20;  //kg
5  T1=363;  //K
6  m2=30;  //kg
7  T2=303;  //K
8  T3=327;  //K
9
10  AE1=integrate('m1*cp*(1-T0/T)', 'T', T0, T1);
11  AE2=integrate('m2*cp*(1-T0/T)', 'T', T0, T2);
12
13  AE_total=AE1 + AE2;  // before mixing
14
15  // If T K is the final temperature after mixing
16  T=(m1*T1+m2*T2)/(m1+m2);
17  m_total=m1+m2;
```

```
18
19  //Available energy of 50kg of water at 54 0C
20  AE3=m_total*cp*[(T3-T0) - T0*log(T3/T0)];
21
22  //Decrease in available energy due to mixing dAE
23  dAE=AE_total - AE3;
24  disp("dAE=")
25  disp(dAE)
26  disp("kJ")
```

Scilab code Exa 6.12 12

```
 1  clc
 2  T_w1=323;  //K
 3  T_w2=343;  //K
 4  T_o1=513;  //K
 5  T_o2=363;  //K
 6  SG_oil=0.82;
 7  c_po=2.6;  //kJ/kg K
 8  c_pw=4.18;  //kJ/kg K
 9  T0=300;  //K
10  m_o=1;  //kg
11
12  //Heat lost by oil=Heat gained by water
13  m_w=(m_o*c_po*(T_o1-T_o2))/(c_pw*(T_w2-T_w1));
14
15  dS_w=m_w*c_pw*log(T_w2/T_w1);
16  dS_o=m_o*c_po*log(T_o2/T_o1);
17
18  dAE_w=m_w*[c_pw*(T_w2-T_w1)]-T0*dS_w;
19  dAE_o=m_o*[c_po*(T_o2-T_o1)]-T0*dS_o;
20
21  // Loss in availability E=
22  E=dAE_w+dAE_o;
23  disp("Loss in availability =")
```

```
24  disp(E)
25  disp("kJ")
```

Scilab code Exa 6.13 13

```
 1  clc
 2  m_i=1;  //kg
 3  T_i=273;  //K
 4  m_w=12;  //kg
 5  T_w=300;  //K
 6  T0=288;  //K
 7  c_pw=4.18;  //kJ/kg K
 8  c_pi=2.1;  //kJ/kg K
 9  L_i=333.5;  //kJ/kg
10
11  Tc=(m_w*c_pw*T_w + m_i*c_pw*T_i - L_i)/(m_w*c_pw +
        m_i*c_pw);
12
13  dS_w=m_w*c_pw*log(Tc/T_w);
14  dS_i=m_i*c_pw*log(Tc/T_i) + L_i/T_i;
15
16  dS_net=dS_w+dS_i;
17  disp("Increase in entropy =")
18  disp(dS_net)
19  disp("kJ/K")
20
21  dAE=T0*dS_net;
22  disp("Increase in unavailable energy = ")
23  disp(dAE)
24  disp("kJ")
```

Scilab code Exa 6.14 14

```scilab
1  clc
2  T1 =673; //K
3  T2 =473; //K
4  T0 =303; //K
5  T1a = T2 ;
6
7  // dSa/dS=T1/T1a
8
9  // W=(T1-T0)*dS; Work done by the power cycle when
       there was no temperature difference between the
       vapour condensing and vapour evaporating
10 // Wa=(T1-T0)*dSa; Work done by the power cycle when
       the vapour condenses at 400 C and vapour
       evaporates at 200 C
11
12 // Fraction of energy that becomes unavailable is
       given by (W-Wa)/W
13
14 UAE = T0 *( T1 - T1a )/ T1a /( T1 - T0 );
15 disp ("the fraction of energy that becomes
       unavailable =")
16 disp ( UAE )
```

Scilab code Exa 6.15 15

```scilab
1  clc
2  T1 =293; //K
3  T2 =353; //K
4  Tf =1773; //K
5  T0 =288; //K
6  c_pl =6.3; //kJ/kg K
7
8  dAE = c_pl *( T2 - T1 ) - T0 * c_pl * log ( T2 / T1 );
9
10 n =(1 - T0 / Tf ); // efficiency
```

```
11
12  //W=heat supplied*efficiency
13  //The possible work from a heat engine is a measure
       of the loss of availability, E
14  E=c_pl*(T2-T1)*n;
15
16  Effectiveness=dAE/E;
17  disp("Effectiveness of the heating process =")
18  disp(Effectiveness)
```

Scilab code Exa 6.16 16

```
1   clc
2   T0=293; //K
3   T1=293; //K
4   T2=373; //K
5   T3=323; //K
6   cp=1.005;
7
8   disp("(i) The ratio of mass flow")
9   //cp=Specific heat of air constant pressure
10  //cp*T1 + x*cp*T2 = (1+x)*cp*T3
11  x=(T3-T1)/(T2-T3);
12  disp("x=")
13  disp(x)
14
15
16  disp("(ii) The effectiveness of heating process")
17  ds_13=cp*log(T3/T1);
18  ds_32=cp*log(T2/T3);
19  A=cp*(T3-T1) - T1*ds_13; //Increase of availability
       of system
20  B=x*[cp*(T2-T3)-T0*(ds_32)];// Loss of availability
       of surroundings
21
```

```
22  Effectiveness=A/B;
23  disp("Effectiveness of heating process=")
24  disp(Effectiveness)
```

Scilab code Exa 6.17 17

```
 1  clc
 2  m=2.5; //kg
 3  p1=6*10^5; //Pa
 4  r=2; //r=V2/V1
 5  cv=0.718; //kJ/kg K
 6  R=0.287; //kJ/kg K
 7  T1=363; //K
 8  p2=1*10^5; //Pa
 9  T2=278; //K
10  V1=m*R*T1/p1;
11  V2=2*V1;
12  T0=278; //K
13  p0=1*10^5; //Pa
14  Q=0; //adiabatic process
15
16  disp("(i)The maximum work")
17  dS=m*cv*log(T2/T1) + m*R*log(V2/V1);
18  Wmax=m*[cv*(T1-T2)] + T0*(cv*log(T2/T1) + R*log(V2/
       V1));
19  disp("Wmax=")
20  disp(Wmax)
21  disp("kJ")
22
23
24  disp("(ii)The change in availability")
25  dA=Wmax+p0*(V1-V2);
26  disp("Change in availability =")
27  disp(dA)
28  disp("kJ")
```

```
29
30
31  disp(" ( i i i )  The  i r r e v e r s i b i l i t y")
32
33  I=T0*m*(cv*log(T2/T1)+R*log(V2/V1));
34
35  disp(" I r r e v e r s i b i l i t y  =")
36  disp(I)
37  disp("kJ")
```

Scilab code Exa 6.18 18

```
 1  clc
 2  m=1;  //kg
 3  p1=7*10^5;  //Pa
 4  T1=873;  //K
 5  p2=1*10^5;  //Pa
 6  T2=523;  //K
 7  T0=288;  //K
 8  Q=-9;  //kJ/kg
 9  cp=1.005;  //kJ/kg K
10  R=0.287;  //kJ/kg K
11  disp(" ( i )  The  d e c r e a s e  in  a v a i l a b i l i t y  ")
12  dA=cp*(T1-T2) - T0*(R*log(p2/p1) - cp*log(T2/T1));
13  disp("dA=")
14  disp(dA)
15  disp("kJ/kg")
16
17
18  disp(" ( i i )  The  maximum  work")
19  Wmax=dA;  //change  in  a v a i l a b i l i t y
20  disp("Wmax")
21  disp(Wmax)
22  disp("kJ/kg")
23
```

```
24
25  disp("The irreversibility")
26  W=cp*(T1-T2) + Q;
27  I=Wmax - W;
28  disp("Irreversibility =")
29  disp(I)
30  disp("kJ/kg")
```

Scilab code Exa 6.19 19

```
 1  clc
 2  cp=1.005; //kJ/kg K
 3  cv=0.718; //kJ/kg K
 4  R=0.287; //kJ/kg K
 5  m=1; //kg
 6  T1=290; //K
 7  T0=290; //K
 8  T2=400; //K
 9  p1=1; //bar
10  p0=1; //bar
11  p2=6; //bar
12
13
14  //Wrev=change in internal energy − T0*change in
        entropy
15  disp("(i) The irreversibility")
16  Wrev=-[cv*(T2-T1) - T0*[cp*log(T2/T1) - R*log(p2/p1)
        ]];
17  n=[1/(1-log(T2/T1)/log(p2/p1))];
18  Wact=m*R*(T1-T2)/(n-1);
19
20  I=Wrev-Wact;
21  disp("Irreversibility=")
22  disp(I)
23  disp("kJ")
```

```
24
25
26 disp (" ( i i ) The  effectiveness  =  " )
27 effectiveness=Wrev/Wact *100;
28 disp ( effectiveness )
29 disp ("%" )
```

Scilab code Exa 6.20 20

```
1 clc
2 I =0.62;  // kg/mˆ2
3 N1=2500;  // rpm
4 w1=2*%pi*N1/60;  // rad / s
5 m=1.9;  // kg ;  Water  equivalent  of  shaft  bearings
6 cp =4.18;
7 T0=293;  //K
8 t0=20;  //0C
9
10 disp (" ( i ) Rise  in  temperature  of  bearings ")
11 KE=1/2* I *w1^2/1000;  //kJ
12 dT=KE/(m* cp );  // rise  in  temperature  of  bearings
13 disp (" dT=" )
14 disp ( dT )
15 disp (" 0C" )
16
17 t2=t0+dT ;
18 disp (" Final  temperature  of  the  bearings  =" )
19 disp ( t2 )
20 disp (" 0C" )
21
22 T2=t2+273;
23
24 disp (" ( i i ) Final  r . p.m.  of  the  flywheel ")
25 AE=integrate ( 'm* cp *(1−T0/T) ' ,  'T ' ,  T0 ,  T2 );
26 UE=KE  -  AE ;
```

```
27
28 disp (" A v a i l a b l e  energy  =")
29 disp (AE)
30 disp (" kJ " )
31
32 UAE=KE - AE ;
33 disp (" U n a v a i l a b l e  energy  =")
34 disp (UAE)
35 disp (" kJ " )
36
37 w2=sqrt (AE*10^3*2/ I ) ;
38 N2=w2*60/2/% pi ;
39 disp (" F i n a l  rpm  of  the  f l y w h e e l  =")
40 disp (N2)
41 disp (" rpm " )
```

Scilab code Exa 6.21 21

```
 1 clc
 2 p1 =8;  // bar
 3 T1 =453;  //K
 4 p2 =1.4;  // bar
 5 T2 =293;  //K
 6 T0=T2 ;
 7 p0 =1;  // bar
 8 m =1;  // kg
 9 C1 =80;  //m/ s
10 C2 =40;  //m/ s
11 cp =1.005;  // kJ / kg  K
12 R =0.287;  // kJ / kg  K
13 disp (" ( i )  R e v e r s i b l e  work  and  a c t u a l  work  " )
14 A1=cp *( T1 - T0 ) - T0 *( cp* log ( T1 / T0 ) -R* log ( p1 / p0 ) ) +C1
      ^2/2/10^3;  // A v a i l a b i l i t y  at  the  i n l e t
15 A2=cp *( T2 - T0 ) - T0 *( cp* log ( T2 / T0 ) -R* log ( p2 / p0 ) ) +C2
      ^2/2/10^3;  // A v a i l a b i l i t y  at  the  e x i t
```

```
16
17  W_rev=A1-A2;
18  disp("W_rev =")
19  disp(W_rev)
20  disp("kJ/kg")
21
22  W_act=cp*(T1-T2) + (C1^2-C2^2)/2/10^3;
23  disp("W_act =")
24  disp(W_act)
25  disp("kJ/kg")
26
27  disp("(ii) Irreversibilty and effectiveness =")
28
29  I=W_rev-W_act;
30  disp("Irreversibilty =")
31  disp(I)
32  disp("kJ/kg")
33
34  Effectiveness=W_act/W_rev*100;
35  disp("Effectiveness =")
36  disp(Effectiveness)
37  disp("%")
```

Scilab code Exa 6.22 22

```
1   clc
2   p1=20;  //bar
3   t1=400;  //0C
4   p2=4;  //bar
5   t2=250;  //0C
6   t0=20;  //0C
7   T0=t0+273;
8   h1=3247.6;  //kJ/kg
9   s1=7.127;  //kJ/kg K
10
```

```
11  //let h2'=h2a and s2'=s2a
12  h2a =2964.3;  //kJ/kg
13  s2a =7.379;  //kJ/kg K
14
15  s2=s1;
16  s1a=s1;
17
18  //By interpolation, we get
19  h2 =2840.8;  //kJ/kg
20
21
22  disp(" (i) Isentropic efficiency")
23  n_isen=(h1-h2a)/(h1-h2);
24  disp(" Isentropic efficiency =")
25  disp(n_isen)
26
27
28  disp(" (ii) Loss of availability")
29  A=h1-h2a + T0*(s2a-s1a);
30  disp(" Loss of availability=")
31  disp(A)
32  disp("kJ/kg")
33
34
35  disp(" (iii) Effectiveness")
36  Effectiveness=(h1-h2a)/A;
37  disp(" Effectiveness =")
38  disp(Effectiveness)
```

Chapter 7

Thermodynamic Relations

Scilab code Exa 7.17 17

```
1  clc
2  B=5*10^(-5); // /K
3  K=8.6*10^(-12); // m^2/N
4  v=0.114*10^(-3); //m^3/kg
5  p2=800*10^5; //Pa
6  p1=20*10^5; //Pa
7  T=288; //K
8  disp("(i) Work done on the copper = ")
9  W=-v*K/2*(p2^2-p1^2);
10 disp(W)
11 disp("J/kg")
12
13 disp("(ii) Change in entropy =")
14 ds=-v*B*(p2-p1);
15 disp(ds)
16 disp("J/kg K")
17
18 disp("(iii) The heat transfer =")
19 Q=T*ds;
20 disp(Q)
21 disp("J/kg")
```

```
22
23 disp("(iv) Change in internal energy =")
24 du=Q-W;
25 disp(du)
26 disp("J/kg")
27
28 disp("(v) cp     cv =")
29 R=B^2*T*v/K;
30 disp(R)
31 disp("J/kg K")
```

Scilab code Exa 7.18 18

```
1 clc
2 vg=0.1274; //m^3/kg
3 vf=0.001157; //m^3/kg
4 // dp/dT=32; //kPa/K
5 T3=473; //K
6
7 h_fg=32*10^3*T3*(vg-vf)/10^3;
8 disp("h_fg=")
9 disp(h_fg)
10 disp("kJ/kg")
```

Scilab code Exa 7.19 19

```
1 clc
2 h_fg=334; //kJ/kg
3 v_liq=1; //m^3/kg
4 v_ice=1.01; //m^3/kg
5 T1=273; //K
6 T2=263; //K
7 p1=1.013*10^5; //Pa
```

```
8
9  p2=(p1+h_fg*10^3/(v_ice-v_liq)*log(T1/T2))/10^5;
10 disp("p2=")
11 disp(p2)
12 disp("bar")
```

Scilab code Exa 7.20 20

```
1  clc
2  h_fg=294.54;  //kJ/kg
3
4  //  log(p)=7.0323 - 3276.6/T - 0.652*log(T)
5  // Differentiating both sides, we get
6  //  1/2.302/p*dp/dT=3276.6/T^2-0.652/2.302/T
7
8  //Putting p=0.1 bar , we get
9  p=0.1;  //bar
10 T=523;  //K
11
12 vg=h_fg*10^3/T/(2.302*3276.6*p*10^5/T^2 - 0.652*p
      *10^5/T);
13 disp("vg=")
14 disp(vg)
15 disp("m^3/kg")
```

Chapter 8

Ideal and Real Gases

Scilab code Exa 8.1 1

```
1  clc
2  R=287; //J/kg K
3  V1=40; //m^3
4  V2=40; //m^3
5  p1=1*10^5; //Pa
6  p2=0.4*10^5; //Pa
7  T1=298; //K
8  T2=278; //K
9
10 m1=p1*V1/R/T1;
11 m2=p2*V2/R/T2;
12
13 //Let mass of air removed be m
14 m=m1-m2;
15 disp("Mass of air removed =")
16 disp(m)
17 disp("kg")
18
19 V=m*R*T1/p1;
20 disp("Volume of gas removed =")
21 disp(V)
```

```
22 disp("m^3")
```

Scilab code Exa 8.2 2

```
1  clc
2  V=0.04; //m^3
3  p=120*10^5; //Pa
4  T=293; //K
5  R0=8314;
6
7  disp("(i) kg of nitrogen the flask can hold")
8  M=28; //molecular weight of Nitrogen
9  R=R0/M;
10
11 m=p*V/R/T;
12 disp("kg of nitrogen=")
13 disp(m)
14 disp("kg")
15
16
17 disp("(ii) Temperature at which fusible plug should
       melt")
18 p=150*10^5; //Pa
19
20 T=p*V/R/m; //K
21 t=T-273; //0C
22 disp("Temperature =")
23 disp(t)
24 disp(" C ")
```

Scilab code Exa 8.3 3

```
1  clc
```

```
2  p1 =1*10^5;  //Pa
3  T1 =293;  //K
4  d=6;  //m; diameter of the spherical balloon
5  p2 =0.94*p1;
6  T2 = T1 ;
7  cv =10400;  //J/kg K
8  R =8314/2;
9  r =3;  //m
10
11  disp (" (i) Mass of original gas escaped ")
12
13  // dm=m1-m2
14  // dm=(p1-p2)*V1/R/T1
15  // m1=p1*V1/R/T1
16
17  %mass_escaped =(p1 -p2)/p1*100;
18  disp (" %mass_escaped =")
19  disp (%mass_escaped)
20  disp ("%")
21
22  disp (" (ii)Amount of heat to be removed ")
23  T2 =0.94*T1;
24  m=p1*4/3*%pi*r^3/R/T1;
25
26  Q=m*cv*(T1 -T2)/10^6;
27  disp ("Q =")
28  disp (Q)
29  disp ("MJ")
```

Scilab code Exa 8.4 4

```
1  clc
2  m =28;  //kg
3  V1 =3;  //m^3
4  T1 =363;  //K
```

```
5  R0 =8314;
6  M=28;  // Molecular  mass  of  N2
7  R=R0/m;
8  V2=V1;
9  T2 =293;  //K
10
11 disp(" (i)  Pressure  (p1)  and  specific  volume  (v1)  of
      the  gas ")
12
13 p1=m*R*T1/V1/10^5;  // bar
14 disp(" Pressure  =")
15 disp(p1)
16 disp(" bar ")
17
18 v1=V1/m;
19 disp(" specific  volume=")
20 disp(v1)
21 disp("m^3/ kg ")
22
23
24 disp(" (ii)  cp  =  ?,  cv  =  ?")
25 // cp-cv=R/1000;
26 // cp - 1.4 cv =0;
27 // solving  the  above  two  eqns
28 A=[1 , -1;1 , -1.4];
29 B=[R/1000;0];
30 X=inv(A)*B;
31
32 cp=X(1 ,1);
33 disp(" cp=")
34 disp(cp)
35 disp(" kJ/kg  K")
36
37 cv=X(2 ,1);
38 disp(" cv=")
39 disp(cv)
40 disp(" kJ/kg  K")
41
```

```
42
43 disp(" (iii) Final pressure of the gas after cooling
        to 20 C")
44 p2=p1*T2/T1;
45 disp("p2=")
46 disp(p2)
47 disp("bar")
48
49
50 disp(" (iv) du, dh, s, Q")
51
52 du=cv*(T2-T1);
53 disp("Increase in specific internal energy=")
54 disp(du)
55 disp("kJ/kg")
56
57 dh=cp*(T2-T1);
58 disp("Increase in specific Enthalpy =")
59 disp(dh)
60 disp("kJ/kg")
61
62 v2=v1;
63 ds=cv*log(T2/T1) + R*log(v2/v1);
64 disp("Increase in specific entropy =")
65 disp(ds)
66 disp("kJ/kg K")
67
68 W=0; //constant volume process
69 Q=m*du+W;
70 disp("Heat transfer =")
71 disp(Q)
72 disp("kJ")
```

Scilab code Exa 8.5 5

```
 1  clc
 2
 3  disp (" Part (a)")
 4
 5  R=0.287;  //kJ/kg K
 6  y=1.4;
 7  m1=1;  //kg
 8  p1=8*10^5;  //Pa
 9  T1=373;  //K
10  p2=1.8*10^5;  //Pa
11  cv=0.717;  //kJ/kg K
12  n=1.2;
13  //pv^1.2 = constant
14
15  disp ("(i) The final specific volume, temperature and
          increase in entropy")
16
17  v1=R*10^3*T1/p1;
18  v2=v1*(p1/p2)^(1/n);
19  disp (" v2=")
20  disp (v2)
21  disp ("m^3/kg")
22
23  T2=p2*v2/R/10^3;  //K
24  t2=T2-273;  //0C
25  disp (" Final temperature =")
26  disp (t2)
27  disp (" 0C")
28
29  ds=cv*log(T2/T1) + R*log(v2/v1);
30  disp (" ds=")
31  disp (ds)
32  disp (" kJ/kg K")
33
34
35  disp ("(ii) Work done and heat transfer")
36
37  W=R*(T1-T2)/(n-1);
```

```
38  disp("Work done=")
39  disp(W)
40  disp("kJ/kg")
41
42  Q=cv*(T2-T1) + W;
43  disp("Heat transfer=")
44  disp(Q)
45  disp("kJ/kg")
46
47
48  disp("Part (b)")
49
50  disp("(i) Though the process is assumed now to be
        irreversible and adiabatic, the end states are
        given to be the same as in (a). Therefore, all
        the properties at the end of the process are the
        same as in (a).")
51
52
53  disp("(ii) Adiabatic process")
54  Q=0;
55  disp("Heat transfer=")
56  disp(Q)
57  disp("kJ/kg")
58
59  W=-cv*(T2-T1);
60  disp("Work done=")
61  disp(W)
62  disp("kJ/kg")
```

Scilab code Exa 8.6 6

```
1  clc
2  d=2.5; //m; diameter
3  V1=4/3*%pi*(d/2)^3; //volume of each sphere
```

```
4  T1=298;  //K
5  T2=298;  //K
6  m1=16;  //kg
7  m2=8;  //kg
8  V=2*V1;  //total  volume
9  m=m1+m2;
10 R=287;  //kJ/kg  K
11
12 p=m*R*T1/V/10^5;  //bar
13 disp("pressure  in  the  spheres  when  the  system
       attains  equilibrium=")
14 disp(p)
15 disp("bar")
```

Scilab code Exa 8.7 7

```
1  clc
2  m=6.5/60;  //kg/s
3  cv=0.837;  //kJ/kg  K
4  p1=10*10^5;  //Pa
5  p2=1.05*10^5;  //Pa
6  T1=453;  //K
7  R0=8.314;
8  M=44;  //Molecular  mass  of  CO2
9
10 R=R0/M;
11 cp=cv+R;
12 y=cp/cv;
13
14 T2=T1*(p2/p1)^((y-1)/y);
15 t2=T2-273;
16 disp("Final  temperature=")
17 disp(t2)
18 disp("0C")
19
```

```
20  v2=R*10^3*T2/p2;  //m^3/kg
21  disp("final specific volume =")
22  disp(v2)
23  disp("m^3/kg")
24
25  ds=0;  //Reversible and adiabatic process
26  disp("Increase in entropy=")
27  disp(ds)
28
29  Q=0;  //Adiabatic process
30  disp("Heat transfer rate from turbine=")
31  disp(Q)
32
33  W=m*cp*(T1-T2);
34  disp("Power delivered by the turbine=")
35  disp(W)
36  disp("kW")
```

Scilab code Exa 8.8 8

```
1  clc
2  p1=8*10^5;  //Pa
3  V1=0.035;  //m^3
4  T1=553;  //K
5  p2=8*10^5;  //Pa
6  V2=0.1;  //m^3
7  n=1.4;
8  R=287;  //J/kg K
9  T3=553;  //K
10 cv=0.71;  //kJ/kg K
11
12 m=p1*V1/R/T1;
13 T2=p2*V2/m/R;
14 p3=p2/((T2/T3)^(n/(n-1)));
15 V3=m*R*T3/p3;
```

```
16
17  disp(" (i) The heat received in the cycle")
18
19  //constant pressure process 1-2
20  W_12=p1*(V2-V1)/10^3;  //kJ
21  Q_12=m*cv*(T2-T1) + W_12;  //kJ
22
23  //polytropic process 2-3
24  W_23=m*R/10^3*(T2-T3)/(n-1);
25  Q_23=m*cv*(T3-T2) + W_23;
26
27  Q_received=Q_12 + Q_23;
28  disp("Total heat received in the cycle=")
29  disp(Q_received)
30  disp("kJ")
31
32
33  disp(" (ii) The heat rejected in the cycle")
34
35  //Isothermal process 3-1
36  W_31=p3*V3*log(V1/V3)/10^3;  //kJ
37  Q_31=m*cv*(T3-T1) + W_31;
38  disp("Heat rejected in the cycle =")
39  disp(-Q_31)
40  disp("kJ")
41
42
43  disp(" (ii) Efficiency of the cycle")
44  n=(Q_received - (-Q_31))/Q_received*100;
45  disp("Efficiency of the cycle =")
46  disp(n)
47  disp("%")
```

Scilab code Exa 8.9 9

```
1  clc
2  v=44;  //m^3/kg−mol
3  T=373;  //K
4
5  disp(" (i) Using Van der Waals  equation")
6
7  a=362850;  //N*m^4/(kg−mol)^2
8  b=0.0423;  //M^3/kg−mol
9  R0=8314;  //J/kg K
10
11  p=((R0*T/(v-b)) - a/v^2);
12  disp("Pressure using Van der Waals equation=")
13  disp(p)
14  disp("N/m^2")
15
16
17  disp(" (ii) Using perfect gas equation")
18
19  p=R0*T/v;
20  disp("Pressure using perfect gas equation=")
21  disp(p)
22  disp("N/m^2")
```

Scilab code Exa 8.10 10

```
1  clc
2  V=3;  //m^3
3  m=10;  //kg
4  T=300;  //K
5
6  disp(" (i) Using perfect gas equation")
7  R0=8314;
8  M=44;
9  R=R0/M;
10  p=m*R*T/V;
```

```
11  disp("Pressure Using perfect gas equation =")
12  disp(p)
13  disp("N/m^2")
14
15
16  disp("(ii) Using Van der Waals  equation")
17  a=362850;  //Nm^4/(kg−mol)^2
18  b=0.0423;  //m^3/(kg−mol)
19  v=13.2;  //m^3/kg−mol
20
21  p=R0*T/(v-b) - a/v^2;
22  disp("Pressure Using Van der Waals  equation=")
23  disp(p)
24  disp("N/m^2")
25
26
27  disp("(iii) Using Beattie Bridgeman equation")
28
29  A0=507.2836;
30  a=0.07132;
31  B0=0.10476;
32  b=0.07235;
33  C=66*10^4;
34  A=A0*(1-a/v);
35  B=B0*(1-b/v);
36  e=C/v/T^3;
37
38  p=R0*T*(1-e)/v^2*(v+B) - A/v^2;
39  disp("Pressure Using Beattie Bridgeman equation = ")
40  disp(p)
41  disp("N/m^2")
```

Scilab code Exa 8.11 11

```
1  clc
```

```
 2  a =139250;  //Nmˆ4/(kg−mol)ˆ2
 3  b =0.0314;  //mˆ3/kg−mol
 4  R0 =8314;  //Nm/kg−mol K
 5  v1 =0.2*32;  //mˆ3/kg−mol
 6  v2 =0.08*32;  //mˆ3/kg−mol
 7  T =333;  //K
 8  disp(" (i) Work done during the process")
 9  W=integrate('R0*T/(v−b) − a/vˆ2', 'v', v1, v2);
10  disp("W=")
11  disp(W)
12  disp("Nm/kg−mol")
13
14
15  disp("(ii) The final pressure")
16  p2=R0*T/(v2-b) - a/v2^2;
17  disp("p2=")
18  disp(p2)
19  disp("N/mˆ2")
```

Scilab code Exa 8.12 12

```
 1  clc
 2  pr =20;
 3  Z =1.25;
 4  Tr =8.0;
 5  Tc =282.4;  //K
 6
 7  T=Tc*Tr;
 8  disp(" Temperature =")
 9  disp(T)
10  disp("K")
```

Scilab code Exa 8.13 13

```
1  clc
2  p=260*10^5; //Pa
3  T=288; //K
4  pc=33.94*10^5; //Pa
5  Tc=126.2; //K
6  R=8314/28;
7
8  pr=p/pc;
9  Tr=T/Tc;
10 Z=1.08;
11
12 rho=p/Z/R/T;
13 disp("Density of N2=")
14 disp(rho)
15 disp("kg/m^3")
```

Scilab code Exa 8.14 14

```
1  clc
2  p=200*10^5; //Pa
3  pc=73.86*10^5; //Pa
4  Tc=304.2; //K
5  pr=p/pc;
6  Z=1;
7  Tr=2.48;
8
9  T=Tr*Tc;
10 disp("Temperature =")
11 disp(T)
12 disp("K")
```

Scilab code Exa 8.15 15

```
1  clc
2  d=12; //m; diameter of spherical balloon
3  V=4/3*%pi*(d/2)^3;
4  T=303; //K
5  p=1.21*10^5; //Pa
6  pc=12.97*10^5; //Pa
7  Tc=33.3; //K
8  R=8314/2;
9
10 pr=p/pc;
11 Tr=T/Tc;
12 Z=1;
13
14 m=p*V/Z/R/T;
15 disp("Mass of H2 in the balloon =")
16 disp(m)
17 disp("kg")
```

Scilab code Exa 8.16 16

```
1  clc
2
3  // dp_c/dv=0
4  // d^2 p/dv^2=0
5
6  // p_cp=R0*T_cp/(v_cp-b) - a/v_cp^2
7
8  // As T_cp is constant
9  // dp_cp/dv_cp=(-R0*T_cp)/(v_cp-b)^2 + 2*a/v_cp^3 =
      0
10
11 // d^2 p_cp/dv_cp=2*R0*T_cp/(v_cp-b)^3 - 6*a/v_cp^4
      = 0
12
13 // Solving these we get v_cp=3*b;
```

```
14  //  2*a/v_cp^3  -  R0*T_cp/[v_cp-1/3*v_cp]^2
15
16  //a=9/8*R0*T_cp*v_cp
17
18  //Z_cp=p_cp*v_cp/R0/T_cp
19
20  Z_cp=3/2-9/8;
21
22  disp("Z_cp=")
23  disp(Z_cp)
```

Chapter 9

Gases and Vapour Mixtures

Scilab code Exa 9.1 1

```scilab
1  clc
2  V=0.35; //m^3
3  m_CO=0.4; //kg
4  m_air=1; //kg
5  m_O2=0.233; //kg
6  m_N2=0.767; //kg
7  T=293; //K
8  R0=8.314; //kJ/kg K
9  M_O2=32; //Molecular mass of O2
10 M_N2=28; //Molecular mass of N2
11 M_CO=28; //Molecular mass of CO
12
13 disp("Partial Pressures=")
14
15 p_O2=m_O2*R0*10^3*T/M_O2/V/10^5; //bar
16 disp("partial pressure for p_O2")
17 disp(p_O2)
18 disp("bar")
19
20 p_N2=m_N2*R0*10^3*T/M_N2/V/10^5; //bar
21 disp("partial pressure for p_N2")
```

```
22 disp(p_N2)
23 disp("bar")
24
25 p_CO=m_CO*R0*10^3*T/M_CO/V/10^5;  //bar
26 disp("partial pressure for p_CO")
27 disp(p_CO)
28 disp("bar")
29
30
31 disp("(ii) Total pressure in the vessel")
32 p=p_O2+p_N2+p_CO;
33 disp("p=")
34 disp(p)
35 disp("bar")
```

Scilab code Exa 9.2 2

```
1 clc
2 R0=8.314;
3
4 M_O2=32;
5 M_N2=28;
6 M_Ar=40;
7 M_CO2=44;
8
9 R_O2=R0/M_O2;  //kJ/kg K
10 R_N2=R0/M_N2;  //kJ/kg K
11 R_Ar=R0/M_Ar;  //kJ/kg K
12 R_CO2=R0/M_CO2;  //kJ/kg K
13
14 %O2=0.2314;
15 %N2=0.7553;
16 %Ar=0.0128;
17 %CO2=0.0005;
18
```

```
19 disp(" (i) Gas constant for air")
20 R=%O2*R_O2 + %N2*R_N2 + %Ar*R_Ar + %CO2*R_CO2;
21 disp("R=")
22 disp(R)
23 disp("kJ/kg K")
24
25 disp(" (ii) Apparent molecular weight.")
26 M=R0/R;
27 disp("M=")
28 disp(M)
```

Scilab code Exa 9.3 3

```
1 clc
2 p=1; //bar
3
4 //For oxygen
5 m_O2=0.2314;
6 M_O2=32;
7 n_O2=m_O2/M_O2;
8
9 //For Nitrogen
10 m_N2=0.7553;
11 M_N2=28;
12 n_N2=m_N2/M_N2;
13
14 //For Argon
15 m_Ar=0.0128;
16 M_Ar=40;
17 n_Ar=m_Ar/M_Ar;
18
19 //For CO2
20 m_CO2=0.0005;
21 M_CO2=44;
22 n_CO2=m_CO2/M_CO2;
```

```
23
24
25  n=n_O2 + n_N2 + n_Ar + n_CO2;
26
27  //Let Vi/V be A
28
29  A_O2=n_O2/n * 100;
30  disp(" Vi/V of O2=")
31  disp(A_O2)
32  disp("%")
33
34  A_N2=n_N2/n * 100;
35  disp(" Vi/V of N2=")
36  disp(A_N2)
37  disp("%")
38
39  A_Ar=n_Ar/n *100;
40  disp(" Vi/V of Ar")
41  disp(A_Ar)
42  disp("%")
43
44  A_CO2=n_CO2/n * 100;
45  disp(" Vi/V of CO2=")
46  disp(A_CO2)
47  disp("%")
48
49
50  P_O2=n_O2/n*p;
51  disp(" Partial pressure of O2=")
52  disp(P_O2)
53  disp(" bar")
54
55  P_N2=n_N2/n*p;
56  disp(" Partial pressure of N2=")
57  disp(P_N2)
58  disp(" bar")
59
60  P_Ar=n_Ar/n*p;
```

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```
61 disp("Partial  pressure  of  Ar=")
62 disp(P_Ar)
63 disp("bar")
64
65 P_CO2=n_CO2/n*p;
66 disp("Partial  pressure  of  CO2=")
67 disp(P_CO2)
68 disp("bar")
```

Scilab code Exa 9.4 4

```
1 clc
2 p=1*10^5;  //Pa
3 T=293;  //K
4 n_CO2=1;  //moles  of  CO2
5 n=4;  //moles  of  air
6 M_CO2=44;
7 M_N2=28;
8 M_O2=32;
9
10 //Let  A  be  the  volumeetric  analysis
11 A_O2=0.21;
12 A_N2=0.79;
13
14 n_O2=A_O2*n;
15 n_N2=A_N2*n;
16
17 disp("(i)  The  masses  of  CO2,  O2  and  N2,  and  the
     total  mass")
18
19 m_CO2=n_CO2*M_CO2;
20 disp("Mass  of  CO2=")
21 disp(m_CO2)
22 disp("kg")
23
```

```
24  m_O2=n_O2*M_O2;
25  disp("Mass of O2=")
26  disp(m_O2)
27  disp("kg")
28
29  m_N2=n_N2*M_N2;
30  disp("Mass of N2=")
31  disp(m_N2)
32  disp("kg")
33
34  m=m_CO2 + m_O2 + m_N2;
35  disp("Total mass =")
36  disp(m)
37  disp("kg")
38
39
40  disp("(ii) The percentage carbon content by mass")
41  //Since the molecular weight of carbon is 12,
        therefore, there are 12 kg of carbon present for
        every mole of CO2
42  m_C=12; //kg
43
44  %C=m_C/m*100;
45  disp("Percentage carbon in mixture")
46  disp(%C)
47  disp("%")
48
49
50  disp("(iii) The apparent molecular weight and the
        gas constant for the mixture")
51  n=n_CO2 + n_O2 + n_N2;
52  M=n_CO2/n*M_CO2 + n_O2/n*M_O2 + n_N2/n*M_N2;
53  disp("Apparent Molecular weight")
54  disp(M)
55
56  R0=8.314;
57  R=R0/M;
58  disp("Gas constant for the mixture=")
```

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```
59  disp(R)
60  disp("kJ/kg K")
61
62
63  disp(" (iv) The specific volume of the mixture")
64  v=R*10^3*T/p;
65  disp(" specific volume=")
66  disp(v)
67  disp("m^3/kg")
```

Scilab code Exa 9.5 5

