

Scilab Textbook Companion for
Basic Engineering Thermodynamics
by R. Joel¹

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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 1

General Introduction

Scilab code Exa 1.1 Work done

```
1 clear ;
2 clc;
3 disp('Example 1.1 ');
4
5
6
7 // Given values
8 P = 700; //pressure ,[kN/m^2]
9 V1 = .28; //initial volume ,[m^3]
10 V2 = 1.68; //final volume ,[m^3]
11
12 //solution
13
14 W = P*(V2-V1); // // Formula for work done at
    constant pressure is , [kJ]
15 mprintf('\n The Work done is = %f MJ\n',W*10^-3);
16
17 //End
```

Scilab code Exa 1.2 Volume of the gas

```
1 clear;
2 clc;
3 disp('Example 1.2 ');
4
5
6
7 //Given values
8 P1 = 138; // initial pressure ,[kN/m^2]
9 V1 = .112; //initial volume ,[m^3]
10 P2 = 690; // final pressure ,[kN/m^2]
11 Gama=1.4; // heat capacity ratio
12
13 // solution
14
15 // since gas is following ,  $PV^{1.4}=\text{constant}$  ,hence
16
17 V2 =V1*(P1/P2)^(1/Gama); // final volume , [m^3]
18
19 mprintf('\n The new volume of the gas is = %f m^3\n'
20 ,V2)
21 //End
```

Scilab code Exa 1.3 Work done

```
1 clear;
2 clc;
3 disp('Example 1.3 ');
4
5
6
7 // Given values
8 P1 = 2070; // initial pressure , [kN/m^2]
```

```

 9 V1 = .014; // initial volume, [m^3]
10 P2 = 207; // final pressure, [kN/m^2]
11 n=1.35; // polytropic index
12
13 // solution
14
15 // since gas is following PV^n=constant
16 // hence
17
18 V2 = V1*(P1/P2)^(1/n); // final volume, [m^3]
19
20 // calculation of workdone
21
22 W=(P1*V1-P2*V2)/(1.35-1); // using work done
    formula for polytropic process, [kJ]
23
24 mprintf('\n The Work done by gas during expansion is
    = %f kJ\n',W);
25
26 //End

```

Scilab code Exa 1.4 Final Pressure and work done

```

1 clear;
2 clc;
3 disp('Example 1.4 ');
4
5
6
7 // Given values
8 P1 = 100; // initial pressure, [kN/m^2]
9 V1 = .056; // initial volume, [m^3]
10 V2 = .007; // final volume, [m^3]
11
12 // To know P2

```

```

13 // since process is hyperbolic so, PV=constant
14 // hence
15
16 P2 = P1*V1/V2; // final pressure, [kN/m^2]
17
18 mprintf('\n The final pressure is = %f kN/m^2\n',
        ,P2);
19
20 // calculation of workdone
21
22 W = P1*V1*log(V2/V1); // formula for work done in
        this process, [kJ]
23
24 mprintf('\n Work done on the gas is = %f kJ\n',W
        );
25
26 //End

```

Scilab code Exa 1.5 Heat transfer

```

1 clear;
2 clc;
3 disp('Example 1.5 ');
4
5
6
7 // Given values
8 m = 5; // mass, [kg]
9 t1 = 15; // initial temperature, [C]
10 t2 = 100; // final temperature, [C]
11 c = 450; // specific heat capacity, [J/kg K]
12
13 // solution
14
15 // using heat transfer equation,[1]

```

```

16 Q = m*c*(t2-t1); // [J]
17 mprintf('\n The heat required is = %f kJ\n',Q
    *10^-3);
18
19 //End

```

Scilab code Exa 1.6 Heat transfer

```

1 clear;
2 clc;
3 disp('Example 1.6 ');
4
5
6 // Given values
7 m_cop = 2; // mass of copper vessel , [kg]
8 m_wat = 6; // mass of water , [kg]
9 c_wat = 4.19; // specific heat capacity of water ,
    [kJ/kg K]
10
11 t1 = 20; // initial temperature , [C]
12 t2 = 90; // final temperature , [C]
13
14 // From the table of average specific heat
    capacities
15 c_cop = .390; // specific heat capacity of copper ,[
    kJ/kg k]
16
17 // solution
18 Q_cop = m_cop*c_cop*(t2-t1); // heat required by
    copper vessel , [kJ]
19
20 Q_wat = m_wat*c_wat*(t2-t1); // heat required by
    water , [kJ]
21
22 // since there is no heat loss ,so total heat

```



```

    transfer is sum of both
23 Q_total = Q_cop+Q_wat ; // [kJ]
24
25 mprintf(' \n Required heat transfer to accomplish
    the change = %f kJ\n',Q_total);
26
27 //End

```

Scilab code Exa 1.7 Temperature

```

1
2 clear;
3 clc;
4 disp('Example 1.7 ');
5
6
7 // Given values
8 m = 10; // mass of iron casting, [kg]
9 t1 = 200; // initial temperature, [C]
10 Q = -715.5; // [kJ], since heat is lost in this
    process
11
12 // From the table of average specific heat
    capacities
13 c = .50; // specific heat capacity of casting iron,
    [kJ/kg K]
14
15 // solution
16 // using heat equation
17 //  $Q = m*c*(t2-t1)$ 
18
19 t2 = t1+Q/(m*c); // [C]
20
21 mprintf(' \n The final temperature is t2 = %f C\n',
    t2);

```

```
22
23 // End
```

Scilab code Exa 1.8 Specific heat capacity

```
1 clear;
2 clc;
3 disp('Example 1.8');
4
5
6
7 // Given values
8 m = 4; // mass of the liquid, [kg]
9 t1 = 15; // initial temperature, [C]
10 t2 = 100; // final temperature, [C]
11 Q = 714; // [kJ],required heat to accomplish this
    change
12
13 // solution
14 // using heat equation
15 //  $Q=m*c*(t2-t1)$ 
16
17 // calculation of c
18  $c=Q/(m*(t2-t1));$  // heat capacity, [kJ/kg K]
19
20 mprintf('\n The specific heat capacity of the liquid
    is c = %f kJ/kg K\n',c);
21
22 //End
```

Scilab code Exa 1.9 Power output and energy rejected

```
1 clear;
```

```

2  clc;
3  disp('Example 1.9');
4
5
6  // Given values
7  m_dot = 20.4; // mass flowrate of petrol, [kg/h]
8  c = 43; // calorific value of petrol, [MJ/kg]
9  n = .2; // Thermal efficiency of engine
10
11 // solution
12 m_dot = 20.4/3600; // [kg/s]
13 c = 43*10^6; // [J/kg]
14
15 // power output
16 P_out = n*m_dot*c; // [W]
17
18 mprintf('\\n The power output of the engine is = %f
          kJ\\n',P_out*10^-3);
19
20 // power rejected
21
22 P_rej = m_dot*c*(1-n); // [W]
23 P_rej = P_rej*60*10^-6; // [MJ/min]
24
25 mprintf('\\n The energy rejected by the engine is =
          %f MJ/min \\n',P_rej);
26
27 //End

```

Scilab code Exa 1.10 Thermal efficiency

```

1  clear;
2  clc;
3  disp('Example 1.10');
4

```

```

5
6
7 // Given values
8 m_dot = 3.045; // use of coal, [tonne/h]
9 c = 28; // calorific value of the coal, [MJ/kg]
10 P_out = 4.1; // output of turbine, [MW]
11
12 // solution
13 m_dot = m_dot*10^3/3600; // [kg/s]
14
15 P_in = m_dot*c; // power input by coal, [MW]
16
17 n = P_out/P_in; // thermal efficiency formula
18
19 mprintf('\n Thermal efficiency of the plant is =
    %f \n',n);
20
21 //End

```

Scilab code Exa 1.11 Power output

```

1 clear;
2 clc;
3 disp('Example 1.11 ');
4
5
6 // Given values
7 v = 50; // speed, [km/h]
8 F = 900; // Resistance to the motion of a car
9
10 // solution
11 v = v*10^3/3600; // [m/s]
12 Power = F*v; // Power formula, [W]
13
14 mprintf('\n The power output of the engine is = %f

