

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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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_H20=1000; //kg/m^3
24 h3=1.35; //m
25 P3=rho_H20*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_H20=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_H20=h_H20/13.6; //mm of Hg
8 Pabs=rho*g*(P_Hg+P_atm-P_H20)/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

```
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

```
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 energy")
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

```

```

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

```
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
```

```

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

```

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; //m^3
4 Q=-45; //kJ
5 p1=(5/V1+1.5)*10^5; //N/m^2
6 p2=(5/V2+1.5)*10^5; //N/m^2
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; //m^3
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_1=105; //kJ
6  W_lm=0;
7  Q_lm=90;

```

```

8  U_m=U_1+90;
9  dU_mn=Qp-W;
10 U_n=U_m+dU_mn;
11 dQ=Qv+Qp;
12 dW=dQ;
13 W_n1=dW-W;
14 disp("W_n1(in kJ)=")
15 disp(W_n1)
16 disp("U_1 in kJ =")
17 disp(U_1)
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")
```

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 crosssectional 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 pipe 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=")

```

```

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

```

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

```
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 )
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

```

```

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

```

```
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
      continuously")
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

```

```

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("(ii)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
```

```

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(T3)];
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("(ii) 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

```
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 ( s 3 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_reservoir
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

```
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

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

```

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("Minimumm 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

```

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

```

1  clc
2  T1=293; //K
3  T2=353; //K
4  Tf=1773; //K
5  T0=288; //K
6  c_p1=6.3; //kJ/kg K
7
8  dAE=c_p1*(T2-T1) - T0*c_p1*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("(iii) The irreversibility")
32
33 I=T0*m*(cv*log(T2/T1)+R*log(V2/V1));
34
35 disp("Irreversibility =")
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 decrease in availability ")
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("(ii) The maximum work")
19 Wmax=dA; //change in availability
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("(ii)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/m^2
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("(ii)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(" Available energy =")
29 disp(AE)
30 disp(" kJ")
31
32 UAE=KE-AE;
33 disp(" Unavailable energy =")
34 disp(UAE)
35 disp(" kJ")
36
37 w2=sqrt(AE*10^3*2/I);
38 N2=w2*60/2/%pi;
39 disp(" Final rpm of the flywheel =")
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) Reversible work and actual work ")
14 A1=cp*(T1-T0)-T0*(cp*log(T1/T0)-R*log(p1/p0))+C1
    ^2/2/10^3; //Availability at the inlet
15 A2=cp*(T2-T0)-T0*(cp*log(T2/T0)-R*log(p2/p0))+C2
    ^2/2/10^3; //Availability at the exit

```

```

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) Irreversibility and effectiveness =")
28
29 I=W_rev-W_act;
30 disp(" Irreversibility =")
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-1.4cv=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; //Nm^4/(kg-mol)^2
3 b=0.0314; //m^3/kg-mol
4 R0=8314; //Nm/kg-mol K
5 v1=0.2*32; //m^3/kg-mol
6 v2=0.08*32; //m^3/kg-mol
7 T=333; //K
8 disp("(i) Work done during the process")
9 W=integrate('R0*T/(v-b) - a/v^2', '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/m^2")

```

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 =
10  0
11 // d^2 p_cp/dv_cp=2*R0*T_cp/(v_cp-b)^3 - 6*a/v_cp^4
12 = 0
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

```
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;

```

```

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=")

```



```

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
```

```

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

```

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
```

```

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

```
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_02=21.07; //kJ/mole K
4  Cv_C0=20.86; //kJ/mole K
5
6  p_02=8*10^5; //Pa
7  p_C0=1*10^5; //Pa
8
9  V_02=1.8; //m^3
10 V_C0=3.6; //m^3
11
12 T_02=323; //K
13 T_C0=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_01A=n_O2*R0*log(V/V_O2); //isothermal process
47 dS_02A=n_O2*Cv_O2*log(T_O2/T); //constant volume
      process
48
49 dS_012=dS_01A - dS_02A; // 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_012 + 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("(ii) 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("(ii) Final pressure")
59
60 p=m*R*T/V/10^5;
61 disp("p=")

```

```
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=")

```



```

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")
```

```

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_C02=0.85; //kJ/kg K
3  cp_N2=1.04; //kJ/kg K
4  m_C02=4; //kg
5  T1_C02=313; //K
6  m_N2=8; //kg
7  T1_N2=433; //K
8  p2=0.7; //bar
9  p1_C02=1.4; //bar
10 p1_N2=1;
11 R=8.314;
12 M_C02=44;
13 M_N2=28;
14 R_C02=R/M_C02;
15 R_N2=R/M_N2;
16
17 disp("(i) Final temperature , T2")
18 T2=(m_C02*cp_C02*T1_C02 + m_N2*cp_N2*T1_N2)/(m_C02*
    cp_C02 + m_N2*cp_N2);
19 disp("T2=")
20 disp(T2)
21 disp("K")
22
23
24 disp("(ii) Change in entropy")
25 n_C02=0.0909;
26 n_N2=0.2857;
27 n=n_C02 + n_N2;
28
29 x_C02=n_C02/n;
30 x_N2=n_N2/n;
31
32 p2_C02=x_C02*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("(ii) 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("(iii) 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 0.004 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 steam
      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

```
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 vapour 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

```
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

```
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; //m3/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("(ii) WBT of heated air =")
13 WBT=16.1; //0C
14 disp(WBT)
15 disp(" C ")
16
17 disp("(iii) 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")

```

```

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;

```

```
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

```

```

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;
```

```

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=z4/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 C0=0.313; //kg
28 C02=2.662; //kg
29 N2=9.24; //kg
30 S02=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;