```
1  clc
2  p=1*10^5; //Pa
3  T=298; //K
4  M_H2=2;
5  M_O2=32;
6  R0=8314;
7
8  // ratio = V_H2/V_O2=2;
9  ratio=2;
10
11  disp(" (i) The mass of O2 required")
12  //Let the mass of O2 per kg of H2 = x kg
13  m_H2=1; //kg
14  n_H2=m_H2/M_H2;
15
16  // n_O2=x/M_O2
17  x=M_O2*n_H2/ratio;
18  disp("Mass of O2 per kg of H2=")
19  disp(x)
20  disp("kg")
21
22
23  disp(" (ii) The volume of the container")
```

```
24  n_O2=x/M_O2;
25  n=n_H2 + n_O2;
26  V=n*R0*T/p;
27  disp("V=")
28  disp(V)
29  disp("m^3")
```

Scilab code Exa 9.6 6

```
1  clc
2
3  //Let composition of mixture by volume be denoted by
        c1
4  //Let Final composition desired be denoted by c2
5
6  c1_H2=0.78;
7  c1_CO=0.22;
8
9  c2_H2=0.52;
10 c2_CO=0.48;
11
12 M_H2=2;
13 M_CO=28;
14
15 M=c1_H2*M_H2 + c1_CO*M_CO;
16
17 // Let x kg of mixture be removed and y kg of CO be
     added.
18
19 x=(c1_H2 - c2_H2)/c1_H2*M;
20 disp("Mass of mixture removed =")
21 disp(x)
22 disp("kg")
23
24 y=M_CO/M*x;
```

```
25  disp("Mass of CO added=")
26  disp(y)
27  disp("kg")
```

Scilab code Exa 9.7 7

```
 1  clc
 2
 3  ratio=1/8;  //volume ratio; v1/v2
 4  T1=1223;  //K
 5
 6  cp_CO2=1.235;  //kJ/kg K
 7  cp_O2=1.088;  //kJ/kg K
 8  cp_N2=1.172;  //kJ/kg K
 9
10  n_CO2=0.13;
11  n_O2=0.125;
12  n_N2=0.745;
13
14  M_CO2=44;
15  M_O2=32;
16  M_N2=28;
17
18  m_CO2=M_CO2*n_CO2;
19  m_O2=M_O2*n_O2;
20  m_N2=M_N2*n_N2;
21
22  m=m_CO2 + m_O2 + m_N2;
23
24  // Let Fraction by mass be denoted by F
25  F_CO2=m_CO2/m;
26  F_O2=m_O2/m;
27  F_N2=m_N2/m;
28
29
```

```scilab
30  cp=F_CO2*cp_CO2 + F_O2*cp_O2 + F_N2*cp_N2;
31
32  R0=8.314;
33  R=F_CO2*R0/M_CO2 + F_O2*R0/M_O2 + F_N2*R0/M_N2;
34
35  cv=cp - R;
36  n=1.2;
37
38  disp(" (i) The workdone")
39  T2=T1*(ratio)^(n-1);
40  W=R*(T1-T2)/(n-1);
41  disp("W=")
42  disp(W)
43  disp("kJ/kg")
44
45
46  disp(" (ii) The heat flow")
47  du=cv*(T2-T1);
48  Q=du + W;
49  disp("Q=")
50  disp(Q)
51  disp("kJ/kg")
52
53
54  disp(" (iii) Change of entropy per kg of mixture")
55  ds_1A=R*log(1/ratio); //isothermal process
56  ds_2A=cv*log(T1/T2);
57
58  ds_12=ds_1A - ds_2A;
59  disp("change of entropy=")
60  disp(ds_12)
61  disp("kJ/kg K")
```

Scilab code Exa 9.8 8

```scilab
1  clc
2
3  M_CO2=44;
4  M_H2=2;
5  M_N2=28;
6  M_CH4=16;
7  M_CO=28;
8
9  // Let volumetric analysis be denoted by V
10  V_CO=0.28;
11  V_H2=0.13;
12  V_CH4=0.04;
13  V_CO2=0.04;
14  V_N2=0.51;
15
16  Cp_CO=29.27; //kJ/mole K
17  Cp_H2=28.89; //kJ/mole K
18  Cp_CH4=35.8; //kJ/mole K
19  Cp_CO2=37.22; //kJ/mole K
20  Cp_N2=29.14; //kJ/mole K
21
22  R0=8.314;
23
24  Cp=V_CO*Cp_CO + V_H2*Cp_H2 + V_CO2*Cp_CO2 + V_CH4*
       Cp_CH4 + V_N2*Cp_N2;
25  disp("Cp=")
26  disp(Cp)
27  disp("kJ/mole K")
28
29  Cv=Cp-R0;
30  disp("Cv=")
31  disp(Cv)
32  disp("kJ/mole K")
33
34  M=V_CO*M_CO + V_H2*M_H2 + V_CO2*M_CO2 + V_CH4*M_CH4
       + V_N2*M_N2;
35
36  cp=Cp/M;
```

```
37  disp("cp=")
38  disp(cp)
39  disp("kJ/kg K")
40
41  cv=Cv/M;
42  disp("cv")
43  disp(cv)
44  disp("kJ/kg K")
```

Scilab code Exa 9.9 9

```
 1  clc
 2
 3  p=1.3;  //bar
 4  R0=8.314;
 5
 6  M_CO2=44;
 7  M_O2=32;
 8  M_N2=28;
 9  M_CO=28;
10
11  m_O2=0.1;
12  m_N2=0.7;
13  m_CO2=0.15;
14  m_CO=0.05;
15
16  //Considering 1 kg of mixture
17  m=1;  //kg
18
19  //let moles be denoted by n
20  n_O2=m_O2/M_O2;
21  n_N2=m_N2/M_N2;
22  n_CO2=m_CO2/M_CO2;
23  n_CO=m_CO/M_CO;
24
```

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```scilab
25  M=1/(m_O2/M_O2 + m_N2/M_N2 + m_CO2/M_CO2 + m_CO/M_CO
       );
26
27  n=m/M;
28
29  x_O2=n_O2/n;
30  x_N2=n_N2/n;
31  x_CO2=n_CO2/n;
32  x_CO=n_CO/n;
33
34  disp(" (i) Partial pressures of the constituents")
35  P_O2=x_O2*p;
36  disp(" Partial pressure of O2=")
37  disp(P_O2)
38  disp(" bar")
39
40  P_N2=x_N2*p;
41  disp(" Partial pressure of N2=")
42  disp(P_N2)
43  disp(" bar")
44
45  P_CO2=x_CO2*p;
46  disp(" Partial pressure of CO2=")
47  disp(P_CO2)
48  disp(" bar")
49
50  P_CO=x_CO*p;
51  disp(" Partial pressure of CO=")
52  disp(P_CO)
53  disp(" bar")
54
55  disp(" Gas constant of mixture =")
56  R_mix=R0/M;
57  disp(R_mix)
58  disp(" kJ/kg K")
```

Scilab code Exa 9.10 10

```scilab
1  clc
2  p=4*10^5;  //Pa
3  T=293;  //K
4  R0=8.314;
5
6  m_N2=4;  //kg
7  m_CO2=6;  //kg
8
9  M_N2=28;  //Molecular mass
10 M_CO2=44;  //Molecular mass
11
12 n_N2=m_N2/M_N2;  //moles of N2
13 n_CO2=m_CO2/M_CO2;  //moles of CO2
14
15 x_N2=n_N2/(n_N2+n_CO2);
16 disp("x_N2=")
17 disp(x_N2)
18
19 x_CO2=n_CO2/(n_CO2+n_N2);
20 disp("x_CO2=")
21 disp(x_CO2)
22
23
24 disp("(ii) The equivalent molecular weight of the
       mixture")
25 M=x_N2*M_N2 + x_CO2*M_CO2;
26 disp("M=")
27 disp(M)
28 disp("kg/kg-mole")
29
30
31 disp("(iii) The equivalent gas constant of the
```

```
        mixture")
32  m=m_N2+m_CO2;
33  Rmix=(m_N2*(R0/M_N2) + m_CO2*(R0/M_CO2))/m;
34  disp("Rmix=")
35  disp(Rmix)
36  disp("kJ/kg K")
37
38
39  disp("(iv) The partial pressures and partial volumes
        ")
40  P_N2=x_N2*p/10^5;
41  disp("P_N2=")
42  disp(P_N2)
43  disp("bar")
44
45  P_CO2=x_CO2*p/10^5;
46  disp("P_CO2=")
47  disp(P_CO2)
48  disp("bar")
49
50  V_N2=m_N2*R0/M_N2*T/p*10^3;
51  disp("V_N2")
52  disp(V_N2)
53  disp("m^3")
54
55  V_CO2=m_CO2*R0/M_CO2*T/p*10^3;
56  disp("V_CO2")
57  disp(V_CO2)
58  disp("m^3")
59
60  disp("(v) The volume and density of the mixture")
61
62  V=m*Rmix*10^3*T/p;
63  disp("V=")
64  disp(V)
65  disp("m^3")
66
67  rho_mix=m/V;
```

```
 68  disp("Density of mixture=")
 69  disp(rho_mix)
 70  disp("kg/m^3")
 71
 72
 73  disp("(vi) cp and cv of the mixture")
 74
 75  y_N2=1.4;
 76  cv_N2=(R0/M_N2)/(y_N2 - 1);
 77  cp_N2=cv_N2*y_N2;
 78
 79  y_CO2=1.286;
 80  cv_CO2=(R0/M_CO2)/(y_CO2 - 1);
 81  cp_CO2=cv_CO2*y_CO2;
 82
 83  cp=(m_N2*cp_N2 + m_CO2*cp_CO2)/(m_N2+m_CO2);
 84  disp("cp=")
 85  disp(cp)
 86  disp("kJ/kg K")
 87
 88  cv=(m_N2*cv_N2 + m_CO2*cv_CO2)/(m_N2+m_CO2);
 89  disp("cv=")
 90  disp(cv)
 91  disp("kJ/kg K")
 92
 93
 94
 95  T1=293;  //K
 96  T2=323;  //K
 97  dU=m*cv*(T2-T1);
 98  disp("Change in internal energy =")
 99  disp(dU)
100  disp("kJ")
101
102  dH=m*cp*(T2-T1);
103  disp("Change in enthalpy =")
104  disp(dH)
105  disp("kJ")
```

```
106
107  dS=m*cv*log(T2/T1);  //Constant  volume  process
108  disp("Change  in  entropy=")
109  disp(dS)
110  disp("kJ/kg  K")
111
112
113  disp("When  the  mixture  is  heated  at  constant
         pressure")
114
115  disp("If  the  mixture  is  heated  at  constant  pressure
         U  and    H  will  remain  the  same")
116
117  dS=m*cp*log(T2/T1);
118  disp("Change  in  entropy  =")
119  disp(dS)
120  disp("kJ/kg  K")
```

Scilab code Exa 9.11 11

```
1  clc
2
3  Cv_O2=21.07;  //kJ/mole  K
4  Cv_CO=20.86;  //kJ/mole  K
5
6  p_O2=8*10^5;  //Pa
7  p_CO=1*10^5;  //Pa
8
9  V_O2=1.8;  //m^3
10  V_CO=3.6;  //m^3
11
12  T_O2=323;  //K
13  T_CO=293;  //K
14
15  R0=8314;
```

```
16
17  n_O2=p_O2*V_O2/R0/T_O2;
18  n_CO=p_CO*V_CO/R0/T_CO;
19
20  n=(n_O2+n_CO);
21  V=(V_O2+V_CO);
22
23  disp("(i) Final temperature (T) and pressure (p) of
       the mixture")
24
25  //Before mixing
26  U1=n_O2*Cv_O2*T_O2 + n_CO*Cv_CO*T_CO;
27
28  //After mixing
29  //U2=T*(n_O2*Cv_O2 + n_CO*Cv_CO);
30  //U1=U2
31
32  T=U1/(n_O2*Cv_O2 + n_CO*Cv_CO);
33  t=T-273;
34  disp("Final temperature =")
35  disp(t)
36  disp(" C")
37
38  p=n*R0*T/V/10^5;
39  disp("Final pressure =")
40  disp(p)
41  disp("bar")
42
43
44  disp("(ii) Change of entropy")
45  //For oxygen
46  dS_O1A=n_O2*R0*log(V/V_O2); //isothermal process
47  dS_O2A=n_O2*Cv_O2*log(T_O2/T); //constant volume
       process
48
49  dS_O12=dS_O1A - dS_O2A; // Change of entropy of O2
50
51  //For CO
```

```
52
53  dS_CO12=n_CO*R0*log(V/V_CO) + n_CO*Cv_CO*log(T/T_CO)
        ; //Change of entropy of CO
54
55
56  dS=(dS_O12 + dS_CO12)/10^3;
57  disp("Change of entropy of system =")
58  disp(dS)
59  disp("kJ/K")
```

Scilab code Exa 9.12 12

```
1   clc
2
3   p_A=16*10^5; //Pa
4   p_B=6.4*10^5; //Pa
5
6   T_A=328; //K
7   T_B=298; //K
8
9   n_A=0.6; //kg-mole
10  m_B=3; //kg
11
12  R0=8314;
13  M_A=28;
14  y=1.4;
15
16  V_A=n_A*R0*T_A/p_A;
17
18  m_A=n_A*M_A;
19  R=R0/M_A;
20
21  V_B=m_B*R*T_B/p_B;
22
23  V=V_A+V_B;
```

```
24  m=m_A+m_B ;
25  T=303;  //K
26
27
28  disp ( " ( a )  ( i )  Final  equilibrium  pressure ,  p" )
29  p=m*R*T/V/10^5 ;
30  disp ( " p=" )
31  disp ( p )
32  disp ( " bar " )
33
34  cv=R/10^3/( y-1) ;
35
36  disp ( " ( i i )  Amount  of  heat  transferred ,  Q  : " )
37
38  U1=cv *( m_A*T_A  +  m_B*T_B ) ;
39  U2=m* cv*T ;
40
41  Q=U2-U1 ;
42  disp ( " Q=" )
43  disp (Q )
44  disp ( " kJ " )
45
46
47  disp ( " ( b )  If  the  vessel  were  insulated  : " )
48
49  disp ( " ( i )  Final  temperature , " )
50
51  T=cv *( m_A*T_A  +  m_B*T_B ) /( m* cv ) ;
52  t=T-273 ;
53  disp ( " T=" )
54  disp ( t )
55  disp ( "  C " )
56
57
58  disp ( " ( i i )  Final  pressure " )
59
60  p=m*R*T/V/10^5 ;
61  disp ( " p=" )
```

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```
62 disp(p)
63 disp("bar")
```

Scilab code Exa 9.13 13

```
1  clc
2
3  m_O2=3;  //kg
4  M_O2=32;
5
6  m_N2=9;  //kg
7  M_N2=28;
8
9  R0=8.314;
10
11 R_O2=R0/M_O2;
12 R_N2=R0/M_N2;
13
14 x_O2=(m_O2/M_O2)/((m_O2/M_O2) + (m_N2/M_N2));
15 x_N2=(m_N2/M_N2)/((m_O2/M_O2) + (m_N2/M_N2));
16
17 dS=-m_O2*R_O2*log(x_O2) -m_N2*R_N2*log(x_N2);
18 disp("Change in entropy =")
19 disp(dS)
20 disp("kJ/kg K")
```

Scilab code Exa 9.14 14

```
1  clc
2  m_N2=2.5;  //kg
3  M_N2=28;
4
5  p_N2=15;  //bar
```

```
6  p_total=20;  //bar
7
8  n_N2=m_N2/M_N2;
9  p_O2=p_total-p_N2;
10
11 n_O2=p_O2/p_N2*n_N2;
12 M_O2=32;
13
14 m_O2=n_O2*M_O2;
15 disp("Mass  of  O2  added  =")
16 disp(m_O2)
17 disp("kg")
```

Scilab code Exa 9.15 15

```
1  clc
2  n_O2=1;
3
4  //V_O2=0.21*V;
5  //V_N2=0.79*V;
6  M_N2=28;
7  M_O2=32;
8
9  disp("(i)  Moles  of  N2  per  mole  of  O2  :")
10 n_N2=n_O2*0.79/0.21;
11 disp("n_N2=")
12 disp(n_N2)
13 disp("moles")
14
15 n=n_O2+n_N2;
16 disp("(ii)  p_O2  and  p_N2  :")
17 p=1;  //atm
18
19 p_O2=n_O2/n*p;
20 disp("p_O2=")
```

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```
21  disp(p_O2)
22  disp("atm")
23
24  p_N2=n_N2/n*p;
25  disp("p_N2=")
26  disp(p_N2);
27  disp("atm")
28
29
30  disp("(iii) The kg of nitrogen per kg of mixture :")
31  x=n_N2*M_N2/(n_N2*M_N2+n_O2*M_O2);
32  disp(" The kg of nitrogen per kg of mixture =")
33  disp(x)
34  disp("kg N2/kg mix")
```

Scilab code Exa 9.16 16

```
1   clc
2   V=0.6;  //m^3
3   p1=12*10^5;  //Pa
4   p2=18*10^5;  //Pa
5   T=298;  //K
6   R0=8.314;
7   x_O2=0.23;
8   x_N2=0.77;
9
10  n=p1*V/R0/10^3/T;
11
12  //Considering 100 kg of air
13  m_O2=23;  //kg
14  m_N2=77;  //kg
15  M_O2=32;
16  M_N2=28;
17  m=100;  //kg
18
```

```
19  R=(m_O2/M_O2 + m_N2/M_N2)*R0/m; //for  air
20  M=R0/R; //for  air
21
22  m=p1*V/R/T/10^3;
23
24  m_O2=x_O2*m;
25  disp("Mass  of  O2=")
26  disp(m_O2)
27  disp("kg")
28
29  m_N2=x_N2*m;
30  disp("Mass  of  N2=")
31  disp(m_N2)
32  disp("kg")
33
34
35  //After  adding  CO2  in  the  vessel
36  p2=18*10^5; //Pa;
37
38  //  p_CO2+p_N2+p_O2=18*10^5
39  //  p_N2 + p_O2=12*10^5
40
41  p_CO2=6*10^5; //Pa
42  M_CO2=44;
43  R_CO2=R0/M_CO2;
44
45  m_CO2=p_CO2*V/(R_CO2*10^3*T);
46  disp("Mass  of  CO2 = ")
47  disp(m_CO2)
48  disp("kg")
```

Scilab code Exa 9.17 17

```
1  clc
2  V=6; //m^3
```

```
 3  %A=0.45;
 4  %B=0.55;
 5  R_A=0.288;  //kJ/kg K
 6  R_B=0.295;  //kJ/kg K
 7  m=2;  //kg
 8  T=303;  //K
 9
10  disp(" ( i )  The  partial  pressures")
11  m_A=%A*m;
12  m_B=%B*m;
13
14  p_A=m_A*R_A*10^3*T/V/10^5;  //bar
15  disp(" p_A=")
16  disp(p_A)
17  disp(" bar")
18
19  p_B=m_B*R_B*10^3*T/V/10^5;  //bar
20  disp(" p_B=")
21  disp(p_B)
22  disp(" bar")
23
24
25  disp(" ( ii )  The  total  pressure")
26  p=p_A+p_B;
27  disp(" p=")
28  disp(p)
29  disp(" bar")
30
31
32  disp(" ( iii )  The  mean  value  of  R  for  the  mixture")
33  Rm=(m_A*R_A + m_B*R_B)/(m_A + m_B);
34  disp(" Rm=")
35  disp(Rm)
36  disp(" kJ/kg  K")
```

Scilab code Exa 9.18 18

```
1  clc
2  m_O2=4;  //kg
3  m_N2=6;  //kg
4  p=4*10^5;  //Pa
5  T=300;  //K
6  M_O2=32;
7  M_N2=28;
8  m=10;  //kg
9
10 disp(" (i) The mole fraction of each component")
11 n_O2=m_O2/M_O2;
12 n_N2=m_N2/M_N2;
13
14 x_O2=n_O2/(n_O2+n_N2);
15 disp("x_O2=")
16 disp(x_O2)
17
18 x_N2=n_N2/(n_N2+n_O2);
19 disp("x_N2=")
20 disp(x_N2)
21
22
23 disp(" (ii) The average molecular weight")
24 M=(n_O2*M_O2 + n_N2*M_N2)/(n_O2 + n_N2);
25 disp("M=")
26 disp(M)
27
28
29 disp(" (iii) The specific gas constant")
30 R0=8.314;
31 R=R0/M;
32 disp("R=")
33 disp(R)
34 disp("kJ/kg K")
35
36 disp(" (iv) The volume and density")
```

```scilab
37
38  V=m*R*T*10^3/p;
39  disp("V=")
40  disp(V)
41  disp("m^3")
42
43  rho=(m_O2/V) + (m_N2/V);
44  disp("density=")
45  disp(rho)
46  disp("kg/m^3")
47
48
49  disp("(v) The partial pressures and partial volumes"
       )
50
51  p_O2=n_O2*R0*10^3*T/V/10^5;  //bar
52  disp("p_O2=")
53  disp(p_O2)
54  disp("bar")
55
56  p_N2=n_N2*R0*10^3*T/V/10^5;  //bar
57  disp("p_N2=")
58  disp(p_N2)
59  disp("bar")
60
61  V_O2=x_O2*V;
62  disp("V_O2=")
63  disp(V_O2)
64  disp("m^3")
65
66  V_N2=x_N2*V;
67  disp("V_N2=")
68  disp(V_N2)
69  disp("m^3")
```

Scilab code Exa 9.19 19

```
 1  clc
 2  cp_CO2=0.85; //kJ/kg K
 3  cp_N2=1.04; //kJ/kg K
 4  m_CO2=4; //kg
 5  T1_CO2=313; //K
 6  m_N2=8; //kg
 7  T1_N2=433; //K
 8  p2=0.7; //bar
 9  p1_CO2=1.4; //bar
10  p1_N2=1;
11  R=8.314;
12  M_CO2=44;
13  M_N2=28;
14  R_CO2=R/M_CO2;
15  R_N2=R/M_N2;
16
17  disp(" (i) Final temperature, T2")
18  T2=(m_CO2*cp_CO2*T1_CO2 + m_N2*cp_N2*T1_N2)/(m_CO2*
        cp_CO2 + m_N2*cp_N2);
19  disp("T2=")
20  disp(T2)
21  disp("K")
22
23
24  disp(" (ii) Change in entropy")
25  n_CO2=0.0909;
26  n_N2=0.2857;
27  n=n_CO2 + n_N2;
28
29  x_CO2=n_CO2/n;
30  x_N2=n_N2/n;
31
32  p2_CO2=x_CO2*p2;
33  p2_N2=x_N2*p2;
34
35
```

```
36  dS=m_CO2*cp_CO2*log(T2/T1_CO2) - m_CO2*R_CO2*log(
        p2_CO2/p1_CO2) + m_N2*cp_N2*log(T2/T1_N2) - m_N2*
        R_N2*log(p2_N2/p1_N2);
37  disp("dS=")
38  disp(dS)
39  disp("kJ/K")
```

Scilab code Exa 9.20 20

```
 1  clc
 2
 3  cv_O2=0.39;  //kJ/kg K
 4  cv_N2=0.446;  //kJ/kg K
 5  n_O2=1;
 6  n_N2=2;
 7  M_O2=32;
 8  M_N2=28;
 9  m_O2=32;  //kg
10  m_N2=2*28;  //kg
11  T_O2=293;  //K
12  T_N2=301;  //K
13  R0=8.314;
14  p_O2=2.5*10^5;  //Pa
15  p_N2=1.5*10^5;  //Pa
16
17  T2=(m_O2*cv_O2*T_O2 + m_N2*cv_N2*T_N2)/(m_O2*cv_O2 +
        m_N2*cv_N2);
18
19  V_O2=n_O2*R0*10^5*T_O2/p_O2;
20  V_N2=n_N2*R0*10^5*T_N2/p_N2;
21  V=V_O2+V_N2;
22
23  dS=m_O2*[cv_O2*log(T2/T_O2) + R0/M_O2*log(V/V_O2)] +
        m_N2*[cv_N2*log(T2/T_N2) + R0/M_N2*log(V/V_N2)];
24  disp("dS=")
```

```
25 disp(dS)
26 disp("kJ")
```

Scilab code Exa 9.21 21

```
1  clc
2  cv_N2=0.744; //kJ/kg K
3  cv_H2=10.352; //kJ/kg K
4  cp_N2=1.041; //kJ/kg K
5  cp_H2=14.476; //kJ/kg K
6
7  V=0.45; //m^3
8  V_H2=0.3; //m^3
9  V_N2=0.15; //m^3
10
11 p_H2=3*10^5; //Pa
12 p_N2=6*10^5; //Pa
13
14 T_H2=403; //K
15 T_N2=303; //K
16
17 R_H2=8.314/2;
18 R_N2=8.314/28;
19
20 disp("(i) Temperature of equilibrium mixture")
21
22 m_H2=p_H2*V_H2/(R_H2*10^3)/T_H2;
23 m_N2=p_N2*V_N2/(R_N2*10^3)/T_N2;
24
25 T2=(m_H2*cv_H2*T_H2 + m_N2*cv_N2*T_N2)/(m_H2*cv_H2 +
       m_N2*cv_N2);
26 disp("T2=")
27 disp(T2)
28 disp("K")
29
```

```
30
31  disp(" ( i i ) Pressure of the mixture")
32  p2_H2=m_H2*R_H2*10^3*T2/V;
33  p2_N2=m_N2*R_N2*10^3*T2/V;
34
35  p2=p2_H2+p2_N2;
36  disp(" p2=")
37  disp(p2/10^5)
38  disp(" bar")
39
40  disp(" ( i i i ) Change in entropy :")
41
42  dS_H2=m_H2*[cp_H2*log(T2/T_H2) - R_H2*log(p2_H2/p_H2
        )];
43  disp(" Change in entropy of H2 =")
44  disp(dS_H2)
45  disp(" kJ/K")
46
47  dS_N2=m_N2*[cp_N2*log(T2/T_N2) - R_N2*log(p2_N2/p_N2
        )];
48  disp(" Change in entropy of N2 =")
49  disp(dS_N2)
50  disp(" kJ/K")
51
52  dS=dS_H2+dS_N2;
53
54  disp(" Total change in entropy =")
55  disp(dS)
56  disp(" kJ/K")
```

Scilab code Exa 9.22 22

```
1  clc
2
3  cv_N2=0.745;  //kJ/kg K
```

```
 4  cv_CO2=0.653;  //kJ/kg K
 5
 6  cp_N2=1.041;  //kJ/kg K
 7  cp_CO2=0.842;  //kJ/kg K
 8
 9  m_N2=4;  //kg
10  m_CO2=6;  //kg
11  pmix=4;  //bar
12  m=m_N2+m_CO2;
13
14  T1=298;  //K
15  T2=323;  //K
16
17  cv_mix=(m_N2*cv_N2 + m_CO2*cv_CO2)/(m_N2+m_CO2);
18  disp("cv_mix=")
19  disp(cv_mix)
20  disp("kJ/kg K")
21
22  cp_mix=(m_N2*cp_N2 + m_CO2*cp_CO2)/(m_N2+m_CO2);
23  disp("cp_mix=")
24  disp(cp_mix)
25  disp("kJ/kg K")
26
27  dU=m*cv_mix*(T2-T1);
28  disp("Change in internal energy=")
29  disp(dU)
30  disp("kJ")
31
32  dH=m*cp_mix*(T2-T1);
33  disp("Change in enthalpy=")
34  disp(dH)
35  disp("kJ")
36
37  dS=m_N2*cv_N2*log(T2/T1) + m_CO2*cv_CO2*log(T2/T1);
38  disp("Change in entropy=")
39  disp(dS)
40  disp("kJ/K")
```

Chapter 10

Psychrometrics

Scilab code Exa 10.1 1

```
1  clc
2  t_db=293;  //K
3  W=0.0095;  //kg/kg of dry air
4  p_t=1.0132;
5  disp(" (i) Partial pressure of vapour")
6  p_v=p_t*W/(W+0.622);
7  disp(" p_v=")
8  disp(p_v)
9  disp(" bar")
10
11
12 disp(" (ii) Relative humidity phi :")
13 p_vs=0.0234;  //bar; From steam tables corresponding
       to 20 0C
14 phi=p_v/p_vs;
15 disp(" relative hmidity =")
16 disp(phi)
17
18
19 disp(" (iii) Dew point temperature")
20 t_dp=13 + (14-13)/(0.01598 - 0.0150)
```

```
      *(0.01524 -0.0150) ; //From stea table by
          interpolation
21 disp (" t_dp=")
22 disp (t_dp)
23 disp ("0C")
```

Scilab code Exa 10.2 2

```
1 clc
2 t_db =290; //K
3 phi =0.6; // relative humidity
4 p_t =1.01325; // bar
5 p_vs =0.0194; // bar
6
7 p_v=phi*p_vs ;
8
9 W=0.622* p_v /( p_t - p_v ) ;
10 disp (" Specific Humidity=")
11 disp (W)
12 disp (" kg/kg of dry air ")
13
14
15 t_dp =9 + (10 -9) *(0.01164 -0.01150) /(0.01230 -
      0.01150) ; //By interpolation from steam tables
16 disp (" dew point temperature =")
17 disp (t_dp)
18   disp ("0C")
```

Scilab code Exa 10.3 3

```
1 clc
2 phi =0.55;
3 p_vs =0.0425; // bar
```

```
 4  p_t=1.0132;  //bar
 5
 6  p_v=phi*p_vs;
 7  W=0.622*p_v/(p_t-p_v);
 8
 9  //Specific  humidity  after  removing  o.oo4  kg  of  water
        vapour
10  Wnew=W-0.004;
11  p_v=p_t*Wnew/(Wnew+0.622);
12  p_vs=0.0234;  //bar
13
14  disp(" (i)  Relative  humidity")
15  phi=p_v/p_vs;
16  disp(" phi=")
17  disp(phi)
18
19
20  disp(" (ii)  Dew  point  temperature")
21
22  disp(" Corresponding  to  0.0171  bar ,  from  steam  tables
      ")
23  t_dp=15;  //0C
24  disp(" t_dp=")
25  disp(t_dp)
26  disp(" 0C")
```

Scilab code Exa 10.4 4

```
1  clc
2  t_db=35;  //0C
3  t_wb=25;  //0C
4  p_t=1.0132;  //bar
5
6  //Corresponding  to  25  0C  in  steam  tables
7  p_vs_wb=0.0317;  //bar
```

```
8
9  p_v=p_vs_wb - (p_t - p_vs_wb)*(t_db - t_wb)/(1527.4
      - 1.3*t_wb);
10
11
12 disp(")(i) Specific humidity")
13 W=0.622*p_v/(p_t-p_v);
14 disp("W=")
15 disp(W)
16 disp("kg/kg of dry air")
17
18 disp("(ii) Relative humidity")
19
20 //Corresponding to 35 0C, from steam tables
21 p_vs=0.0563;
22
23 phi=p_v/p_vs;
24 disp("phi")
25 disp(phi)
26
27
28 disp("(iii) Vapour density")
29 R_v=8314.3/18;
30 T_v=308; //K
31
32 rho_v=p_v*10^5/(R_v*T_v);
33 disp("rho_v=")
34 disp(rho_v)
35 disp("kg/m^3")
36
37
38 disp("(iv) Dew point temperature")
39 t_dp=21 + (22-21)*(0.0252-0.0249)/(0.0264-0.0249);
40 disp("t_dp")
41 disp(t_dp)
42 disp("0C")
43
44
```

```
45  disp(”(v) Enthalpy of mixture per kg of dry air”)
46  cp=1.005;
47  h_g=2565.3; //kJ/kg; corresponding to 35 0C
48  h_vapour=h_g + 1.88*(t_db - t_dp);
49
50  h=cp*t_db + W*h_vapour;
51  disp(”h=”)
52  disp(h)
53  disp(”kJ/kg of dry air”)
```

Scilab code Exa 10.5 5

```
1   clc
2
3   //For the air at 35 0C DBT and 60% R.H.
4   p_vs=0.0563; //bar; Corresponding to 35 0C from stem
         tables
5
6   phi=0.6;
7   p_t=1.0132; //bar
8   cp=1.005;
9   t_db=35; //0C
10  h_g=2565.5; //kJ/kg
11  m1=1; //kg
12  m2=2; //kg
13  m=m1+m2;
14
15  p_v=phi*p_vs;
16  W1=0.622*p_v/(p_t-p_v);
17
18  //Corresponding to 0.0388 bar, from steam tables
19  t_dp=26+(27-26)*(0.0338-0.0336)/(0.0356-0.0336);
20
21  h_vapour=h_g + 1.88*(t_db - t_dp);
22  h1=cp*t_db+W1*h_vapour;
```

```
23
24 //For the air at 20 C DBT and 13 C dew point
       temperature :
25 p_v=0.0150; //bar
26
27 W2=0.622*p_v/(p_t-p_v);
28 t_db=20; //0C
29 t_dp=13;
30 h_g=2538.1; //kJ/kg
31 h_vapour=h_g + 1.88*(t_db - t_dp);
32
33 h2=cp*t_db+W2*h_vapour;
34
35 //let enthalpy per kg of moist air be h
36 h=((m1*h1/(1+W1)) + (m2*h2/(1+W2)))/m;
37
38 //Let Mass of vapour/kg of moist air be M
39 M=(m1*W1/(1+W1) + m2*W2/(1+W2))/m;
40
41
42 //Let specific humidity be denoted by SH
43 SH=M/(1-M);
44 disp("Specific humidity =")
45 disp(SH)
46 disp("kg/kg of dry air")
```

Scilab code Exa 10.6 6

```
1 clc
2
3 //For air at 20 0C and 75% R.H
4 p_vs=0.0234; //bar
5 phi=0.75;
6 p_t=1.0132;
7 cp=1.005;
```

```
8  t_db=20;  //0C
9
10
11  p_v=phi*p_vs;
12  t_dp=15 + (16-15)*(0.01755-0.017)/(0.0182-0.017);
13  W=0.622*p_v/(p_t-p_v);
14
15  h_g=2538.1;  //kJ/kg
16  h_vapour=h_g + 1.88*(t_db - t_dp);
17  h1=cp*t_db + W*h_vapour;
18
19
20  disp("(i) Relative humidity of heated air :")
21
22  //For air at 30 C DBT
23  p_vs=0.0425;  //bar; corresponding to 30 0C
24  phi=p_v/p_vs;
25  disp("Relative humidity=")
26  disp(phi*100)
27  disp("%")
28
29
30  disp("(ii) Heat added to air per minute")
31  h_g=2556.3;  //kJkg
32  t_db=30;
33  h2=cp*t_db+W*h_vapour;
34  V=90;  //m^3
35  R=287;
36  T=293;  //K
37
38  m=(p_t-p_v)*V*10^5/R/T;
39
40  Amt=m*(h2-h1);
41  disp("Amount of heat added per minute=")
42  disp(Amt)
43  disp("kJ")
```

Scilab code Exa 10.7 7

```scilab
1  clc
2
3  //For air at 35 0C DBT and 50% RH
4  p_vs=0.0563; //bar; At 35 0C, from steam tables
5  phi=0.5;
6  p_t=1.0132;
7  t_db1=35; //0C
8  t_dp1=23; //0C
9  cp=1.005;
10 R=287;
11 p_v=phi*p_vs;
12 W1=0.622*p_v/(p_t-p_v);
13 h_g1=2565.3; //kJ/kg
14
15 h_vapour=h_g1 + 1.88*(t_db1 - t_dp1);
16 h1=cp*t_db1+W1*h_vapour;
17
18
19 disp("(i) R.H. of cooled air")
20 p_vs=0.0317;
21 phi=p_v/p_vs;
22 disp("RH of cooled air=")
23 disp(phi*100)
24 disp("%")
25
26
27 disp("(ii) Heat removed from air")
28 h_g2=2547.2; //kJ/kg
29 t_db2=25; //0C
30 t_dp2=23; //0C
31 W2=W1;
32 T=308; //K
```

```
33  V=40;  //m^3
34
35  h_vapour=h_g2 + 1.88*(t_db2 - t_dp2);
36  h2=cp*t_db2+W2*h_vapour;
37  m=(p_t-p_v)*10^5*V/R/T;
38
39  //Let Heat removed be denoted by H
40  H=m*(h1-h2);
41  disp("Heat removed =")
42  disp(H)
43  disp("kJ")
```