```

```
        kW\n',Power*10^-3);
15
16 // End
```

Scilab code Exa 1.12 Power output

```
1
2 clear;
3 clc;
4 disp('Example 1.12 ');
5
6
7
8 // Given values
9 V = 230; // volatage , [volts]
10 I = 60; // current , [amps]
11 n_gen = .95; // efficiency of generator
12 n_eng = .92; // efficiency of engine
13
14 // solution
15
16 P_gen = V*I; // Power delivered by generator , [W]
17 P_gen=P_gen*10^-3; // [kW]
18
19 P_in_eng=P_gen/n_gen;//Power input from engine ,[kW]
20
21 P_out_eng=P_in_eng/n_eng;//Power output from engine
    ,[kW]
22
23 mprintf('\n The power output from the engine is =
    %f kW\n',P_out_eng);
24
25 // End
```

Scilab code Exa 1.13 Current

```
1 clear;
2 clc;
3 disp('Example 1.13 ');
4
5
6
7 // Given values
8 V = 230; // Voltage, [volts]
9 W = 4; // Power of heater, [kW]
10
11 // solution
12
13 // using equation P=VI
14 I = W/V; // current, [K amps]
15 mprintf('\n The current taken by heater is = %f
16         amps \n', I*10^3);
17 // End
```

Scilab code Exa 1.14 Mass of coal burnt

```
1 clear;
2 clc;
3 disp('Example 1.14 ');
4
5
6
7 // Given values
8 P_out = 500; // output of power station, [MW]
9 c = 29.5; // calorific value of coal, [MJ/kg]
```

```
10 r=.28;
11
12 // solution
13
14 // since P represents only 28 percent of energy
    available from coal
15 P_coal = P_out/r; // [MW]
16
17 m_coal = P_coal/c; // Mass of coal used, [kg/s]
18 m_coal = m_coal*3600; // [kg/h]
19
20 //After one hour
21 m_coal = m_coal*1*10^-3; // [tonne]
22 mprintf('\n Mass of coal burnt by the power station
    in 1 hour is = %f tonne \n',m_coal);
23
24 // End
```

Chapter 2

Systems

Scilab code Exa 2.1 Change in total energy

```
1 clear;
2 clc;
3 disp('Example 2.1 ');
4
5
6
7 // Given values
8 Q = 2500; // Heat transferred into the system, [kJ]
9 W = 1400; // Work transferred from the system, [kJ
   ]
10
11 // solution
12
13 // since process carried out on a closed system, so
   using equation [4]
14 del_E = Q-W; // Change in total energy, [kJ]
15
16 mprintf('\n The Change in total energy is , del_E =
   %f kJ\n',del_E);
17
18 if(del_E>0)
```



```

19     disp('Since del_E is positive , so there is an
        increase in total energy')
20 else
21     disp('Since del_E is negative , so there is an
        decrease in total energy')
22 end
23
24 // There is mistake in the book's results unit
25
26 // End

```

Scilab code Exa 2.2 Heat transferred

```

1 clear;
2 clc;
3 disp('Example 2.2');
4
5
6 // Given values
7 del_E = 3500; // Increase in total energy of the
    system, [kJ]
8 W = -4200; // Work transfer into the system, [kJ]
9
10 // solution
11 // since process carried out on a closed system, so
    using equation [3]
12 Q = del_E+W; // [kJ]
13
14 mprintf('\n The Heat transfer is , Q = %f kJ \n',Q);
15
16 if(Q>0)
17     disp('Since Q>0, so heat is transferred into
        the system')
18 else
19     disp('Since Q<0, so heat is transferred from

```

```
        the system ')
20 end
21
22 // End
```

Scilab code Exa 2.3 Work done

```
1 clear;
2 clc;
3 disp('Example 2.3 ');
4
5
6
7 // Given values
8 Q = -150; // Heat transferred out of the system, [kJ
           /kg]
9 del_u = -400; // Internal energy decreased ,[kJ/kg]
10
11 // solution
12 // using equation [3], the non flow energy equation
13 //  $Q = \Delta u + W$ 
14 W = Q - del_u; // [kJ/kg]
15 mprintf('\n The Work done is , W = %f kJ/kg \n', W);
16
17 if(W > 0)
18     disp('Since  $W > 0$ , so Work done by the engine
           per kilogram of working substance')
19 else
20     disp('Since  $W < 0$ , so Work done on the engine per
           kilogram of working substance')
21 end
22
23 // End
```

Scilab code Exa 2.4 Power of the system

```
1 clear;
2 clc;
3 disp('Example 2.4');
4
5
6
7 // Given values
8 m_dot = 4; // fluid flow rate, [kg/s]
9 Q = -40; // Heat loss to the surrounding, [kJ/kg]
10
11 // At inlet
12 P1 = 600; // pressure, [kN/m^2]
13 C1 = 220; // velocity, [m/s]
14 u1 = 2200; // internal energy, [kJ/kg]
15 v1 = .42; // specific volume, [m^3/kg]
16
17 // At outlet
18 P2 = 150; // pressure, [kN/m^2]
19 C2 = 145; // velocity, [m/s]
20 u2 = 1650; // internal energy, [kJ/kg]
21 v2 = 1.5; // specific volume, [m^3/kg]
22
23 // solution
24 // for steady flow energy equation for the open
    system is given by
25 //  $u_1 + P_1 v_1 + \frac{C_1^2}{2} + Q = u_2 + P_2 v_2 + \frac{C_2^2}{2} + W$ 
26 // hence
27
28 W = (u1-u2)+(P1*v1-P2*v2)+(C1^2/2-C2^2/2)*10^-3+Q;
    // [kJ/kg]
29
30 mprintf('\n workdone is , W = %f kJ/kg ',W);
```

```

31
32 if(W>0)
33     disp('Since W>0, so Power is output from
           the system')
34 else
35     disp('Since <0, so Power is input to the
           system')
36 end
37
38 // Hence
39
40 P_out = W*m_dot; // power out put from the system, [
           kW]
41 mprintf('\\n The power output from the system is =
           %f kW \\n',P_out);
42
43 // End

```

Scilab code Exa 2.5 Temperature rise

```

1 clear;
2 clc;
3 disp('Example 2.5');
4
5
6
7 // Given values
8 del_P = 154.45; // pressure difference across the
           die, [MN/m^2]
9 rho = 11360; // Density of the lead, [kg/m^3]
10 c = 130; // specific heat capacity of the lead, [J/
           kg*K]
11
12 // solution
13 // since there is no cooling and no external work

```

```

    is done, so energy balane becomes
14 // P1*V1+U1=P2*V2+U2 ,so
15 // del_U=U2-U1=P1*V1-P2*V2
16
17 // also, for temperature rise, del_U=m*c*t, where,
    m is mass; c is specific heat capacity; and t is
    temperature rise
18
19 // Also given that lead is incompressible, so V1=V2
    =V and assuming one m^3 of lead
20
21 // using above equations
22 t = del_P/(rho*c)*10^6 ;// temperature rise [C]
23
24 mprintf('\n The temperature rise of the lead is =
    %f C\n',t);
25
26 // End

```

Scilab code Exa 2.6 Area velocity and power

```

1 clear;
2 clc;
3 disp('Example 2.6 ');
4
5
6 // Given values
7 m_dot = 4.5; // mass flow rate of air, [kg/s]
8 Q = -40; // Heat transfer loss, [kJ/kg]
9 del_h = -200; // specific enthalpy reduce, [kJ/kg]
10
11 C1 = 90; // inlet velocity, [m/s]
12 v1 = .85; // inlet specific volume, [m^3/kg]
13
14 v2 = 1.45; // exit specific volume, [m^3/kg]

```

```

15 A2 = .038; // exit area of turbine , [m^2]
16
17 // solution
18
19 // part (a)
20 // At inlet , by equation [4] , m_dot=A1*C1/v1
21 A1 = m_dot*v1/C1;//inlet area , [m^2]
22 mprintf('\n (a) The inlet area is , A1 = %f m^2 \n'
    ,A1);
23
24 // part (b),
25 // At outlet , since mass flow rate is same, so
    m_dot=A2*C2/v2, hence
26 C2 = m_dot*v2/A2; // Exit velocity ,[m/s]
27 mprintf('\n (b) The exit velocity is , C2 = %f m/s
    \n',C2);
28
29 // part (c)
30 // using steady flow equation ,  $h_1 + \frac{C_1^2}{2} + Q = h_2 + \frac{C_2^2}{2} + W$ 
31 W = -del_h+(C1^2/2-C2^2/2)*10^-3+Q; // [kJ/kg]
32
33 // Hence power developed is
34 P = W*m_dot;// [kW]
35 mprintf('\n (c) The power developed by the turbine
    system is = %f kW \n',P);
36
37 // End