```

```

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 leakage =")
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_02=3*32/46*100/23; //For complete combustion of 1
    kg of C2H6O, oxygen required
4
5  ratio=w_02;
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

```
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 C02=m_CO2/m_total*100;
15 H20=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(C02)
22 disp("%")
23
24 disp("H2O=")
25 disp(H20)
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("(ii) 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) N2 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)* N2
   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 C02=0.0734/n_wet*100;
33 disp(C02)
34 disp("%")
35
36 disp("H2O =")
37 H20=0.0200/n_wet*100;
38 disp(H20)
39 disp("%")
40
41 disp("SO2 =")
42 S02=0.0002/n_wet*100;
43 disp(S02)

```

```
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

```

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;

```



```

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 C02=2/nd*100;
49 disp(C02)
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

```

```

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 C02=0.55/n*100;
15 disp(C02)
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/Yy;
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  )
4  m=4*18;
5  h_fg=2443; //kJ/kg
6  LHVp=2044009; //kJ/kg
7  R0=8.3143; //kJ/kg K
8  T=298; //K
9
10 HHVp=LHVp+m*h_fg;
11 disp("HHVp =")
12 disp(HHVp)
13 disp("kJ/kg")
14
15 disp("(ii) Higher heating value at constant volume")
16 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) + 7.5O2(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) + 12.5O2(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_H20*u_fg;
11  disp(LHVv)
12  disp(" kJ/kg")
13
14  disp(" (ii) (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_H20/18/2);
19
20  // 1 kg fuel + 3.31 kg O2 = 3.23CO2 + 1.08H2O
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_H20*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

```

```

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

```



```

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)

```

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;
```

```

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

```
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;
```

```

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 =")

```

```
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

```

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_1=355.988; //kJ/kg
4 s_1=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_1-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_1-h_m)+(h1-h2); //total
40
41 n_overall=W_T/Q1; //WP 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)

```

```

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
    entering 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
```

```
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("Maximum 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

```
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 // $T2=\text{sqrt}(T1*T3)$ 
11
12 // Similarly  $T4=T3/[(T3/T1)^{(1/2/(y-1))}]^{(y-1)}$ 
13 // $T4=\text{sqrt}(T1*T3)$ 
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

```
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

```
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

```
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. Of 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')

```

```

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')

```

```

52
53 s=[12 12];
54 T=[fb(12) fc(12)];
55 plot(s,T,'-p')
56
57 s=[45 45];
58 T=[fb(45) fc(45)]
59 plot(s,T,'m')
60
61 s=10:1:27;
62 T=5*(s)^2;
63 plot(s,T,'g')
64
65 s=10:1:20;
66 T=7*s^2;
67 plot(s,T,'-r')
68
69 xtitle("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 //  $\eta = 1 - (\text{Heat rejected}) / (\text{Heat supplied}) = 1 - \text{constant} / Q_s$ 
74
75 // The cycle with greater heat addition will be more
    efficient.
76 // From the T-s diagram
77
78 //  $Q_s(\text{diesel}) = \text{Area under } 2b-3$ 
79 //  $Q_s(\text{dual}) = \text{Area under } 2a-3a-3$ 
80 //  $Q_s(\text{otto}) = \text{Area under } 2-3.$ 
81
82 //  $Q_s(\text{diesel}) > Q_s(\text{dual}) > Q_s(\text{otto})$ 
83
84 disp("Thus,    diesel    >    dual    >    otto    ")

```

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;
```

```

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 cpq=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/cpq;
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=cpq*(T8-T9a)*n_mech; //Net work output
32 T5=e*(T9a-T4a)+T4a;
33
34 Q=cpq*(T6-T5)+cpq*(T8-T7a); //Heat supplied
35 n_thermal=W/Q*100;
36 disp("n_thermal =")
37 disp(n_thermal)
38 disp("%")
39

```

```

40 disp(" (ii) 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 with 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("(ii) 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("(ii) 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;

```

```

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 =")

```



```
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); //Theoretical 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_theoretical=(h2-h1)/(h3-h2);
16 COP_actual=0.62*COP_theoretical;
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

```

```

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

```

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 reducing 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")
```


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(" (iii) ")
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 required =")
128 disp(W)
129 disp("kW")

```

Scilab code Exa 14.17 17

```

1 clc
2 disp(" (ii) Mass of refrigerant circulated 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  cp12=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-cp12*(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_12; //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("Theoretical 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 solution will 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

```
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

```
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


```

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.m4/m2
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/m2")
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)*T5;
24 disp(E_lambda_b_max)
25 disp("W/m2 per metre length")
26
27
28 disp("(iv) Total emissive power =")
29 Eb=a*T4;
30 disp(Eb)
31 disp("W/m2")
32
33
34 disp("(v) Total emissive power =")
35 E=e*a*T4;
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  $\epsilon_1 = 0.42$ ")
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;
```

```

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

```

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)

```

22 `disp("%")`

Chapter 16

Compressible Flow

Scilab code Exa 16.1 1

```
1  clc
2  V1=300; //m/s
3  p1=78; //kN/m^2
4  T1=313; //K
5  p2=117; //kN/m^2
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; //J/kg 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/m3")`

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/m2
5  p=9.81; //kN/m2
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*M02))(y/(y-1));
15 disp(ps)
16 disp(" kN/m2")
17
18
19 disp(" Stagnation temperature =")
20 Ts=T0*(1+((y-1)/2*M02));
21 disp(Ts)
22 disp("K")
23
24
25 disp(" Stagnation density =")
26 rho_s=ps*103/R/Ts;
27 disp(rho_s)
28 disp(" kg/m3")
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/m^2
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/m^2
5 T1=293; //K
6 p2=1750*10^3; //N/m^2
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

```

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)
```