Scilab code Exa 10.8 8

```
1  clc
2
3  //For the air at 35 C DBT and 50% R.H.
4  p_vs=0.0563;  //bar; At 35 0C, from steam tables
5  phi=0.5;
6  p_v=phi*p_vs;
7  p_t=1.0132;  //bar
8
9  t_dp1=23;  //0C
10 t_db1=35;  //0C
11 W1=0.622*p_v/(p_t-p_v);
12 h_g1=2565.3;  //kJ/kg
13 R=287;
14 cp=1.005;
15
16 h_vapour=h_g1 + 1.88*(t_db1 - t_dp1);
17 h1=cp*t_db1+W1*h_vapour;
18
19
20 disp("(i) Relative humidity of out coming air and
        its wet bulb temperature.")
```

```
21
22  disp("Relative humidity of exit air is 100 per cent.
        ")
23
24  t_wb=20; //0C
25  disp("Wet bulb temperture=")
26  disp(t_wb)
27  disp("0C")
28
29  p_v=0.0234; //bar
30  p_vs=p_v;
31  t_db2=20; //0C
32  h_g2=2538.1; //kJ/kg
33  t_dp2=t_db2;
34
35  W2=0.622*p_v/(p_t-p_v);
36  h_vapour=h_g2 + 1.88*(t_db2 - t_dp2);
37  h2=cp*t_db2+W2*h_vapour;
38
39  T=308; //K
40  V=120; //m^3
41
42  W=W1-W2; //Weight of water vvapour removed per kg of
          dry air
43  h=h1-h2; //Heat removed per kg of dry air
44  m=(p_t-p_v)*10^5*V/R/T;
45
46
47  disp("(ii) Capacity of the cooling coil in tonnes of
          refrigeration")
48  C=m*(h1-h2)*60/14000;
49  disp("Capacity =")
50  disp(C)
51  disp("TR")
52
53
54  disp("(iii) Amount of water removed per hour")
55  Amt=m*(W1-W2)*60;
```

```
56  disp("Amount of water removed per hour=")
57  disp(Amt)
58  disp("kg/h")
```

Scilab code Exa 10.9 9

```
1  clc
2  p_vs=0.0563;  //bar
3  phi=0.2;
4  p_v=phi*p_vs;
5  p_t=1.0132;  //bar
6
7  W1=0.622*p_v/(p_t-p_v);
8
9  disp("(i) Dew point temperature")
10  //
11  t_dp=8+(9-8)*(0.01126-0.01072)/(0.01150-0.01072);
12  disp("dew point temperature=")
13  disp(t_dp)
14  disp("0C")
15
16
17  disp("(ii) Relative humidity of the exit air :")
18  p_vs_wb=0.0170;  //bar
19  p_vs=0.0234;  //bar
20  t_db=20;  //0C
21  t_wb=15;  //0C
22
23  p_v=p_vs_wb - (p_t-p_vs_wb)*(t_db-t_wb)/(1527.4-1.3*
       t_wb);
24  W2=0.622*p_v/(p_t-p_v);
25
26  RH=p_v/p_vs;
27  disp("Relative humidity=")
28  disp(RH)
```

```
29
30  p_v=0.01126;  //bar
31  R=287;
32  T=308;  //K
33  V=150;
34
35  m=(p_t-p_v)*V*10^5/R/T;
36
37
38  disp(" (iii) Amount of water vapour added to the air
        per minute")
39  amt=m*(W2-W1);
40  disp("Amount =")
41  disp(amt)
42  disp("kg/min")
```

Scilab code Exa 10.10 10

```
1  clc
2  p_s=0.0206;  //bar
3  p_t=1;  //bar
4  p_s1=0.03782;  //bar
5  W_2s=0.622*p_s/(p_t-p_s);
6
7  cp=1.005;
8  t_db2=18;  //0C
9  t_db1=28;  //0C
10
11  h_g2=2534.4;  //kJ/kg
12  h_f2=75.6;  //kJ/kg
13  h_g1=2552.6;  //kJ/kg
14
15  W1=(cp*(t_db1-t_db2) + W_2s*(h_g2-h_f2))/(h_g1-h_f2)
        ;
16
```

```
17  p_v1=W1*p_t/(0.622+W1);
18
19  RH=p_v1/p_s1;  //Relative humidity
20  disp("Relative humidity")
21  disp(RH)
```

Scilab code Exa 10.11 11

```
1   clc
2   t_db1=38;  //0C
3   t_db2=18;  //0C
4   phi_1=0.75;
5   phi_2=0.85;
6   p_t=1;  //bar
7   cp=1.005;
8
9   //At 38 0C
10  p_vs=0.0663;  //bar
11  h_g1=2570.7;  //kJ/kg
12  p_v=phi_1*p_vs;
13  W1=0.622*p_v/(p_t-p_v);
14
15  //At 18 0C
16  p_vs=0.0206;  //bar
17  h_g2=2534.4;  //kJ/kg
18  h_f2=75.6;  //kJ/kg
19  p_v=phi_2*p_vs;
20  W2=0.622*p_v/(p_t-p_v);
21
22  q=(W2*h_g2 - W1*h_g1) + cp*(t_db2-t_db1) + (W1-W2)*
        h_f2;
23  disp("Heat transfer rate=")
24  disp(q)
25  disp("kJ/kg of dry air")
```

Scilab code Exa 10.12 12

```scilab
1  clc
2
3  //At 38 0C
4  p_vs =0.0663;  //bar
5  h_g1 =2570.7;  //kJ/kg
6  phi =0.25;
7  p_t =1.0132;
8  p_v =phi*p_vs;
9  cp =1.005;
10
11 //At 18 0C
12 h_g2 =2534.4;  //kJ/kg
13 p_vs =0.0206;  //bar
14 W1 =0.622*p_v/(p_t-p_v);
15
16 t_db1 =38;  //0C
17 t_db2 =18;  //0C
18
19 W2 =(cp*(t_db1-t_db2) + W1*h_g1)/h_g2;
20
21 //amount of water added =amt
22 amt =W2-W1;
23 disp("amt=")
24 disp(amt)
25 disp("kg/kg of dry air")
26
27 p_v2 =amt*p_t/(0.622+amt);
28
29 RH =p_v2/p_vs;
30 disp("Final relative humidity")
31 disp(RH)
```

Scilab code Exa 10.13 13

```scilab
1  clc
2
3  disp("(i) Mass of spray water required")
4
5  //At 22 0c
6  p_vs=0.0264; //bar
7  phi_3=0.55;
8  p_t=1.0132; //bar
9
10 p_v3=phi_3*p_vs;
11 W3=0.622*p_v3/(p_t-p_v3);
12
13 //At 3 0C
14 p_vs1=0.0076; //bar
15 p_v1=p_vs1;
16
17 W1=0.622*p_v1/(p_t-p_v1);
18
19 R=287;
20 T_3=295; //K
21
22 v=R*T_3/(p_t-p_v3)/10^5;
23
24 m=(W3-W1)/v;
25 disp(" Mass of spray water required=")
26 disp(m)
27 disp("kg moisture/m^3")
28
29
30 disp("(ii) Temperature to which the air must be
       heated")
31 t_dp=12.5; //0C
```

```
32  cp =1.005;
33  t_db3 =22;  //0C
34  h_g3 =2524;  //kJ/kg
35  h_vapour3 = h_g3 + 1.88*( t_db3 - t_dp );
36  W2 =0.0047;
37  h_g2 =2524;  //kJ/kg
38  h4 =41.87;
39
40  t_db2 =( cp * t_db3 + W3 * h_vapour3 - W2 * h_g2 + 1.88* W2 *
        t_dp - (W3 - W2 )* h4 )/( cp - W2 *1.88);
41  disp (" t_db2 =")
42  disp ( t_db2 )
43  disp ("0C")
```

Scilab code Exa 10.14 14

```
1  clc
2
3  disp ("( i ) Make-up water required ")
4  p_vs =0.0206;  //bar
5  phi =0.6;
6  p_t =1.013;  //bar
7
8  p_v1 = phi * p_vs ;
9  p_a1 = p_t - p_v1 ;
10  V =9;  //m^3
11  R =287;
12  T =291;  //K
13
14  m_a = p_a1 *10^5* V / R / T ;
15
16  m_v1 =0.0828;  //kg/s
17
18  // At exit at 26 0C
19  p_vs =0.0336;  //bar
```

```
20  phi=1;
21  p_v=p_vs;
22  W2=0.622*p_v/(p_t-p_v);
23  m_v2=W2*m_a;
24
25  m=m_v2-m_v1;
26  disp("Make-up water required=")
27  disp(m)
28  disp("kg/s")
29
30
31  disp("(ii) Final temperature of the water")
32  m_w1=5.5; //kg/s
33  m_w2=m_w1-m;
34
35  Wi=4.75; //kJ/s
36
37  h_w1=184.3; //kJ/kg
38  h_a1=18.09; //kJ/kg
39  h_v1=2534.74; //kJ/kg
40
41  h_v2=2549; //kJ/kg
42  h_a2=26.13; //kJ/kg
43
44  h_w2=(Wi + m_w1*h_w1 + m_a*h_a1 + m_v1*h_v1 - m_a*
       h_a2 - m_v2*h_v2)/m_w2;
45
46  //By interpolation, h_w2 corresponds to t
47  t=26.7; //0C
48  disp("final temperature of water=")
49  disp(t)
50  disp("0C")
```

Scilab code Exa 10.15 15

```
1  clc
2
3  m_water =60000; //kg/s
4  c=4.186;
5  t1=30; //0C
6  t2=35; //0C
7  Q=m_water*c*(t2-t1);
8
9  h1=76.5; //kJ/kg
10 W1=0.016; //kg/kg of air
11 h2=92.5; //kJ/kg
12 W2=0.0246; //kg/kg of air
13
14 m_air=Q/(h2-h1);
15
16 A=m_air/10; //Quantity of air handled per fan
17 disp("Quantity of air handled per fan=")
18 disp(A)
19 disp("kg/h")
20
21
22 B=m_air*(W2-W1);
23 disp("Quantity of make up water=")
24 disp(B)
25 disp("kg/h")
```

Scilab code Exa 10.17 17

```
1  clc
2  h1=35.4; //kJ/kg
3  h2=45.2; //kJ/kg
4  v_s1=0.8267; //m^3/kg
5  m_a=241.9;
6
7  disp("(i) R.H. of heated air =")
```

```
8  RH =41;  // From chart
9  disp ( RH )
10 disp ( "%" )
11
12 disp ( " ( i i ) WBT of heated air =" )
13 WBT =16.1;  //0C
14 disp ( WBT )
15 disp ( "  C " )
16
17 disp ( " ( i i i ) Heat added to air per minute =" )
18 Q= m_a *( h2 - h1 ) ;
19 disp ( Q )
20 disp ( " kJ " )
```

Scilab code Exa 10.18 18

```
1  clc
2  h1 =29.3;  // kJ / kg
3  h2 =42.3;  // kJ / kg
4  h3 = h2 ;
5  t_db2 =24.5;  //0C
6  t_db1 =12;  //0C
7  v_s1 =0.817;  // m ^3/ kg
8  amt =0.30;  // Amount of air circulation m ^3/ min / person
9  capacity =60;  // Seating capacity of office
10 BF =0.4;  // By - pass factor
11 W3 =8.6;
12 W1 =6.8;
13
14 m_a = amt * capacity / v_s1 ;
15
16 disp ( " ( i ) Heating capacity of the heating coil =" )
17 Q= m_a *( h2 - h1 ) /60;
18 disp ( Q )
19 disp ( " kW " )
```

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```
20
21  t_db4=(t_db2-BF*t_db1)/(1-BF);
22  disp("Coil surface temperature =")
23  disp(t_db4)
24  disp(" C ")
25
26  disp("(ii) The capacity of the humidifier =")
27  c=m_a*(W3-W1)/1000*60;
28  disp(c)
29  disp("kg/h")
```

Scilab code Exa 10.19 19

```
1  clc
2  h1=82.5;  //kJ/kg
3  h2=47.5;  //kJ/kg
4  h3=55.7;  //kJ/kg
5  h5=36.6;  //kJ/kg
6  W1=19.6;  //gm/kg
7  W3=11.8;  //gm/kg
8  t_db2=17.6;  //0C
9  t_db3=25;  //0C
10  v_s1=0.892;  //m^3/kg
11  amt=250;  //m^3/min
12
13  m_a=amt/v_s1;
14  disp("(i) The capacity of the cooling coil =")
15  capacity=m_a*(h1-h2)*60/14000;
16  disp(capacity)
17  disp("TR")
18
19  BF=(h2-h5)/(h1-h5);
20  disp("by-pass factor of the cooling coil =")
21  disp(BF)
22
```

```
23  disp(" (ii) The heating capacity of the heating coil
        =")
24  Q=m_a*(h3-h2)/60;
25  disp(Q)
26  disp("kW")
27
28  BF=0.3;
29  t_db6=(t_db3-BF*t_db2)/(1-BF);
30  disp("surface temperature of heating coil =")
31  disp(t_db6)
32  disp(" C ")
33
34  disp(" (iii) The mass of water vapour removed per
        hour =")
35  m=m_a*(W1-W3)*60/1000;
36  disp(m)
37  disp("kg/h")
```

Chapter 11

Chemical Thermodynamics

Scilab code Exa 11.1 1

```
 1 clc
 2
 3 %C=0.88; //Fraction of carbon in coal
 4 %H=0.042; //Fraction of Hydrogen in coal
 5 w_f=0.848; //gm
 6 w_fw=0.027; //gm
 7 w=1950; //gm
 8 w_e=380; //gm
 9 dt=3.06; //0C; Observed temperature rise
10 tc=0.017; //0C
11 dt1=dt+tc; //Corrected temperature rise
12 Cal=6700; //J/gm; Calorific value of fuse wire
13
14 Q_received=(w+w_e)*4.18*dt1; //Heat received by
      water
15
16 Q_rejected=w_fw*Cal; //Heat given out by fuse wire
17
18 Q_produced=Q_received - Q_rejected;
19
20 HCV=Q_produced/w_f;
```

```
21  disp ("Higher  calorific  value=")
22  disp (HCV)
23  disp ("kJ/kg")
24
25  LCV=HCV  -  2465*9*%H;
26  disp ("Lower  Calorific  value=")
27  disp (LCV)
28  disp ("kJ/kg")
```

Scilab code Exa 11.2 2

```
1  clc
2  p1 =75.882;  //cm  of  Hg
3  T1 =286;  //K
4  V1 =0.08;  //m^3
5  p2 =76;  //cm  of  Hg
6  T2 =288;  //K
7
8  V2=p1*V1*T2/p2/T1;
9
10 m=28;  //kg
11 c=4.18;
12 t2 =23.5;  //0C
13 t1 =10;  //0C
14
15 Q_received=m*c*(t2-t1);
16
17 HCV=Q_received/V2;
18 disp ("Higher  calorific  value =")
19 disp (HCV)
20 disp ("kJ/m^3")
21
22 amt =0.06/0.08;  //Amount  of  vapour  formed  per  m^3  of
       gas  burnt
23 LCV=HCV -2465* amt ;
```

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```
24 disp("Lower calorific value =")
25 disp(LCV)
26 disp("kJ/kg")
```

Scilab code Exa 11.3 3

```
1  clc
2  C=0.85; //Weight of Carbon present
3  H2=0.06; //Weight of Hydrogen present
4  O2=0.06; //Weight of Oxygen present
5
6  w_required=C*8/3 + H2*8; //Weight of O2 required
7  w_needed=w_required-O2; //Weight of O2 to be
       supplied
8
9  w_air=w_needed*100/23;
10 disp("Weight of air needed=")
11 disp(w_air)
12 disp("kg")
```

Scilab code Exa 11.4 4

```
1  clc
2  C=0.848; //kg
3  H2=0.152; //kg
4  O2_used=C*8/3 + H2*8;
5
6
7  disp("(i) Minimum weight of air needed for
       combustion")
8  w_min=O2_used*100/23;
9  disp("Minimum weight of air needed for combustion=")
10 disp(w_min)
```

```
11  disp("kg")
12
13  w_excess=w_min*0.15; //Excess air supplied
14
15  w_O2=w_excess*23/100; //Weight of O2 in excess air
16
17  w_total=w_min + w_excess; //Total air supplied for
        combustion
18  w_N2=w_total*77/100; //Weight of N2 in flue gases
19
20
21  disp("(ii) the volumetric composition of the
        products of combustion")
22
23  //For CO2
24  x1=3.109;
25  y1=44;
26  z1=x1/y1;
27
28  //For O2
29  x2=w_O2;
30  y2=32;
31  z2=x2/y2;
32
33  //For N2
34  x3=w_N2;
35  y3=28;
36  z3=x3/y3;
37
38  z=z1+z2+z3;
39
40  //For CO2
41  %V1=z1/z*100;
42  disp("%volume of CO2 =")
43  disp(%V1)
44  disp("%")
45
46  //For O2
```

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```
47  %V2=z2/z*100;
48  disp("%volume of O2 =")
49  disp(%V2)
50  disp("%")
51
52  //For CO2
53  %V3=z3/z*100;
54  disp("%volume of N2 =")
55  disp(%V3)
56  disp("%")
```

Scilab code Exa 11.5 5

```
1  clc
2  C=0.78;
3  H2=0.06;
4  O2=0.03;
5
6  w_O2=C*8/3 + H2*8;
7  w_min=(w_O2-O2)*100/23; //Minimum wt. of air needed
       for combustion
8
9  disp("(i) Weight of dry flue gases per kg of fuel")
10
11  //For CO2
12  x1=0.104;
13  y1=44;
14  z1=x1*y1;
15
16  //For CO
17  x2=0.002;
18  y2=28;
19  z2=x2*y2;
20
21  //For N2
```

```
22  x3 =0.816;
23  y3 =28;
24  z3 = x3 * y3 ;
25
26  // For O2
27  x4 =0.078;
28  y4 =32;
29  z4 = x4 * y4 ;
30
31  z = z1 + z2 + z3 + z4 ;
32
33  W_CO2 = z1 / z ; // Weight per kg of flue gas
34  W_CO = z2 / z ; // Weight per kg of flue gas
35  W_N2 = z3 / z ; // Weight per kg of flue gas
36  W_O2 = z4 / z ; // Weight per kg of flue gas
37
38  amt =3/11* W_CO2 + 3/7* W_CO ;
39
40  W = C / amt ; // Weight of dry flue gas per kg of fuel
41  disp ( " Weight of dry flue gas per kg of fuel = " )
42  disp ( W )
43  disp ( " kg " )
44
45  disp ( " ( ii ) Weight of excess air per kg of fuel " )
46  m_O2 = W_O2 -4/7* W_CO ; // Weight of excess oxygen per kg
        of flue gas
47  m_excess = W * m_O2 ; // Weight of excess O2 per kg of
      fuel
48
49  w_excess = m_excess *100/23; // Weight of excess air per
        kg of fuel
50  disp ( " Weight of excess air per kg of fuel = " )
51  disp ( w_excess )
52  disp ( " kg " )
```

Scilab code Exa 11.6 6

```
1  clc
2  v_CO =0.05;
3  v_CO2 =0.10;
4  v_H2 =0.50;
5  v_CH4 =0.25;
6  v_N2 =0.10;
7
8  V_fuel =1;
9
10 V_O2 = v_CO /2+ v_H2 /2+2* v_CH4 ; // Volume of O2 needed
11
12 V_air = V_O2 *100/21; // Volume of air required
13
14 V_N2 = V_air *79/100; // Volume of nitrogen in the air
15
16 V= v_CO + v_CO2 + v_CH4 + v_N2 + V_N2 ; // Dry
      combustion products
17
18 O2 =6;
19 V_excess = O2 * V /(21 - O2 );
20
21 V_total = V_air + V_excess ;
22
23 ratio = V_total / V_fuel ;
24 disp (" Air fuel ratio =")
25 disp ( ratio )
```

Scilab code Exa 11.7 7

```
1 clc
2
3 C =0.85;
4 H2 =0.15;
```

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```
 5
 6  // For CO2
 7  x1 = 0.115;
 8  y1 = 44;
 9  z1 = x1 * y1;
10
11  // For CO
12  x2 = 0.012;
13  y2 = 28;
14  z2 = x2 * y2;
15
16  // For O2
17  x3 = 0.009;
18  y3 = 32;
19  z3 = x3 * y3;
20
21  // For N2
22  x4 = 0.86;
23  y4 = 28;
24  z4 = x4 * y4;
25
26  z = z1 + z2 + z3 + z4;
27
28  W_CO2 = z1 / z; // Weight per kg of flue gas
29  W_CO = z2 / z; // Weight per kg of flue gas
30  W_O2 = z3 / z; // Weight per kg of flue gas
31  W_N2 = 4 / z; // Weight per kg of flue gas
32
33  W_C = 3 / 11 * W_CO2 + 3 / 7 * W_CO; // Weight of carbon per kg
          of flue gas
34
35  W = C / W_C; // Weight of dry flue gas per kg of fuel
36
37  Vapour = 1.35; // kg; Vapour of combustion
38
39  W_total = W + Vapour; // Total weight of gas
40
41  W_air = W_total - 1; // Air supplied
```

```
42
43  ratio=W_air/1;
44  disp("Ratio of air to petrol =")
45  disp(ratio)
46
47  S_air=[C*8/3 + H2*8]*100/23; //Stoichiometric air
48
49  W_excess=W_air-S_air; //Excess air
50
51  %Excess=W_excess/S_air*100; //Percentage excess air
52  disp("Percentage excess air")
53  disp(%Excess)
54  disp("%")
```

Scilab code Exa 11.8 8

```
 1  clc
 2  C=0.86;
 3  H2=0.08;
 4  S=0.03;
 5  O2=0.02;
 6
 7  W_O2=C*8/3 + H2*8 + S*1;
 8
 9  A=W_O2-O2; //Weight of oxygen to be supplied per kg
        of fuel
10
11  W_min=A*100/23;
12  r_correct=1/W_min/1; //  correct  fuel-air ratio
13  r_actual=1/12;
14
15
16  disp("(i) Mixture strength")
17  s=r_actual/r_correct*100; //Mixture strength
18
```

```
19  richness=s-100;
20  disp(" richness=")
21  disp(richness)
22  disp("%")
23  disp("This show that mixture is 6.5% rich.")
24
25  D=1/r_correct-1/r_actual;
26
27  CO=0.313; //kg
28  CO2=2.662; //kg
29  N2=9.24; //kg
30  SO2=0.06; //kg
31
32  disp("(ii) The percentage composition of dry flue
        gases")
33
34  //For CO
35  x1=0.313; //kg
36  y1=28;
37  z1=x1/y1;
38
39  //For CO2
40  x2=2.662; //kg
41  y2=44;
42  z2=x2/y2;
43
44  //For N2
45  x3=9.24; //kg
46  y3=28;
47  z3=x3/y3;
48
49  //For SO2
50  x4=0.06; //kg
51  y4=64;
52  z4=x4/y4;
53
54  z=z1+z2+z3+z4;
55
```

```
56  //Let percentage volume be denoted by V
57
58  V_CO=z1/z*100;
59  disp("Percentage volume of CO=")
60  disp(V_CO)
61  disp("%")
62
63  V_CO2=z2/z*100;
64  disp("Percentage volume of CO2=")
65  disp(V_CO2)
66  disp("%")
67
68  V_N2=z3/z*100;
69  disp("Percentage volume of N2=")
70  disp(V_N2)
71  disp("%")
72
73
74  V_SO2=z4/z*100;
75  disp("Percentage volume of SO2=")
76  disp(V_SO2)
77  disp("%")
```

Scilab code Exa 11.9 9

```
1  clc
2
3  A=992/284*100/23; //Air required for complete
        combustion
4
5  B=13; //kg/kg of fuel; Air actually supplied
6
7  D=A-B; //Deficiency of air
8
9  W_CO2=0.466*11/3;
```

```scilab
10  W_CO =0.379*7/3;
11  W_H2O =22/142*9;
12  W_N2 =13*0.77;
13
14  //For CO2
15  x1=W_CO2
16  y1=44;
17  z1=x1/y1;
18
19  //For CO
20  x2=W_CO;
21  y2=28;
22  z2=x2/y2;
23
24  //For H2O
25  x3=W_H2O;
26  y3=18;
27  z3=x3/y3;
28
29  //For N2
30  x4=W_N2;
31  y4=28;
32  z4=x4/y4;
33
34  z=z1+z2+z3+z4;
35
36  %CO2=z1/z*100;
37  disp("Percentage of CO2=")
38  disp(%CO2)
39  disp("%")
40
41  %CO=z2/z*100;
42  disp("Percentage of CO=")
43  disp(%CO)
44  disp("%")
45
46  %H2O=z3/z*100;
47  disp("Percentage of H2O=")
```

```
48  disp(%H2O)
49  disp("%")
50
51  %N2=z4/z*100;
52  disp("Percentage of N2=")
53  disp(%N2)
54  disp("%")
```

Scilab code Exa 11.11 11

```
1   clc
2
3   C=80;
4
5   //Analysis of gas entering the economiser
6   CO2_1=8.3;
7   CO_1=0;
8   O2_1=11.4;
9   N2_1=80.3;
10
11  //Analysis of gas leaving the economiser
12  CO2_2=7.9;
13  CO_2=0;
14  O2_2=11.5;
15  N2_2=80.6;
16
17  A1=N2_1*C/33/(CO2_1 + CO_1); //Air supplied on the
        basis of conditions at entry to the economiser
18
19  A2=N2_2*C/33/(CO2_2 + CO_2); //Air applied on the
        basis of conditions at exit
20
21  leakage=A2-A1; //Air leakage
22  disp("Air leakege =")
23  disp(leakage)
```

```
24 disp("kg of air per kg of fuel")
25
26 W_fuel=0.85; //kg; Weight of fuel passing up the
      chimney
27
28 c=1.05;
29 T2=410;
30 T1=0;
31
32 W=A1+W_fuel; //Total weight of products
33 Q1=W*c*(T2-T1); //Heat in flue gases per kg of coal
34 Q2=leakage*1.005*(20-0); //Heat in leakage air
35
36 t=(Q1+Q2)/(1.005*leakage + W*1.05);
37
38 dT=T2-t;
39 disp("Fall in temperature as a result of the air
      leakage into the economiser")
40 disp(dT)
41 disp(" C ")
```

Scilab code Exa 11.12 12

```
1 clc
2
3 w_O2=3*32/46*100/23; //For complete combustion of 1
      kg of C2H6O, oxygen required
4
5 ratio=w_O2;
6 disp("A:F ratio=")
7 disp(ratio)
8
9 w1=88; //kg
10 w2=54; //kg
11
```

```
12  w=w1+w2;  //kg
13  W=46;  //kg
14
15  w_CO2=w1/W*100;
16  disp("CO2 produced by fuel")
17  disp(w_CO2)
18  disp("%")
19
20  w_H2O=w2/W*100;
21  disp("H2O produced by fuel")
22  disp(w_H2O)
23  disp("%")
```

Scilab code Exa 11.13 13

```
1  clc
2  // C2H2+xO2------>aCO2+bH2O
3  // 2C=aC; a=2
4  // 2H=2bH; b=1
5  // x=2.5
6
7  // C2H2+2.5O2+2.5*(79/21)N2 --> 2CO2+H2O+2.5*(79/21)
      N2
8
9  // 26 kg C2H2 + 80 kg O2 + 263.3 N2        88 kg CO2 +
      18 kg H2O + 263.3 kg N2
10  // 1 kg C2H2 + 3.076 kg O2 + 10.12 kg N2          3.38
       kg CO2 + 0.69 kg H2O + 10.12 kg N2
11
12  Amount= 3.076 + 10.12;
13  disp("Hence amount of theoretical air required for
       combustion of 1 kg acetylene =")
14  disp(Amount)
15  disp("kg")
```

Scilab code Exa 11.14 14

```scilab
1  clc
2  // C2H2+2.5O2+2.5*(79/21)N2 --> 2CO2+H2O+2.5*(79/21)
       N2
3
4  //26 kg C2H2 + 160 kg O2 + 526.6 kg N2        88 kg CO2
        + 18 kg H2O + 526.6 kg N2 + 80 kg O2
5
6  //1 kg C2H2 + 6.15 kg O2 + 20.25 kg N2        3.38 kg
       CO2 + 0.69 kg H2O + 20.25 kg N2 + 3.07 kg O2
7
8  m_CO2=3.38; //kg
9  m_H2O=0.69; //kg
10 m_O2=3.07; //kg
11 m_N2=20.25; //kg
12 m_total=m_CO2+m_H2O+m_O2+m_N2;
13
14 CO2=m_CO2/m_total*100;
15 H2O=m_H2O/m_total*100;
16 O2=m_O2/m_total*100;
17 N2=m_N2/m_total*100;
18
19 disp("Hence the gravimetric analysis of the complete
       combustion is :")
20 disp("CO2=")
21 disp(CO2)
22 disp("%")
23
24 disp("H2O=")
25 disp(H2O)
26 disp("%")
27
28 disp("O2=")
```

```
29  disp(O2)
30  disp("%")
31
32  disp("N2=")
33  disp(N2)
34  disp("%")
```

Scilab code Exa 11.15 15

```
1  clc
2  AF_mole=(12.5+12.5*(79/21))/1;
3  AF_mass=AF_mole*28.97/(8*12+1*18);
4
5  disp("Air fuel ratio =")
6  disp(AF_mass)
7  disp("kg air/kg fuel")
```

Scilab code Exa 11.16 16

```
1  clc
2  // C8H18+12.5*O2+12.5*(79/21)N2 --> 8CO2+9H2O
       +12.5*(79/21)*N2
3
4  // C8H18 + (2) (12.5) O2 + (2) (12.5)*(79/21)N2-->8
       CO2 + 9H2O + (1) (12.5) O2 + (2) (12.5)*(79/21)*
       N2
5
6  m_fuel=1*(8*12+1*18);
7  m_air=2*12.5*(1+79/21)*28.97;
8
9  disp("(i) Air-fuel ratio =")
10 AF=m_air/m_fuel;
11 disp(AF)
```

```
12
13 disp(" ( i i ) Dew point of the products")
14 n=8+9+12.5+2*12.5*(79/21);
15
16 x=9/n;
17 p=100*x;
18
19 //Hence
20 t_dp=39.7; //0C
21
22 disp(" t_dp=")
23 disp(t_dp)
24 disp("  C ")
```

Scilab code Exa 11.17 17

```
1 clc
2 // C2H6 + 3.5O2     2CO2 + 3H2O
3 // C2H6 + (0.9)*(3.5) O2 + (0.9)*(3.5)*(79/21) N 2   a
       CO2 + b CO + 3H2O + (0.9)*(3.5)*(79/21)*N2
4
5 // a+b=2
6 // 2*a+b+3=0.9*3.5*2
7 // a=1.3
8 // b=0.7
9 // C2H6 + (0.9)*(3.5) O2 + (0.9)*(3.5)*(79/21)* N 2
       1.3CO2 + 0.7CO + 3H2O + (0.9)*(3.5)*(79/21)N2
10
11 n=1.3+0.7+0.9*3.5*(79/21);
12
13 CO2=1.3/n*100;
14 CO=0.7/n*100;
15 N2=11.85/n*100;
16
17 disp(" Volumetric analysis of dry products of
```

```
       combustion is as follows ")
18
19 disp (" CO2 =")
20 disp (CO2)
21 disp ("%")
22
23 disp (" CO =")
24 disp (CO)
25 disp ("%")
26
27 disp (" N2 =")
28 disp (N2)
29 disp ("%")
```

Scilab code Exa 11.18 18

```
 1 clc
 2 disp (" (i) Combustion equation")
 3
 4 // x CH4 + y O2 + z N2          10.0 CO2 + 0.53 CO +
      2.37 O2 + a H2O + 87.1 N2
 5
 6 z=87.1;
 7 y=z*(79/21);
 8 x=10+0.53;
 9 a=2*x;
10
11 //10.53 CH4 + 23.16 O2 + 87.1 N2      10.0 CO2 + 0.53
      CO + 2.37 O2 + 21.06 H2O + 87.1 N2
12
13 disp (" CH4 + 2.2 O2 + 8.27 N2     0.95 CO2 + 0.05 CO
      + 2H2O + 0.225 O2 + 8.27 N2")
14
15 disp (" (ii) Air-fuel ratio ")
16
```

```
17  AF_mole=2.2+8.27;
18  disp("air-fuel ratio on a mole basis =")
19  disp(AF_mole)
20  disp("moles air/mole fuel")
21
22  AF_mass=AF_mole*28.97/(12+1*4);
23  disp("air-fuel ratio on a mass basis =")
24  disp(AF_mass)
25  disp("air/kg fuel")
26
27  // CH4 + 2O2 + 2*(79/21)N2      CO2 + 2H2O + (2)
        *(79/21)N2
28  AF_theor=(2+2*(79/21))*28.97/(12+1*4);
29  disp("theoretical air-fuel ratio =")
30  disp(AF_theor)
31  disp("kg air/kg fuel")
32
33  disp("(iii) Percent theoretical air =")
34  %theo=AF_mass/AF_theor*100;
35  disp(%theo)
36  disp("%")
```

Scilab code Exa 11.19 19

```
1  clc
2  disp("(i) The stoichiometric A/F ratio")
3
4  // 1 kg of coal contains 0.82 kg C and 0.10 kg H2.
5  // Let the oxygen required for complete combustion =
        x moles
6  // the nitrogen supplied with the oxygen = x
        *79/21=3.76*x
7  // 0.82/12*C+0.10/2*H2 + x CO2 + 3.76x N2      a CO2
        + b H2O + 3.76 x N2
8  a=0.82/12; // Carbon balance
```

```
9  b=0.10/2; //Hydrogen balance
10 x=(2*a+b)/2; // Oxygen balance
11
12 Stoichiometric_AF_ratio=2.976/0.233;
13 disp("Stoichiometric AF ratio =")
14 disp(Stoichiometric_AF_ratio)
15
16 n=a+b+3.76*x;
17
18 CO2=0.068/n*100;
19 H2=0.05/n*100;
20 N2=3.76*0.093/n*100;
21
22 disp("the analysis of the products is")
23 disp("CO2 =")
24 disp(CO2)
25 disp("%")
26
27 disp("H2 =")
28 disp(H2)
29 disp("%")
30
31 disp("N2 =")
32 disp(N2)
33 disp("%")
```

Scilab code Exa 11.20 20

```
1 clc
2
3 // C + O2       CO2
4 // 2H2 + O2        2H2O
5 // S + O2        SO2
6
7 O2_req=2.636; //kg
```

```
 8
 9  AF=O2_req/0.233;
10  disp("The stoichiometric A/F ratio =")
11  disp(AF)
12
13  disp("(i) Actual A/F ratio =")
14  AF_act=AF+0.3*AF;
15  disp(AF_act)
16
17  disp("(ii) Wet and dry analyses of products of
        combustion by volume")
18
19  // As per actual A/F ratio, N2 supplied = 0.767 *
        14.7 = 11.27 kg
20  // Also O2 supplied = 0.233 * 14.7 = 3.42 kg
21
22  // In the products then, we have
23  // N2 = 11.27 + 0.01 = 11.28 kg
24  // excess O2 = 3.42        2.636 = 0.78 kg
25
26  n_wet=0.5208;
27  n_dry=0.5008;
28
29  disp("Analysis of wet products is as follows :")
30
31  disp("CO2 =")
32  CO2=0.0734/n_wet*100;
33  disp(CO2)
34  disp("%")
35
36  disp("H2O =")
37  H2O=0.0200/n_wet*100;
38  disp(H2O)
39  disp("%")
40
41  disp("SO2 =")
42  SO2=0.0002/n_wet*100;
43  disp(SO2)
```

```
44  disp("%")
45
46  disp("O2 =")
47  O2=0.0244/n_wet*100;
48  disp(O2)
49  disp("%")
50
51  disp("N2 =")
52  N2=0.4028/n_wet*100;
53  disp(N2)
54  disp("%")
55
56  disp("Analysis of dry products is as follows :")
57
58  disp("CO2 =")
59  CO2=0.0734/n_dry*100;
60  disp(CO2)
61  disp("%")
62
63  disp("SO2 =")
64  SO2=0.0002/n_dry*100;
65  disp(SO2)
66  disp("%")
67
68  disp("O2 =")
69  O2=0.0244/n_dry*100;
70  disp(O2)
71  disp("%")
72
73  disp("N2 =")
74  N2=0.4028/n_dry*100;
75  disp(N2)
76  disp("%")
```

Scilab code Exa 11.21 21

```scilab
1  clc
2
3  // 2H2 + O2      2H2O
4  // 2CO + O2      2CO2
5  // CH4 + 2O2      CO2 + 2H2O
6  // C4H8 + 6O2      4CO2 + 4H2O
7
8  n_O2=0.853; //total moles of O2
9
10 disp(")(i) Stoichiometric A/F ratio =")
11 AF=n_O2/0.21;
12 disp(AF)
13
14 disp("(ii) Wet and dry analyses of the products of
       combustion if the actual mixture is 30% weak :")
15 AF_act=AF+0.3*AF;
16 n_N2=0.79*AF_act;
17 O2_excess=0.21*AF_act-n_O2;
18
19 n_wet=5.899;
20 n_dry=4.915;
21
22 disp("Analysis by volume of wet products is as
       follows :")
23
24 disp("CO2 =")
25 CO2=0.490/n_wet*100;
26 disp(CO2)
27 disp("%")
28
29 disp("H2O =")
30 H2O=0.984/n_wet*100;
31 disp(H2O)
32 disp("%")
33
34 disp("O2 =")
35 O2=O2_excess/n_wet*100;
36 disp(O2)
```

```
37  disp("%")
38
39  disp("N2 =")
40  N2=n_N2/n_wet*100;
41  disp(N2)
42  disp("%")
43
44  disp("Analysis by volume of dry products is as
        follows :")
45
46  disp("CO2 =")
47  CO2=0.490/n_dry*100;
48  disp(CO2)
49  disp("%")
50
51  disp("O2 =")
52  O2=O2_excess/n_dry*100;
53  disp(O2)
54  disp("%")
55
56  disp("N2 =")
57  N2=n_N2/n_dry*100;
58  disp(N2)
59  disp("%")
```