```

Chapter 4

Steam and two phase systems

Scilab code Exa 4.1 specific enthalpies

```
1 clear;
2 clc;
3 disp('Example 4.1 ');
4
5 // aim : To determine
6 // the enthalpy
7
8 // Given values
9 P = .50; // Pressure , [MN/m^2]
10
11 // solution
12
13 // From steam tables , at given pressure
14 hf = 640.1; // specific liquid enthalpy ,[kJ/kg]
15 hfg = 2107.4; // specific enthalpy of evaporation ,[
    kJ/kg]
16 hg = 2747.5; // specific enthalpy of dry saturated
    steam ,[kJ/kg]
17 tf = 151.8; // saturation temperature ,[C]
18
19 mprintf('\n The specific liquid enthalpy is = %f
```

```

    kJ/kg \n',hfg);
20 mprintf(' \n The specific enthalpy of evaporation is
    = %f kJ/kg \n',hfg);
21 mprintf(' \n The specific enthalpy of dry saturated
    steam is = %f kJ/kg \n',hg);
22
23 // End

```

Scilab code Exa 4.2 Saturation temperature and specific enthalpies

```

1 clear;
2 clc;
3 disp('Example 4.2 ');
4
5 // aim : To determine
6 // saturation temperature and enthalpy
7
8 // Given values
9 P = 2.04; // pressure , [MN/m^2]
10
11 // solution
12 // since in the steam table values of enthalpy and
    saturation temperature at 2 and 2.1 MN/m^2 are
    given , so for knowing required values at given
    pressure ,there is need to do interpolation
13
14 // calculation of saturation temperature
15 // from steam table
16 Table_P_tf = [[2.1,2.0];[214.9,212.4]]; // P in [MN
    /m^2] and tf in [C]
17 // using interpolation
18 tf = interp1n(Table_P_tf,2.04); // saturation
    temperature at given condition
19 mprintf(' \n The Saturation temperature is = %f C \
    n',tf);

```



```

20
21 // calculation of specific liquid enthalpy
22 // from steam table
23 Table_P_hf = [[2.1,2.0];[920.0,908.6]]; // P in [MN/
    m^2] and hf in [kJ/kg]
24 // using interpolation
25 hf = interpln(Table_P_hf,2.04); // enthalpy at
    given condition , [kJ/kg]
26 mprintf(' \n The Specific liquid enthalpy is = %f
    kJ/kg \n',hf);
27
28 // calculation of specific enthalpy of evaporation
29 // from steam table
30 Table_P_hfg = [[2.1,2.0];[1878.2,1888.6]]; // P in [
    MN/m^2] and hfg in [kJ/kg]
31 // using interpolation
32 hfg = interpln(Table_P_hfg,2.04); // enthalpy at
    given condition , [kJ/kg]
33 mprintf(' \n The Specific enthalpy of evaporation is
    = %f kJ/kg \n',hfg);
34
35 // calculation of specific enthalpy of dry
    saturated steam
36 // from steam table
37 Table_P_hg = [[2.1,2.0];[2798.2,2797.2]]; //P in [MN/
    m^2] and hg in [kJ/kg]
38 // using interpolation
39 hg = interpln(Table_P_hg,2.04); // enthalpy at
    given condition , [kJ/kg]
40 mprintf(' \n The Specific enthalpy of dry saturated
    steam is = %f kJ/kg \n',hg);
41
42 // End

```

Scilab code Exa 4.3 specific enthalpy

```

1  clear;
2  clc;
3  disp('Example 4.3 ');
4
5  //  aim : To determine
6  //  the specific enthalpy
7
8  //  given values
9  P = 2; //  pressure ,[MN/m^2]
10 t = 250; //  Temperature, [C]
11 cp = 2.0934; //  average value of specific heat
    capacity, [kJ/kg K]
12
13 //  solution
14
15 //  looking up steam table it shows that at given
    pressure saturation temperature is 212.4 C,so
16 tf = 212.4; //  [C]
17 //  hence ,
18 Degree_of_superheat = t-tf;//  [C]
19 //  from table at given temperature 250 C
20 h = 2902; //  specific enthalpy of steam at 250 C ,[
    kJ/kg]
21 mprintf('\nThe specific enthalpy of steam at 2 MN/m
    ^2 with temperature 250 C is = %f kJ/kg \n',h)
    ;
22
23 //  Also from steam table enthalpy at saturation
    temperature is
24 hf = 2797.2 ;//  [kJ/kg]
25 //  so enthalpy at given temperature is
26 h = hf+cp*(t-tf);//  [kJ/kg]
27
28 mprintf('\n The specific enthalpy at given T and P
    by alternative path is = %f kJ/kg \n',h);
29
30 //  End

```

Scilab code Exa 4.4 specific enthalpy

```
1 clear;
2 clc;
3 disp('Example 4.4 ');
4
5 // aim : To determine
6 // the specific enthalpy of steam
7
8 // Given values
9 P = 2.5; // pressure , [MN/m^2]
10 t = 320; // temperature , [C]
11
12 // solution
13 // from steam table at given condition the
    saturation temperature of steam is 223.9 C,
    therefore steam is superheated
14 tf = 223.9; // [C]
15
16 // first let's calculate estimated enthalpy
17 // again from steam table
18
19 hg = 2800.9; // enthalpy at saturation temp, [kJ/kg]
20 cp = 2.0934; // specific heat capacity of steam, [kJ/
    kg K]
21
22 // so enthalpy at given condition is
23 h = hg+cp*(t-tf); // [kJ/kg]
24 mprintf('\n The estimated specific enthalpy is =
    %f kJ/kg \n',h);
25
26 // calculation of accurate specific enthalpy
27 // we need double interpolation for this
28
```

```

29 // first interpolation w.r.t. to temperature
30 // At 2 MN/m^2
31 Table_t_h = [[325,300];[3083,3025]]; // where, t in [
    C] and h in [kJ/kg]
32 h1 = interpln(Table_t_h,320); // [kJ/kg]
33
34 // at 4 MN/m^2
35 Table_t_h = [[325,300];[3031,2962]]; // t in [C]
    and h in [kJ/kg]
36 h2 = interpln(Table_t_h,320); // [kJ/kg]
37
38 // now interpolation w.r.t. pressure
39 Table_P_h = [[4,2];[h2,h1]]; // where P in NM/m^2
    and h1,h2 in kJ/kg
40 h = interpln(Table_P_h,2.5); // [kJ/kg]
41 mprintf('\n The accurate specific enthalpy of steam
    at pressure of 2.5 MN/m^2 and with a temperature
    320 C is = %f kJ/kg \n',h);
42
43 // End

```

Scilab code Exa 4.5 specific enthalpy

```

1 clear;
2 clc;
3 disp('Example 4.5 ');
4
5 // aim : To determine
6 // the specific enthalpy
7
8 // Given values
9 P = 70; // pressure, [kn/m^2]
10 x = .85; // Dryness fraction
11
12 // solution

```

```

13
14 // from steam table , at given pressure
15 hf = 376.8; // [kJ/kg]
16 hfg = 2283.3; // [kJ/kg]
17
18 // now using equation [2]
19 h = hf+x*hfg; // specific enthalpy of wet steam,[kJ/
    kg]
20
21 mprintf('\n The specific enthalpy of wet steam is =
    %f kJ/kg \n',h);
22
23 // There is minor variation in the book's answer
24
25 // End

```

Scilab code Exa 4.8 specific volume

```

1 clear;
2 clc;
3 disp('Example 4.8 ');
4
5 // aim : To determine
6 // the specific volume of wet steam
7
8 // Given values
9 P = 1.25; // pressure , [MN/m^2]
10 x = .9; // dry fraction
11
12 // solution
13 // from steam table at given pressure
14 vg = .1569; // [m^3/kg]
15 // hence
16 v = x*vg; // [m^3/kg]
17

```

```

18 mprintf('\\nThe specific volume of wet steam is =
    %f m^3/kg \\n',v);
19
20 // End