Scilab code Exa 11.22 22

```
1  clc
2
3  // C2H6O + 3O2 + 3*79/21 N2        2CO2 + 3H2O +
       3*79/21 N2
4
5  O2_req=3*32/46;
6
7  AF=O2_req/0.233;
```

```scilab
 8  disp("Stoichiometric A/F ratio =")
 9  disp(AF)
10
11  mix=0.8; //mixture strength
12
13  AF_actual=AF/mix;
14  disp("Actual A/F ratio =")
15  disp(AF_actual)
16
17  // C2H6O + 1.25*(3 O2 + 3*79/21 N2)    2CO2 + 3H2O
       + 0.25*3O2 + 1.25*3*79/21 N2
18
19  n=2+3+0.75+14.1;
20
21  disp("Hence wet analysis is")
22
23  disp("CO2 =")
24  CO2=2/n*100;
25  disp(CO2)
26  disp("%")
27
28  disp("H2O =")
29  H2O=3/n*100;
30  disp(H2O)
31  disp("%")
32
33  disp("O2 =")
34  O2=0.75/n*100;
35  disp(O2)
36  disp("%")
37
38  disp("N2 =")
39  N2=14.1/n*100;
40  disp(N2)
41  disp("%")
42
43  nd=2+0.75+14.1; //total dry moles
44
```

```
45  disp("Hence dry analysis is : ")
46
47  disp("CO2 =")
48  CO2=2/nd*100;
49  disp(CO2)
50  disp("%")
51
52  disp("O2 =")
53  O2=0.75/nd*100;
54  disp(O2)
55  disp("%")
56
57  disp("N2 =")
58  N2=14.1/nd*100;
59  disp(N2)
60  disp("%")
61
62  mix=1.3;
63  AF_act=AF/mix;
64  disp("Actual A/F ratio =")
65  disp(AF_act)
```

Scilab code Exa 11.23 23

```
1  clc
2  // C2H6O + 3O2 + 3*79/21 N2      2CO2 + 3H2O +
       3*79/21 N2
3  R0=8.314*10^3; //kJ/kg K
4  m=46; //kg
5
6  disp("(i) Volume of reactants per kg of fuel ")
7
8  n=1+3+3*79/21;
9  T=323; //K
10 p=1.013*10^5; //Pa
```

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```
11
12  V=n*R0*T/p;
13
14  disp("Vr=")
15  Vr=V/m;
16  disp(Vr)
17  disp("m^3")
18
19  disp("(ii) Volume of products per kg of fuel")
20
21  n=2+3+3*79/21;
22  T=403;  //K
23  p=1*10^5;  //Pa
24
25  V=n*R0*T/p;
26
27  Vp=V/m;
28  disp("Vp=")
29  disp(Vp)
30  disp("m^3")
```

Scilab code Exa 11.24 24

```
1  clc
2
3  //  0.506H2 + 0.1CO + 0.26CH4 + 0.04C4H8 + 0.004O2 +
        0.03CO2 + 0.06N2 + 0.21    7O2 + 0.79      7N2
        a CO2 + b H2O + c O2 + d N2
4
5  a=0.1*0.26+4*0.04+0.03;
6  b=(2*0.506+4*0.26+8*0.04)/2;
7  c=(0.1+2*0.004+2*0.03+0.21*7*2-2*a-b)/2;
8  d=(2*0.06+2*0.79*7)/2;
9
10 n=0.55+0.411+5.59;
```

```
11
12 disp("analysis by volume is")
13 disp("CO2=")
14 CO2=0.55/n*100;
15 disp(CO2)
16 disp("%")
17
18 disp("O2=")
19 O2=0.411/n*100;
20 disp(O2)
21 disp("%")
22
23 disp("N2 =")
24 N2=5.59/n*100;
25 disp(N2)
26 disp("%")
```

Scilab code Exa 11.25 25

```
1 clc
2 // C_aH_bO_cN_dS_e
3
4 a=60/12;
5 b=20;
6 c=5/16;
7 d=10/14;
8 e=5/32;
9
10 // C_5 H_20 O_0.3125 N_0.7143 S_0.1562 + x O2 + x
      *(79/21)N2      p CO2 + q H2O + r SO2 + s N2
11 p=5;
12 q=20/2;
13 r=0.1562;
14 x=(2*p+q+2*r-0.3125)/2;
15 s=(0.7143+2*x*79/21)/2;
```

```
16
17  air=(9.92*32+x*79/21*28)/100;
18  disp("Stoichiometric air required =")
19  disp(air)
20  disp("kg/kg of fuel")
```

Scilab code Exa 11.26 26

```
1  clc
2
3  disp("(i) Stoichiometric air fuel ratio ")
4  // C_aH_bO_cN_d
5
6  a=84/12;
7  b=10;
8  c=3.5/16;
9  d=1.5/14;
10
11  // C7 H10 O0.218 N0.107 + x O2 + x*(79/21)N2       p
        CO2 + q H2O + r N2
12
13  p=7;
14  q=10/2;
15  x=(2*p+q-c)/2;
16  r=(d+2*x*(79/21))/2;
17
18  AF=(x*32+x*79/21*28)/100;
19  disp("Stoichiometric A/F ratio =")
20  disp(AF)
21
22  disp("(ii) Percentage composition of dry flue gases
        by volume with 20 per cent excess air :")
23
24  // C7H10O0.218N0.107 + (1.2)(9.39) O2 + (1.2)(9.39)
        *(79/21)N2       7CO2 + 5H2O + (0.2)(9.39) O2 +
```

```
            (1.2)(35.4) N2
25
26  n=7+0.2*9.39+1.2*35.4;
27
28  disp("Percentage composition of dry flue gases by
        volume is as follows :")
29  disp("CO2 =")
30  CO2=7/n*100;
31  disp(CO2)
32  disp("%")
33
34  disp("O2 =")
35  O2=1.878/n*100;
36  disp(O2)
37  disp("%")
38
39  disp("N2 =")
40  N2=42.48/n*100;
41  disp(N2)
42  disp("%")
```

Scilab code Exa 11.27 27

```
1  clc
2  // a C + b H + c O2 + (79/21)*c N2 = 8CO2 + 0.5CO +
        6.3O2 + x H2O + 85.2N2
3
4  a=8+0.5;
5  c=85.2/(79/21);
6  x=2*(c-8-0.5/2-6.3);
7  b=2*x;
8
9  disp("(i) Air-fuel ratio =")
10  AF=(c*32+(79/21)*c*28)/(a*12+b*1);
11  disp(AF)
```

```
12  disp("kg of air/kg of fuel")
13
14  disp("(ii) Per cent theoretical air required for
        combustion ")
15  mf_C=12*a/(12*a+b);
16  mf_H2=b*1/(12*a+b);
17  air=mf_C*8/3*100/23.3 + mf_H2*8*100/23.3; //air
        required for complete combustion
18  percent=AF/air*100;
19  disp("Per cent theoretical air required for
        combustion =")
20  disp(percent)
21  disp("%")
```

Scilab code Exa 11.28 28

```
1  clc
2  disp("(i) By a carbon balance")
3
4  // a C8H18 + 78.1N2 + 78.1*(21/79)O2        8.9CO2 +
        8.2CO + 4.3H2 + 0.5CH4 + 78.1N2 + x H2O
5  a=(8.9+8.2+0.5)/8;
6
7  AF1=(78.1*28+78.1*21/79*32)/a/(8*12+1*18);
8  disp("Air fuel ratio =")
9  disp(AF1)
10
11
12  disp("(ii) By a hydrogen−oxygen balance ")
13
14  // a C8H18 + b O2 + b*(79/21)N2        8.9CO2 + 8.2CO +
        4.3H2 + 0.5CH4 + b*(79/21)N2 + x*H2O
15
16  a=(8.9+8.2+0.5)/8;
17  x=(18*a-4.3*2-4*0.5)/2;
```

```
18  b=(8.9*2+8.2+x)/2;
19
20  AF2=(b*32+b*(79/21)*28)/a/(8*12+1*18);
21  disp("Air fuel ratio =")
22  disp(AF2)
```

Scilab code Exa 11.29 29

```
1  clc
2  // X(0.88/12 C + 0.12/2 H2) + Y O2 + 79/21*Y N2
       0.12CO2 + a O2 + (0.88      a) N2 + b H2O
3
4  X=0.12/(0.88/12);
5  b=0.06*X;
6  a=0.0513;
7  Y=0.2203;
8  Air_supplied=0.2203*32/0.233;
9
10 AF=Air_supplied/X;
11 disp("A/F ratio =")
12 disp(AF)
```

Scilab code Exa 11.30 30

```
1  clc
2  // X*(x/12 C + y/2 H2) + Y O2 + 79/21*Y/N2      0.15
       CO2 + 0.03CO + 0.03CH4 + 0.01H2 + 0.02O2 + a H2O
       + 0.76N2
3
4  Y=0.76/(79/21);
5  a=2*(Y-0.15-0.03/2-0.02);
6  Xx=12*(0.15+0.03+0.03);
7  Xy=2*(2*0.03+0.01+a);
```

```
8 ratio=Xx/Xy;
9
10 disp("Ratio of C to H2 in fuel =")
11 disp(ratio)
```

Scilab code Exa 11.31 31

```
1 clc
2 h_fg0=2441.8; //kJ/kg
3 m=3*18;
4 dH0_liq=-3301000; //kJ/mole
5
6 dH0_vap=dH0_liq+m*h_fg0;
7 disp("dH0_vapour =")
8 disp(dH0_vap)
9 disp("kJ/mole")
```

Scilab code Exa 11.32 32

```
1 clc
2
3 // C6H6 + 7.5O2        6CO2 + 3H2O (vapour)
4 dH0=-3169100; //kJ
5 n_R=1+7.5;
6 n_P=6+3;
7 R0=8.314;
8 T0=298; //K
9
10 dU0=(dH0-(n_P-n_R)*R0*T0)/(6*12+1*6);
11 disp("dU0 =")
12 disp(dU0)
13 disp("kJ/kg")
```

Scilab code Exa 11.33 33

```
1  clc
2  // CO+1/2 O2      CO2
3  H_R0=1*9705+1/2*9696;  //kJ
4  H_RT=1*94080+1/2*99790;  //kJ
5  H_P0=1*10760;  //kJ
6  H_PT=1*149100;  //kJ
7
8  dH_T=-(285200+(143975-14553)-(149100-10760));
9  disp("dH_T =")
10 disp(dH_T)
11 disp("kJ/mole")
```

Scilab code Exa 11.34 34

```
1  clc
2  disp("(i) Higher heating value at constant pressure"
       )
3  m=4*18;
4  h_fg=2443;  //kJ/kg
5  LHVp=2044009;  //kJ/kg
6  R0=8.3143;  //kJ/kg K
7  T=298;  //K
8
9  HHVp=LHVp+m*h_fg;
10 disp("HHVp =")
11 disp(HHVp)
12 disp("kJ/kg")
13
14 disp("(ii) Higher heating value at constant volume")
15 dn=3-(1+5);
```

```
16
17  HHVv = HHVp + dn * R0 * T ;
18  disp ( " HHVv =" )
19  disp ( HHVv )
20  disp ( " kJ / kg " )
```

Scilab code Exa 11.35 35

```
1  clc
2  HHV =5494977;  // kJ / kg
3  m =9*18;
4  u_fg =2305;  // kJ / kg
5  LHVv = HHV - m * u_fg ;
6  disp ( " LHVv =" )
7  disp ( LHVv )
8  disp ( " kJ / kg " )
```

Scilab code Exa 11.36 36

```
1  clc
2  disp ( " ( i ) Air and benzene vapour " )
3
4  // C6H6 ( g ) + 7.5 O2 ( g ) + 7.5*(79/21) N2 ( g ) = 6CO2 ( g ) +
        3H2O ( g ) + 7.5*(79/21)* N2 ( g )
5
6  LHVp =3169500;  // kJ / mole
7
8  LHVv = LHVp / ((12*6+6*1) + (7.5*32) +7.5*(79/21) *28)
9  disp ( " LHVv per kg of mixture =" )
10  disp ( LHVv )
11  disp ( " kJ / kg " )
12
13  m =54;  // kg / kg mole of fuel
```

```
14  h_fg =2442;  // kJ / kg
15
16  HHVp =( LHVp+m * h_fg ) / (78+240+790);
17  disp ("HHVp per kg of mixture =")
18  disp (HHVp)
19  disp ("kJ/kg")
20
21  disp ("(ii) Air and octane vapour ")
22  LHVp =5116200;  // kJ/ mole of C8H18
23
24  // C8H18( g ) + 12.5 O2( g )        8CO2( g ) + 9H2O( g ) +
        12.5 *(79/21) N2( g )
25
26  LHVp1 = LHVp / ((12 * 8+18 * 1) +12.5 * 32+12.5 * 79/21 * 28);
27  disp ("LHVp per kg of mixture =")
28  disp ( LHVp1 )
29  disp ("kJ/kg")
30
31  m =9*18;
32  HHVp = LHVp+m * h_fg;
33  HHVp1 = HHVp / (114+400+1317);
34  disp ("HHVp per kg of mixture =")
35  disp (HHVp1)
36  disp ("kJ/kg")
```

Scilab code Exa 11.37 37

```
1  clc
2  m_CO2 =44/12 * 0.88;  // kg
3  m_H2O =18/2 * 0.12;  // kg
4  u_fg =2304;  // kJ / kg
5  h_fg =2442;  // kJ / kg
6  HHVv =45670;  // kJ / kg
7  R0 =8.3143;  // kJ / kg K
8  T =298;  // K
```

```
 9  disp (" ( i )  (LHV) v =")
10  LHVv = HHVv - m_H2O * u_fg ;
11  disp ( LHVv )
12  disp (" kJ / kg ")
13
14  disp (" ( i i )  (HHV) p ,  (LHV) p")
15
16  //1  mole  fuel + x /32  O2 - - >3.23/44  CO2 +  1.08/18  H2O
17
18  x =32*( m_CO2 /44+ m_H2O /18/2) ;
19
20  // 1  kg  fuel  +  3.31  kg  O2 =  3.23 CO2 +  1.08 H2O
21
22  dn =( m_CO2 /44 - x /32) ;
23
24  HHVp = HHVv - dn * R0 * T ;
25  disp (" HHVp =")
26  disp ( HHVp )
27  disp (" kJ / kg ")
28
29  LHVp = HHVp - m_H2O * h_fg ;
30  disp (" LHVp =")
31  disp ( LHVp )
32  disp (" kJ / kg ")
```

Chapter 12

Vapour Power Cycles

Scilab code Exa 12.1 1

```
1  clc
2  p1=60;  //bar; Inlet to turbine
3  p2=0.1;  //bar; Exit from turbine
4  p3=0.09;  //bar; Exit from condenser
5  p4=70;  //bar ; Exit from pump
6  p5=65;  //bar; Exit from boiler
7
8  t1=380;  //0C
9  t5=400;  //0C
10
11  x2=0.9;  //Quality at exit from turbine
12
13  C=200;  //m/s; Velocity at the exit from turbine
14
15  disp("(i) Power output of the turbine")
16
17  //At 60 bar 380 0C, From steam tables
18
19  h1=3123.5;  //kJ/kg; By interpolation
20  h_f2=191.8;  //kJ/kg
21  h_fg2=2392.8;  //kJ/kg
```

```
22  x2=0.9;
23
24  h2=h_f2+x2*h_fg2;
25  m_s=10000/3600;  //Rate of stem flow in kg/s
26
27  P=m_s*(h1-h2);
28  disp("Power output of the turbine =")
29  disp(P)
30  disp("kW")
31
32
33  disp("(ii) Heat transfer per hour in the boiler and
          condenser")
34
35  h_f4=1267.4;  //kJ/kg
36  h_a=3167.6;  //kJ/kg
37
38  Q1=10000*(h_a - h_f4);
39  disp("Heat transfer per hour in the boiler =")
40  disp(Q1)
41  disp("kJ/h")
42
43  h_f3=183.3;  //kJ/kg
44  Q2=10000*(h2-h_f3);
45  disp("Heat transfer per hour in the condenser =")
46  disp(Q2)
47  disp("kJ/h")
48
49
50  disp("(iii) Mass of cooling water circulated per
          hour in the condenser")
51  c_pw=4.18;
52  t2=30;
53  t1=20;
54
55  m_w=Q2/c_pw/(t2-t1);
56  disp("m_w=")
57  disp(m_w)
```

```
58  disp("kg/h")
59  disp("This is the exact answer.")
60
61  disp("(iv) Diameter of the pipe connecting turbine
        with condenser")
62
63  v_g2=14.67; //m^3/kg
64
65  d=sqrt(m_s*x2*v_g2*4/%pi/C)*1000;
66  disp("Diameter =")
67  disp(d)
68  disp("mm")
```

Scilab code Exa 12.2 2

```
1  clc
2  p1=15; //bar
3  x1=1;
4  p2=0.4; //bar
5
6  //At 15 bar
7  t_s1=198.3; //0C
8  h_g1=2789.9; //kJ/kg
9  s_g1=6.4406; //kJ/kg K
10
11  //At 0..4 bar
12  t_s2=198.3; //0C
13  h_f2=317.7; //kJ/kg
14  h_fg2=2319.2; //kJ/kg
15  s_f2=1.0261; //kJ/kg K
16  s_fg2=6.6448; //kJ/kg K
17  T1=471.3; //K
18  T2=348.9; //K
19
20  n_carnot=(T1-T2)/T1;
```

```
21  disp("Carnot  efficiency=")
22  disp(n_carnot)
23
24
25  x2=(s_g1 - s_f2)/s_fg2;
26  h2=h_f2+x2*h_fg2;
27
28  n_rankine=(h_g1-h2)/(h_g1-h_f2);
29  disp("Rankine  efficiency=")
30  disp(n_rankine)
```

Scilab code Exa 12.3 3

```
1  clc
2  p1=20;  //bar
3  p2=0.08;  //bar
4
5  //At  20  bar ,  360  0C
6
7  h1=3159.3;  //kJ/kg
8  s1=6.9917;  //kJ/kg  K
9
10  //At  0.08  bar
11  h_f2=173.88;  //kJ/kg
12  s_f2=0.5926;  //kJ/kg  K
13
14  h_fg2=2403.1;  //kJ/kg
15  s_g=8.2287;  //kJ/kg  K
16  v_f=0.001008;  //m^3/kg
17  s_fg=7.6361;  //kJ/kg  K
18
19  x2=(s1-s_f2)/s_fg;
20
21  h2=h_f2+x2*h_fg2;
22
```

```
23  W_pump=v_f*(p1-p2)*100;  //kJ/kg
24  W_turbine=h1-h2;
25
26  W_net=h1-h2;
27  disp("Net work done=")
28  disp(W_net)
29  disp("kJ/kg")
30
31  h_f4=W_pump+h_f2;
32  Q1=h1-h_f4;
33
34  n_cycle=W_net/Q1;
35  disp("Cycle efficiency=")
36  disp(n_cycle)
```

Scilab code Exa 12.4 4

```
1  clc
2
3  n_turbine=0.9;
4  n_pump=0.8;
5  p1=80;  //bar
6  p2=0.1;  //bar
7  v_f=0.0010103;  //m^3
8
9  //At 80 bar, 600 0C
10 h1=3642;  //kJ/kg
11 s1=7.0206;  //kJ/kg K
12 s_f2=0.6488;  //kJ/kg K
13 s_fg2=7.5006;  //kJ/kg K
14 h_f2=191.9;  //kJ/kg
15 h_fg2=2392.3;  //kJ/kg
16
17 x2=(s1-s_f2)/s_fg2;
18 h2=h_f2+x2*h_fg2;
```

```
19
20  W_turbine=n_turbine*(h1-h2);
21  W_pump=v_f*(p1-p2)*10^2;
22
23  W_actual=W_pump/n_pump;  //Actual pump work
24
25  W_net=W_turbine - W_actual;
26  disp("Specific work =")
27  disp(W_net)
28  disp("kJ/kg")
29
30  h_f4=h_f2+W_actual;
31  Q1=h1-h_f4;
32
33  n_thermal=W_net/Q1;  //Thermal efficiency
34  disp("Thermal efficiency =")
35  disp(n_thermal)
```

Scilab code Exa 12.5 5

```
1  clc
2  p1=28;  //bar
3  p2=0.06;  //bar
4
5  //At 28 bar
6  h1=2802;  //kJ/kg
7  s1=6.2104;  //kJ/kg K
8
9  //At 0.06 bar
10 h_f2=151.5;  //kJ/kg
11 h_f3=h_f2;
12 h_fg2=2415.9;  //kJ/kg
13 s_f2=0.521;  //kJ/kg K
14 s_fg2=7.809;  //kJ/kg K
15 v_f=0.001;  //m^3/kg
```

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```
16
17  x2=(s1-s_f2)/s_fg2;
18
19  h2=h_f2 + x2*h_fg2;
20
21  W_turbine=h1-h2;
22  W_pump=v_f*(p1-p2)*100;  //kJ/kg
23
24  h_f4=h_f2+W_pump;
25  Q1=h1-h_f4;
26  W_net=W_turbine - W_pump;
27
28  n_cycle=W_net/Q1;
29  disp("cyclic efficiency =")
30  disp(n_cycle)
31
32  ratio=W_net/W_turbine; //Work ratio
33  disp("Work ratio =")
34  disp(ratio)
35
36  S=3600/W_net; //Specific steam combustion
37  disp("Specific steam combustion=")
38  disp(S)
39  disp("kg/kWh")
```

Scilab code Exa 12.6 6

```
1  clc
2  p1=35;  //bar
3  x=1;
4  p2=0.2;  //bar
5  m=9.5;  //kg/s
6
7  //At 35 bar
8  h1=2802;  //kJ/kg
```

```
 9  h_g1=h1;
10  s_g1=6.1228;  //kJ/kg K
11
12  //At0.26 bar
13  h_f=251.5;  //kJ/kg
14  h_fg=2358.4;  //kJ/kg
15  v_f=0.001017;  //m^3/kg
16  s_f=0.8321;  //kJ/kg
17  s_fg=7.0773;  //kJ/kg K
18
19  disp(" (i) The pump work")
20  W_pump=v_f*(p1-p2)*100;  //kJ/kg
21  P=m*W_pump;  //power required
22  disp("Power required to drive the pump")
23  disp(P)
24  disp("kW")
25
26
27  disp(" (ii) The turbine work")
28
29  x2=(s_g1-s_f)/s_fg;
30  h2=h_f+x2*h_fg;
31
32  W_turbine=m*(h1-h2);
33  disp("Turbine work=")
34  disp(W_turbine)
35  disp("kW")
36
37
38  disp(" (iii) The Rankine efficiency")
39  n_rankine=(h1-h2)/(h1-h_f);
40  disp("rankine efficiency=")
41  disp(n_rankine)
42
43
44  disp(" (iv) The condenser heat flow :")
45  Q=m*(h2-h_f);
46  disp("The condenser heat flow=")
```

```
47  disp(Q)
48  disp("kW")
49
50
51  disp("(v) The dryness at the end of expansion=")
52  disp(x2)
```

Scilab code Exa 12.7 7

```
1   clc
2   dh=840; //kJ/kg; Adiabatic enthalpy drop
3   h1=2940; ///kJ/kg;
4   p2=0.1; //bar
5   h_f2=191.8; //kJ/kg
6
7   n_rankine=(dh)/(h1-h_f2)*100;
8   disp("rankine efficiency=")
9   disp(n_rankine)
10
11  S=3600/dh; //Specific steam combustion
12  disp("Specific steam combustion=")
13  disp(S)
14  disp("kg/kWh")
```

Scilab code Exa 12.8 8

```
1   clc
2   IP=35; // Power developed by the engine in kW
3   S=284; //Steam combustion in kg/h
4   p2=0.14; //Condenser pressure in bar
5   p1=15; //bar
6
7   h1=2923.3; //kJ/kg
```

```
8  s1=6.709; //kJ/kg K
9
10 h_f=220; //kJ/kg
11 h_fg=2376.6; //kJ/kg
12 s_f=0.737; //kJ/kg K
13 s_fg=7.296; //kJ/kg K
14
15 x2=(s1-s_f)/s_fg;
16 disp("(i) Final condition of steam =")
17 disp(x2)
18
19 h2=h_f+x2*h_fg;
20
21 disp("(ii) Rankine efficiency=")
22 n_rankine=(h1-h2)/(h1-h_f);
23 disp(n_rankine)
24
25 disp("(iii) Relative efficiency")
26 n_thermal=IP/(S/3600)/(h1-h_f);
27
28 n_relative=n_thermal/n_rankine;
29 disp("relative efficiency=")
30 disp(n_relative)
```

Scilab code Exa 12.9 9

```
1  clc
2  P=5000; //kW
3  C=40000; //kJ/kg
4  n_rankine=0.5;
5  n_turbine=0.9;
6  n_heat_transfer=0.85;
7  n_combustion=0.98;
8
9  m_f=P/n_turbine/(C*n_heat_transfer*n_combustion*
```

```
      n_rankine );
10 disp ( " Fuel  oil  combustion=" )
11 disp ( m_f )
12 disp ( " kg / s " )
```

Scilab code Exa 12.10 10

```
 1 clc
 2 p2 =2;  // bar
 3 p3 =1.1;  // bar
 4 IP =1;
 5 m =12.8/3600;  // kg/kWs
 6 n_mech =0.8;  // Mechanical  efficiency
 7 h1 =3037.6;  // kJ/ kg
 8 v1 =0.169;  // m^3/ kg
 9 s1 =6.918;  // kJ/ kg  K
10 t_s2 =120.2;  // 0C
11 h_f2 =504.7;  // kJ/ kg
12 h_fg2 =2201.6;  // kJ/ kg
13 s_f2 =1.5301;  // kJ/ kg  K
14 s_fg2 =5.5967;  // kJ/ kg  K
15 v_f2 =0.00106;  // m^3/ kg
16 v_g2 =0.885;  // m^3/ kg
17 t_s3 =102.3;  // 0C
18 h_f3 =428.8;  // kJ/ kg
19 h_fg3 =2250.8;  // kJ/ kg
20 s_f3 =1.333;  // kJ/ kg  K
21 s_fg3 =5.9947;  // kJ/ kg  K
22 v_f3 =0.001;  // m^3/ kg
23 v_g3 =1.549;  // m^3/ kg
24
25 x2 =( s1 - s_f2 )/ s_fg2 ;
26 h2 = h_f2 + x2 * h_fg2 ;
27 v2 = x2 * v_g2 +(1 - x2 )* v_f2 ;
28
```

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```
29  disp(")(i)Ideal work=")
30  W=(h1-h2) + (p2-p3)*v2*100; //kJ/kg
31  disp(W)
32  disp("kJ/kg")
33
34
35  disp(")(ii) Rankine engine efficiency=")
36  n_rankine=W/(h1-h_f3);
37  disp(n_rankine)
38
39
40  disp(")(iii) Indicated and brake work per kg")
41  W_indicated=IP/m;
42  disp("Indicated worK =")
43  disp(W_indicated)
44  disp("kJ/kg")
45
46  W_brake=n_mech*IP/m;
47  disp("Brake work =")
48  disp(W_brake)
49  disp("kJ/kg")
50
51  disp(")(iv) Brake thermal efficiency=")
52  n_brake=W_brake/(h1-h_f3);
53  disp(n_brake)
54
55
56  disp(")(v) Relative efficiency :")
57
58  n1=W_indicated/W; //on the basis of indicated work
59  disp("Relative efficiency on the basis of indicated
        work=")
60  disp(n1)
61
62  n2=W_brake/W; //on the basis of brake work
63  disp("Relative efficiency on the basis of brake work
        =")
64  disp(n2)
```

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Scilab code Exa 12.11 11

```
1  clc
2  p2=0.75; //bar
3  p3=0.3; //bar
4  h1=3263.9; //kJ/kg
5  v1=0.307; //m^3/kg
6  s1=7.465; //kJ/kg K
7  T_s2=369.7; //K
8  h_g2=2670.9; //kJ/kg
9  s_g2=7.3954; //kJ/kg K
10 v_g2=1.869; //m^3/kg
11 h_f3=289.3; //kJ/kg
12 v_g3=5.229; //m^3/kg
13 cp=2.1;
14
15 disp("(i) Quality of steam at the end of expansion")
16 T_sup2=T_s2*(%e^((s1-s_g2)/cp));
17 t_sup2=T_sup2-273;
18 disp("t_sup2=")
19 disp(t_sup2)
20 disp(" C ")
21
22 h2=h_g2+cp*(T_sup2-366.5);
23
24 disp("(ii) Quality of steam at the end of constant
        volume operation, x3 :")
25 v2=v_g2/T_s2*T_sup2;
26 v3=v2;
27 x3=v3/v_g3;
28 disp("x3=")
29 disp(x3)
30
31
```

```
32  disp(" (iii) Power developed")
33  P=(h1-h2) + (p2-p3)*v2*100;
34  disp("P=")
35  disp(P)
36  disp("kW")
37
38
39  disp(" (iv) Specific steam consumption =")
40  ssc=3600/P;
41  disp(ssc)
42  disp("kg/kWh")
43
44
45  disp(" (v) Modified Rankine cycle efficiency =")
46  n_mR=((h1-h2)+(p2-p3)*v2*100)/(h1-h_f3);
47  disp(n_mR)
```

Scilab code Exa 12.12 12

```
1   clc
2   h1=3100;  //kJ/kg
3   h2=2100;  //kJ/kg
4   h3=2500;  //kJ/kg
5   h_f2=570.9;  //kJ/kg
6   h_f5=125;  //kJ/kg
7   h_f2=570.9;  //kJ/kg
8   a=11200;  //Quantity of bled steam in kg/h
9
10  m=(h_f2-h_f5)/(h2-h_f5);
11
12  S=a/m;  //Steam supplied to the turbine per hour
13
14  W_net=(h1-h3) + (1-m)*(h3-h2);
15
16  P=W_net*S/3600;  //Power developed by the turbine
```

```
17 disp("Power developed by the turbine=")
18 disp(P)
19 disp("kW")
```

Scilab code Exa 12.13 13

```
1  clc
2  //At 30bar, 400 0C
3
4  h1=3230.9; //kJ/kg
5  s1=6.921; //kJ/kg
6  s2=s1;
7  s3=s1;
8  //At 5 bar
9  s_f1=1.8604;
10 s_g1=6.8192; //kJ/kg K
11 h_f1=640.1; //kJ/kg
12
13 t2=172 //0C
14 h2=2796; //kJ/kg
15
16 //At 0.1 bar
17 s_f3=0.649; //kJ/kg K
18 s_fg3=7.501; //kJ/kg K
19 h_f3=191.8; //kJ/kg
20 h_fg3=2392.8; //kJ/kg
21
22 x3=(s2-s_f3)/s_fg3;
23 h3=h_f3+x3*h_fg3;
24
25 h_f4=191.8; //kJ/kg
26 h_f5=h_f4;
27
28 h_f6=640.1; //kJ/kg
29 h_f7=h_f6;
```

```scilab
30 s7=1.8604; //kJ/kg K
31 s4=0.649; //kJ/kg K
32
33 m=(h_f6-h_f5)/(h2-h_f5);
34
35 W_T=(h1-h2) + (1-m)*(h2-h3);
36
37 Q1=h1-h_f6;
38
39 disp("(i) Efficiency of cycle =")
40 n_cycle=W_T/Q1;
41 disp(n_cycle)
42
43 SR=3600/W_T; //Steam rate
44 disp("Steam rate =")
45 disp(SR)
46 disp("kg/kWh")
47
48
49 T_m1=(h1-h_f7)/(s1-s7);
50
51 T_m1r=(h1-h_f4)/(s1-s4); //Without regeneration
52
53 dT_m1=T_m1-T_m1r;
54 disp("Increase in T_m1 due to regeneration=")
55 disp(dT_m1)
56 disp("0C")
57
58 W_Tr=h1-h3; //Without regeneration
59 SR1=3600/W_Tr; //Steam rate without regeneration
60 dSR=SR-SR1;
61 disp("Increase in steam rate due to regeneration=")
62 disp(dSR)
63 disp("kg/kWh")
64
65 n_cycle1=(h1-h3)/(h1-h_f4); //without regeneration
66 dn_cycle=n_cycle-n_cycle1;
67 disp("Increase in cycle efficiency due to
```

```
            regeneration")
68 disp(dn_cycle*100)
69 disp("%")
```

Scilab code Exa 12.14 14

```
 1 clc
 2
 3 //At 3 bar
 4 t_s1=133.5; //0C
 5 h_f1=561.4; //kJ/kg
 6
 7 //At 0.04 bar
 8 t_s2=29; //0C
 9 h_f2=121.5; //0C
10
11 h0=3231; //kJ/kg
12 h1=2700; //kJ/kg
13 h2=2085; //kJ/kg
14
15 t1=130; //0C
16 t2=27; //0C
17 c=4.186;
18
19 disp("(i) Mass of steam used")
20 m1=c*(t1-t2)/(h1-h_f2);
21 disp("m1=")
22 disp(m1)
23 disp("kg")
24
25
26 disp("(ii) Thermal efficiency of the cycle")
27 W=(h0-h1)+(1-m1)*(h1-h2);
28 Q=h0-c*t1;
29
```

```
30  n_thermal = W/Q ;
31  disp (" n_thermal=")
32  disp ( n_thermal )
```

Scilab code Exa 12.15 15

```
 1  clc
 2
 3  h0 =3115.3;  //kJ/kg
 4  h1 =2720;  //kJ/kg
 5  h2 =2450;  //kJ/kg
 6  h3 =2120;  //kJ/kg
 7
 8  h_f1 =640.1;  //kJ/kg
 9  h_f2 =417.5;  //kJ/kg
10  h_f3 =173.9;  //kJ/kg
11
12  m1 =( h_f1 - h_f2 )/( h1 - h_f1 );
13  disp ("m1=")
14  disp (m1)
15  disp (" kJ/kg")
16
17  m2 =(( h_f2 - h_f3 ) -m1 *( h_f1 - h_f3 ))/( h2 - h_f3 );
18  disp ("m2=")
19  disp (m2)
20  disp (" kJ/kg")
21
22  W=h0 - h1 + (1-m1)*(h1 - h2) + (1 - m1 - m2)*(h2 - h3);
23  Q=h0 - h_f1 ;
24
25  n=W/Q ;
26  disp (" Thermal  Efficiency  of  the  cycle=")
27  disp (n)
```

Scilab code Exa 12.16 16

```scilab
1  clc
2  h0=2905; //kJ/kg
3  h1=2600; //kJ/kg
4  h2=2430; //kJ/kg
5  h3=2210; //kJ/kg
6  h4=2000; //kJ/kg
7
8  h_f1=640.1; //kJ/kg
9  h_f2=467.1; //kJ/kg
10 h_f3=289.3; //kJ/kg
11 h_f4=137.8; //kJ/kg
12
13 disp("(i) Mass of bled steam")
14
15 m1=(h_f1-h_f2)/(h1-h_f1);
16 disp("m1=")
17 disp(m1)
18 disp("kJ/kg")
19
20 m2=((h_f2-h_f3) - (m1*(h_f1-h_f2)))/(h2-h_f2);
21 disp("m2=")
22 disp(m2)
23 disp("kJ/kg")
24
25 m3=((h_f3-h_f4)-(m1+m2)*(h_f2-h_f4))/(h3-h_f4);
26 disp("m3=")
27 disp(m3)
28 disp("kJ/kg")
29
30 W=(h0-h1) + (1-m1)*(h1-h2)+(1-m1-m2)*(h2-h3) + (1-m1
     -m2-m3)*(h3-h4);
31
```

```
32  Q=h0-h_f1;
33
34  disp(" (ii) Thermal efficiency of the cycle=")
35  n_thermal=W/Q;
36  disp(n_thermal)
37
38
39  disp(" (iii) Thermal efficiency of Rankine cycle =")
40  n_rankine=(h0-h4)/(h0-h_f4);
41  disp(n_rankine)
42
43
44  disp(" (iv) Theoretical gain due to regenerative feed
        heating =")
45  gain=(n_thermal-n_rankine)/(n_thermal);
46  disp(gain)
47
48  disp(" (v) Steam consumption with regenerative feed
       heating =")
49  S1=3600/W;
50  disp(S1)
51  disp("kg/kWh")
52
53  disp("Steam consumption without regenerative feed
       heating =")
54  S2=3600/(h0-h4);
55  disp(S2)
56  disp("kg/kWh")
57
58  disp(" (vi) Quantity of steam passing through the
       last stage of a 50000 kW turbine with
       regenerative feed-heating =")
59  quantity1=S1*(1-m1-m2-m3)*50000;
60  disp(quantity1)
61  disp("kg/h")
62
63  disp("quantity of steam without regeneration =")
64  quantity2=S2*50000;
```

```
65  disp(quantity2)
66  disp("kg/h")
```

Scilab code Exa 12.17 17

```
 1  clc
 2  h1=3460;  //kJ/kg
 3  h2=3460;  //kJ/kg
 4  h3=3111.5;  //kJ/kg
 5  h4=3585;  //kJ/kg
 6  h5=3207;  //kJ/kg
 7  h6=2466;  //kJ/kg
 8  h7=137.8;  //kJ/kg
 9  h8=962;  //kJ/kg
10  h9=670.4;  //kJ/kg
11  h10=962;  //kJ/kg
12
13  p1=100;  //bar
14  p2=95;  //bar
15  p3=25;  //bar
16  p4=22;  //bar
17  p5=6;  //bar
18  p6=0.05;  //bar
19
20  n_mech=0.9;
21  n_gen=0.96;
22  n_boiler=0.9;
23
24  P=120*10^3;  //kW
25
26  m1=(h10-h9)/(h3-h8);
27
28  m2=(h9-m1*h8-(1-m1)*h7)/(h5-h7);
29
30  W_IP=(1-m1-m2)*(p5-p6)*0.001*10^2;
```

```scilab
31  W_HP=(p1-p5)*0.001*10^2;
32
33  W_total=(W_IP+W_HP)/n_mech;
34
35  W_indicated=(h2-h3) + (1-m1)*(h4-h5) + (1-m1-m2)*(h5
        -h6);
36
37  Output=(W_indicated - W_total)*n_mech*n_gen; //net
         electrical output
38
39  rate=P*3600/Output;
40
41  amt1=m1*rate; //Amounts of bled off, surface(high
         pressure) heater
42  disp("Amounts of bled off, surface(high pressure)
         heater =")
43  disp(amt1)
44  disp("kg/h")
45
46  amt2=m2*rate; //Amounts of bled off, surface(low
         pressure) heater
47  disp("Amounts of bled off, surface(low pressure)
         heater")
48  disp(amt2)
49  disp("kg/h")
50
51
52  disp("(iii) Overall thermal efficiency")
53  Q_boiler=(h1-h10)/n_boiler;
54  Q_reheater=(h4-h3)/n_boiler;
55
56  n_overall=Output/(Q_boiler+Q_reheater)*100;
57  disp("Overall thermal efficiency =")
58  disp(n_overall)
59  disp("%")
60
61
62  disp("(iv) Specific steam consumption =")
```

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```
63  ssc=rate/P; //Specific steam consumption
64  disp(ssc)
65  disp("kg/kWh")
```

Scilab code Exa 12.18 18

```
 1  clc
 2  p1=15; //bar
 3  p2=4; //bar
 4  p4=0.1; //bar
 5
 6  h1=2920; //kJ/kg
 7  h2=2660; //kJ/kg
 8  h3=2960; //kJ/kg
 9  h4=2335; //kJ/kg
10
11  W=h1-h2+h3-h4;
12  disp("work done per kg of steam")
13  disp(W)
14  disp("kJ/kg")
15
16  h_reheat=h3-h2;
17  disp("Amount of heat supplied during reheat =")
18  disp(h_reheat)
19  disp("kJ/kg")
20
21  h_4a=2125; //kJ/kg
22
23  W1=h1-h_4a;
24  disp("Work output without reheat =")
25  disp(W1)
26  disp("kJ/kg")
```

Scilab code Exa 12.19 19

```
1  clc
2
3  h1=3450;  //kJ/kg
4  h2=3050;  //kJ/kg
5  h3=3560;  //kJ/kg
6  h4=2300;  //kJ/kg
7
8  h_f4=191.8;  //kJ/kg
9
10 //From mollier diagram
11 x4=0.88;
12 disp(" (i) Quality of steam at turbine exhaust =")
13 disp(x4)
14
15
16 n_cycle=((h1-h2) + (h3-h4))/((h1-h_f4) + (h3-h2));
17 disp(" (ii) Cycle efficiency =")
18 disp(n_cycle)
19
20
21 SR=3600/((h1-h2) + (h3-h4));
22 disp(" (iii) Steam rate in kg/kWh =")
23 disp(SR)
24 disp(" kg/kWh")
```

Scilab code Exa 12.20 20

```
1  clc
2
3  h1=3250;  //kJ/kg
4  h2=2170;  //kJ/kg
5  h_f2=173.9;  //kJ/kg
6
```

```
7  W=h1 -h2 ;
8  Q=h1 -h_f2 ;
9
10 n_thermal =W/Q ;
11 disp ("Thermal effifciency=")
12 disp ( n_thermal ) ;
13
14 x2 =0.83 ; //From mollier chart
15 disp ("x2=")
16 disp ( x2 )
17
18
19 disp ("Second case")
20
21 h1 =3250 ; //kJ/kg
22 h2 =2807 ; //kJ/kg
23 h3 =3263 ; //kJ/kg
24 h4 =2426 ; //kJ/kg
25 h_f4 =173.9 ; //kJ/kg
26 W=h1 -h2+h3 -h4 ;
27 Q=h1 -h_f4+h3 -h2 ;
28
29 n_thermal =W/Q ;
30 disp ("Thermal effifciency=")
31 disp ( n_thermal ) ;
32
33 x4 =0.935 ; //From mollier chart
34 disp ("x4=")
35 disp ( x4 )
```

Scilab code Exa 12.21 21

```
1  clc
2
3  disp ("(a) The erosion of the moving blades is caused
```

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```
     by the presence of water particles in (wet)
     steam in the L.P. stages. The water particles
     strike the leading surface of the blades. Such
     impact, if sufficiently heavy, produces severe
     local stresses in the blade material causing the
     surface metal to fail and flake off.")
 4
 5 disp(" The erosion, if any, is more likely to occur
     in the region where the steam is wettest, i.e.,
     in the last one or two stages of the turbine.
     Moreover, the water droplets are concentrated in
     the outer parts of the flow annuals where the
     velocity of impact is highest.")
 6 disp("Erosion difficulties due to moisture in the
     steam may be avoided by reheating. The whole of
     steam is taken from the turbine at a suitable
     point 2, and a further supply of heat is given to
      it along 2-3 after which the steam is readmitted
      to the turbine and expanded along 3-4 to
     condenser pressure. Erosion may also be reduced
     by using steam traps in between the stages to
     separate moisture from the steam.")
 7
 8
 9
10 disp("(b) TTD means   Terminal temperature
     difference  . It is the difference between
     temperatures of bled steam/condensate and the
     feed water at the two ends of the feed water
     heater")
11
12
13
14 disp("Part (c)")
15
16 h1=3580;  //kJ/kg
17 h2=3140;  //kJ/kg
18 h3=3675;  //kJ/kg
```

```
19  h4 =2335; //kJ/kg
20  h5 =191.8; //kJ/kg
21
22  P=15*10^3; //kW
23  a=0.104; //moisture content in exit from LP turbine
24
25  p=40; //bar; From the mollier diagram
26  disp(" (i) Reheat pressure=")
27  disp(p)
28  disp(" bar")
29
30  disp(" (ii) Thermal efficiency")
31  W=h1-h2+h3-h4;
32  Q=h1-h5+h3-h2;
33  n_th=W/Q*100;
34  disp(" n_th=")
35  disp(n_th)
36  disp("%")
37
38  sc=P/W;//steam consumption
39  ssc=sc*3600/P; //specific steam consumption
40  disp(" Specific steam consumption=")
41  disp(ssc)
42  disp(" kg/kWh")
43
44  disp(" (iv) Rate of pump work =")
45  rate=sc*0.15;
46  disp(rate)
```

Scilab code Exa 12.22 22

```
1  clc
2
3  h_l=355.988; //kJ/kg
4  s_l=0.5397; //kJ/kg K
```

```
 5  s_f =0.0808;  // kJ/kg K
 6  s_g =0.6925;  // kJ/kg K
 7  h_f =29.98;  // kJ/kg
 8  h_g =329.85;  // kJ/kg
 9
10  p1 =4;  // bar
11  p2 =0.04;  // bar
12  v_f2 =76.5*10^( -6);  //m^3/kg
13
14  h1 =2789.9;  // kJ/kg
15  s1 =6.4406;  // kJ/kg
16  h_f =121.5;  // kJ/kg
17  h_fg =2432.9;  // kJ/kg
18  s_f =0.432;  // kJ/kg K
19  s_fg2 =8.052;  // kJ/kg K
20
21  p4 =15;  // bar
22  p3 =0.04;  // bar
23
24  v_f =0.0001;  // kJ/kg K
25
26  h_f4 =123;  // kJ/kg
27  h_m =254.88;  // kJ/kg
28  h_fn =29.98;  // kJ/kg
29  h_fk =29.988;  // kJ/kg
30
31  disp ("(i) Overall thermal efficiency ")
32  m=(h1 - h_f4)/(h_m - h_fn);  //The amount of mercury
         circulating for 1kg of steam in the bottom cycle
33  Q1 =m*(h_l - h_fk);  // total
34
35  x2 =(s1 - s_f)/(s_fg2);
36
37  h2 =h_f + x2* h_fg;
38
39  W_T =m*(h_l - h_m)+(h1 - h2);  // total
40
41  n_overall =W_T/Q1;  //W_P may be neglected
```

```
42  disp("n_overall =")
43  disp(n_overall)
44
45
46  disp("(ii) Flow through mercury turbine=")
47  A=48000; //kg/h
48  m_Hg=m*A;
49  disp(m_Hg)
50  disp("kg/h")
51
52
53  disp("(iii) Useful work in binary vapour cycle=")
54  W_total=A*W_T/3600;
55  disp(W_total)
56  disp("kW")
57
58
59  disp("(iv) Overall efficiency under new conditions "
       )
60  n_Hg=0.84;
61  n_steam=0.88;
62
63  W_Hg=n_Hg*101.1;
64  h_m1=h_l-W_Hg;
65  m1=(h1-h_f4)/(h_m1-h_fn);
66
67  h_g=3037.6; //kJ/kg
68  s_g=6.918; //kJ/kg
69  s_f2=0.423; //kJ/kg K
70  s_fg2=8.052; //kJ/kg K
71
72  Q1=m1*(h_l - h_fk) + (h_g-h1);
73
74  x2=(s_g-s_f2)/s_fg2;
75  h2=h_f+x2*h_fg;
76
77  W_steam=n_steam*(h_g-h2);
78
```

```
79  W_total=m1*W_Hg + W_steam;
80
81  n_overall=W_total/Q1;
82  disp(" n_overall")
83  disp(n_overall)
```

Scilab code Exa 12.23 23

```
1  clc
2  p1=60; //bar
3  t1=450; //0C
4  p2=3; //bar
5  p3=0.07; //bar; p3=(760-707.5)/760*1.013
6
7  n_turbine=0.87;
8  n_boiler=0.86;
9  n_alt=0.94;
10 n_mech=0.97;
11
12 P=22500; //kW
13
14 h1=3300; //kJ/kg
15 h2=2607; //kJ/kg
16
17 h2a=h1-n_turbine*(h1-h2);
18 h3=2165; //kJ/kg
19
20 h3a=h2a-n_turbine*(h2a-h3);
21
22 h_f4=163.4; //kJ/kg
23 h_f5=561.4; //kJ/kg
24
25 disp(" (i) The steam bled per kg of steam supplied to
        the turbine")
26 m=(h_f5-h_f4)/(h2a-h_f4);
```

```
27  disp ("m=")
28  disp (m)
29  disp ("kJ/kg")
30
31
32  disp ("( ii ) Steam  generated  per  hour")
33  W=(h1-h2a) + (1-m)*(h2a-h3a); //Work developed per
        kg  of  steam  in  the  turbine
34  W_act=P/n_alt/n_mech; //actual  work
35
36  steam=W_act/W*3600/1000; //tonnes/h
37  disp ("Steam  generated=")
38  disp (steam)
39  disp ("tonnes/h")
40
41
42  disp ("( iii ) The  overall  efficiency  of  the  plant")
43  P_avail=P*(1-0.09); //Net power available deducting
        pump power
44  Q=steam*1000*(h1-h_f5)/n_boiler/3600; //kW
45
46  n_overall=P_avail/Q
47  disp ("n_overall=")
48  disp (n_overall)
```

Scilab code Exa 12.24 24

```
1  clc
2  t1=350; //0C
3  t_s=350; //0C
4
5  p2=7; //bar
6  p3=7; //bar
7  p4=0.4; //bar
8  t3=350; //0C
```

```
 9
10  h1 =2985;  //kJ/kg
11  h2 =2520;  //kJ/kg
12  h3 =3170;  //kJ/kg
13  h4 =2555;  //kJ/kg
14
15  h_f2 =697.1;  //kJ/kg
16  h_f4 =317.7;  //kJ/kg
17
18  P =110*10^3;  //kW
19
20  disp(" (i) The ratio of steam bled to steam generated
        ")
21  m=(h_f2-h_f4)/(h2-h_f4);
22
23  ratio =1/m;
24  disp(" ratio=")
25  disp(ratio)
26
27
28  disp(" (ii) The boiler generating capacity =")
29  m_s=P/(h1-h2+(1-m)*(h3-h4))*3600/1000;  //tonnes/hour
30  disp(m_s)
31  disp(" tonnes/hour")
32
33
34  disp(" (iii) Thermal efficiency of the cycle =")
35  n_thermal=((h1-h2) + (1-m)*(h3-h4))/((h1-h_f2)+(1-m)
        *(h3-h2));
36  disp(n_thermal)
```

Scilab code Exa 12.25 25

```
1  clc
2  h1 =3315;  //kJ/kg
```

```
 3  h2=2716;  //kJ/kg
 4  h3=3165;  //kJ/kg
 5  h4=2236;  //kJ/kg
 6  h_f2=697.1;//kJ/kg
 7  h_f6=h_f2;
 8  h_f4=111.9;  //kJ/kg
 9  h_f5=h_f4;
10
11  disp(")(i)  Amount  of  steam  bled  off  for  feed  heating
        =")
12  m=(h_f2-h_f4)/(h2-h_f4);
13  disp(m)
14  disp("steam  bled  off  is  22.5%  of  steam  generated  by
        the  boiler.")
15
16
17  disp(")(ii)  Amount  of  steam  supplied  to  L.P.  turbine
        =")
18  amt=100-m*100;
19  disp(amt)
20  disp("77.5%  of  the  steam  generated  by  the  boiler.")
21
22
23  disp(")(iii)  Heat  supplied  in  the  boiler  and  reheater
        ")
24  Q_boiler=h1-h_f6;
25  disp("Q_boiler=")
26  disp(Q_boiler)
27  disp("kJ/kg")
28
29  Q_reheater=(1-m)*(h3-h2);
30  disp("Q_reheater=")
31  disp(Q_reheater)
32  disp("kJ/kg")
33
34  Qs=Q_boiler+Q_reheater;
35
36  disp(")(iv)  Cycle  efficiency")
```

```
37  W=h1 -h2 + (1-m)*(h3-h4);
38
39  n_cycle=W/Qs;
40  disp("n_cycle=")
41  disp(n_cycle)
42
43
44  disp("(v) Power developed by the system")
45  ms =50;  //kg/s
46  Power=ms*W/1000;  //MW
47  disp("Power=")
48  disp(Power)
49  disp("MW")
```

Scilab code Exa 12.26 26

```
 1  clc
 2
 3  h1 = 3578;  //kJ/kg
 4  h2 = 3140;  //kJ/kg
 5  h3 = 3678;  //kJ/kg
 6  h4 = 3000;  //kJ/kg
 7  h5 = 2330;  //kJ/kg
 8  h_f1=1611;  //kJ/kg
 9  h_f2=1087.4;  //kJ/kg
10  h_f4=640.1;  //kJ/kg
11  h_f5=191.8;  //kJ/kg
12  h_f6=h_f5;
13
14  disp("(i) Fraction of steam extracted from the
         turbines at each bled heater =")
15
16  disp("closed feed heater")
17  m1=(h_f2 -h_f4)/(h2-h_f4);
18  disp(m1)
```

```scilab
19  disp("kg/kg of steam supplied by the boiler")
20
21  disp("open feed heater")
22  m2=(1-m1)*(h_f4-h_f5)/(h4-h_f6);
23  disp(m2)
24  disp("kg/kg of steam supplied by the boiler")
25
26
27  disp("(ii) Thermal efficiency of the system")
28
29  W_total=(h1-h2) + (1-m1)*(h3-h4) + (1-m1-m2)*(h4-h5)
        ;
30  p1=150; //bar
31  p2=40; //bar
32  p4=5; //bar
33  p5=0.1; //bar
34
35  v_w1=1/1000; //m^3/kg
36  v_w2=v_w1;
37  v_w3=v_w1;
38
39  W_P1=v_w1*(1-m1-m2)*(p4-p5)*100; //kJ/kg
40  W_P2=v_w2*(1-m1)*(p1-p4)*100; //kJ/kg
41  W_P3=v_w3*m1*(p1-p2)*100; //kJ/kg
42
43  W_P=W_P1+W_P2+W_P3; //Total pump work
44  W_net=W_total-W_P;
45
46  Q=(1-m1)*h_f1 +m1*(h_f1); //Heat of feed water
        extering the boiler
47  Qs1=h1-Q;
48  Qs2=(1-m1)*(h3-h2);
49  Qst=Qs1+Qs2;
50
51  n_thermal=W_net/Qst*100;
52  disp("n_thermal=")
53  disp(n_thermal)
54  disp("%")
```

Scilab code Exa 12.27 27

```
1  clc
2
3  disp(" (i) The minimum pressure at which bleeding is
       necessary=")
4
5  //It would be assumed that the feed water heater is
       an open heater. Feed water is heated to 180 C.
       So psat at 180 C ~= 10 bar is the pressure at
       which the heater operates. Thus, the pressure at
       which bleeding is necessary is 10 bar.
6  p_min=10; //bar
7  disp(p_min)
8  disp("bar")
9
10 h1=3285; //kJ/kg
11 h2=2980; //kJ/kg
12 h3=3280; //kJ/kg
13 h4a=3072.5; //kJ/kg
14 h5=2210; //kJ/kg
15 h5a=2356.6; //kJ/kg
16
17 h_f6=163.4; //kJ/kg
18 h_f8=762.6; //kJ/kg
19 h2a=3045.6; //kJ/kg
20
21
22 disp(" (ii) The quantity of steam bled per kg of flow
        at the turbine inlet =")
23 m=(h_f8-h_f6)/(h4a-h_f6);
24 disp(m)
25 disp("kg of steam flow at turbine inlet .")
26
```

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```
27
28  disp(" (iii) Cycle  efficiency =")
29  n_cycle=((h1-h2a)+(h3-h4a)+(1-m)*(h4a-h5a))/((h1-
        h_f8) + (h3 - h2a))*100;
30  disp(n_cycle)
31  disp("%")
```

Chapter 13

Gas Power Cycles

Scilab code Exa 13.1 1

```
1  clc
2  T1 =671;  //K
3  T2 = T1 ;
4  T3 =313;  //K
5  T4 = T3 ;
6  W =130;  // kJ
7
8  disp ( " ( i )  Engine  thermal  efficiency  =" )
9  n_th =( T2 - T3 )/ T2 ;
10 disp ( n_th )
11
12
13 disp ( " ( ii )  Heat  added  =" )
14 Q = W / n_th ;
15 disp ( Q )
16 disp ( " kJ " )
17
18
19 disp ( " ( iii )  The  entropy  changes  during  heat
       rejection  process " )
20 Q_rejected = Q - W ;
```

```
21  dS=Q_rejected/T3;
22  disp("dS=")
23  disp(dS)
24  disp("kJ/K")
```

Scilab code Exa 13.2 2

```
1   clc
2   cv=0.721; //kJ/kg K
3   cp=1.008; //kJ/kg K
4   m=0.5; //kg
5   n_th=0.5;
6   Q_isothermal=40; //kJ
7   p1=7*10^5; //Pa
8   V1=0.12; //m^3
9   R=287; //J/kg K
10
11  disp("(i) The maximum and minimum temperatures")
12  T1=p1*V1/m/R;
13  disp("Maximun temperature =")
14  disp(T1)
15  disp("K")
16
17  T2=(1-n_th)*T1;
18  disp("Minimum temperature =")
19  disp(T2)
20  disp("K")
21
22
23  disp("(ii) The volume at the end of isothermal
         expansion =")
24  V2=V1*%e^(Q_isothermal*10^3/m/R/T1);
25  disp(V2)
26  disp("m^3")
27
```

```
28
29 disp("(iii) The heat transfer for each of the four
      processes")
30
31 Q1=Q_isothermal;
32 disp("Isothermal expansion")
33 disp(Q1)
34 disp("kJ")
35
36 Q2=0;
37 disp("Adiabatic reversible expansion")
38 disp(Q2)
39
40 Q3=-Q_isothermal;
41 disp("Isothermal compression")
42 disp(Q3)
43
44 Q4=0;
45 disp("Adiabatic reversible compression")
46 disp(Q4)
```

Scilab code Exa 13.3 3

```
1 clc
2 p1=18*10^5;  //Pa
3 T1=683;  //K
4 T2=T1;
5 r1=6;  // ratio V4/V1; Isentropic compression
6 r2=1.5;  // ratio V2/V1; Isothermal expansion
7 y=1.4;
8 V1=0.18;  //m^3
9
10 disp("(i) Temperatures and pressures at the main
      points in the cycle")
11
```

```
12  T4=T1/(r1)^(y-1);
13  disp("T4=")
14  disp(T4)
15  disp("K")
16
17  T3=T4;
18  disp("T3=")
19  disp(T3)
20  disp("K")
21
22  p2=p1/r2;
23  disp("p2=")
24  disp(p2/10^5)
25  disp("bar")
26
27  p3=p2/(r1)^y;
28  disp("p3=")
29  disp(p3/10^5)
30  disp("bar")
31
32  p4=p1/(r1)^y;
33  disp("p4=")
34  disp(p4/10^5)
35  disp("bar")
36
37
38  disp("(ii) Change in entropy =")
39  dS=p1*V1/T1/10^3*log(r2);
40  disp(dS)
41  disp("kJ/K")
42
43
44  disp("(iii) Mean thermal efficiency of the cycle")
45  Qs=T1*(dS);
46  Qr=T4*(dS);
47
48  n=1-Qr/Qs;
49  disp("n=")
```

```
50  disp(n)
51
52
53  disp(" (iv) Mean effective pressure of the cycle =")
54  pm=(Qs-Qr)/8/V1/100; //bar
55  disp(pm)
56  disp("bar")
57
58
59  n=210; //cycles per minute
60  disp(" (v) Power of the engine =")
61  P=(Qs-Qr)*n/60; //kW
62  disp(P)
63  disp("kW")
```

Scilab code Exa 13.4 4

```
 1  clc
 2
 3  // First case
 4  //(T1-T2)/T1=1/6
 5  //T1=1.2*T2
 6
 7
 8  // Second case
 9  //(T1-(T2-(70+273)))/T3=1/3
10
11  T2=1029/0.6;
12  T1=1.2*T2;
13
14  disp(" Temperature of the source =")
15  disp(T1)
16  disp("K")
17
18
```

```
19  disp("Temperature of the sink=")
20  disp(T2)
21  disp("K")
```

Scilab code Exa 13.5 5

```
1   clc
2
3   T1=1990; //K
4   T2=850; //K
5   Q=32.5/60; //kJ/s
6   P=0.4; //kW
7
8   n_carnot=(T1-T2)/T1;
9   disp("most efficient engine is one that works on
        Carnot cycle")
10  disp(n_carnot)
11
12  n_th=P/Q;
13  disp("n_thermal =")
14  disp(n_th)
15
16  disp("which is not feasible as no engine can be more
        efficient than that working on Carnot")
17  disp("Hence claims of the inventor is not true.")
```

Scilab code Exa 13.7 7

```
1   clc
2
3   n=0.6;
4   y=1.5;
5
```

```
6 r=(1/(1-n))^(1/(y-1));
7 disp("Compression ratio =")
8 disp(r)
```

Scilab code Exa 13.8 8

```
1  clc
2
3  D=0.25; //m
4  L=0.375; //m
5  Vc=0.00263; //m^3
6  p1=1; //bar
7  T1=323; //K
8  p3=25; //bar
9  Vs=%pi/4*D^2*L;
10 r=(Vs+Vc)/Vc;
11 y=1.4;
12
13 disp("(i) Air standard efficiency=")
14 n_otto=1-1/(r^(y-1));
15 disp(n_otto)
16
17
18 disp("(ii) Mean effective pressure ")
19 p2=p1*(r)^(y);
20 r_p=p3/p2;
21
22 p_m=p1*r*(r^(y-1) - 1)*(r_p - 1)/(y-1)/(r-1);
23 disp("Mean effective pressure =")
24 disp(p_m)
25 disp("bar")
```

Scilab code Exa 13.9 9

```
1  clc
2  cv=0.72; //kJ/kg K
3  y=1.4;
4  p1=1; //bar
5  T1=300; //K
6  Q=1500; //kJ/kg
7  r=8;
8  y=1.4;
9
10 disp("(i) Pressures and temperatures at all points")
11 T2=T1*(r)^(y-1);
12 disp("T2=")
13 disp(T2)
14 disp("K")
15
16 p2=p1*(r)^y;
17 disp("p2=")
18 disp(p2)
19 disp("bar")
20
21 T3=Q/cv + T2;
22 disp("T3=")
23 disp(T3)
24 disp("K")
25
26 p3=p2*T3/T2;
27 disp("p3=")
28 disp(p3)
29 disp("bar")
30
31 T4=T3/r^(y-1);
32 disp("T4=")
33 disp(T4)
34 disp("K")
35
36 p4=p3/r^(y);
37 disp("p4=")
38 disp(p4)
```

```
39  disp("bar")
40
41
42  disp("(ii) Specific work and thermal efficiency")
43  SW=cv*[(T3-T2) - (T4-T1)];
44  disp("Specific work =")
45  disp(SW)
46  disp("kJ/kg")
47
48  n_th=1-1/r^(y-1);
49  disp("Thermal efficiency =")
50  disp(n_th)
```

Scilab code Exa 13.10 10

```
 1  clc
 2  r=6; //v1/v2=v4/v3=r
 3  p1=1; //bar
 4  T1=300; //K
 5  T3=1842; //K
 6  y=1.4;
 7
 8  disp("(i) Temperature and pressure after the
        isentropic expansion")
 9  p2=p1*(r)^y;
10  T2=T1*r^(y-1);
11  p3=p2*(T3/T2);
12
13  T4=T3/r^(y-1);
14  disp("T4=")
15  disp(T4)
16  disp("K")
17
18  p4=p3/(r)^(y);
19  disp("p4 =")
```

```
20  disp(p4)
21  disp("bar")
22
23  disp("(ii) Process required to complete the cycle")
24
25  disp("Process required to complete the cycle is the
        constant pressure scavenging. The cycle is called
         Atkinson cycle")
26
27  disp("(iii) Percentage improvement/increase in
        efficiency")
28  p5=1; //bar
29  T5=T3*(p5/p3)^((y-1)/y);
30
31  n_otto=(1-1/r^(y-1))*100;
32  disp("n_otto = ")
33  disp(n_otto)
34  disp("%")
35
36  n_atkinson=(1-y*(T5-T1)/(T3-T2))*100;
37  disp("n_atkinson=")
38  disp(n_atkinson)
39  disp("%")
40
41  dn=n_atkinson - n_otto; //Improvement in efficiency
42  disp("Improvement in efficiency =")
43  disp(dn)
44  disp("%")
```

Scilab code Exa 13.11 11

```
1  clc
2  p1=1; //bar
3  T1=343; //K
4  p2=7; //bar
```

```
 5  Qs =465;  //kJ/kg of air
 6  cp =1;  //kJ/kg K
 7  cv =0.706;  //kJ/kg K
 8  y =1.41;
 9
10  disp(" (i) Compression ratio of engine =")
11  r=(p2/p1)^(1/y);
12  disp(r)
13
14
15  disp(" (ii) Temperature at the end of compression =")
16  T2=T1*(r)^(y-1);
17  t2=T2-273;
18  disp(t2)
19  disp(" 0C")
20
21  disp(" (iii) Temperature at the end of heat addition
        =")
22  T3=Qs/cv+T2;
23  t3=T3-273;
24  disp(t3)
25  disp(" 0C")
```

Scilab code Exa 13.12 12

```
 1  clc
 2
 3  y =1.4;
 4  R =0.287;  //kJ/kg K
 5  T1 =311;  //K
 6  T3 =2223;  //K
 7  //p2/p1=15
 8
 9  disp(" (i) Compression ratio =")
10  r=15^(1/1.4);
```

```
11 disp(r)
12
13
14 disp("(ii) Thermal efficiency =")
15 n_th=1-1/r^(y-1);
16 disp(n_th)
17
18 disp("(iii) Work done")
19 T2=T1*(r)^(y-1);
20 T4=T3/r^(y-1);
21 cv=R/(y-1);
22
23 Q_supplied=cv*(T3-T2);
24 Q_rejected=cv*(T4-T1);
25
26 W=Q_supplied-Q_rejected;
27 disp("Work done=")
28 disp(W)
29 disp("kJ")
```

Scilab code Exa 13.13 13

```
1 clc
2 V1=0.45; //m^3
3 p1=1; //bar
4 T1=303; //K
5 p2=11; //bar
6 Qs=210; //kJ
7 n=210; //number of working cycles/min
8 R=287; //J/kg K
9 cv=0.71; //kJ/kg K
10 y=1.4;
11
12 disp("(i) Pressures, temperatures and volumes at
      salient points")
```

```
13  r=(p2/p1)^(1/y);
14
15  T2=T1*(r)^(y-1);
16  disp("T2=")
17  disp(T2)
18  disp("K")
19
20  V2=T2/T1*p1/p2*V1;
21  disp("V2=")
22  disp(V2)
23  disp("m^3")
24
25  m=p1*10^5*V1/R/T1;
26  T3=Qs/m/cv+T2;
27  disp("T3=")
28  disp(T3)
29  disp("K")
30
31  p3=T3/T2*p2;
32  disp("p3=")
33  disp(p3)
34  disp("bar")
35
36  V3=V2;
37  disp("V3=")
38  disp(V3)
39  disp("m^3")
40
41  p4=p3/r^y;
42  disp("p4=")
43  disp(p4)
44  disp("bar")
45
46  T4=T3/r^(y-1);
47  disp("T4=")
48  disp(T4)
49  disp("K")
50
```

```
51  V4=V1;
52  disp("V4=")
53  disp(V4)
54  disp("m^3")
55
56
57  disp("(ii) Percentage clearance =")
58  %clearance=V2/(V1-V2)*100;
59  disp(%clearance)
60  disp("%")
61
62
63  disp("(iii) Efficiency =")
64  Qr=m*cv*(T4-T1);
65  n_otto=(Qs-Qr)/Qs;
66  disp(n_otto)
67
68
69  disp("(iv) Mean effective pressure =")
70  p_m=(Qs-Qr)/(V1-V2)/100; //bar
71  disp(p_m)
72  disp("bar")
73
74
75  disp("(v) Power developed =")
76  P=(Qs-Qr)*n/60;
77  disp(P)
78  disp("kW")
```

Scilab code Exa 13.14 14

```
1  clc
2
3  // W=Qs-Qr=cv*(T3-T2) - cv*(T4-T1)
4  // T2=T1*(r^(y-1))
```

```
5  //  T3=T4∗(r^(y−1))
6  //  W=cv∗[T3−T1∗r^(y−1) − T3/r^(y−1)+T1];
7  //  dW/dr=−T1∗(y−1)∗r^(y−2) − T3∗(1−y)∗r^(−y)=0
8
9  //By solving this we get
10
11 disp(" r=(T3/T1)^(1/2/(y−1))")
12
13 disp(" (b)Change in efficiency")
14
15 T3=1220; //K
16 T1=310; //K
17
18 // For air
19 y=1.4;
20 r1=(T3/T1)^(1/2/(y-1));
21 n1=1-1/r1^(y-1); //air standard Efficiency
22 disp("Air standard Efficiency =")
23 disp(n1)
24
25 //For helium
26 cp=5.22; //kJ/kg K
27 cv=3.13; //kJ/kg K
28 y=cp/cv;
29 r2=(T3/T1)^(1/2/(y-1));
30
31 n2=1-1/r2^(y-1);
32 disp("Air standard efficiency for helium =")
33 disp(n2)
34
35 change=n1-n2;
36 disp("Change in efficiency=")
37 disp(change)
38
39 disp("Hence change in efficiency is nil")
```

Scilab code Exa 13.15 15

```scilab
1  clc
2  // W=cv*[T3-T1*r^(y-1) - T3/r^(y-1)+T1]
3  //  r=(T3/T1)^(1/2/(y-1))
4  //  T2=T1*r^(y-1)
5  //  T4=T3/r^(y-1)
6
7  //  T2=T1*[(T3/T1)^(1/2/(y-1))]^(y-1)
8
9
10 //T2=sqrt(T1*T3)
11
12 //Similarly  T4=T3/[(T3/T1)^(1/2/(y-1))]^(y-1)
13 //T4=sqrt(T1*T3)
14
15 disp("T2=T4=sqrt(T1*T3)")
16
17
18 disp("(b) Power developed ")
19 T1=310; //K
20 T3=1450; //K
21 m=0.38; //kg
22 cv=0.71; //kJ/kg K
23
24 T2=sqrt(T1*T3);
25 T4=T2;
26
27 W1=cv*[(T3-T2) - (T4-T1)]; //Work done
28 W=m/60*W1; //Work done per second
29
30 disp("Power =")
31 disp(W)
32 disp("kW")
```

Scilab code Exa 13.17 17

```
1  clc
2  r=15;
3  y=1.4;
4
5  //V3-V2=0.06*(V1-V2)
6  rho=1.84; //cut off ratio rho=V3/V2
7
8  n_diesel=1-1/y/r^(y-1)*((rho^y-1)/(rho-1));
9  disp("efficiency =")
10 disp(n_diesel)
```

Scilab code Exa 13.18 18

```
1  clc
2
3  L=0.25; //m
4  D=0.15; //m
5  V2=0.0004; //m^3
6  Vs=%pi/4*D^2*L;
7  V_total=Vs+V2;
8  y=1.4;
9  V3=V2+5/100*Vs;
10 rho=V3/V2;
11 r=(Vs+V2)/V2; //V1=Vs+V2
12
13 n_diesel=1-1/y/r^(y-1)*((rho^y-1)/(rho-1));
14 disp("efficiency =")
15 disp(n_diesel)
```

Scilab code Exa 13.19 19

```scilab
1  clc
2  r=14; //let clearance volume be unity
3  y=1.4;
4
5  //When the fuel is cut-off at 5%
6  rho1=5/100*(r-1)+1;
7  n_diesel1=1-1/y/r^(y-1)*((rho1^y-1)/(rho1-1));
8
9  //When the fuel is cut-off at 8%
10 rho2=8/100*(r-1)+1;
11 n_diesel2=1-1/y/r^(y-1)*((rho2^y-1)/(rho2-1));
12
13 %loss=(n_diesel1-n_diesel2)*100;
14 disp(" percentage loss in efficiency due to delay in
       fuel cut off =")
15 disp(%loss)
16 disp("%")
```

Scilab code Exa 13.20 20

```scilab
1  clc
2
3  pm=7.5; //bar
4  r=12.5;
5  p1=1; //bar
6  y=1.4;
7
8  // pm = p1*r^y*[y*(rho-1) - r^(1-y)*(rho^y-1)]/(y-1)
       /(r-1)
9  //Solving above equation we get
```

```
10  rho =2.24;
11
12  %cutoff =( rho -1)/( r -1)*100;
13  disp(" %cutoff=")
14  disp(%cutoff)
15  disp("%")
```