```

Scilab code Exa 4.9 specific volume

```

1 clear;
2 clc;
3 disp('Example 4.9 ');
4
5 // aim : To determine
6 // the specific volume
7
8 // Given values
9 t = 325; // temperature , [C]
10 P = 2; // pressure , [MN/m^2]
11
12 // solution
13 // from steam table at given t and P
14 vf = .1321; // [m^3/kg]
15 tf = 212.4; // saturation temperature , [C]
16
17 mprintf('\\n The specific volume of steam at pressure
    of 2 MN/m^2 and with temperature 325 C is = %f
    m^3/kg \\n',vf);
18 doh= t-tf; // degree of superheat , [C]
19 mprintf('\\n The degree of superheat is = %f C\\n',
    doh);
20
21 // End

```

Scilab code Exa 4.10 mass of steam and water

```

1 clear;
2 clc;
3 disp('Example .10 ');
4
5 // aim : To determine
6 // (a) the mass of steam entering the heater
7 // (b) the mass of water entering the heater
8
9 // Given values
10 x = .95; // Dryness fraction
11 P = .7; // pressure ,[MN/m^2]
12 d = 25; // internal diameter of heater ,[mm]
13 C = 12; // steam velocity in the pipe ,[m/s]
14
15 // solution
16 // from steam table at .7 MN/m^2 pressure
17 hf = 697.1; // [kJ/kg]
18 hfg = 2064.9; // [kJ/kg]
19 hg = 2762.0; // [kJ/kg]
20 vg = .273; // [m^3/kg]
21
22 // (a)
23 v = x*vg; // [m^3/kg]
24 ms_dot = %pi*(d*10^-3)^2*C*3600/(4*v); // mass of
    steam entering , [kg/h]
25 fprintf('\n (a) The mass of steam entering the
    heater is = %f kg/h \n',ms_dot);
26
27 // (b)
28 h = hf+x*hfg; // specific enthalpy of steam entering
    heater ,[kJ/kg]
29 // again from steam tables
30 hf1 = 376.8; // [kJ/kg] at 90 C
31 hf2 = 79.8; // [kJ/kg] at 19 C
32
33 // using energy balance ,mw_dot*(hf1-hf2)=ms_dot*(h-
    hf1)
34 mw_dot = ms_dot*(h-hf1)/(hf1-hf2); // mass of water

```

```

    entering to heater ,[kg/h]
35
36 mprintf(' \n (b) The mass of water entering the
    heater is = %f kg/h \n',mw_dot);
37
38 // End

```

Scilab code Exa 4.11 change of internal energy

```

1 clear;
2 clc;
3 disp('Example 4.11 ');
4
5 // aim: To determine
6 // the change of internal energy
7
8 // Given values
9 m = 1.5; // mass of steam ,[kg]
10 P1 = 1; // initial pressure , [MN/m^2]
11 t = 225; // temperature , [C]
12 P2 = .28; // final pressure , [MN/m^2]
13 x = .9; // dryness fraction of steam at P2
14
15 // solution
16
17 // from steam table at P1
18 h1 = 2886; // [kJ/kg]
19 v1 = .2198; // [m^3/kg]
20 // hence
21 u1 = h1 - P1*v1*10^3; // internal energy [kJ/kg]
22
23 // at P2
24 hf2 = 551.4; // [kJ/kg]
25 hfg2 = 2170.1; // [kJ/kg]
26 vg2 = .646; // [m^3/kg]

```



```

27 // so
28 h2 = hf2+x*hfg2;// [kJ/kg]
29 v2 = x*vg2;// [m^3/kg]
30
31 // now
32 u2 = h2-P2*v2*10^3;// [kJ/kg]
33
34 // hence change in specific internal energy is
35 del_u = u2-u1;// [kJ/kg]
36
37 del_u = m*del_u;// [kJ];
38 mprintf('\n The change in internal energy is = %f
          kJ \n',del_u);
39
40 // End

```

Scilab code Exa 4.12 dryness fraction

```

1 clear;
2 clc;
3 disp('Example 4.12 ');
4
5 // aim : To determine
6 // the dryness fraction of steam after throttling
7
8 // given values
9 P1 = 1.4;// pressure before throttling, [MN/m^2]
10 x1 = .7;// dryness fraction before throttling
11 P2 = .11;// pressure after throttling, [MN/m^2]
12
13 // solution
14 // from steam table
15 hf1 = 830.1;// [kJ/kg]
16 hfg1 = 1957.7;// [kJ/kg]
17 h1 = hf1 + x1*hfg1; // [kJ/kg]

```

```

18
19 hf2 = 428.8; // [kJ/kg]
20 hfg2 = 2250.8; // [kJ/kg]
21
22 // now for throttling ,
23 // hf1+x1*hfg1=hf2+x2*hfg2; where x2 is dryness
    fraction after throttling
24
25 x2=(h1-hf2)/hfg2; // final dryness fraction
26
27 mprintf('\n Dryness fraction of steam after
    throttling is = %f \n',x2);
28
29 // End

```

Scilab code Exa 4.13 condition of steam and internal diameter

```

1 clear;
2 clc;
3 disp('Example 4.13 ');
4
5 // aim : To determine
6 // the dryness fraction of steam
7 // and the internal diameter of the pipe
8
9 // Given values
10
11 // steam1
12 P1 = 2; // pressure before throttling , [MN/m^2]
13 t = 300; // temperature ,[C]
14 ms1_dot = 2; // steam flow rate , [kg/s]
15 P2 = 800; // pressure after throttling , [kN/m^2]
16
17 // steam2
18 P = 800; // pressure , [N/m^2]

```

```

19 x2 = .9; // dryness fraction
20 ms2_dot = 5; // [kg/s]
21
22 // solution
23 // (a)
24 // from steam table specific enthalpy of steam1
    before throttling is
25 hf1 = 3025; // [kJ/kg]
26 // for throttling process specific enthalpy will
    same so final specific enthalpy of steam1 is
27 hf2 = hf1;
28 // hence
29 h1 = ms1_dot*hf2; // [kJ/s]
30
31 // calculation of specific enthalpy of steam2
32 hf2 = 720.9; // [kJ/kg]
33 hfg2 = 2046.5; // [kJ/kg]
34 // hence
35 h2 = hf2+x2*hfg2; // specific enthalpy, [kJ/kg]
36 h2 = ms2_dot*h2; // total enthalpy, [kJ/s]
37
38 // after mixing
39 m_dot = ms1_dot+ms2_dot; // total mass of mixture, [
    kg/s]
40 h = h1+h2; // Total enthalpy of the mixture, [kJ/s]
41 h = h/7; // [kJ/kg]
42
43 // At pressure 800 N/m^2
44 hf = 720.9; // [kJ/kg]
45 hfg = 2046.5; // [kJ/kg]
46 // so total enthalpy is, hf+x*hfg, where x is
    dryness fraction of mixture and which is equal to
    h
47 // hence
48 x = (h-hf)/hfg; // dryness fraction after mixing
49 fprintf('\n (a) The condition of the resulting
    mixture is dry with dryness fraction = %f \n', x
    );

```

```

50
51 // (b)
52 // Given
53 C = 15; // velocity , [m/s]
54 // from steam table
55 v = .1255; // [m^3/kg]
56 A = ms1_dot*v/C; // area , [m^2]
57 // using ms1_dot = A*C/v, where A is cross section
    area in m^2 and
58 // A = %pi*d^2/4, where d is diameter of the pipe
59
60 // calculation of d
61 d = sqrt(4*A/%pi); // diameter , [m]
62
63 mprintf('\n (b) The internal diameter of the pipe is
    = %f mm \n',d*1000);
64
65 // End

```

Scilab code Exa 4.14 dryness fraction

```

1 clear;
2 clc;
3 disp('Example 4.14 ');
4
5 // aim : To estimate
6 // the dryness fraction
7
8 // Given values
9 M = 1.8; // mass of condensate , [kg]
10 m = .2; // water collected , [kg]
11
12 // solution
13 x = M/(M+m); // formula for calculation of dryness
    fraction using separating calorimeter

```

```

14
15 mprintf(' \n The dryness fraction of the steam
    entering seprating calorimeter is = %f \n',x);
16
17 // End

```

Scilab code Exa 4.15 dryness fraction

```

1 clear;
2 clc;
3 disp('Example 4.15 ');
4
5 // aim : To determine
6 // the dryness fraction of the steam at 2.2 MN/m^2
7
8 // Given values
9 P1 = 2.2; // [MN/m^2]
10 P2 = .13; // [MN/m^2]
11 t2 = 112; // [C]
12 tf2 = 150; // temperature, [C]
13
14 // solution
15 // from steam table, at 2.2 MN/m^2
16 // saturated steam at 2 MN/m^2 Pressure
17 hf1 = 931; // [kJ/kg]
18 hfg1 = 1870; // [kJ/kg]
19 hg1 = 2801; // [kJ/kg]
20
21 // for superheated steam
22 // at .1 MN/m^2
23 hg2 = 2675; // [kJ/kg]
24 hg2_150 = 2777; // specific enthalpy at 150 C, [kJ/kg]
25 ]
26 tf2 = 99.6; // saturation temperature, [C]

```

```

27 // at .5 MN/m^2
28 hg3 = 2693; // [kJ/kg]
29 hg3_150 = 2773; // specific enthalpy at 150 C, [kJ/kg
   ]
30 tf3 = 111.4; // saturation temperature, [C]
31
32 Table_P_h1 = [[.1,.5];[hg2,hg3]]; // where, P in MN/m
   ^2 and h in [kJ/kg]
33 hg = interp1n(Table_P_h1,.13); // specific entahlpy
   at .13 MN/m^2, [kJ/kg]
34
35 Table_P_h2 = [[.1,.5];[hg2_150,hg3_150]]; // where,
   P in MN/m^2 and h in [kJ/kg]
36 hg_150 = interp1n(Table_P_h2,.13); // specific
   entahlpy at .13 MN/m^2 and 150 C, [kJ/kg]
37
38 Table_P_tf = [[.1,.5];[tf2,tf3]]; // where, P in MN/m
   ^2 and h in [kJ/kg]
39 tf = interp1n(Table_P_tf,.13); // saturation
   temperature, [C]
40
41 // hence
42 h2 = hg+(hg_150-hg)/(t2-tf)/(tf2-tf); // specific
   enthalpy at .13 MN/m^2 and 112 C, [kJ/kg]
43
44 // now since process is throttling so h2=h1
45 // and h1 = hf1+x1*hfg1, so
46 x1 = (h2-hf1)/hfg1; // dryness fraction
47 mprintf(' \n The dryness fraction of steam is = %f
   \n',x1);
48
49 // There is a calculation mistake in book so answer
   is not matching
50
51 // End

```

Scilab code Exa 4.16 minimum dryness fraction

```
1 clear;
2 clc;
3 disp('Example 4.16');
4
5 // aim : To determine
6 // the minimum dryness fraction of steam
7
8 // Given values
9 P1 = 1.8; // testing pressure ,[MN/m^2]
10 P2 = .11; // pressure after throttling ,[MN/m^2]
11
12 // solution
13 // from steam table
14 // at .11 MN/m^2 steam is completely dry and
   specific enthalpy is
15 hg = 2680; // [kJ/kg]
16
17 // before throttling steam is wet, so specific
   enthalpy is=hf+x*hfg, where x is dryness fraction
18 // from steam table
19 hf = 885; // [kJ/kg]
20 hfg = 1912; // [kJ/kg]
21
22 // now for throttling process ,specific enthalpy
   will same before and after
23 // hence
24 x = (hg-hf)/hfg;
25 mprintf('\n The minimum dryness fraction of steam is
   x = %f \n',x);
26
27 // End
```

Scilab code Exa 4.17 mass dryness fraction and heat transfer

```
1 clear;
2 clc;
3 disp('Example 4.17');
4
5 // aim : To determine the
6 // (a) mass of steam in the vessel
7 // (b) final dryness of the steam
8 // (c) amount of heat transferred during the
   cooling process
9
10 // Given values
11 V1 = .8; // [m^3]
12 P1 = 360; // [kN/m^2]
13 P2 = 200; // [kN/m^2]
14
15 // solution
16
17 // (a)
18 // at 360 kN/m^2
19 vg1 = .510; // [m^3]
20 m = V1/vg1; // mass of steam, [kg]
21 mprintf('\n (a) The mass of steam in the vessel is =
   %f kg\n',m);
22
23 // (b)
24 // at 200 kN/m^2
25 vg2 = .885; // [m^3/kg]
26 // the volume remains constant so
27 x = vg1/vg2; // final dryness fraction
28 mprintf('\n (b) The final dryness fraction of the
   steam is = %f \n',x);
29
```



```

30 // (c)
31 // at 360 kN/m^2
32 h1 = 2732.9; // [kJ/kg]
33 // hence
34 u1 = h1-P1*vg1; // [kJ/kg]
35
36 // at 200 kN/m^2
37 hf = 504.7; // [kJ/kg]
38 hfg=2201.6; // [kJ/kg]
39 // hence
40 h2 = hf+x*hfg; // [kJ/kg]
41 // now
42 u2 = h2-P2*vg1; // [kJ/kg]
43 // so
44 del_u = u2-u1; // [kJ/kg]
45 // from the first law of thermodynamics del_U+W=Q,
46 W = 0; // because volume is constant
47 del_U = m*del_u; // [kJ]
48 // hence
49 Q = del_U; // [kJ]
50 mprintf('\n (c) The amount of heat transferred
    during cooling process is = %f kJ \n',Q);
51
52 // End

```

Scilab code Exa 4.18 specific heat

```

1 clear;
2 clc;
3 disp('Example 4.18');
4
5 // aim : To determine
6 // the heat received by the steam per kilogram
7
8 // Given values

```

```

 9 // initial
10 P1 = 4; // pressure , [MN/m^2]
11 x1 = .95; // dryness fraction
12
13 // final
14 t2 = 350; // temperature ,[C]
15
16 // solution
17
18 // from steam table , at 4 MN/m^2 and x1=.95
19 hf = 1087.4; // [kJ/kg]
20 hfg = 1712.9; // [kJ/kg]
21 // hence
22 h1 = hf+x1*hfg; // [kJ/kg]
23
24 // since pressure is kept constant ant temperature
    is raised so at this condition
25 h2 = 3095; // [kJ/kg]
26
27 // so by energy balance
28 Q = h2-h1; // Heat received ,[kJ/kg]
29 mprintf('\n The heat received by the steam is = %f
    kJ/kg \n',Q);
30
31 // End

```

Scilab code Exa 4.19 condition of steam

```

1 clear;
2 clc;
3 disp('Example 4.19 ');
4
5 // aim : To determine the condition of the steam
    after
6 // (a) isothermal compression to half its initial

```

```

    volume, heat rejected
7 // (b) hyperbolic compression to half its initial
    volume
8
9 // Given values
10 V1 = .3951; // initial volume, [m^3]
11 P1 = 1.5; // initial pressure, [MN/m^2]
12
13 // solution
14
15 // (a)
16 // from steam table, at 1.5 MN/m^2
17 hf1 = 844.7; // [kJ/kg]
18 hfg1 = 1945.2; // [kJ/kg]
19 hg1 = 2789.9; // [kJ/kg]
20 vg1 = .1317; // [m^3/kg]
21
22 // calculation
23 m = V1/vg1; // mass of steam, [kg]
24 vg2b = vg1/2; // given, [m^3/kg] (vg2b is actual
    specific volume before compression)
25 x1 = vg2b/vg1; // dryness fraction
26 h1 = m*(hf1+x1*hfg1); // [kJ]
27 Q = m*x1*hfg1; // heat loss, [kJ]
28 mprintf('\n (a) The Quantity of steam present is =
    %f kg \n', m);
29 mprintf('\n      Dryness fraction is = %f \n', x1);
30 mprintf('\n      The enthalpy is = %f kJ \n', h1);
31 mprintf('\n      The heat loss is = %f kJ \n', Q);
32
33 // (b)
34 V2 = V1/2;
35 // Given compression is according to the law PV=
    Constant, so
36 P2 = P1*V1/V2; // [MN/m^2]
37 // from steam table at P2
38 hf2 = 1008.4; // [kJ/kg]
39 hfg2 = 1793.9; // [kJ/kg]

```

```

40 hg2 = 2802.3; // [kJ/kg]
41 vg2 = .0666; // [m^3/kg]
42
43 // calculation
44 x2 = vg2b/vg2; // dryness fraction
45 h2 = m*(hf2+x2*hfg2); // [kJ]
46
47 mprintf('\n (b) The dryness fraction is = %f \n',
          x2);
48 mprintf('\n      The enthalpy is = %f kJ\n',h2);
49
50 // End