Scilab code Exa 13.21 21

```
1  clc
2  D=0.2;  //m
3  L=0.3;  //m
4  p1=1;  //bar
5  T1=300;  //K
6  R=287;
7  r=15;
8  y=1.4;
9
10  disp("(i) Pressures and temperatures at salient
      points")
11  Vs=%pi/4*D^2*L;
12
13  V1=r/(r-1)*Vs;
14  disp("V1=")
15  disp(V1)
16  disp("m^3")
17
18  m=p1*10^5*V1/R/T1;
19
20  p2=p1*r^y;
21  disp("p2=")
22  disp(p2)
23  disp("bar")
24
25  T2=T1*r^(y-1);
```

```
26  disp("T2=")
27  disp(T2)
28  disp("K")
29
30  V2=Vs/(r-1);
31  disp("V2=")
32  disp(V2)
33  disp("m^3")
34
35  rho=8/100*(r-1) + 1;
36  V3=rho*V2;
37  disp("V3=")
38  disp(V3)
39  disp("m^3")
40
41  T3=T2*V3/V2;
42  disp("T3=")
43  disp(T3)
44  disp("K")
45
46  p3=p2;
47  disp("p3=")
48  disp(p3)
49  disp("bar")
50
51  p4=p3*(rho/r)^y;
52  disp("p4=")
53  disp(p4)
54  disp("bar")
55
56  T4=T3*(rho/r)^(y-1);
57  disp("T4=")
58  disp(T4)
59  disp("K")
60
61  V4=V1;
62  disp("V4=")
63  disp(V4)
```

```
64  disp("m^3")
65
66  disp("(ii) Theoretical air standard efficiency =")
67  n_diesel=1-1/y/r^(y-1)*((rho^y-1)/(rho-1));
68  disp("efficiency =")
69  disp(n_diesel)
70
71
72  disp("(iii) Mean effective pressure =")
73  pm=(p1*r^y*(y*(rho-1) - r^(1-y)*(rho^y-1)))/(y-1)/(r
       -1);
74  disp(pm)
75  disp("bar")
76
77  disp("(iv) Power of the engine =")
78  n=380; //number of cycles per min
79  P=n/60*pm*Vs*100; //kW
80  disp(P)
81  disp("kW")
```

Scilab code Exa 13.22 22

```
 1  clc
 2  r1=15.3; //V1/V2
 3  r2=7.5;   //V4/V3
 4  p1=1; //bar
 5  T1=300; //K
 6  n_mech=0.8;
 7  C=42000; //kJ/kg
 8  y=1.4;
 9  R=287;
10  cp=1.005;
11  cv=0.718;
12  V2=1; ////Assuming V2=1 m^3
13
```

```
14  T2=T1*r1^(y-1);
15  p2=p1*r1^y;
16  T3=r1/r2*T2;
17  m=p2*10^5*V2/R/T2;
18  T4=T3/r2^(y-1);
19
20  Q_added=m*cp*(T3-T2);
21  Q_rejected=m*cv*(T4-T1);
22  W=Q_added-Q_rejected;
23
24  pm=W/(r1-1)/V2/100;
25  disp("Mean effective pressure =")
26  disp(pm)
27  disp("bar")
28
29  ratio=p2/pm;
30  disp("Ratio of maximum pressure to mean effective
        pressure =")
31  disp(ratio)
32
33  n_cycle=W/Q_added;
34  disp("Cycle efficiency =")
35  disp(n_cycle)
36
37  n_thI=0.5;
38  n_cycle1=n_thI*n_cycle;
39
40  n_thB=n_mech*n_cycle1;
41
42  BP=1;
43  mf=BP/C/n_thB*3600;
44  disp("Fuel consumption per kWh =")
45  disp(mf)
46  disp("kg/kWh")
```

Scilab code Exa 13.23 23

```
 1 clc
 2 Vs =0.0053; //m^3
 3 Vc =0.00035; //m^3
 4 V3=Vc;
 5 V2=V3;
 6 p3 =65; //bar
 7 p4 =65; //bar
 8 T1 =353; //K
 9 p1 =0.9; //bar
10 y =1.4;
11
12 r=(Vs+Vc)/Vc;
13 rho =(5/100* Vs+V3)/V3;
14 p2=p1*(r)^y;
15 B=p3/p2;
16
17 n_dual =1 -1/r^(y-1)*[(B*rho^y-1)/((B-1)+B*y*(rho -1))
      ];
18 disp("Efficiency of the cycle =")
19 disp(n_dual)
```

Scilab code Exa 13.24 24

```
1 clc
2 r=14;
3 B=1.4;
4 rho =6/100*(r-1) + 1;
5 y =1.4;
6
7 n_dual =1 -1/r^(y-1)*[(B*rho^y-1)/((B-1)+B*y*(rho -1))]
8 disp("Efficiency of the cycle =")
9 disp(n_dual)
```

Scilab code Exa 13.25 25

```
 1  clc
 2  D=0.25;  //m
 3  r=9;
 4  L=0.3;  //m
 5  cv=0.71;  //kJ/kg K
 6  cp=1;  //kJ/kg K
 7  p1=1;  //bar
 8  T1=303;  //K
 9  p3=60;  //bar
10  p4=p3;
11  n=3;  //number of working cycles/ sec
12  y=1.4;
13  R=287;
14
15  disp("(i) Air standard efficiency")
16  Vs=%pi/4*D^2*L;
17
18  Vc=Vs/(r-1);
19  V1=Vs+Vc;
20  p2=p1*(r)^y;
21  T2=T1*r^(y-1);
22  T3=T2*p3/p2;
23  rho=4/100*(r-1)+1;
24  T4=T3*rho;
25
26  T5=T4*(rho/r)^(y-1);
27  p5=p4*(r/rho)^(y);
28
29  Qs=cv*(T3-T2)+cp*(T4-T3)
30
31  Qr=cv*(T5-T1);
32
```

```
33  n_airstandard=(Qs-Qr)/Qs;
34  disp("efficiency =")
35  disp(n_airstandard)
36
37
38  disp("(ii) Power developed by the engine")
39  m=p1*10^5*V1/R/T1;
40
41  W=m*(Qs-Qr);
42
43  P=W*n;
44  disp("P=")
45  disp(P)
46  disp("kW")
```

Scilab code Exa 13.26 26

```
1   clc
2   p1=1;  //bar
3   T1=363;  //K
4   r=9;
5   p3=68;  //bar
6   p4=68;  //bar
7   Q=1750;  //kJ/kg
8   y=1.4;
9   cv=0.71;
10  cp=1.0;
11
12  disp("(i) Pressures and temperatures at salient
        points")
13  p2=p1*(r)^y;
14  disp("p2=")
15  disp(p2)
16  disp("bar")
17
```

```
18  T2=T1*r^(y-1);
19  disp("T2=")
20  disp(T2)
21  disp("K")
22
23  disp("p3=")
24  disp(p3)
25  disp("bar")
26
27  disp("p4=")
28  disp(p4)
29  disp("bar")
30
31  T3=T2*(p3/p2);
32  disp("T3=")
33  disp(T3)
34  disp("K")
35
36  Q1=cv*(T3-T2); //heat added at constant volume
37  Q2=Q-Q1; //heat added at constant pressure
38
39  T4=Q2/cp+T3;
40  disp("T4=")
41  disp(T4)
42  disp("K")
43
44  rho=T4/T3; //V4/V3=T4/T3
45
46  p5=p4*(rho/r)^y;
47  disp("p5=")
48  disp(p5)
49  disp("bar")
50
51  T5=T4*(rho/r)^(y-1);
52  disp("T5=")
53  disp(T5)
54  disp("K")
55
```

```
56
57  disp("( ii )  Air  standard  efficiency  =")
58  Qr = cv * ( T5 - T1 ) ;
59  n_airstandard = ( Q - Qr ) / Q ;
60  disp ( n_airstandard )
61
62
63  disp("( iii )  Mean  effective  pressure  =")
64  pm = 1 / ( r -1) * ( p3 * ( rho -1)  +  ( p4 * rho - p5 * r ) / ( y -1)  -  ( p2 -
        p1 * r ) / ( y -1) ) ;
65  disp ( pm )
66  disp (" bar ")
```

Scilab code Exa 13.27 27

```
 1  clc
 2  T1 =300;  //K
 3  r =15;
 4  y =1.4;
 5  // p3 / p1 =70
 6
 7  T2 = T1 * ( r ) ^( y -1) ;
 8
 9  // p2 / p1 = r ^ y
10  // p2 =44.3* p1
11
12  T3 =1400;  //K;  T3 = T2 * p3 / p2
13
14  T4 = T3  +  ( T3 - T2 ) / y ;
15
16  // v1 / v3 =15
17  // v4 =0.084* v1
18  // v5 = v1
19  // T5 = T4 *( v5 / v1 ) ^( y -1)
20  T5 =656.9;  //K
```

```
21
22 n_airstandard=1-(T5-T1)/((T3-T2) + y*(T4-T3));
23 disp("Efficiency =")
24 disp(n_airstandard)
25
26 disp("Reasons for actual thermal efficiency being
       different from the theoretical value :")
27
28 disp("1. In theoretical cycle working substance is
       taken air whereas in actual cycle air with fuel
       acts as working substance")
29
30 disp("2. The fuel combustion phenomenon and
       associated problems like dissociation of gases,
       dilution of charge during suction stroke, etc.
       have not been taken into account")
31
32 disp("3. Effect of variable specific heat, heat loss
        through cylinder walls, inlet and exhaust
       velocities of air/gas etc. have not been taken
       into account.")
```

Scilab code Exa 13.28 28

```
1 clc
2 T1=373; //K
3 p1=1; //bar
4 p3=65; //bar
5 p4=p3;
6 Vs=0.0085; //m^3
7 ratio=21; //Air fuel ratio
8 r=15;
9 C=43890; //kJ/kg
10 cp=1;
11 cv=0.71;
```

```
12  V2 =0.0006;  //m^3
13  V1 =0.009;  //m^3
14  y =1.41;
15  V5 = V1;
16  V3 = V2;
17  R =287;
18
19  p2 = p1 *( r )^ y ;
20  T2 = T1 * r ^( y -1);
21  T3 = T2 * p3 / p2 ;
22  m = p1 *10^5* V1 / R / T1 ;
23
24  Q1 = m * cv *( T3 - T2 ); // Heat  added  during  constant  volume
          process  2 -3
25  amt = Q1 / C ; // Amount  of  fuel  added  during  the  constant
          volume  process  2 -3
26  total = m / ratio ; // Total  amount  of  fuel  added
27  quantity = total - amt ; // Quantity  of  fuel  added  during
        the  process  3 -4
28
29  Q2 = quantity * C ; // Heat  added  during  constant  pressure
          process
30
31  T4 = Q2 /( m + total )/ cp + T3 ;
32  V4 = V3 * T4 / T3 ;
33  T5 = T4 *( V4 / V5 )^( y -1);
34
35  Q3 =( m + total )* cv *( T5 - T1 ); // Heat  rejected  during
        constant  volume  process  5 -1
36
37  W =( Q1 + Q2 )  -  Q3 ;
38
39  n_th = W /( Q1 + Q2 );
40  disp (" Thermal  efficiency  =")
41  disp ( n_th )
```

Scilab code Exa 13.29 29

```scilab
1  clc
2  T1=303;  //K
3  p1=1;  //bar
4  rc=9;
5  re=5;
6  n=1.25;
7  D=0.25;  //m
8  L=0.4;  //m
9  R=287;
10 cv=0.71;
11 cp=1;
12 num=8;  //no. 0f cycles/sec
13
14 disp("(i) Pressure and temperatures at all salient
        points =")
15 p2=p1*(rc)^n;
16 disp("p2=")
17 disp(p2)
18 disp("bar")
19
20 T2=T1*(rc)^(n-1);
21 disp("T2=")
22 disp(T2)
23 disp("K")
24
25 //T4=1.8*T3
26 //Heat liberated at constant pressure= 2     heat
        liberated at constant volume
27 //cp*(T4-T3)=2*cv*(T3-T2)
28 //T4/T3=1.8
29
30 rho=rc/re;
```

```
31  T3=1201.9;  //K
32  disp("T3=")
33  disp(T3)
34  disp("K")
35
36  p3=p2*T3/T2;
37  disp("p3=")
38  disp(p3)
39  disp("bar")
40
41  p4=p3;
42  disp("p4=")
43  disp(p4)
44  disp("bar")
45
46  T4=1.8*T3;
47  disp("T4=")
48  disp(T4)
49  disp("K")
50
51  p5=p4*(1/re)^(n);
52  disp("p5=")
53  disp(p5)
54  disp("bar")
55
56  T5=T4*(1/re)^(n-1)
57  disp("T5=")
58  disp(T5)
59  disp("K")
60
61
62  disp("(ii) Mean effective pressure = ")
63  pm=1/(rc-1)*[p3*(rho-1)+(p4*rho-p5*rc)/(n-1)-(p2-p1*
        rc)/(n-1)];
64  disp(pm)
65  disp("bar")
66
67  disp("(iii) Efficiency of the cycle")
```

```
68  Vs=%pi/4*D^2*L;
69  W=pm*10^5*Vs/1000;
70
71  V1=rc/(rc-1)*Vs
72  m=p1*10^5*V1/R/T1;
73  Q=m*(cv*(T3-T2) + cp*(T4-T3));
74
75  Efficiency=W/Q;
76  disp("Efficiency =")
77  disp(Efficiency)
78
79
80  disp("(iv) Power of the engine =")
81  P=W*num;
82  disp(P)
83  disp("kW")
```

Scilab code Exa 13.30 30

```
1  clc
2  v=10:1:100;
3  function p=f(v)
4      p=1/v^1.4;
5  endfunction
6  plot(v,f)
7
8  v=[10 20]
9  p=[f(10) f(10)]
10 plot(v,p,'r')
11
12 v=20:1:100;
13 function p=fa(v)
14     p=2.6515/v^1.4;
15 endfunction
16 plot(v,fa,'g')
```

```scilab
17
18  v =[100  100]
19  p =[ f (100)  fa (100)]
20  plot ( v , p , '−−p ')
21
22  v =[15  15]
23  p =[ f (15)  0.040]
24  plot ( v , p , '−−')
25
26  v =[20  20]
27  p =[ f (20)  0.040]
28  plot ( v , p , '−−r ')
29
30  xtitle ("p−v  diagram " , "v" , "p")
31  legend ("1−2b" ," 2b−3" , "3−4" , "4−1" , "2a−3a" , "2−3")
32
33  //The  air −standard  Otto , Dual  and  Diesel  cycles  are
         drawn  on  common  p−v  and  T−s  diagrams  for  the  same
          maximum  pressure  and  maximum  temperature , for
         the  purpose  of  comparison .
34  //  Otto  1−2−3−4−1
35  //  Dual  1−2a−3a−3−4−1
36  //  Diesel  1−2b−3−4−1
37
38
39  xset ('window ', 1)
40
41  s =10:1:50;
42  function  T = fb ( s )
43       T = s ^2
44  endfunction
45  plot ( s , fb )
46
47  s =10:1:50;
48  function  T = fc ( s )
49       T =( s +30)^2
50  endfunction
51  plot ( s , fc , 'r ')
```

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```
52
53  s = [ 1 2   1 2 ] ;
54  T = [ fb ( 1 2 )   f c ( 1 2 ) ] ;
55  plot ( s , T , '−−p ' )
56
57  s = [ 4 5   4 5 ] ;
58  T = [ fb ( 4 5 )   f c ( 4 5 ) ]
59  plot ( s , T , 'm' )
60
61  s = 1 0 : 1 : 2 7 ;
62  T = 5 ∗ ( s ) ^ 2 ;
63  plot ( s , T , ' g ' )
64
65  s = 1 0 : 1 : 2 0 ;
66  T = 7 ∗ s ^ 2 ;
67  plot ( s , T , '−−r ' )
68
69  x t i t l e ( "T−s  diagram" ,  " s" ,  "T" )
70  legend ( "1−4" ,  " 2b−3" ,  " 1−2b" ,  " 3−4" ,  " 2−3" ,  " 2a−3a" )
71
72  // The  construction  of  cycles  on  T−s  diagram  proves
        that  for  the  given  conditions  the  heat  rejected
        is  same  for  all  the  three  cycles  ( area  under
        process  line  4−1).
73  //     =1−(Heat  rejected )/(Heat  supplied )=1−constant /
        Qs
74
75  // The  cycle  with  greater  heat  addition  will  be  more
        efficient .
76  // From  the  T−s  diagram
77
78  // Qs ( diesel )  =  Area  under  2b−3
79  // Qs ( dual )  =  Area  under  2a−3a−3
80  // Qs ( otto )  =  Area  under  2−3.
81
82  // Qs ( diesel )  >  Qs ( dual )  >  Qs ( otto )
83
84  disp ( " Thus ,    d i e s e l  >    d u a l  >    o t t o " )
```

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Scilab code Exa 13.31 31

```
1  clc
2  cp=0.92;
3  cv=0.75;
4  y=1.22; //y=cp/cv
5  p1=1; //bar
6  p2=p1;
7  p3=4; //bar
8  p4=16; //bar
9  T2=300; //K
10
11 T3=T2*(p3/p2)^((y-1)/y);
12 T4=p4/p3*T3;
13 T1=T4/(p4/p1)^((y-1)/y);
14
15 disp("(i) Work done per kg of gas ")
16 Q_supplied=cv*(T4-T3);
17 Q_rejected=cp*(T1-T2);
18
19 W=Q_supplied-Q_rejected;
20 disp("W=")
21 disp(W)
22 disp("kJ/kg")
23
24
25 disp("(ii) Efficiency of the cycle =")
26 n=W/Q_supplied;
27 disp(n)
```

Scilab code Exa 13.32 32

```
1  clc
2  p1 =101.325;  //kPa
3  T1 =300;  //K
4  rp =6;
5  y =1.4;
6
7  T2=T1*rp^((y-1)/y);
8
9  //T3/T4=rp^((y-1)/y)
10 //T4=T3/1.668
11
12 //W_T=2.5*W_C
13
14 T3 =2.5*(T2-T1)/(1-1/1.668);
15 disp(" (i) Maximum temperature in the cycle =")
16 disp(T3)
17 disp("K")
18
19
20 disp(" (ii) Cycle efficiency")
21 T4=T3/1.668;
22
23 n_cycle=((T3-T4) - (T2-T1))/(T3-T2);
24 disp(" Cycle efficiency =")
25 disp(n_cycle)
```

Scilab code Exa 13.33 33

```
1  clc
2  p1 =1;  //bar
3  p2 =5;  //bar
4  T3 =1000;  //K
5  cp =1.0425;  //kJ/kg K
6  cv =0.7662;  //kJ/kg K
7  y=cp/cv;
```

```
 8
 9  disp ( " ( i ) Temperature  entropy  diagram " )
10
11  s =10:1:50;
12  function  T=fb ( s )
13       T=s ^2
14  endfunction
15  plot ( s , fb , '--' )
16
17  s =10:1:50;
18  function  T=fc ( s )
19       T=(s +30) ^2
20  endfunction
21  plot ( s , fc , 'r' )
22
23  s =[12  12];
24  T=[fb (12)  fc (12) ];
25  plot ( s ,T, 'm' )
26
27  s =[45  45];
28  T=[fb (45)  fc (45) ]
29  plot ( s ,T, 'g' )
30
31
32  xtitle ( "T-s  diagram" ,  "s" ,  "T" )
33  legend ( "p1=1  bar" ,  "p2=5  bar" ,  "1-2" ,  "3-4" )
34
35  disp ( " ( ii )  Power  required  =" )
36  T4=T3 *( p1/p2 ) ^(( y -1)/y ) ;
37  P=cp *(T3 -T4 ) ;
38  disp ( "P=" )
39  disp (P)
40  disp ( "kW" )
```

Scilab code Exa 13.34 34

```
1  clc
2  m=0.1; //kg/s
3  p1=1; //bar
4  T4=285; //K
5  p2=4; //bar
6  cp=1; //kJ/kg K
7  y=1.4;
8
9  T3=T4*(p2/p1)^((y-1)/y);
10 disp("Temperature at turbine inlet =")
11 disp(T3)
12 disp("K")
13
14 P=m*cp*(T3-T4);
15 disp("Power developed =")
16 disp(P)
17 disp("kW")
```

Scilab code Exa 13.35 35

```
1  clc
2  y=1.4;
3  cp=1.005; //kJ/kg K
4  p1=1; //bar
5  T1=293; //K
6  p2=3.5; //bar
7  T3=873; //K
8  rp=p2/p1;
9
10 disp("(i) Efficiency of the cycle =")
11 n_cycle=1-1/rp^((y-1)/y);
12 disp(n_cycle)
13
14
15 disp("(ii) Heat supplied to air =")
```

```
16  T2=T1*(p2/p1)^((y-1)/y);
17  Q1=cp*(T3-T2);
18  disp(Q1)
19  disp("kJ/kg")
20
21  disp("(iii) Work available at the shaft =")
22  W=n_cycle*Q1;
23  disp(W)
24  disp("kJ/kg")
25
26  disp("(iv) Heat rejected in the cooler =")
27  Q2=Q1-W;
28  disp(Q2)
29  disp("kJ/kg")
30
31  disp("(v) Temperature of air leaving the turbine =")
32  T4=T3/rp^((y-1)/y);
33  disp(T4)
34  disp("K")
```

Scilab code Exa 13.36 36

```
1  clc
2  T1=303; //K
3  T3=1073; //K
4  C=45000; //kJ/kg
5  cp=1; //kJ/kg K
6  y=1.4;
7
8  T2=sqrt(T1*T3);
9  T4=T2;
10
11 //W_turbine-W_compressor=m_f*C*n=100;
12
13 m_f=100/C/(1-(T4-T1)/(T3-T2));
```

```
14  disp("m_f=")
15  disp(m_f)
16  disp("kg/s")
17
18  m_a=(100-m_f*(T3-T4))/(T3-T4-T2+T1);
19  disp("m_a=")
20  disp(m_a)
21  disp("kg/s")
```

Scilab code Exa 13.37 37

```
1  clc
2  T1=300; //K
3  p1=1;  //bar
4  rp=6.25;
5  T3=1073;  //K
6  n_comp=0.8;
7  n_turbine=0.8;
8  cp=1.005;  //kJ/kg K
9  y=1.4;
10
11  T2=T1*(rp)^((y-1)/y);
12
13  //Let  T2'=T2a
14  T2a=(T2-T1)/n_comp + T1;
15
16  W_comp=cp*(T2a-T1);
17  disp("Compressor  work  =")
18  disp(W_comp)
19  disp("kJ/kg")
20
21  T4=T3/rp^((y-1)/y);
22  T4a=T3-n_turbine*(T3-T4);
23
24  W_turbine=cp*(T3-T4a);
```

```
25  disp ( " Turbine  work  =" )
26  disp ( W_turbine )
27  disp ( " kJ / kg " )
28
29  Q_s = cp *( T3 - T2a );
30  disp ( " Heat  supplied  =" )
31  disp ( Q_s )
32  disp ( " kJ / kg " )
33
34  W_net = W_turbine  -  W_comp ;
35
36  n_cycle = W_net / Q_s *100;
37  disp ( " n_cycle " )
38  disp ( n_cycle )
39  disp ( "%" )
40
41  t4a = T4a -273;
42  disp ( " Turbine  exhaust  temperature  =" )
43  disp ( t4a )
44  disp ( " 0C " )
```

Scilab code Exa 13.38 38

```
1  clc
2  n_turbine =0.85;
3  n_compressor =0.80;
4  T3 =1148;  // K
5  T1 =300;  // K
6  cp =1;  // kJ / kg  K
7  y =1.4;
8  p1 =1;  // bar
9  p2 =4;  // bar
10  C =42000;  // kJ / kg  K
11  n_cc =0.90;
12
```

```
13  T2=T1*(p2/p1)^((y-1)/y);

14

15  T2a=(T2-T1)/n_compressor + T1;

16

17  ratio=0.9*C/cp/(T3-T2a) - 1;  //ratio=ma/mf
18  disp("A/F ratio =")
19  disp(ratio)
```

Scilab code Exa 13.39 39

```
1  clc
2  cp=1.005;  //kJ/kg K
3  y1=1.4;
4  y2=1.333;
5  p1=1;  //bar
6  p4=p1;
7  T1=300;  //K
8  p2=6.2;  //bar
9  p3=p2;
10 n_compressor=0.88;
11 C=44186;  //kJ/kg
12 ratio=0.017;  //Fuel-air ratio; kJ/kg of air
13 n_turbine=0.9;  //
14 cpg=1.147;

15

16 T2=T1*(p2/p1)^((y1-1)/y1);
17 T2a=(T2-T1)/n_compressor + T1;  //T2'

18

19 T3=ratio*C/(1+ratio)/cp + T2a;
20 T4=T3*(p4/p3)^((y2-1)/y2);
21 T4a=T3-n_turbine*(T3-T4);
22 W_compressor=cp*(T2a-T1);
23 W_turbine=cpg*(T3-T4a);
24 W_net=W_turbine-W_compressor;
25 Qs=ratio*C;
```

```
26
27  n_th=W_net/Qs*100;
28  disp("Thermal  efficiency  =")
29  disp(n_th)
30  disp("%")
```

Scilab code Exa 13.40 40

```
1   clc
2   cp=1;  //kJ/kg  K
3   y=1.4;
4   C=41800;  //kJ/kg
5   p1=1;  //bar
6   T1=293;  //K
7   p2=4;  //bar
8   p4=p1;
9   p3=p2;
10  n_compressor=0.80;
11  n_turbine=0.85;
12  ratio=90;  //Air−Fuel  ratio
13  m_a=3;  //kg/s
14
15  disp("(i)Power  developed  ")
16  T2=T1*(p2/p1)^((y-1)/y);
17  T2a=(T2-T1)/n_compressor + T1;
18  T3=C/(1+ratio)/cp + T2a;
19  T4=T3*(p4/p3)^((y-1)/y);
20  T4a=T3-n_turbine*(T3-T4);
21
22  W_turbine=(ratio+1)/ratio*cp*(T3-T4a);
23  W_compressor=cp*(T2a-T1);
24  W_net=W_turbine-W_compressor;
25  Qs=1/ratio*C;
26
27  P=m_a*W_net;
```

```
28  disp("Power=")
29  disp(P)
30  disp("kW/kg of air")
31
32
33  disp("(ii) Thermal efficiency of cycle =")
34  n_thermal=W_net/Qs;
35  disp(n_thermal)
36  disp("%")
```

Scilab code Exa 13.41 41

```
 1  clc
 2  T1=288; //K
 3  T3=883; //K
 4  rp=6; //rp=p2/p1
 5  n_compressor=0.80;
 6  n_turbine=0.82;
 7  m_a=16; //kg/s
 8  cp1=1.005; //kJ/kg K, For compression process
 9  y1=1.4; // For compression process
10  cp2=1.11; //kJ/kg K
11  y2=1.333;
12
13  T2=T1*(rp)^((y1-1)/y1);
14  T2a=(T2-T1)/n_compressor + T1;
15  T4=T3/rp^((y2-1)/y2);
16  T4a=T3-n_turbine*(T3-T4);
17
18  W_compressor=cp1*(T2a-T1);
19  W_turbine=cp2*(T3-T4a);
20  W_net=W_turbine-W_compressor;
21
22  Power=m_a*W_net;
23  disp("Power =")
```

```
24 disp(Power)
25 disp("kW")
```

Scilab code Exa 13.42 42

```
1  clc
2  cp=1.11;
3  T3=883; //K
4  T2a=529; //K
5  W_turbine=290.4; //kJ/kg
6  W_net=48.2; //kJ/kg
7
8  Qs=cp*(T3-T2a);
9
10 n_thermal=W_net/Qs*100;
11 disp("Thermal efficiency =")
12 disp(n_thermal)
13 disp("%")
14
15 W_ratio=W_net/W_turbine; //Work ratio=net work
       output/Gross work output
16 disp("Work ratio =")
17 disp(W_ratio)
```

Scilab code Exa 13.43 43

```
1 clc
2 p1=1; //bar
3 p2=5; //bar
4 p3=4.9; //bar
5 p4=1; //bar
6 T1=293; //K
7 T3=953; //K
```

```
 8  n_compressor =0.85;
 9  n_turbine =0.80;
10  n_combustion =0.85;
11  y=1.4;
12  cp=1.024;  //kJ/kg K
13  P=1065;  //kW
14
15  disp(" (i) The quantity of air circulation")
16  T2=T1*(p2/p1)^((y-1)/y);
17  T2a=(T2-T1)/n_compressor + T1;
18  T4=T3*(p4/p3)^((y-1)/y);
19  T4a=T3-n_turbine*(T3-T4);
20
21  W_compressor =cp*(T2a-T1);
22  W_turbine =cp*(T3-T4a);
23  W_net=W_turbine-W_compressor;
24
25  m_a=P/W_net;
26  disp("m_a =")
27  disp(m_a)
28  disp("kg")
29
30
31  disp(" (ii) Heat supplied per kg of air circulation =
       ")
32  Qs=cp*(T3-T2a)/n_combustion;
33  disp(Qs)
34  disp("kJ/kg")
35
36
37  disp(" (iii) Thermal efficiency of the cycle =")
38  n_thermal=W_net/Qs*100;
39  disp(n_thermal)
40  disp("%")
```

Scilab code Exa 13.44 44

```
1  clc
2  m_a =20;  //kg/s
3  T1 =300;  //K
4  T3 =1000;  //K
5  rp =4;  //rp=p2/p1
6  cp =1;  //kJ/kg K
7  y =1.4;
8
9  T2=T1*(rp)^((y-1)/y);
10 T4=T3-T2+T1;
11
12 //p5/p4=(p5/p3)*(p3/p4)
13 //let p3/p4=r1
14 r1=(T3/T4)^(y/(y-1));
15
16 //r2=p5/p4;
17 r2=1/4*r1;
18 P_ratio=1/r2;  //Pressure ratio of low pressure
       turbine
19 disp("Pressure ratio of low pressure turbine =")
20 disp(P_ratio)
21
22 T5=T4/(P_ratio)^((y-1)/y);
23 disp("Temperature of the exhaust from the unit =")
24 disp(T5)
25 disp("K")
```

Scilab code Exa 13.45 45

```
1  clc
2  T1 =288;  //K
3  p1 =1.01;  //bar
4  rp =7;
```

```scilab
 5  p2=rp*p1;
 6  p3=p2;
 7  p5=p1;
 8  n_compressor=0.82;
 9  n_turbine=0.85;
10  n_turbine=0.85;
11  T3=883; //K
12  cpa=1.005;
13  cpg=1.15;
14  y1=1.4;
15  y2=1.33;
16
17  disp(")(i) Pressure and temperature of the gases
        entering the power turbine =")
18
19  T2=T1*rp^((y1-1)/y1);
20  T2a=(T2-T1)/n_compressor + T1;
21
22  W_compressor=cpa*(T2a-T1);
23
24  T4a=(cpg*T3-W_compressor)/cpg;
25  disp("Temperature of gases entering the power
        turbine =")
26  disp(T4a)
27  disp("K")
28
29  T4=T3-(T3-T4a)/n_turbine;
30
31  p4=p3/(T3/T4)^(y2/(y2-1));
32  disp("Pressure of gases entering the power turbine =
        ")
33  disp(p4)
34  disp("bar")
35
36
37  disp("(ii) Net power developed per kg/s mass flow")
38  T5=T4a/(p4/p5)^((y2-1)/y2);
39  T5a=T4a-n_turbine*(T4a-T5);
```

```
40
41  W_turbine=cpg*(T4a-T5a);
42  disp(" Net power developed per kg/s mass flow =")
43  disp(W_turbine)
44  disp("kW")
45
46
47  disp("(iii) Work ratio =")
48  W_ratio=W_turbine/(W_turbine+W_compressor);
49  disp(W_ratio)
50
51
52  disp("(iv) Thermal efficiency of the unit")
53  Qs=cpg*(T3-T2a);
54  n_thermal=W_turbine/Qs*100;
55  disp("n_thermal =")
56  disp(n_thermal)
57  disp("%")
```

Scilab code Exa 13.46 46

```
1  clc
2  T1=288; //K
3  rp=4; //rp=p2/p1=p3/p4
4  n_compressor=0.82;
5  e=0.78; //Effectiveness of the heat exchanger
6  n_turbine=0.70;
7  T3=873; //K
8  y=1.4;
9  R=0.287;
10
11  T2=T1*(rp)^((y-1)/y);
12  T2a=(T2-T1)/n_compressor + T1;
13  T4=T3/rp^((y-1)/y);
14  T4a=T3-n_turbine*(T3-T4);
```

```
15
16  cp=R*y/(y-1);
17  W_compressor=cp*(T2a-T1);
18  W_turbine=cp*(T3-T4a);
19  W_net=W_turbine-W_compressor;
20
21  T5=e*(T4a-T2a) + T2a;
22  Qs=cp*(T3-T5);
23
24  n_cycle=W_net/Qs*100;
25  disp("Efficiency =")
26  disp(n_cycle)
27  disp("%")
```

Scilab code Exa 13.47 47

```
1  clc
2
3  //Simple cycle
4  p2=4;  //bar
5  p1=1;  //bar
6  T1=293;
7  n_compressor=0.8;
8  n_turbine=0.85;
9  ratio=90;  //Air Fuel ratio
10 C=41800;  //kJ/kg
11 cp=1.024;
12 p4=1.01;  //bar
13 p3=3.9;  //bar
14 y=1.4;
15 e=0.72;  //thermal ratio
16
17 T2=T1*(p2/p1)^((y-1)/y);
18 T2a=(T2-T1)/n_compressor + T1;
19 T3=C/cp/(ratio+1)+471;
```

```
20  T4=T3*(p4/p3)^((y-1)/y);
21
22  T4a=T3-n_turbine*(T3-T4);
23
24  n_thermal1=((T3-T4a)-(T2a-T1))/(T3-T2a)*100;
25  disp("Thermal efficiency of simple cycle=")
26  disp(n_thermal1)
27  disp("%")
28
29
30  //Heat exchanger cycle
31
32  T2a=471; // K (as for simple cycle)
33  T3=919.5; // K (as for simple cycle)
34  p3=4.04-0.14-0.05; //bar
35  p4=1.01+0.05; //bar
36
37  T4=T3*(p4/p3)^((y-1)/y);
38  T4a=T3-n_turbine*(T3-T4);
39
40  T5=e*(T4a-T2a) + T2a;
41
42  n_thermal2=((T3-T4a) - (T2a-T1))/(T3-T5)*100;
43  disp("Thermal efficiency of heat exchanger cycle =")
44  disp(n_thermal2)
45  disp("%")
46
47  dn=n_thermal2-n_thermal1;
48  disp("Increase in thermal efficiency =")
49  disp(dn)
50  disp("%")
```

Scilab code Exa 13.48 48

```
1  clc
```

```
 2  T1=293; //K
 3  T6=898; //K
 4  T8=T6;
 5  n_c=0.8; //Efficiency of each compressor stage
 6  n_t=0.85; //Efficiency of each turbine stage
 7  n_mech=0.95;
 8  e=0.8;
 9  cpa=1.005; //kJ/kg K
10  cpg=1.15; //kJ/kg K
11  y1=1.4;
12  y2=1.333;
13
14  disp(")(i) Thermal efficiency")
15  T3=T1;
16
17  // p2/p1=sqrt(9)=3
18  T2=T1*(3)^((y1-1)/y1);
19  T2a=(T2-T1)/n_c + T1;
20  T4a=T2a;
21  W_c=cpa*(T2a-T1); //Work input per compressor stage
22  W_t=2*W_c/n_mech; //Work output of H.P. turbine
23  T7a=T6-W_t/cpg;
24  T7=T6-(T6-T7a)/n_t;
25
26  // (p6/p7)=(T6/T7)^(y2/(y2-1))=4.82;
27  // p8/p9=9/4.82=1.86
28  T9=T8/(1.86)^((y2-1)/y2);
29  T9a=T8-n_t*(T8-T9);
30
31  W=cpg*(T8-T9a)*n_mech; //Net work output
32  T5=e*(T9a-T4a)+T4a;
33
34  Q=cpg*(T6-T5)+cpg*(T8-T7a); //Heat supplied
35  n_thermal=W/Q*100;
36  disp("n_thermal =")
37  disp(n_thermal)
38  disp("%")
39
```

```
40  disp(" ( i i )  Work  ratio")
41  Gross_work=W_t+W/n_mech;
42  W_ratio=W/Gross_work;
43  disp("Work  ratio=")
44  disp(W_ratio)
45
46
47  disp(" ( iii )  Mass  flow  rate  =")
48  m=4500/W;
49  disp(m)
50  disp("kg/s")
```

Scilab code Exa 13.49 49

```
1   clc
2   T1=293;  //K
3   T5=1023;  //K
4   T7=T5;
5   p1=1.5;  //bar
6   p2=6;  //bar
7   n_c=0.82;
8   n_t=0.82;
9   e=0.70;
10  P=350;  //kW
11  cp=1.005;  //kJ/kg K
12  y=1.4;
13
14  T3=T1;
15  px=sqrt(p1*p2);
16  T2=T1*(px/p1)^((y-1)/y);
17  T2a=T1+(T2-T1)/n_c;
18  T4a=T2a;
19  p5=p2;
20  T6=T5/(p5/px)^((y-1)/y);
21  T6a=T5-n_t*(T5-T6);
```