```

Scilab code Exa 4.20 mass work change in internal energy and heat transfer

```

1 clear;
2 clc;
3 disp('Example 4.20 ');
4
5 // aim : To determine the
6 // (a) mass of steam
7 // (b) work transfer
8 // (c) change of internal energy
9 // (d) heat exchange b/w the steam and surroundings
10
11 // Given values
12 P1 = 2.1; // initial pressure ,[MN/m^2]
13 x1 = .9; // dryness fraction
14 V1 = .427; // initial volume ,[m^3]
15 P2 = .7; // final pressure ,[MN/m^2]
16 // Given process is polytropic with
17 n = 1.25; // polytropic index
18
19 // solution

```

```

20 // from steam table
21
22 // at 2.1 MN/m^2
23 hf1 = 920.0; // [kJ/kg]
24 hfg1=1878.2; // [kJ/kg]
25 hg1=2798.2; // [kJ/kg]
26 vg1 = .0949; // [m^3/kg]
27
28 // and at .7 MN/m^2
29 hf2 = 697.1; // [kJ/kg]
30 hfg2 = 2064.9; // [kJ/kg]
31 hg2 = 2762.0; // [kJ/kg]
32 vg2 = .273; // [m^3/kg]
33
34 // (a)
35 v1 = x1*vg1; // [m^3/kg]
36 m = V1/v1; // [kg]
37 fprintf('\n (a) The mass of steam present is = %f
    kg\n',m);
38
39 // (b)
40 // for polytropic process
41 v2 = v1*(P1/P2)^(1/n); // [m^3/kg]
42
43 x2 = v2/vg2; // final dryness fraction
44 // work transfer
45 W = m*(P1*v1-P2*v2)*10^3/(n-1); // [kJ]
46 fprintf('\n (b) The work transfer is = %f kJ\n',W
    );
47
48 // (c)
49 // initial
50 h1 = hf1+x1*hfg1; // [kJ/kg]
51 u1 = h1-P1*v1*10^3; // [kJ/kg]
52
53 // final
54 h2 = hf2+x2*hfg2; // [kJ/kg]
55 u2 = h2-P2*v2*10^3; // [kJ/kg]

```

```

56
57 del_U = m*(u2-u1); // [kJ]
58 mprintf('\n (c) The change in internal energy is =
          %f kJ',del_U);
59 if(del_U<0)
60     disp('since del_U<0,so this is loss of internal
          energy ')
61 else
62     disp('since del_U>0,so this is gain in internal
          energy ')
63 end
64
65 // (d)
66 Q = del_U+W; // [kJ]
67 mprintf('\n (d) The heat exchange between the steam
          and surrounding is = %f kJ',Q);
68 if(Q<0)
69     disp('since Q<0,so this is loss of heat energy
          to surrounding ')
70 else
71     disp('since Q>0,so this is gain in heat energy
          to the steam ')
72 end
73
74 // there are minor vairations in the values reported
    in the book
75
76 // End

```

Scilab code Exa 4.21 volume dryness fraction and change of internal energy

```

1 clear;
2 clc;
3 disp('Example 4.21 ');

```

```

4
5 // aim : To determine the
6 // (a) volume occupied by steam
7 // (b)(1) final dryness fraction of steam
8 // (2) Change of internal energy during
    expansion
9
10 // (a)
11 // Given values
12 P1 = .85; // [mN/m^2]
13 x1 = .97;
14
15 // solution
16 // from steam table , at .85 MN/m^2,
17 vg1 = .2268; // [m^3/kg]
18 // hence
19 v1 = x1*vg1; // [m^3/kg]
20 mprintf('\n (a) The volume occupied by 1 kg of steam
    is = %f m^3/kg\n',v1);
21
22 // (b)(1)
23 P2 = .17; // [MN/m^2]
24 // since process is polytropic process with
25 n = 1.13; // polytropic index
26 // hence
27 v2 = v1*(P1/P2)^(1/n); // [m^3/kg]
28
29 // from steam table at .17 MN/m^2
30 vg2 = 1.031; // [m^3/kg]
31 // steam is wet so
32 x2 = v2/vg2; // final dryness fraction
33 mprintf('\n (b)(1) The final dryness fraction of the
    steam is = %f \n',x2);
34
35 // (2)
36 W = (P1*v1-P2*v2)*10^3/(n-1); // [kJ/kg]
37 // since process is adiabatic , so
38 del_u = -W; // [kJ/kg]

```

```
39 mprintf('\n      (2) The change in internal energy of
      the steam during expansion is = %f kJ/kg (
      This is a loss of internal energy)\n',del_u);
40 // There are minor variation in the answer
41
42 // End
```

Chapter 5

Gases and single phase systems

Scilab code Exa 5.1 pressure exerted and difference in two mercury column levels

```
1 clear;
2 clc;
3 disp('Example 5.1 ');
4
5 // aim : To determine
6 // new pressure exerted on the air and the
   difference in two mercury column level
7
8 // Given values
9 P1 = 765; // atmospheric pressure , [mmHg]
10 V1 = 20000; // [mm^3]
11 V2 = 17000; // [mm^3]
12
13 // solution
14
15 // using boyle 's law P*V=constant
16 // hence
17 P2 = P1*V1/V2; // [mmHg]
18 mprintf('\n The new pressure exerted on the air is
   = %f mmHg \n ',P2);
```

```

19
20 del_h = P2-P1; // difference in Height of mercury
    column level
21 mprintf('\n The difference in the two mercury column
    level is = %f mm\n',del_h);
22
23 // End

```

Scilab code Exa 5.2 volume

```

1 clear;
2 clc;
3 disp('Example 5.2 ');
4
5 // aim : To determine
6 // the new volume
7
8 // Given values
9 P1 = 300; // original pressure ,[kN/m^2]
10 V1 = .14; // original volume ,[m^3]
11
12 P2 = 60; // new pressure after expansion ,[kn/m^2]
13
14 // solution
15 // since temperature is constant so using boyle's
    law P*V=constant
16 V2 = V1*P1/P2; // [m^3]
17
18 mprintf('\n The new volume after expansion is = %f
    m^3\n',V2);
19
20 // End

```

Scilab code Exa 5.3 volume

```
1 clear;
2 clc;
3 disp('Example 5.3 ');
4
5 // aim : To determine
6 // the new volume of the gas
7
8 // Given values
9 V1 = 10000; // [mm^3]
10 T1 = 273+18; // [K]
11 T2 = 273+85; // [K]
12
13 // solution
14 // since pressure exerted on the apparatus is
15 // constant so using charle's law V/T=constant
16 // hence
17 V2 = V1*T2/T1; // [mm^3]
18 mprintf('\n The new volume of the gas trapped in the
19 // apparatus is = %f mm^3\n',V2);
20 // End
```

Scilab code Exa 5.4 temperature

```
1 clear;
2 clc;
3 disp('Example 5.4 ');
4
5 // aim : To determine
6 // the final temperature
7
8 // Given values
```

```

 9 V1 = .2; // original volume, [m^3]
10 T1 = 273+303; // original temperature, [K]
11 V2 = .1; // final volume, [m^3]
12
13 // solution
14 // since pressure is constant, so using charle's
    law V/T=constant
15 // hence
16 T2 = T1*V2/V1; // [K]
17 t2 = T2-273; // [C]
18 mprintf('\n The final temperature of the gas is =
    %f C\n', t2);
19
20 // End

```

Scilab code Exa 5.5 volume

```

1 clear;
2 clc;
3 disp('Example 5.5 ');
4
5 // aim : To determine
6 // the new volume of the gas
7
8 // Given values
9
10 // initial condition
11 P1 = 140; // [kN/m^2]
12 V1 = .1; // [m^3]
13 T1 = 273+25; // [K]
14
15 // final condition
16 P2 = 700; // [kN/m^2]
17 T2 = 273+60; // [K]
18

```

```

19 // by charasteristic equation ,  $P_1*V_1/T_1=P_2*V_2/T_2$ 
20
21  $V_2=P_1*V_1*T_2/(T_1*P_2)$ ; // final volume , [m^3]
22
23 mprintf(' \n The new volume of the gas is = %f m^3 \
      n ',V2);
24
25 // End

```

Scilab code Exa 5.6 mass and temperature

```

1 clear;
2 clc;
3 disp('Example 5.6 ');
4
5 // aim : To determine
6 // the mas of the gas and new temperature
7
8 // Given values
9  $P_1 = 350$ ; // [kN/m^2]
10  $V_1 = .03$ ; // [m^3]
11  $T_1 = 273+35$ ; // [K]
12  $R = .29$ ; // Gas constant , [kJ/kg K]
13
14 // solution
15 // using charasteristic equation ,  $P*V=m*R*T$ 
16  $m = P_1*V_1/(R*T_1)$ ; // [Kg]
17 mprintf(' \n The mass of the gas present is = %f kg
      \n ',m);
18
19 // Now the gas is compressed
20  $P_2 = 1050$ ; // [kN/m^2]
21  $V_2 = V_1$ ;
22 // since mass of the gas is constant so using ,  $P*V/T$ 
      =constant

```

```

23 // hence
24 T2 = T1*P2/P1// [K]
25 t2 = T2-273;// [C]
26
27 mprintf('\n The new temperature of the gas is = %f
          C\n',t2);
28
29 // End

```

Scilab code Exa 5.7 heat transfer and pressure

```

1 clear;
2 clc;
3 disp('Example 5.7 ');
4
5 // aim : To determine
6 // the heat transferred to the gas and its final
   pressure
7
8 // Given values
9 m = 2;// mass of the gas , [kg]
10 V1 = .7;// volume ,[m^3]
11 T1 = 273+15;// original temperature ,[K]
12 T2 = 273+135;// final temperature ,[K]
13 cv = .72;// specific heat capacity at constant
   volume ,[kJ/kg K]
14 R = .29;// gas law constant ,[kJ/kg K]
15
16 // solution
17 Q = m*cv*(T2-T1);// Heat transferred at constant
   volume ,[kJ]
18 mprintf('\n The heat transferred to the gas is =
          %f kJ\n',Q);
19
20 // Now, using  $P_1*V_1=m*R*T_1$ 

```

```

21 P1 = m*R*T1/V1; // [kN/m^2]
22
23 // since volume of the system is constant, so P1/T1
    =P2/T2
24 // hence
25 P2 = P1*T2/T1; // final pressure, [kN/m^2]
26 mprintf('\n The final pressure of the gas is = %f
    kN/m^2 \n',P2);
27
28 // End

```

Scilab code Exa 5.8 heat transfer and work done

```

1 clear;
2 clc;
3 disp('Example 5.8');
4
5 // aim : To determine
6 // the heat transferred from the gas and the work
    done on the gas
7
8 // Given values
9 P1 = 275; // pressure, [kN/m^2]
10 V1 = .09; // volume, [m^3]
11 T1 = 273+185; // initial temperature, [K]
12 T2 = 273+15; // final temperature, [K]
13 cp = 1.005; // specific heat capacity at constant
    pressure, [kJ/kg K]
14 R = .29; // gas law constant, [kJ/kg K]
15
16 // solution
17 // using P1*V1=m*R*T1
18 m = P1*V1/(R*T1); // mass of the gas
19
20 // calculation of heat transfer

```

```

21 Q = m*cp*(T2-T1); // Heat transferred at constant
    pressure ,[kJ]
22 mprintf('\n The heat transferred to the gas is =
    %f kJ\n',Q);
23
24 // calculation of work done
25 // Now,since pressure is constant so, V/T=constant
26 // hence
27 V2 = V1*T2/T1; // [m^3]
28
29 W = P1*(V2-V1); // formula for work done at constant
    pressure ,[kJ]
30 mprintf('\n Work done on the gas during the process
    is = %f kJ\n',W);
31
32 // End

```

Scilab code Exa 5.9 pressure

```

1 clear;
2 clc;
3 disp('Example 5.9 ');
4
5 // aim : To determine
6 // the new pressure of the gas
7
8 // Given values
9 P1 = 300; // original pressure ,[kN/m^2]
10 T1 = 273+25; // original temperature ,[K]
11 T2 = 273+180; // final temperature ,[K]
12
13 // solution
14 // since gas compressing according to the law ,P*V
    ^1.4=constant
15 // so ,for polytropic process ,T1/T2=(P1/P2) ^((n-1)/n

```



```

    ), here n=1.4
16
17 // hence
18 P2 = P1*(T2/T1)^((1.4)/(1.4-1)); // [kN/m^2]
19
20 mprintf('\n The new pressure of the gas is = %f
    kN/m^2\n', P2);
21
22 // End

```

Scilab code Exa 5.10 temperature

```

1 clear;
2 clc;
3 disp('Example 5.10');
4
5 // aim : To determine
6 // the new temperature of the gas
7
8 // Given values
9 V1 = .015; // original volume, [m^3]
10 T1 = 273+285; // original temperature, [K]
11 V2 = .09; // final volume, [m^3]
12
13 // solution
14 // Given gas is following the law,  $P*V^{1.35} = \text{constant}$ 
15 // so process is polytropic with
16 n = 1.35; // polytropic index
17
18 // hence
19 T2 = T1*(V1/V2)^(n-1); // final temperature, [K]
20
21 t2 = T2-273; // [C]
22
23 mprintf('\n The new temperature of the gas is = %f

```

```

        C \n',t2);
24
25 // there is minor error in book's answer
26
27 // End

```

Scilab code Exa 5.11 volume pressure and temperature

```

1 clear;
2 clc;
3 disp('Example 5.11 ');
4
5 // aim : To determine the
6 // (a) original and final volume of the gas
7 // (b) final pressure of the gas
8 // (c) final temperature of the gas
9
10 // Given values
11 m = .675; // mass of the gas, [kg]
12 P1 = 1.4; // original pressure, [MN/m^2]
13 T1 = 273+280; // original temperature, [K]
14 R = .287; // gas constant, [kJ/kg K]
15
16 // solution
17
18 // (a)
19 // using characteristic equation,  $P_1*V_1=m*R*T_1$ 
20 V1 = m*R*T1*10^-3/P1; // [m^3]
21 // also Given
22 V2 = 4*V1; // [m^3]
23 mprintf('\n (a) The original volume of the gas is =
        %f m^3\n',V1);
24 mprintf('\n          and The final volume of the gas is
        = %f m^3\n',V2);
25

```

```

26 // (b)
27 // Given that gas is following the law  $P*V^{1.3} =$ 
    constant
28 // hence process is polytropic with
29 n = 1.3; // polytropic index
30 P2 = P1*(V1/V2)^n; // formula for polytropic process
    ,[MN/m^2]
31 mprintf('\n (b) The final pressure of the gas is =
    %f kN/m^2\n',P2*10^3);
32
33 // (c)
34 // since mass is constant so, using  $P*V/T = \text{constant}$ 
35 // hence
36 T2 = P2*V2*T1/(P1*V1); // [K]
37 t2 = T2-273; // [C]
38 mprintf('\n (c) The final temperature of the gas is
    = %f C\n',t2);
39
40 // End

```

Scilab code Exa 5.12 change of internal energy work done and heat transfer

```

1 clear;
2 clc;
3 disp('Example 5.12');
4
5 // aim : T0 determine
6 // (a) change in internal nergy of the air
7 // (b) work done
8 // (c) heat transfer
9
10 // Given values
11 m = .25; // mass, [kg]
12 P1 = 140; // initial pressure, [kN/m^2]

```

```

13 V1 = .15; // initial volume, [m^3]
14 P2 = 1400; // final volume, [m^3]
15 cp = 1.005; // [kJ/kg K]
16 cv = .718; // [kJ/kg K]
17
18 // solution
19
20 // (a)
21 // assuming ideal gas
22 R = cp-cv; // [kJ/kg K]
23 // also,  $P1*V1=m*R*T1$ , hence
24 T1 = P1*V1/(m*R); // [K]
25
26 // given that process is polytropic with
27 n = 1.25; // polytropic index
28 T2 = T1*(P2/P1)^((n-1)/n); // [K]
29
30 // Hence, change in internal energy is,
31 del_U = m*cv*(T2-T1); // [kJ]
32 mprintf('\n (a) The change in internal energy of the
    air is del_U = %f kJ',del_U);
33 if(del_U>0)
34     disp('since del_U>0, so it is gain of internal
    energy to the air')
35 else
36     disp('since del_U<0, so it is gain of internal
    energy to the surrounding')
37 end
38
39 // (b)
40 W = m*R*(T1-T2)/(n-1); // formula of work done for
    polytropic process, [kJ]
41 mprintf('\n (b) The work done is W = %f kJ',W);
42 if(W>0)
43     disp('since W>0, so the work is done by the air
    ')
44 else
45     disp('since W<0, so the work is done on the air')