```
22  T8a=T6a;
23  Ta=T4a+e*(T8a-T4a);
24  W_net=2*cp*[(T5-T6a)-(T2a-T1)];
25
26  Q1=cp*(T5-T4a)+cp*(T7-T6a); //Without regenerator
27  Q2=cp*(T5-Ta)+cp*(T7-T6a);
28
29  disp("n_thermal without regenerator =")
30  n1=W_net/Q1*100;
31  disp(n1)
32  disp("%")
33
34  disp("n_thermal woth regenerator =")
35  n2=W_net/Q2*100;
36  disp(n2)
37  disp("%")
38
39  disp("(iii) Mass of fluid circulated =")
40  m=P/W_net;
41  disp(m)
42  disp("kg/s")
```

Chapter 14

Refrigeration Cycles

Scilab code Exa 14.1 1

```
1  clc
2  T2=235;  //K
3  P=1.3;  //kW
4
5  disp(" (i) C.O.P. of Carnot refrigerator =")
6  COP=14000/P/60/60;
7  disp(COP)
8
9
10  disp(" (ii) Higher temperature of the cycle =")
11  T1=T2/COP + T2;
12  t1=T1-273;
13  disp(t1)
14  disp("0C")
15
16
17  disp(" (iii) Heat delivered as heat pump")
18  Qabs=14000/60;  //Heat absorbed
19  W=P*60;
20  Q=Qabs+W;
21  disp("Q=")
```

```
22  disp (Q)
23  disp (" kJ/min ")
24
25  COP = Q/W;
26  disp ("COP of heat pump =")
27  disp (COP)
```

Scilab code Exa 14.2 2

```
1   clc
2   T1 =308;  //K
3   T2 =258;  //K
4   capacity =12;  // tonne
5
6   COP = T2 /( T1 - T2 );
7   disp (" ( i ) Co−efficient of performance =")
8   disp ( COP )
9
10
11  disp (" ( ii ) Heat rejected from the system per hour ")
12  W = capacity *14000/5.16;
13  Q = capacity *14000+ W;
14  disp ("Q=")
15  disp (Q)
16  disp (" kJ/h ")
17
18
19  disp (" ( iii ) Power required =")
20  P = W /60/60;
21  disp (P)
22  disp ("kW")
```

Scilab code Exa 14.3 3

```
1  clc
2  T2=268; //K
3  T1=308; //K
4  Q=29; //Heat leakage from the surroundings into the
        cold storage in kW
5  COP_ideal=T2/(T1-T2);
6  COP_actual=1/3*COP_ideal;
7
8  W=Q/COP_actual;
9  disp("Power required =")
10 disp(W)
11 disp("kW")
```

Scilab code Exa 14.4 4

```
1  clc
2  T1=293; //K
3  T2=265; //K
4  T0=273; //K
5  L=335; //Latent heat of ice in kJ/kg
6  cpw=4.18;
7
8  COP=T2/(T1-T2);
9  Rn=cpw*(T1-T0)+L;
10 m_ice=COP*3600/Rn;
11 disp("ice formed per kWh =")
12 disp(m_ice)
13 disp("kg")
```

Scilab code Exa 14.5 5

```
1  clc
2  T1=291; //K
```

```
3 T2=265;  //K
4 T0=273;  //K
5 cpw=4.18;  //kJ/kg
6 cpi=2.09;  //kJ/kg
7 L=334;  //kJ/kg
8 m=400;  //kg
9
10 COP=T2/(T1-T2);
11 Rn=cpw*(T1-T0) + L + cpi*(T0-T2);
12
13 W=Rn*m/COP/3600;  //kJ/s
14 disp("Least  power  =")
15 disp(W)
16 disp("kW")
```

Scilab code Exa 14.6 6

```
1 clc
2 cpw=4.18;  //kJ/kg
3
4 disp("(i) Quantity  of  ice  produced")
5 t=20;  //0C
6 L=335;  //kJ/kg
7 capacity=280;  //tonnes
8
9 Q1=cpw*t + L;  //Heat  to  be  extracted  per  kg  of  water
       (to  form  ice  at  0  C)
10 Rn=capacity*14000;  //kJ/h
11
12 m_ice=Rn*24/Q1/1000;
13 disp("Quantity  of  ice  produced  in  24  hours  =")
14 disp(m_ice)
15 disp("tonnes")
16
17
```

```
18  disp(" ( i i ) Minimum power required =")
19  T1=298;  //K
20  T2=263;  //K
21
22  COP=T2/(T1-T2) ;
23  W=Rn/COP/3600;  //kJ/s
24  disp(" Power required =")
25  disp(W)
26  disp("kW")
```

Scilab code Exa 14.7 7

```
 1  clc
 2  cp1=1.25;  //kJ/kg 0C
 3  cp2=2.93;  //kJ/kg 0C
 4  L=232;  //kJ/kg
 5  T1=-3;  //0C
 6  T2=-8;  //0C
 7  T3=25;  //0C
 8
 9  Q1=cp2*(T3-T1) + L + cp1*(T1-T2);  //Heat removed in
         8 hours from each kg of fish
10
11  Q=Q1*20*1000/8;  //Heat removed by the plant /min
12
13  disp(" ( i ) Capacity of the refrigerating plant =")
14  capacity=Q/14000;  //tonnes
15  disp(capacity)
16  disp(" tonnes")
17
18  disp(" ( i i ) Carnot cycle C.O.P. between this
         temperature range.")
19  T1=298;  //K
20  T2=265;  //K
21
```

```
22  COP = T2 /( T1 - T2 );
23  disp ("COP of reversed carnot cycle =")
24  disp ( COP )
25
26
27  disp (" ( iii ) Power required ")
28  COP_actual =1/3* COP ;
29
30  W=Q/ COP_actual /3600;  // kJ / s
31  disp (" Power =")
32  disp (W)
33  disp ("kW")
```

Scilab code Exa 14.8 8

```
1  clc
2  T1 =1273;  //K
3  T2 =298;  //K
4  T3 =268;  //K
5  T4 =298;  //K
6
7  // Let  Q2/Q1=r1 ,  r2=Q3/Q4;
8  r1 =298/1273;  //Q2/Q1
9  r2 =268/298;  //Q3/Q4
10
11  // Let  Q4/Q1=r
12  r=(1 - r1 )/(1 - r2 );
13  disp (" The ratio in which the heat pump and heat
       engine share the heating load =")
14  disp (r)
```

Scilab code Exa 14.9 9

```
 1  clc
 2  y=1.4;
 3  n=1.35;
 4  cp=1.003;  //kJ/kg K
 5  p2=1;  //bar
 6  p1=8;  //bar
 7  T3=282;  //K
 8  T4=302;  //K
 9  T1=T4;
10  T4=T3*(p1/p2)^((n-1)/n);
11  T2=T1*(p2/p1)^((n-1)/n);
12
13  Q1=cp*(T3-T2);  //Heat extracted from cold chamber
        per kg of air
14  Q2=cp*(T4-T1);  //Heat rejected in the cooling
        chamber per kg of air
15  cv=cp/y;
16  R=cp-cv;
17  W=n/(n-1)*R*((T4-T3) - (T1-T2));
18
19  COP=Q1/W;
20  disp("COP=")
21  disp(COP)
```

Scilab code Exa 14.10 10

```
 1  clc
 2  p1=1000;  //kPa
 3  p2=100;  //kPa
 4  p4=p1;
 5  p3=p2;
 6  E=2000;  // Refrigerating effect produced in kJ/min
 7  T3=268;  //K
 8  T1=303;  //K
 9  y=1.4;
```

```scilab
10
11  disp(" ( i ) Mass of air circulated per minute")
12  T2=T1*(p2/p1)^((y-1)/y);
13  e=cp*(T3-T2); //Refrigerating effect per kg; kJ/kg
14
15  m=E/e;
16  disp("m=")
17  disp(m)
18  disp("kg/min")
19
20
21  disp(" ( ii ) Compressor work (Wcomp.) , expander work (
          Wexp.) and cycle work (Wcycle)")
22  T4=T3*(p4/p3)^((y-1)/y);
23
24  Wcomp=y/(y-1)*m*R*(T4-T3);
25  disp(" Compressor work =")
26  disp(Wcomp)
27  disp("kJ/min")
28
29  Wexp=y/(y-1)*m*R*(T1-T2);
30  disp(" Expander work =")
31  disp(Wexp)
32  disp("kJ/min")
33
34  W_cycle=Wcomp-Wexp;
35  disp("Wcycle=")
36  disp(W_cycle)
37  disp("kJ/min")
38
39
40  disp(" ( iii ) C.O.P. and power required")
41  COP=E/W_cycle;
42  disp("COP =")
43  disp(COP)
44
45  P=W_cycle/60;
46  disp("Power required =")
```

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```
47  disp(P)
48  disp("kW")
```

Scilab code Exa 14.11 11

```
 1  clc
 2  y=1.4;
 3  cp=1.003;  //kJ/kg K
 4  T3=289;  //K
 5  T1=314;  //K
 6  p1=5.2;  //bar
 7  p2=1;  //bar
 8  capacity=6;  //tonnes
 9  R=287;  //J/kg K
10  l=0.2;  //m
11
12  T4=T3*(p1/p2)^((y-1)/y);
13  T2=T1*(p2/p1)^((y-1)/y);
14
15
16  disp("(i) C.O.P. =")
17  COP=T2/(T1-T2);
18  disp(COP)
19
20  disp("(ii) Mass of air in circulation")
21  e=cp*(T3-T2);  //Refrigerating effect per kg of air
22  E=capacity*14000;  //Refrigerating effect produced by
        the refrigerating machine in kJ/h
23
24  m=E/e/60;
25  disp("mass of air in circulation =")
26  disp(m)
27  disp("kg/min")
28
29
```

```
30 disp("Piston displacement of compressor")
31 V3=m*R*T3/p2/10^5;
32
33 V_swept=V3/2/240;
34
35 d_c=sqrt(V_swept/l/%pi*4);
36
37 disp("Diameter or bore of the compressor cylinder =")
38 disp(d_c*1000)
39 disp("mm")
40
41 disp("Piston displacement of expander")
42 V2=m*R*T2/p2/10^5;
43 V_swept=V2/2/240;
44
45 d_c=sqrt(V_swept/l/%pi*4);
46 disp("Diameter or bore of the expander cylinder =")
47 disp(d_c*1000)
48 disp("mm")
49
50
51 disp("(v) Power required to drive the unit")
52 W=capacity*14000/COP/3600;
53 disp("power =")
54 disp(W)
55 disp("kW")
```

Scilab code Exa 14.12 12

```
1 clc
2 m=6; //kg/min
3 n_relative=0.50;
4 cpw=4.187; //kJ/kg K
5 L=335; //kJ/kg
```

```
 6
 7  h_f2=31.4;  //kJ/kg
 8  h_fg2=154;  //kJ/kg
 9  h_f3=59.7;  //kJ/kg
10  h_fg3=138;  //kJ/kg
11  h_f4=59.7;  //kJ/kg
12  x2=0.6;
13  s_f3=0.2232;  //kJ/kg K
14  s_f2=0.1251;  //kJ/kg K
15  T2=268;  //K
16  T3=298;  //K
17
18  h2=h_f2+x2*h_fg2;
19  x3=((s_f2-s_f3)+x2*(h_fg2/T2))*T3/h_fg3;
20  h3=h_f3+x3*h_fg3;
21  h1=h_f4;
22  COP_th=(h2-h1)/(h3-h2);  //Theoritical COP
23  COP=n_relative*COP_th;
24
25  Q=cpw*(20-0) + L;  //Heat extracted from 1 kg of
        water at 20 C for the formation of 1 kg of ice
        at 0 C
26
27  m_ice=COP*m*(h3-h2)/Q*60*24/1000;  //in 24 hours
28  disp("m_ice=")
29  disp(m_ice)
30  disp("tonnes")
```

Scilab code Exa 14.13 13

```
1  clc
2  L=335;  //kJ/kg
3  h3=1319.22;  //kJ/kg
4  h1=100.04;  //kJ/kg
5  h4=h1;
```

```
6  s_f2 = -2.1338;  //kJ/kg K
7  s_g2 =5.0585;  //kJ/kg K
8  s_g3 =4.4852;  //kJ/kg K
9  h_f2 = -54.56;  //kJ/kg
10 h_g2 =1304.99;  //kJ/kg
11
12 x2 =( s_g3 - s_f2 )/( s_g2 - s_f2 );
13
14 h2 = h_f2 + x2 *( h_g2 - h_f2 );
15 COP_theoritical =( h2 - h1 )/( h3 - h2 );
16 COP_actual =0.62* COP_theoritical ;
17 RE = COP_actual *( h3 - h2 );  // Actual  refrigerating  effect
       per  kg
18 Q=28*1000* L /24/3600;  // Heat  to  be  extracted  per
      second
19
20 m= Q / RE ;  // Mass  of  refrigerant  circulated  per  second
21
22 W= m *( h3 - h2 );
23 disp (" Power  required  =")
24 disp ( W )
25 disp (" kW ")
```

Scilab code Exa 14.14 14

```
1  clc
2  h_f2 =158.2;  //kJ/kg
3  x2 =0.62;
4  h_fg2 =1280.8;
5  h1 =298.9;  //kJ/kg
6  h_f4 = h1 ;
7  s_f2 =0.630;  //kJ/kg K
8  T2 =268;  //K
9  T3 =298;  //K
10 s_f3 =1.124;  //kJ/kg K
```

```scilab
11  h_fg3=1167.1; //kJ/kg
12  m=6.4; //kg/min
13  cp=4.187;
14  L=335; //kJ/kg
15  h_f3=298.9; //kJ/kg
16
17  h2=h_f2+x2*h_fg2;
18  x3=((s_f2-s_f3)+x2*h_fg2/T2)/h_fg3*T3;
19  h3=h_f3+x3*h_fg3;
20
21  COP_theoritical=(h2-h1)/(h3-h2);
22  COP_actual=0.55*COP_theoritical;
23
24  W1=h3-h2; //Work done per kg of refrigerant
25  W=m*W1/60; //Work done per second kJ/s
26
27  Q=15*cp+L;
28  m_ice=W*3600*24/Q;
29  disp("Amount of ice formed in 24 hours =")
30  disp(m_ice)
31  disp("kg")
```

Scilab code Exa 14.15 15

```scilab
1  clc
2  RE=5*14000/3600; //Total refrigeration produced in
      kg/s
3  h2=183.19; //kJ/kg
4  h3=209.41; //kJ/kg
5  h4=74.59; //kJ/kg
6  h1=h4;
7
8  disp("(i) The refrigerant flow rate")
9  RE_net=h2-h1; //Net refrigerating effect produced
      per kg
```

```
10  m=RE/RE_net;
11  disp("Refrigerant flow rate =")
12  disp(m)
13  disp("kg/s")
14
15
16  disp("(ii) The C.O.P. =")
17  COP=(h2-h1)/(h3-h2);
18  disp(COP)
19
20
21  disp("(iii) The power required to drive the
        compressor =")
22  P=m*(h3-h2);
23  disp(P)
24  disp("kW")
25
26
27  disp("(iv) The rate of heat rejection to the
        condenser =")
28  rate=m*(h3-h4);
29  disp(rate)
30  disp("kW")
```

Scilab code Exa 14.16 16

```
1  clc
2
3  disp("(i) If an expansion cylinder is used in a
        vapour compression system, the work recovered
        would be extremely small, in fact not even
        sufficient to overcome the mechanical friction.
        It will not be possible to gain any work. Further
        , the expansion cylinder is bulky. On the other
        hand the expansion valve is a very simple and
```

```
         handy device, much cheaper than the expansion
         cylinder. It does not need installation,
         lubrication or maintenance.")
 4  disp("The expansion valve also controls the
         refrigerant flow rate according to the
         requirement, in addition to serving the function
         of reducting the pressure of the refrigerant.")
 5
 6
 7  disp("(ii) The comparison between centrifugal and
         reciprocating compressors ")
 8
 9  disp("1. Suitability")
10
11  disp("Centrifugal compressor")
12  disp("Suitable for handling large volumes of air at
         low pressures")
13
14  disp("Reciprocating compressor")
15  disp("Suitable for low discharges of air at high
         pressure.")
16
17
18  disp("2. Operational speeds")
19
20  disp("Centrifugal compressor")
21  disp("Usually high")
22
23  disp("Reciprocating compressor")
24  disp("Low")
25
26
27  disp("3. Air supply")
28
29  disp("Centrifugal compressor")
30  disp("Continuous")
31
32  disp("Reciprocating compressor")
```

```
33  disp("Pulsating")
34
35
36  disp("4.Balancing")
37
38  disp("Centrifugal compressor")
39  disp("Less Vibrations")
40
41  disp("Reciprocating compressor")
42  disp("Cyclic vibrations occur")
43
44
45  disp("5.Lubrication system")
46
47  disp("Centrifugal compressor")
48  disp("Generally simple lubrication systems are
       required.")
49
50  disp("Reciprocating compressor")
51  disp("Generally complicated")
52
53
54  disp("6.Quality of air delivered")
55
56  disp("Centrifugal compressor")
57  disp("Air delivered is relatively more clean")
58
59  disp("Reciprocating compressor")
60  disp("Generally contaminated with oil.")
61
62
63  disp("7.Air compressor size")
64
65  disp("Centrifugal compressor")
66  disp("Small for given discharge")
67
68  disp("Reciprocating compressor")
69  disp("Large for same discharge")
```

```scilab
70
71
72  disp("8.Free air handled")
73
74  disp("Centrifugal compressor")
75  disp("2000−3000 m3/min")
76
77  disp("Reciprocating compressor")
78  disp("250−300 m3/min")
79
80
81  disp("9.Delivery pressure")
82
83  disp("Centrifugal compressor")
84  disp("Normally below 10 bar")
85
86  disp("Reciprocating compressor")
87  disp("500 to 800 bar")
88
89
90  disp("10.Usual standard of compression")
91
92  disp("Centrifugal compressor")
93  disp("Isentropic compression")
94
95  disp("Reciprocating compressor")
96  disp("Isothermal compression")
97
98
99  disp("11.Action of compressor")
100
101  disp("Centrifugal compressor")
102  disp("Dynamic action")
103
104  disp("Reciprocating compressor")
105  disp("Positive displacement")
106
107
```

```
108  disp (" ( i i i )")
109  h2 =344.927;  //kJ/kg
110  h4 =228.538;  //kJ/kg
111  h1 =h4 ;
112  cpv =0.611;  ///kJ/kg0C
113  //  s2=s3
114  t3 =39.995;  //0C
115  h3 =363.575+ cpv *( t3 -30) ;
116  Rn =h2 -h1 ;
117  W=h3 -h2 ;
118
119  COP =Rn /W;
120  disp ("COP =")
121  disp ( COP )
122
123  cp =2.0935;  //kJ/kg  0C
124  Q =2400/24/3600*[4.187*(15 -0) +335+ cp *(0 -(-5)) ];
125
126  W=Q/ COP ;
127  disp (" Work  r e q u i r e d  =")
128  disp (W)
129  disp ("kW")
```

Scilab code Exa 14.17 17

```
1  clc
2  disp (" ( i i )  Mass  o f  r e f r i g e r a n t  c i r c u l a t e d  per  minute
        ")
3  h2 =352;  //kJ/kg
4  h3 =374;  //kJ/kg
5  h4 =221;  //kJ/kg
6  h1 =h4 ;
7  v2 =0.08;  //m^3/kg
8  rpm =500;
9  D =0.2;
```

```
10  L =0.15;
11  n_vol =0.85;
12
13  RE=h2 - h1;
14  V =%pi /4* D ^2* L * rpm *2* n_vol ;
15
16  m=V/ v2 ;
17  disp ( " Mass  of  refrigerant  circulated  per  minute  =  " )
18  disp (m)
19  disp ( " kg / min " )
20
21  disp ( " ( iii )  Cooling  capacity  in  tonnes  of
           refrigeration  =" )
22  cc =50*( h2 - h1 )*60/14000;
23  disp ( cc )
24  disp ( "TR" )
25
26  disp ( " ( iv )COP  =" )
27  COP =( h2 - h1 )/( h3 - h2 );
28  disp ( COP )
```

Scilab code Exa 14.18 18

```
 1  clc
 2  te = -10;  //0C
 3  tc =40;  //0C
 4  h3 =220;  // kJ / kg
 5  h2 =183.1;  // kJ / kg
 6  h1 =74.53;  // kJ / kg
 7  h_f4 =26.85;  // kJ / kg
 8  m=1;  // kg
 9
10  disp ( " ( i )  The  C.O.P.  the  cycle  =" )
11  COP =( h2 - h1 )/( h3 - h2 );
12  disp ( COP )
```

```
13
14  disp("( ii )  Refrigerating  capacity  =")
15  RC=m*(h2-h1);
16  disp(RC)
17  disp("kJ/min")
18
19  disp("Compressor  power  =")
20  CP=m*(h3-h2)/60;
21  disp(CP)
22  disp("kJ/s")
```

Scilab code Exa 14.19 19

```
1  clc
2  h2=178.61;  //kJ/kg
3  h3a=203.05;  //kJ/kg
4  h_f4=74.53;  //kJ/kg
5  h1=h_f4;
6  s3a=0.682;  //kJ/kg K
7  s2=0.7082;  //kJ/kg K
8  cp=0.747;  //kJ/kg K
9  T3a=313;  //K
10  CE=20;  //Cooling  effect
11  C=0.03;
12  v_g=0.1088;
13  p_d=9.607;
14  p_s=1.509;
15  n=1.13;
16
17  m=CE/(h2-h1);
18  T3=T3a*%e^((s2-s3a)/cp)
19  h3=h3a+cp*(T3-T3a);
20
21  P=m*(h3-h2);
22  disp("Power  required  by  the  machine  =")
```

```
23  disp(P)
24  disp("kW")
25
26  n_vol=1+C-C*(p_d/p_s)^(1/n); //Volumetric efficiency
27  V1=m*v_g; //volume of refrigerant at the intake
        conditions
28  V_swept=V1/n_vol;
29
30  V=V_swept*60/300;
31  disp("Piston displacement =")
32  disp(V)
33  disp("m^3")
```

Scilab code Exa 14.20 20

```
 1  clc
 2  h2=1450.22; //kJ/kg
 3  h3a=1488.57; //kJ/kg
 4  h_f4=366.072; //kJ/kg
 5  cpl2=4.556; //kJ/kg K
 6  cpv1=2.492; //kJ/kg K
 7  cpv2=2.903; //kJ/kg K
 8  T1=303; //K
 9  T2=308; //K
10  s3a=5.2086; //kJ/kg K
11  s2=5.755; //kJ/kg K
12  T3a=308; //K
13  N=1000;
14
15  h_f4a=h_f4-cpl2*(T2-T1);
16  h1=h_f4a;
17  T3=T3a*%e^((s2-s3a)/cpv2);
18  h3=h3a+cpv2*(T3-T3a);
19  m=50/(h2-h1);
20
```

```
21
22  disp(" ( i )  Power  required  =")
23  P=m*(h3-h2);
24  disp(P)
25  disp("kW")
26
27
28  disp(" ( ii )  Cylinder  dimensions  ")
29  D=(m*4*60/%pi/1.2/N/0.417477)^(1/3);
30  disp("Diameter  of  cylinder  =")
31  disp(D)
32  disp("m")
33
34  L=1.2*D;
35  disp("Length  of  the  cylinder=")
36  disp(L)
37  disp("m")
```

Scilab code Exa 14.21 21

```
1  clc
2  cooling_load=150;  //W
3  n_vol=0.8;
4  N=720;  //rpm
5  h2=183;  //kJ/kg
6  h1=74.5;  //kJ/kg
7  v2=0.08;  //m^3/kg
8
9  m=cooling_load/(108.5*1000);
10  disp("Mass  flow  rate  of  the  refrigerant  =")
11  disp(m)
12  disp("kJ/s")
13
14  d=m*v2/n_vol;
15  disp("Displacement  volume  of  the  compressor  =")
```

```
16  disp(d)
17  disp("m^3/s")
```

Scilab code Exa 14.22 22

```
1   clc
2   h2=183.2;  //kJ/kg
3   h3=222.6;  //kJ/kg
4   h4=84.9;  //kJ/kg
5
6   v2=0.0767;  //m^3/kg
7   v3=0.0164;  //m^3/kg
8   v4=0.00083;  //m^3/kg
9
10  V=1.5*1000*10^(-6);  //Piston displacement volume m
         ^3/revolution
11  n_vol=0.80;
12
13  disp("(i) Power rating of the compressor (kW)")
14  discharge=V*1600*n_vol;  //Compressor discharge
15  m=discharge/v2;
16
17  P=m/60*(h3-h2);  //kW
18  disp("Power =")
19  disp(P)
20  disp("kW")
21
22
23  disp("(ii) Refrigerating effect =")
24  RE=m/60*(h2-h4);
25  disp(RE)
26  disp("kW")
```

Scilab code Exa 14.23 23

```
1  clc
2  COP=6.5;
3  W=50; //kW
4  h3a=201.45; //kJ/kg
5  h_f4=69.55; //kJ/kg
6  h1=h_f4;
7  h2=187.53; //kJ/kg
8  cp=0.6155; //kJ/kg
9  t3a=35; //0C
10
11 RC=W*COP; //Refrigerating capacity
12 Q1=h2-h_f4; //Heat extracted per kg of refrigerant
13 rate=RC/Q1; //Refrigerant flow rate
14 Q2=W/rate; //Heat input per kg
15 h=h2+Q2; //Enthalpy of vapour after compression
16 Q=h-h3a; //Superheat
17
18 t3=Q/cp+t3a;
19 disp("t3=")
20 disp(t3)
21 disp(" C ")
```

Scilab code Exa 14.24 24

```
1  clc
2  Q1=500; //total heating requirement of 500 kJ/min
3  n_compressor=0.8;
4  s1=0.7035; //kJ/kg K
5  s2=0.6799; //kJ/kg K
6  T2=322.31; //K
7  cp=0.7; //kJ/kg K
8  h_v2=206.24; //kJ/kg
9  h_l2=84.21; //kJ/kg
```

```
10  h_v1 =182.07  //kJ/kg
11
12  Q2=Q1/n_compressor;  //Heat rejected by the cycle
13
14  //Entropy of dry saturated vapour at 2 bar= Entropy
        of superheated vapour at 12 bar
15  T=T2*%e^((s1-s2)/cp);
16
17  H=h_v2+cp*(T-T2);  //Enthalpy of superheated vapour
        at 12 bar
18  Q3=H-h_l2;  //Heat rejected per cycle
19  m=Q2/Q3;  //kg/min
20  W=m*(H-h_v1)/60;  //kW
21  W_actual=W/n_compressor;
22  disp("Power =")
23  disp(W_actual)
24  disp("kW")
```

Scilab code Exa 14.25 25

```
 1  clc
 2  h2a =183.2;  //kJ/kg K
 3  cpv =0.733;  //Vapour specific heat in kJ/kg K
 4  cpl =1.235;  //Liquid specific heat in kJ/kg K
 5  s2a =0.7020;  //Entropy of vapour in kJ/kg K
 6  s3a =0.6854;  //Entropy of vapour in kJ/kg K
 7  T2=270;  //K
 8  T2a =263;  //K
 9  T3a =303;  //K
10  h3a =199.6;  //kJ/kg
11  h_f4 =64.6;  //kJ/kg
12  dT4 =6;  //dT4=T4-T4a
13  v2a =0.0767;
14  n=2;  //number of cylinder
15
```

```
16  h2=h2a+cpv*(T2-T2a);
17  s2=s2a+cpv*log(T2/T2a);
18
19  T3=T3a*%e^((s2-s3a)/cpv);
20  h3=h3a+cpv*(T3-T3a);
21  h_f4a=h_f4-cpl*dT4;
22  h1=h_f4a;
23
24  v2=v2a/T2a*T2;
25
26  disp("(i) Refrigerating effect per kg =")
27  RE=h2-h1;
28  disp(RE)
29  disp("kJ/kg")
30
31  disp("(ii) Mass of refrigerant to be circulated per
        minute =")
32  m=2400/RE;
33  disp(m)
34  disp("kg/min")
35
36  disp("(iii) Theoretical piston displacement per
        minute =")
37  v=m*v2;
38  disp(v)
39  disp("m^3/min")
40
41  disp("(iv) Theoretical power required to run the
        compressor = ")
42  P=m/60*(h3-h2);
43  disp(P)
44  disp("kW")
45
46  disp("(v) Heat removed through the condenser per min
        =")
47  Q=m*(h3-h_f4a);
48  disp(Q)
49  disp("kJ/min")
```

```
50
51  disp(" ( vi )   Theoretical   bore   ( d )   and   stroke   ( l ) " )
52  d =( v/n/%pi *4/1.25/1000) ^(1/3) *1000;
53  disp(" Theroritical   bore  =")
54  disp(d)
55  disp("mm")
56
57  disp(" stroke  =")
58  l =1.25* d ;
59  disp(l)
60  disp("mm")
```

Scilab code Exa 14.26 26

```
1  clc
2  h2 =1597;  // kJ / kg
3  h3 =1790;  // kJ / kg
4  h4 =513;  // kJ / kg
5  h1 = h4 ;
6  t3 =58;  // 0C
7  x1 =0.13;
8  tc =27;  // 0C
9  capacity =10.5;  // tonnes
10
11  disp(" ( i )   Condition   of   the   vapour   at   the   outlet   of
        the   compressor  =")
12  t = t3 - tc ;
13  disp(t)
14  disp("  C ")
15
16  disp(" ( ii )   Condition   of   vapour   at   entrance   to
        evaporator  =")
17  disp(x1)
18
19  disp("COP =")
```

```
20  COP=(h2-h1)/(h3-h2);
21  disp(COP)
22
23  disp("(iv) Power required =")
24  P=capacity*14000/COP/3600;
25  disp(P)
26  disp("kW")
```

Scilab code Exa 14.27 27

```
1  clc
2  h2=615;  //kJ/kg
3  h3=664;  //kJ/kg
4  h4=446;  //kJ/kg
5  h1=h4;
6  v2=0.14;  //m^3/kg
7  capacity=20;  //tonnes
8  n=6;  //number of cylinder
9
10  disp("(i) Refrigerating effect per kg =")
11  RE=h2-h1;
12  disp(RE)
13  disp("kJ/kg")
14
15  disp("(ii) Mass of refrigerant to be circulated per
        minute =")
16  m=capacity*14000/RE/60;
17  disp(m)
18  disp("kg/min")
19
20  disp("(iii) Theoretical piston displacement =")
21  v=v2*m;
22  disp(v)
23  disp("m^3/min")
24
```

```
25  disp(" (iv) Theoretical power =")
26  P=m/60*(h3-h2);
27  disp(P)
28  disp("kW")
29
30  disp(" (v)COP =")
31  COP=(h2-h1)/(h3-h2);
32  disp(COP)
33
34  disp(" (vi) Heat removed through the condenser =")
35  Q=m*(h3-h4);
36  disp(Q)
37  disp("kJ/min")
38
39  disp(" (vii) Theoretical displacement per minute per
         cylinder")
40
41  d=(v/n*4/%pi/950)^(1/3)*1000;
42  disp("Diameter of cylinder =")
43  disp(d)
44  disp("mm")
45
46  l=d;
47  disp("Stroke length =")
48  disp(l)
49  disp("mm")
```

Chapter 15

Heat Transfer

Scilab code Exa 15.1 1

```
1  clc
2  t1=60;  //0C
3  t2=35;  //0C
4  L=0.22;  //m
5  k=0.51;  //W/m 0C
6
7  q=k*(t1-t2)/L;
8  disp("Rate of heat transfer per m^2 =")
9  disp(q)
10 disp("W/m^2")
```

Scilab code Exa 15.2 2

```
1  clc
2  t1=1325;  //0C
3  t2=1200;  //0C
4  t3=25;  //0C
5  L=0.32;  //m
```

```
6  k_A=0.84;  //W/m 0C
7  k_B=0.16;  //W/m 0C
8
9  //L_B=0.32-L_A
10 //(t1-t2)/(L_A/k_A)=(t1-t3)/((L_A/k_A + L_B/k_B)
11
12 L_A=(t1-t2)*k_A/k_B*L/((t1-t3)-(t1-t2)*k_A/k_A+(t1-
       t2)*k_A/k_B);  //m
13 disp("L_A=")
14 disp(L_A*1000)
15 disp("mm")
16
17 L_B=0.32-L_A;  //m
18 disp("L_B")
19 disp(L_B*1000)
20 disp("mm")
21
22
23 disp("(ii) Heat loss per unit area =")
24 q=(t1-t2)/L_A*k_A;
25 disp(q)
26 disp("W/m^2")
27
28
29 disp("If another layer of insulating material is
       added, the heat loss from the wall will reduce ;
       consequently the temperature drop across the fire
        brick lining will drop and the interface
       temperature t2 will rise. As the interface
       temperature is already fixed. Therefore, a
       satisfactory solutionwill not be available by
       adding layer of insulation.")
```

Scilab code Exa 15.3 3

```
1  clc
2  L_A=0.1;  //m
3  L_B=0.04;  //m
4  k_A=0.7;  //W/m 0C
5  k_B=0.48;  //W/m 0C
6  k_C=0.065;  //W/m 0C
7
8  //Q2=0.2*Q1
9  L_C=0.8*[(L_A/k_A) + (L_B/k_B)]*k_C/0.2;
10 disp("thickness of rock wool insulation =")
11 disp(L_C*1000)
12 disp("mm")
```

Scilab code Exa 15.4 4

```
1  clc
2  L_A=0.2;  //m
3  L_C=0.006;  //m
4  L_D=0.1;  //m
5  t1=1150;  //0C
6  t2=40;  //0C
7  dt=t1-t2;
8  k_A=1.52;  //W/m 0C
9  k_B=0.138;  //W/m 0C
10 k_D=0.138;  //W/m 0C
11 k_C=45;  //W/m 0C
12 q=400;  //W/m^2
13
14 disp("(i) The value of x = (L_C) ")
15 L_B=((t1-t2)/q - (L_A/k_A+L_C/k_C+L_D/k_D))*k_B
       *1000;
16 disp("L_B =")
17 disp(L_B)
18 disp("mm")
19
```

```
20
21 disp(" (ii) Temperature of the outer surface of the
       steel plate t_so =")
22 t_so=q*L_D/k_D + t2;
23 disp(t_so)
24 disp("0C")
```

Scilab code Exa 15.5 5

```
 1 clc
 2 k_A=150;  //W/m 0C
 3 k_B=30;  //W/m 0C
 4 k_C=65;  //W/m 0C
 5 k_D=50;  //W/m 0C
 6
 7 L_A=0.03;  //m
 8 L_B=0.08;  //m
 9 L_C=L_B;
10 L_D=0.05;  //m
11
12 A_A=0.01;  //m^2
13 A_B=0.003;  //m^2
14 A_C=0.007;  //m^2
15 A_D=0.01;  //m^2
16
17 t1=400;  //0C
18 t4=60;  //0C
19
20 R_thA=L_A/k_A/A_A;
21 R_thB=L_B/k_B/A_B;
22 R_thC=L_C/k_C/A_C;
23 R_thD=L_D/k_D/A_D;
24
25 R_th_eq=R_thB*R_thC/(R_thB+R_thC);
26 R_th_total=R_thA+R_th_eq+R_thD;
```

```
27
28  Q=(t1-t4)/R_th_total;
29  disp("Q=")
30  disp(Q)
31  disp("W")
```

Scilab code Exa 15.6 6

```
1   clc
2   L=0.012; //m
3   t_hf=95; //0C
4   t_cf=15; //0C
5   k=50; //W/m 0C
6   h_hf=2850; //W/m^2 0C
7   h_cf=10; //W/m^2 0C
8
9   disp("(i) Rate of heat loss per m^2 of the tank
        surface area")
10  U=1/(1/h_hf + L/k + 1/h_cf);
11  A=1; //m^2
12  q=U*A*(t_hf-t_cf);
13  disp("q=")
14  disp(q)
15  disp("W/m^2")
16
17
18  disp("(ii) Temperature of the outside surface of the
        tank =")
19  t2=q/h_cf+t_cf;
20  disp(t2)
21  disp("0C")
```

Scilab code Exa 15.7 7

```
1  clc
2  L_A=0.003; //m
3  L_B=0.05; //m
4  L_C=L_A;
5
6  k_A=46.5; //W/m 0C
7  k_B=0.046; //W/m 0C
8  k_C=k_A;
9  h0=11.6; //W/m^2 0C
10 hi=14.5; //W/m^2 0C
11 t0=25; //0C
12 ti=6; //0C
13
14 A=0.5*0.5*2+0.5*1*4; //m^2
15
16 disp(" (i) The rate of removal of heat =")
17 Q=A*(t0-ti)/(1/h0 + L_A/k_A + L_B/k_B + L_C/k_C + 1/
      hi);
18 disp(Q)
19 disp("W")
20
21
22 disp(" (ii) The temperature at the outer surface of
      the metal sheet =")
23 t1=t0-Q/h0/A;
24 disp(t1)
25 disp("0C")
```

Scilab code Exa 15.8 8

```
1  clc
2  L_A=0.25; //m
3  L_B=0.1; //m
4  L_C=0.15; //m
5  k_A=1.65; //W/m  C
```

```
 6  k_C =9.2;  //W/m  C
 7  t_hf =1250;  //  C
 8  t1 =1100;  //  C
 9  t_cf =25;  //  C
10  h_hf =25;  //W/m^2  C
11  h_cf =12;  //W/m^2  C
12
13  disp (" ( i ) Thermal conductivity =")
14  q=h_hf *( t_hf -t1 ) ;
15
16  k_B=L_B/(( t_hf -t_cf )/q -1/ h_hf -L_A/k_A -L_C/k_C -1/ h_cf
        );
17  disp (" Thermal conductivity ,k=")
18  disp (k_B)
19  disp ("W/m^2  C ")
20
21
22  disp (" ( ii ) The overall transfer coefficient =")
23  R_th_total =1/ h_hf +L_A/k_A+L_B/k_B+L_C/k_C +1/ h_cf ;
24  U=1/ R_th_total ;
25  disp (U)
26  disp ("W/m^2  C ")
27
28
29  disp (" ( iii ) All surface temperature ")
30
31  disp (" t1=")
32  disp (t1)
33  disp (" C ")
34
35  t2=t1 -q*L_A/k_A ;
36  disp (" t2=")
37  disp (t2)
38  disp (" C ")
39
40  t3=t2 -q*L_B/k_B ;
41  disp (" t3=")
42  disp (t3)
```

```
43  disp(" C ")
44
45  t4=t3-q*L_C/k_C;
46  disp("t4=")
47  disp(t4)
48  disp(" C ")
```

Scilab code Exa 15.9 9

```
1  clc
2  r1=0.01; //m
3  r2=0.02; //m
4  r3=0.05; //m
5  t1=600; //0C
6  t3=1000; //0C
7  k_B=0.2; //W/m 0C
8
9  q=2*%pi*(t1-t3)/(log(r3/r2)/k_B);
10 disp("Heat transfer per metre of length =")
11 disp(q)
12 disp("W/m")
```

Scilab code Exa 15.10 10

```
1  clc
2  r1=0.06; //m
3  r2=0.12; //m
4  r3=0.16; //m
5  k_A=0.24; //W/m 0C
6  k_B=0.4; //W/m 0C
7  h_hf=60; //W/m^2 0C
8  h_cf=12; //W/m^2 0C
9  t_hf=65; //0C
```

```
10  t_cf =20;  //0C
11  L=60;  //m
12
13  Q=2*%pi*L*(t_hf -t_cf)/(1/h_hf/r1 + log(r2/r1)/k_A +
        log(r3/r2)/k_B + 1/h_cf/r3);
14  disp(" Rate of heat loss =")
15  disp(Q)
16  disp("W")
```

Scilab code Exa 15.11 11

```
 1  clc
 2  r1 =0.06;  //m
 3  r2 =0.08;  //m
 4  k_A =42;  //W/m 0C
 5  k_B =0.8;  //W/m 0C
 6  t_hf =150;  //0C
 7  t_cf =20;  //0C
 8  h_hf =100;  //W/m^2 0C
 9  h_cf =30;  //W/m^2 0C
10
11  //Q=2.1*2*%pi*r*L kW
12  //Q=0.989*L*10^3 W
13
14  //Q=2*%pi*L*(t_hf-t_cf)/(1/h_hf/r1 + log(r2/r1)/k_A
         + log(r3/r2)/k_B + 1/h_cf/r3)
15  //By solving above equation, using hit and trial
         method we get
16  r3 =0.105;  //m
17  thickness =(r3 -r2)*1000;  //mm
18  disp(" Thickness of insulation =")
19  disp(thickness)
20  disp("mm")
```

Scilab code Exa 15.12 12

```scilab
1  clc
2  r2=0.7;  //m
3  r1=0.61;  //m
4  dt=220;  //dt=t1-t2;  0C
5  k=0.083;  //W/m 0C
6
7  Q=dt/((r2-r1)/(4*%pi*k*r1*r2));
8  disp("Rate of heat leakage =")
9  disp(Q)
10 disp("W")
```

Scilab code Exa 15.13 13

```scilab
1  clc
2  r1=0.001;  //m
3  r2=0.0018;  //m
4  k=0.12;  //W/m 0C
5  h0=35;  //W/m^2 0C
6
7  rc=k/h0;
8
9  thickness=(rc-r1)*10^3;  //mm
10 disp("Critical thickness of insulation =")
11 disp(thickness)
12 disp("mm")
13
14 //Percentage change in heat transfer rate :
15 //Case I : The heat flow through an insulated wire
16
17 //Q1=2*%pi*L*(t1-tair)/(log(r2/r1)/k + 1/h0/r2)
```

```
18
19  //Case II : The heat flow through an insulated wire
        when critical thickness is used is given
20
21  //Q2=2*%pi*L*(t1-tair)/(log(rc/r1)/k + 1/h0/rc)
22
23  //%increase=(Q2-Q1)/Q1*100
24  %increase=(1/(log(rc/r1)/k + 1/h0/rc)-1/(log(r2/r1)/
        k + 1/h0/r2))/(1/(log(r2/r1)/k + 1/h0/r2))*100;
25  disp("Percentage change in heat transfer rate =")
26  disp(%increase)
27  disp("%")
```

Scilab code Exa 15.14 14

```
1  clc
2  A=1*1.5;  //m^2
3  ts=300;  //0C
4  tf=20;  //0C
5  h=20;  //W/m^2 0C
6  Q=h*A*(ts-tf)/10^3;  //kW
7  disp("Rate of heat transfer =")
8  disp(Q)
9  disp("kW")
```

Scilab code Exa 15.15 15

```
1  clc
2  d=0.0015;  //m
3  l=0.15;  //m
4  A=%pi*d*l;
5  ts=120;  //0C
6  tf=100;  //0C
```

```
7  h =4500;  //W/m^2  0C
8
9  Q=h*A*(ts-tf);
10 disp(" Electric  power  to  be  supplied  =")
11 disp(Q)
12 disp("W")
```

Scilab code Exa 15.16 16

```
1  clc
2  D=0.045;  //m
3  l=3.2;  //m
4  u=0.78;  //m/s
5  k=0.66;  //W/m K
6  v=0.478*10^(-6);  //m^2/s
7  Pr=2.98;
8  tw=70;  //0C
9  tf=50;  //0C
10
11 A=%pi*D*l;
12 Re=D*u/v;
13
14 h=0.023*(Re)^0.8*(Pr)^0.4/D*k;
15 disp(" Heat  transfer  co−efficient  =")
16 disp(h)
17 disp("W/m^2  K")
18
19 Q=h*A*(tw-tf)/10^3;
20 disp(" Rate  of  heat  transfer  =")
21 disp(Q)
22 disp("kW")
```

Scilab code Exa 15.17 17

```
1  clc
2  rho=983.2; //kg/m^2
3  cp=4.187; //kJ/kg K
4  k=0.659; //W/m 0C
5  v=0.478*10^(-6); //m^2/s
6  m=0.5/60; //kg/s
7  D=0.02; //m
8  ti=20; //0C
9  t0=50; //0C
10 ts=85; //surface temperature in 0C
11
12 tf=1/2*(ts+(ti+t0)/2);
13 A=%pi/4*D^2;
14 u=m/rho/A;
15 Re=D*u/v;
16 //Since Re < 2000, hence the flow is laminar.
17
18 Nu=3.65;
19 h=Nu*k/D;
20 tb=(t0+ti)/2;
21
22 L=m*cp*10^3*(t0-ti)/(ts-tb)/h/D/%pi;
23 disp("Length of the tube required for fully
       developed flow =")
24 disp(L)
25 disp("m")
```

Scilab code Exa 15.18 18

```
1  clc
2  m_h=0.2; //kg/s
3  m_c=0.5; //kg/s
4  t_h1=75; //0C
5  t_h2=45; //0C
6  t_c1=20; //0C
```

```
7  hi =650;  //W/m^2  0C
8  h0= hi ;
9  cph =4.187;
10 cpc = cph ;
11
12 Q=m_h*cph*(t_h1-t_h2);
13 t_c2=m_h*cph/cpc*(t_h1-t_h2)/m_c+t_c1;
14
15 theta=((t_h1-t_c1)- (t_h2-t_c2))/log((t_h1-t_c1)/(
      t_h2-t_c2));  //Logarithmic  mean  temperature
       difference
16
17 U=hi*h0/(hi+h0);
18 A=Q*10^3/U/theta;
19 disp("The  area  of  heat  exchanger  =")
20 disp(A)
21 disp("m^2")
```

Scilab code Exa 15.19 19

```
1  clc
2  t_c1=25;  //0C
3  t_c2=65;  //0C
4  cph =1.45;  //kJ/kg  K
5  m_h=0.9;  //kg/s
6  t_h1=230;  //0C
7  t_h2=160;  //0C
8  U=420;  //W/m^2  0C
9  cpc=4.187;  //kJ/kg  K
10
11 disp("(i)  The  rate  of  heat  transfer  =")
12 Q=m_h*cph*(t_h1-t_h2);
13 disp(Q)
14 disp("kJ/s")
15
```

```
16
17  disp(" ( ii )  The  mass  flow  rate  of  water  =")
18  m_c=Q/cpc/(t_c2-t_c1);
19  disp(m_c)
20  disp("kg/s")
21
22
23  disp(" ( iii )  The  surface  area  of  heat  exchanger  =")
24  LMTD=((t_h1-t_c2)- (t_h2-t_c1))/log((t_h1-t_c2)/(
       t_h2-t_c1)); //logarithmic  mean  temperature
       difference
25  A=Q*10^3/U/LMTD;
26  disp("A=")
27  disp(A)
28  disp("m^2")
```

Scilab code Exa 15.20 20

```
 1  clc
 2  m_s=800/60;  //kg/s
 3  m_c=m_s;
 4  m_g=1350/60;  //kg/s
 5  m_h=m_g;
 6  t_h1=650;  //0C
 7  t_c1=180;  //0C
 8  t_c2=350;  //0C
 9  d=0.03;  //m
10  L=3;  //m
11  cph=1;  //kJ/kg  K
12  cpc=2.71;  //kJ/kg  K
13  h_g=250;
14  h_s=600;
15
16  t_h2=t_h1-(m_c*cpc*(t_c2-t_c1)/cph/m_h);
17  U=h_g*h_s/(h_g+h_s);
```

```
18  Q=m_h*cph*10^3*(t_h1-t_h2);
19  theta=((t_h1-t_c2)- (t_h2-t_c1))/log((t_h1-t_c2)/(
       t_h2-t_c1)); //logarithmic mean temperature
       difference
20  //A=N*%pi*d*L
21
22  N=Q/U/theta/(%pi*d*L);
23  disp("number of tubes required =")
24  disp(N)
25  disp("tubes")
```

Scilab code Exa 15.21 21

```
1  clc
2  di=0.0296; //m
3  d0=0.0384; //m
4  U=4000; //W/m^2 0C
5  V=3; //m/s
6  t_c1=24; //0C
7  x=0.9;
8  ps=(760-660)/760*1.0133; //bar
9  t_h1=51; //0C
10  t_h2=51; //0C
11  h_fg=2592; //kJ/kg
12  t_c2=47; //0C
13  P=15; //MW
14  ssc=5; //specific steam consumption in kg/kWh
15  cpc=4.187; //kJ?kg K
16  rho=1000;
17
18  m_s=P*10^3*ssc/60; //kg/min
19
20  disp("(i) Mass of cooling water circulated per
       minute =")
21  m_w=m_s*x*h_fg/cpc/(t_c2-t_c1);
```

```
22 disp(m_w)
23 disp("kg/min")
24
25
26 disp("(ii) Condenser surface area")
27 Q=m_s*x*h_fg*10^3/60;
28
29 theta=((t_h1-t_c1)- (t_h2-t_c2))/log((t_h1-t_c1)/(
     t_h2-t_c2)); //Logarithmic mean temperature
     difference
30 A=Q/U/theta;
31 disp(A)
32 disp("m^2")
33
34
35 disp("(iii) Number of tubes required per pass =")
36 Np=m_w/60*4/%pi/di^2/V/rho;
37 disp(Np)
38
39
40 disp("(iv) Tube length =")
41 L=A/%pi/d0/(2*Np);
42 disp(L)
43 disp("m")
```

Scilab code Exa 15.22 22

```
1 clc
2 cp=4.187; //kJ/kg  C
3 u=0.596*10^(-3); //Ns/m^2
4 k=0.635; //W/m  C
5 Pr=3.93;
6 d=0.020; //m
7 l=2; //m
8 m_c=10; //kg/s
```

```
9   t_c1 =17;  ///  C
10  t_h1 =100;  //  C
11  t_h2 =100;  //  C
12  rho =1000;
13  N=200;
14  Np=N/l;
15  h0 =10*10^3;
16
17  V=m_c*4/%pi/d^2/rho/Np;
18  Re=rho*V*d/u;
19  hi=k/d*0.023*(Re)^0.8*(Pr)^0.33;
20  U=hi*h0/(hi+h0);
21
22  //theta1=t_h1-t_c1;
23  //  theta2=t_h2-t_c2;
24  //AMTD=(theta1+theta2)/2
25  //AMTD=91.5 - 0.5*t_c2
26
27  t_c2 =(U*%pi*d*l*N*91.5 + m_c*cp*10^3*t_c1)/(m_c*cp
        *10^3 + U*%pi*d*l*N*0.5);
28  disp(" water exit temperature =")
29  disp(t_c2)
30  disp(" C ")
```

Scilab code Exa 15.23 23

```
1  clc
2  A =0.12;  //m^2
3  T =800;  //K
4  a =5.67*10^(-8);
5
6  disp(" (i) The total rate of energy emission =")
7  Eb=a*A*T^4;
8  disp(Eb)
9  disp("W")
```

```
10
11
12  disp (" ( ii ) The intensity of normal radiation =")
13  Ibn=a*T^4/%pi;
14  disp (Ibn)
15  disp ("W/m^2. sr")
16
17
18  disp (" ( iii ) The wavelength of maximum monochromatic
        emissive power =")
19  wavelength =2898/T;
20  disp (wavelength)
21  disp (" m ")
```

Scilab code Exa 15.24 24

```
1  clc
2  wavelength =0.49; // m
3  a=5.67*10^(-8);
4
5  disp (" ( i ) The surface temperature of the sun")
6  T=2898/ wavelength;
7  disp (T)
8  disp ("K")
9
10
11  disp (" ( ii ) The heat flux at the surface of the sun =
        ")
12  E_sun =a*T^4;
13  disp (E_sun)
14  disp ("W/m^2")
```

Scilab code Exa 15.25 25

```scilab
1  clc
2  T=2773; //K
3  lambda=1.2*10^(-6); //m
4  e=0.9;
5  a=5.67*10^(-8);
6
7  disp("(i) Monochromatic emissive power at 1.2   m
       length")
8  C1=0.3742*10^(-15); //W.m^4/m^2
9  C2=1.4388*10^(-4); //mK
10 E_lambda_b=C1*lambda^(-5)/(exp(C2/lambda/T)-1);
11 disp("E_lambda_b =")
12 disp(E_lambda_b)
13 disp("W/m^2")
14
15
16 disp("(ii) Wavelength at which the emission is
       maximum =")
17 lambda_max=2898/T;
18 disp(lambda_max)
19 disp(" m ")
20
21
22 disp("(iii) Maximum emissive power =")
23 E_lambda_b_max=1.285*10^(-5)*T^5;
24 disp(E_lambda_b_max)
25 disp("W/m^2 per metre length")
26
27
28 disp("(iv) Total emissive power =")
29 Eb=a*T^4;
30 disp(Eb)
31 disp("W/m^2")
32
33
34 disp("(v) Total emissive power =")
35 E=e*a*T^4;
36 disp(E)
```

```
37  disp("W/m^2")
```

Scilab code Exa 15.26 26

```
1  clc
2  T1=1273; //K
3  T2=773; //K
4  e1=0.42;
5  e2=0.72;
6  a=5.67*10^(-8);
7
8  disp("(i) When the body is grey with  1 = 0.42")
9  q=e1*a*(T1^4-T2^4)/10^3; //kW
10 disp("Heat loss per m2 by radiation =")
11 disp(q)
12 disp("kW")
13
14 disp("(ii) When the body is not grey")
15 E_emitted=e1*a*T1^4;
16 E_absorbed=e2*a*(T2)^4;
17
18 q=(E_emitted-E_absorbed)/10^3;
19 disp("Heat loss per m2 by radiation =")
20 disp(q)
21 disp("kW")
```

Scilab code Exa 15.27 27

```
1  clc
2  d=0.022; //m
3  di=0.18; //m
4  e1=0.62;
5  e2=0.82;
```

```scilab
6  rho =7845; //kg/m^3
7  T1a =693; //K; For caseI
8  T1b =813; //K; For caseII
9  T2 =1373; //K
10 l=1; //m
11 a=5.67*10^(-8);
12 cp=0.67; //kJ/kg K
13
14 A1=%pi*d*l;
15 A2=%pi*di*l;
16
17
18 Qi=A1*a*(T1a^4-T2^4)/(1/e1+A1/A2*(1/e2 - 1));
19
20 Qe=A1*a*(T1b^4-T2^4)/(1/e1+A1/A2*(1/e2 - 1));
21
22 Qav=-(Qi+Qe)/2;
23
24 t_h=%pi/4*d^2*rho*cp*(T1b-T1a)*10^3/Qav;
25 disp("Time required for the heating operation")
26 disp(t_h)
27 disp("s")
```

Scilab code Exa 15.28 28

```scilab
1  clc
2  r1=0.05; //m
3  r2=0.1; //m
4  T1=400; //K
5  T2=300; //K
6  e1=0.5;
7  e2=0.5;
8  F_12=1;
9  a=5.67*10^(-8);
10 //A1/A2=r1/r2
```

```
11
12 Q=a*(T1^4-T2^4)/((1-e1)/e1+1/F_12+(1-e2)/e2*r1/r2);
13 disp("heat transfer rate per m2 area by radiation")
14 disp(Q)
15 disp("W/m^2")
```

Scilab code Exa 15.29 29

```
1  clc
2  r1=0.05; //m
3  r2=0.1; //m
4  r3=0.15; //m
5  T1=1000; //K
6  T3=500; //K
7  e1=0.05;
8  e2=e1;
9  e3=e1;
10 a=5.67*10^(-8);
11
12 F_12=1;
13 F_23=1;
14
15 // A1*a*(T1^4−T2^4)/(((1−e1)/e1) + 1/F_12 + ((1−e2)/
      e2)*A1/A2) = A2*a*(T2^4−T3^4)/(((1−e2)/e2) + 1/
      F_23 + ((1−e3)/e3)*A2/A3)
16
17 // A1/A2=r1/r2=5/10=0.5
18 // A2/A3=r2/r3=10/15=0.67
19
20 //Solving this we get
21 T2=770; //K
22
23 Q1=a*(T1^4-T2^4)/(((1-e1)/e1) + 1/F_12 + ((1-e2)/e2)
      *r1/r2);
24 disp("Heat flow per m2 area of cylinder 1 =")
```

```
25  disp(Q1)
26  disp("W")
```

Scilab code Exa 15.30 30

```
1   clc
2   r1=0.105; //m
3   r2=0.15; //m
4   T1=120; //K
5   T2=300; //K
6   e1=0.03;
7   e2=0.03;
8   h_fg=209.35; //kJ/kg
9   a=5.67*10^(-8);
10  F_12=1;
11
12  Q=4*%pi*r1^2*a*(T1^4-T2^4)/( ((1-e1)/e1) + 1/F_12 +
        ((1-e2)/e2)*r1^2/r2^2);
13
14  rate=-Q*3600/h_fg/1000;
15  disp("Rate of evaporation = ")
16  disp(rate)
17  disp("kg/h")
```

Scilab code Exa 15.31 31

```
1   clc
2   T1=91; //K
3   T2=303; //K
4   e1=0.03;
5   e2=0.03;
6   d1=0.3; //m
7   d2=0.45; //m
```

```
 8  a =5.67*10^( -8);
 9  F_12 =1;
10
11  Q=4*%pi*(d1/2)^2*a*(T1^4-T2^4)/( ((1-e1)/e1) + 1/
       F_12 + ((1-e2)/e2)*d1^2/d2^2);
12  disp("Rate of heat flow =")
13  disp(Q)
14  disp("W")
```

Scilab code Exa 15.32 32

```
 1  clc
 2  e1 =0.3;
 3  e2 =0.8;
 4  e3 =0.04;
 5  A1 =1;  //m^2
 6  A2 = A1;
 7  A3 = A1;
 8
 9  // (E_b1 - E_b3)/[(1-e1)/e1+1+(1-e3)/e3]=(E_b3 -
       E_b2)/[(1-e3)/e3+1+(1-e2)/e2]
10
11  // a*(T1^4-T3^4)/(1/e1+1/e3-1)=a*(T3^4-T2^4)/(1/e3
       +1/e2-1)
12
13  // T3^4=0.48*(T1^4+1.08*T2^4)
14
15  // Q12=a*(T1^4-T2^4)/(1/e1+1/e2-1)
16  // Q13=a*(T1^4-T3^4)/(1/e1+1/e3-1)
17
18  // %reduction=(Q_12-Q13)/Q12;
19  %reduction =1-0.131*0.52;
20  disp("Percentage reduction in heat flow due to
       shield =")
21  disp(%reduction)
```

413

```
22   disp("%")
```

Chapter 16

Compressible Flow

Scilab code Exa 16.1 1

```
1  clc
2  V1 =300;  //m/ s
3  p1 =78;  //kN/mˆ2
4  T1 =313;  //K
5  p2 =117;  //kN/mˆ2
6  R=287;  // J/ kg  K
7  y =1.4;
8
9  // Let  r1=p1/rho1
10 r1=R*T1;
11
12 V2=sqrt (2*(y/(y -1)*r1*(1 -(p2/p1)^((y -1)/y)) + V1
      ^2/2));
13 disp (" Velocity  of  gas  at  section  2 =")
14 disp (V2)
15 disp (" m/ s ")
```

Scilab code Exa 16.2 2

```
1  clc
2  p1=35;  //kN/m^2
3  V1=30;  //m/s
4  T1=423;  //K
5  V2=150;  //m/s
6  R=290;  //J/kg K
7  y=1.4;
8
9  //Let  r1=p2/p1
10 r1=R*T1;
11
12 p2=p1*(1-((V2^2/2-V1^2/2)*(y-1)/y/r1))^(y/(y-1));
13 disp("p2=")
14 disp(p2)
15 disp("kN/m^2")
16
17 T2=T1*(p2/p1)^((y-1)/y);
18 t2=T2-273;
19 disp("t2 =")
20 disp(t2)
21 disp(" C ")
```

Scilab code Exa 16.3 3

```
1  clc
2  SG=0.8;
3  rho_oil=800;  //kg/m^3
4  K_oil=1.5*10^9;  //N/m^2; crude oil
5  K_Hg=27*10^9;  //N/m^2; Mercury
6  rho_Hg=13600;  //kg/m^3
7
8  C_oil=sqrt(K_oil/rho_oil);
9  disp("Sonic velocity of crude oil =")
10 disp(C_oil)
11 disp("m/s")
```

```
12
13  C_Hg=sqrt(K_Hg/rho_Hg)
14  disp("Sonic velocity of Mercury =")
15  disp(C_Hg)
16  disp("m/s")
```

Scilab code Exa 16.4 4

```
1  clc
2  T=228; //K
3  M=2;
4  R=287; //Jkg K
5  y=1.4;
6
7  C=sqrt(y*R*T);
8
9  V=M*C*3600/1000;
10  disp("Velocity of the plane =")
11  disp(V)
12  disp("km/h")
```

Scilab code Exa 16.5 5

```
1  clc
2  a=40*%pi/180; //Mach angle in radians
3  y=1.4;
4  R=287; //J/kg K
5  T=288; //K
6
7  C=sqrt(y*R*T);
8
9  V=C/sin(a);
10  disp("Velocity of bullet =")
```

```
11  disp (V)
12  disp ("m/ s")
```

Scilab code Exa 16.6 6

```
1   clc
2   p=88.3;  //kN/m^2
3   T=271;  //K
4   M=40*%pi/180;
5   y=1.4;
6   R=287;  //J/kg K
7
8   C=sqrt(y*R*T);
9
10  V=C/sin(M);
11  disp ("Velocity of the projectile =")
12  disp (V)
13  disp ("m/ s")
```

Scilab code Exa 16.7 7

```
1   clc
2   h=1800;  //m
3   T=277;  //K
4   t=4;  //s
5   y=1.4;
6   R=287;  //J/kg K
7
8   C=sqrt(y*R*T);
9
10  // tan(a)=h/t*V
11  //V=C/sin(a)
12  //From above two equations we get
```

```
13
14  a=(acos(C/h*t));
15
16  V=C/sin(a)*3600/1000;
17  disp("Speed of the aircraft =")
18  disp(V)
19  disp("km/h")
```

Scilab code Exa 16.8 8

```
1  clc
2  R=287; //J/kg K
3  y=1.4;
4  V0=1000*1000/3600; //m/s
5  p0=78.5; //kN/m^2
6  T0=265; //K
7
8  C0=sqrt(y*R*T0);
9  M0=V0/C0;
10
11  disp("(i) Stagnation pressure =")
12  ps=p0*(1+((y-1)/2*M0^2))^(y/(y-1));
13  disp(ps)
14  disp("kN/m^2")
15
16
17  disp("(ii) Stagnation temperature =")
18  Ts=T0*(1+((y-1)/2*M0^2));
19  disp(Ts)
20  disp("K")
21
22
23  disp("(iii) Stagnation density =")
24  rho_s=ps*10^3/R/Ts;
25  disp(rho_s)
```

```
26 disp ("kg/m^3")
```

Scilab code Exa 16.9 9

```
1 clc
2 V0=1000*1000/3600; //m/s
3 T0=320; //K
4 p_atm=98.1; //kN/m^2
5 p=9.81; //kN/m^2
6 p0=98.1-p;
7 R=287; //J/kg K
8 y=1.4;
9
10 C0=sqrt(y*R*T0);
11 M0=V0/C0;
12
13 disp("Stagnation pressure =")
14 ps=p0*(1+((y-1)/2*M0^2))^(y/(y-1));
15 disp(ps)
16 disp("kN/m^2")
17
18
19 disp("Stagnation temperature =")
20 Ts=T0*(1+((y-1)/2*M0^2));
21 disp(Ts)
22 disp("K")
23
24
25 disp("Stagnation density =")
26 rho_s=ps*10^3/R/Ts;
27 disp(rho_s)
28 disp("kg/m^3")
29
30 M=0.8;
31
```

```
32  CF =1+ M0 ^2/4+(2 - y ) /24* M0 ^4;
33  disp ( " Compressibility  factor " )
34  disp ( CF )
```

Scilab code Exa 16.10 10

```
1   clc
2   R =287;  // J / kg  K
3   y =1.4;
4   p0 =220*10^3;  // N/m ^2
5   T0 =300;  // K
6   V0 =200;  // m / s
7   C0 = sqrt ( y * R * T0 ) ;
8   rho_0 = p0 / R / T0 ;
9   disp ( " Stagnation  pressure  =" )
10
11  disp ( " ( i )  Compressibility  is  neglected " )
12  ps =( p0 + rho_0 * V0 ^2/2) /10^3;
13  disp ( " ps =" )
14  disp ( ps )
15  disp ( " kN/m ^2 " )
16
17
18  disp ( " ( ii )  Compressibility  is  accounted  for " )
19  M0 = V0 / C0 ;
20
21  ps =( p0 + rho_0 * V0 ^2/2*(1+ M0 ^2/4+(2 - y ) /24* M0 ^4) ) /10^3;
22  disp ( " ps =" )
23  disp ( ps )
24  disp ( " kN/m ^2 " )
```

Scilab code Exa 16.11 11

```
1  clc
2  p0 =35*10^3; //Pa
3  T0 =235; //K
4  ps =65.4*10^3; //N/m^2
5  R0 =8314; //Nm/mole K
6  M=28;
7
8  R=R0/M;
9  rho_0 = p0/R/T0 ;
10
11 Va=sqrt (2*( ps -p0 )/ rho_0 );
12 disp (" Speed of the aircraft =")
13 disp (Va)
14 disp ("m/s")
```

Scilab code Exa 16.12 12

```
1  clc
2  p0 =30*10^3; //N/m^2
3  V0 =152; //m/s
4  y=1.4;
5
6  rho_0 =1.224; //kg/m^3
7  ps =p0+rho_0 *V0 ^2/2;
8
9  rho_0 =0.454; //kg/m^3
10 V0=sqrt (2*( ps -p0 )/ rho_0 );
11 C0=sqrt (y*p0/ rho_0 );
12 M=V0/C0;
13
14 ccf =(1+M^2/4); //Compressibility correction factor
15
16 V=V0/sqrt (ccf); //True speed of aircraft
17 disp (" True speed of aircraft =")
18 disp (V)
```

```
19  disp("m/s")
```

Scilab code Exa 16.13 13

```
1  clc
2  M=3; //Mach number
3  d=0.2; //m
4  p_nozzle=7.85; //kN/m^2
5  T_nozzle=200; //K
6  y=1.4;
7  A=%pi/4*d^2;
8
9  disp("Reservoir pressure =")
10 p_res=p_nozzle*(1+((y-1)/2*M^2))^(y/(y-1));
11 disp(p_res)
12 disp("kN/m^2")
13
14 disp("Reservoir temperature =")
15 T_res=T_nozzle*(1+((y-1)/2*M^2));
16 disp(T_res)
17 disp("K")
18
19 disp("Throat area (critical) =")
20 Ac=A*M/((2+(y-1)*M^2)/(y+1))^((y+1)/2/(y-1));
21 disp(Ac)
22 disp("m^2")
```

Scilab code Exa 16.14 14

```
1  clc
2  R=287; //J/kg K
3  y=1.4;
4  p_atm=100; //kN/m^2
```

```
5  p1 =284+ p_atm ;  //kN/mˆ2
6  T1 =297;  //K
7  D=0.02;  //m
8
9  A2=%pi/4*D^2;
10 rho_1=p1*10^3/R/T1;
11
12 m_max =0.685* A2*sqrt(p1*10^3*rho_1);
13 disp("Maximum  flow  rate =")
14 disp(m_max)
15 disp("kg/s")
```

Scilab code Exa 16.15 15

```
1  clc
2  R=287;  //J/kg  K
3  y=1.4;
4  p1 =2500*10^3;  //N/mˆ2
5  T1 =293;  //K
6  p2 =1750*10^3;  //N/mˆ2
7
8  rho_1=p1/R/T1;
9
10 V2=sqrt(2*y/(y-1)*p1/rho_1*(1-(p2/p1)^((y-1)/y)));
11 disp("Velocity  of  air =")
12 disp(V2)
13 disp("m/s")
```

Scilab code Exa 16.16 16

```
1  clc
2  R=287;  //J/kg  K
3  y=1.4;
```

```
4  p_atm=10^5;  //N/m^2
5  T1=293;  //K
6  D2=0.025;  //m
7  p1=140*10^3;  //N/m^2
8
9  A2=%pi/4*D2^2;
10
11 disp(”(i) Mass rate of flow of air when pressure in
       the tank is 140 kN/m2 (abs.)”)
12 rho_1=p1/R/T1;
13 p2=10^5;  //N/m^2
14
15 m=A2*sqrt(2*y/(y-1)*p1*rho_1*((p2/p1)^(2/y) - (p2/p1
       )^((y+1)/y)));
16 disp(”m=”)
17 disp(m)
18 disp(”kg/s”)
19
20
21 disp(”(ii) Mass rate of flow of air when pressure in
        the tank is 300 kN/m2 (abs.)”)
22 p1=300*10^3;  //N/m^2
23 p2=10^5;  //N/m^2
24 rho_1=p1/R/T1;
25
26 disp(”The pressure ratio p2/p1 being less than the
       critical ratio 0.528, the flow in the nozzle will
        be sonic”);
27
28 m_max=0.685*A2*sqrt(p1*rho_1);
29 disp(”m_max=”)
30 disp(m_max)
31 disp(”kg/s”)
```

Scilab code Exa 16.17 17

```scilab
1  clc
2  p1=200; //kN/m^2
3  V1=170; //m/s
4  T1=473; //K
5  A1=0.001; //m^2
6  R=287; //J/kg K
7  cp=1000; //J/kg K
8  y=1.4;
9
10 disp(" (i) Stagnation temperature (Ts) and stagnation
         pressure (ps)")
11
12 Ts=T1+V1^2/2/cp;
13 disp("Ts=")
14 disp(Ts)
15 disp("K")
16
17 ps=p1*(Ts/T1)^(y/(y-1));
18 disp("ps=")
19 disp(ps)
20 disp("kN/m^2")
21
22
23 disp(" (ii) Sonic velocity and Mach number at this
         section")
24
25 C1=sqrt(y*R*T1);
26 disp("Sonic velocity =")
27 disp(C1)
28 disp("m/s")
29
30 M1=V1/C1;
31 disp("Mach number = ")
32 disp(M1)
33
34
35 disp(" (iii) Velocity, Mach number and flow area at
         outlet section where pressure is 110 kN/m2")
```

```
36  p2=110;  //kN/m^2
37  M2=sqrt(2/(y-1)*((ps/p2)^((y-1)/y) - 1));
38  disp("M2=")
39  disp(M2)
40
41  T2=Ts*(p2/ps)^((y-1)/y);
42  C2=sqrt(y*R*T2);
43  V2=M2*C2;
44  disp("V2=")
45  disp(V2)
46  disp("m/s")
47
48  A2=(p1*A1*V1*T2/T1/p2/V2)*10^6;
49  disp("A2=")
50  disp(A2)
51  disp("mm^2")
52
53
54  disp("(iv) Pressure (pt), temperature (Tt), velocity
          (Vt), and flow area (At) at throat of the nozzle
        ")
55  Mt=1;
56  Tt=Ts/(1+(y-1)/2*Mt^2);
57  disp("Tt =")
58  disp(Tt)
59  disp("K")
60
61  pt=ps*(Tt/Ts)^(y/(y-1));
62  disp("pt")
63  disp(pt)
64  disp("kN/m^2")
65
66  Ct=sqrt(y*R*Tt);
67  Vt=Mt*Ct;
68
69  At=(p1*A1*V1*Tt/T1/pt/Vt)*10^6;
70  disp("At=")
71  disp(At)
```

```
72 disp("mm^2")
```

Scilab code Exa 16.18 18

```
 1 clc
 2 y=1.4;
 3 p1=26.5;  //kN/m^2
 4 rho_1=0.413;  //kg/m^3
 5 M1=2;
 6 R=287;
 7
 8 M2=sqrt(((y-1)*M1^2 + 2)/(2*y*M1^2 - (y-1)));
 9 disp("Mach number M2=")
10 disp(M2)
11
12 p2=p1*(2*y*M1^2 - (y-1))/(y+1);
13 disp("p2=")
14 disp(p2)
15 disp("kN/m^2")
16
17 rho_2=rho_1*((y+1)*M1^2)/((y-1)*M1^2 + 2);
18 disp("density, rho_2 =")
19 disp(rho_2)
20 disp("kg/m^3")
21
22 T1=p1*10^3/rho_1/R;
23 disp("T1=")
24 disp(T1)
25 disp("K")
26
27 T2=T1*((y-1)*M1^2 + 2)*(2*y*M1^2 - (y-1))/((y+1)^2*
     M1^2);
28 disp("T2=")
29 disp(T2)
30 disp("K")
```

```
31
32  C1=sqrt(y*R*T1);
33  V1=M1*C1;
34  disp("V1=")
35  disp(V1)
36  disp("m/s")
37
38  C2=sqrt(y*R*T2);
39  V2=M2*C2;
40  disp("V2 =")
41  disp(V2)
42  disp("m/s")
```

Scilab code Exa 16.19 19

```
1  clc
2  M1=1.5;
3  p1=170;  //kN/m^2
4  T1=296;  //K
5  y=1.4;
6
7  disp("(i) Pressure, temperature and Mach number
       downstream of the shock")
8
9  p2=p1*(2*y*M1^2 - (y-1))/(y+1);
10 disp("p2=")
11 disp(p2)
12 disp("kN/m^2")
13
14 T2=T1*((y-1)*M1^2 + 2)*(2*y*M1^2 - (y-1))/(y+1)^2/M1
       ^2;
15 disp("T2=")
16 disp(T2)
17 disp("K")
18
```

```
19  M2=sqrt(((y-1)*M1^2 + 2)/(2*y*M1^2 - (y-1)));
20  disp("M2=")
21  disp(M2)
22
23  strength=p2/p1 - 1;
24  disp("Strength of stock =")
25  disp(strength)
```