```

```

    )
46 end
47
48 // (c)
49 Q = del_U+W; // using 1st law of thermodynamics,[kJ]
50 mprintf('\n (c) The heat transfer is Q = %f kJ',Q
    );
51 if(Q>0)
52     disp('since Q>0, so the heat is received by the
        air ')
53 else
54     disp('since Q<0, so the heat is rejected by the
        air ')
55 end
56
57 // End

```

Scilab code Exa 5.13 volume work done and change of internal energy

```

1 clear;
2 clc;
3 disp('Example 5.13 ');
4
5 // aim : To determine the
6 // final volume, work done and the change in
    internal energy
7
8 // Given values
9 P1 = 700; // initial pressure ,[kN/m^2]
10 V1 = .015; // initial volume, [m^3]
11 P2 = 140; // final pressure , [kN/m^2]
12 cp = 1.046; // [kJ/kg K]
13 cv = .752; // [kJ/kg K]
14
15 // solution

```

```

16
17 Gamma = cp/cv;
18 // for adiabatic expansion , P*V^gamma=constant , so
19 V2 = V1*(P1/P2)^(1/Gamma); // final volume , [m^3]
20 mprintf('\n The final volume of the gas is V2 = %f
        m^3\n',V2);
21
22 // work done
23 W = (P1*V1-P2*V2)/(Gamma-1); // [kJ]
24 mprintf('\n The work done by the gas is = %f kJ\n
        ',W);
25
26 // for adiabatic process
27 del_U = -W; // [kJ]
28 mprintf('\n The change of internal energy is = %f
        kJ',del_U);
29 if(del_U>0)
30     disp('since del_U>0, so the the gain in internal
        energy of the gas ')
31 else
32     disp('since del_U<0, so this is a loss of
        internal energy from the gas')
33 end
34
35 // End

```

Scilab code Exa 5.14 heat transfer change of internal energy and mass

```

1 clear;
2 clc;
3 disp('Example 5.14');
4
5 // aim : To determine the
6 // (a)heat transfer
7 // (b)change of internal energy

```

```

8 // (c) mass of gas
9
10 // Given values
11 V1 = .4; // initial volume, [m^3]
12 P1 = 100; // initial pressure, [kN/m^2]
13 T1 = 273+20; // temperature, [K]
14 P2 = 450; // final pressure, [kN/m^2]
15 cp = 1.0; // [kJ/kg K]
16 Gamma = 1.4; // heat capacity ratio
17
18 // solution
19
20 // (a)
21 // for the isothermal compression, P*V=constant, so
22 V2 = V1*P1/P2; // [m^3]
23 W = P1*V1*log(P1/P2); // formula of workdone for
    isothermal process, [kJ]
24
25 // for isothermal process, del_U=0; so
26 Q = W;
27 mprintf('\\n (a) The heat transferred during
    compression is Q = %f kJ\\n', Q);
28
29
30 // (b)
31 V3 = V1;
32 // for adiabatic expansion
33 // also
34
35 P3 = P2*(V2/V3)^Gamma; // [kN/m^2]
36 W = -(P3*V3-P2*V2)/(Gamma-1); // work done formula
    for adiabatic process, [kJ]
37 // also, Q=0, so using Q=del_U+W
38 del_U = -W; // [kJ]
39 mprintf('\\n (b) The change of the internal energy
    during the expansion is, del_U = %f kJ\\n', del_U)
    ;
40

```

```

41 // (c)
42 // for ideal gas
43 //  $cp - cv = R$ , and  $cp/cv = \gamma$ , hence
44 R = cp*(1-1/Gamma); // [kJ/kg K]
45
46 // now using ideal gas equation
47 m = P1*V1/(R*T1); // mass of the gas, [kg]
48 mprintf('\n (c) The mass of the gas is ,m = %f kg\n
         n',m);
49
50 // There is calculation mistake in the book
51
52
53 // End

```

Scilab code Exa 5.15 heat transfer and polytropic heat capacity

```

1 clear;
2 clc;
3 disp('Example 5.15');
4
5 // aim : To determine
6 // the heat transferred and polytropic specific
   heat capacity
7
8 // Given values
9 P1 = 1; // initial pressure, [MN/m^2]
10 V1 = .003; // initial volume, [m^3]
11 P2 = .1; // final pressure, [MN/m^2]
12 cv = .718; // [kJ/kg*K]
13 Gamma=1.4; // heat capacity ratio
14
15 // solution
16 // Given process is polytropic with
17 n = 1.3; // polytropic index

```



```

18 // hence
19 V2 = V1*(P1/P2)^(1/n); // final volume ,[m^3]
20 W = (P1*V1-P2*V2)*10^3/(n-1); // work done ,[kJ]
21 // so
22 Q = (Gamma-n)*W/(Gamma-1); // heat transferred ,[kJ]
23
24 mprintf('\n The heat received or rejected by the gas
    during this process is Q = %f kJ',Q);
25 if(Q>0)
26     disp('since Q>0, so heat is received by the gas'
    )
27 else
28     disp('since Q<0, so heat is rejected by the gas'
    )
29 end
30
31 // now
32 cn = cv*(Gamma-n)/(n-1); // polytropic specific heat
    capacity ,[kJ/kg K]
33 mprintf('\n The polytropic specific heat capacity is
    cn = %f kJ/kg K\n',cn);
34
35 // End

```

Scilab code Exa 5.16 pressures

```

1 clear;
2 clc;
3 disp('Example 5.16 ');
4
5 // aim : To determine the
6 // (a) initial partial pressure of the steam and
    air
7 // (b) final partial pressure of the steam and air
8 // (c) total pressure in the container after

```

```

          heating
9
10 // Given values
11 T1 = 273+39; // initial temperature ,[K]
12 P1 = 100; // pressure , [MN/m^2]
13 T2 = 273+120.2; // final temperature ,[K]
14
15 // solution
16
17 // (a)
18 // from the steam tables , the pressure of wet steam
    at 39 C is
19 Pw1 = 7; // partial pressure of wet steam ,[kN/m^2]
20 // and by Dalton 's law
21 Pa1 = P1-Pw1; // initial pressure of air , [kN/m^2]
22
23 mprintf('\n (a) The initial partial pressure of the
    steam is = %f kN/m^2 ',Pw1);
24 mprintf('\n          The initial partial pressure of the
    air is = %f kN/m^2\n',Pa1);
25
26 // (b)
27 // again from steam table , at 120.2 C the pressure
    of wet steam is
28 Pw2 = 200; // [kN/m^2]
29
30 // now since volume is constant so assuming air to
    be ideal gas so for air P/T=contant , hence
31 Pa2 = Pa1*T2/T1 ; // [kN/m^2]
32
33 mprintf(' \n(b) The final partial pressure of the
    steam is = %f kN/m^2 ',Pw2);
34 mprintf('\n          The final partial pressure of the
    air is = %f kN/m^2\n',Pa2);
35
36 // (c)
37 Pt = Pa2+Pw2; // using dalton 's law , total pressure
    ,[kN/m^2]

```

```

38 mprintf('\n (c) The total pressure after heating is
    = %f kN/m^2\n',Pt);
39
40 // End

```

Scilab code Exa 5.17 partial pressure and mass

```

1 clear;
2 clc;
3 disp('Example 5.17');
4
5 // aim : To determine
6 // the partial pressure of the air and steam, and
   the mass of the air
7
8 // Given values
9 P1 = 660; // vaccum gauge pressure on condenser [
   mmHg]
10 P = 765; // atmospheric pressure, [mmHg]
11 x = .8; // dryness fraction
12 T = 273+41.5; // temperature, [K]
13 ms_dot = 1500; // condense rate of steam, [kg/h]
14 R = .29; // [kJ/kg]
15
16 // solution
17 Pa = (P-P1)*.1334; // absolute pressure, [kN/m^2]
18 // from steam table, at 41.5 C partial pressure of
   steam is
19 Ps = 8; // [kN/m^2]
20 // by dalton's law, partial pressure of air is
21 Pg = Pa-Ps; // [kN/m^2]
22
23 mprintf('\n The partial pressure of the air in the
   condenser is = %f kN/m^2\n',Pg);
24 mprintf('\n The partial pressure of the steam in the

```

```

    condenser is = %f kN/m^2\n',Ps);
25
26 // also
27 vg = 18.1; // [m^3/kg]
28 // so
29 V = x*vg; // [m^3/kg]
30 // The air associated with 1 kg of the steam will
    occupiy this same volume
31 // for air , Pg*V=m*R*T,so
32 m = Pg*V/(R*T); // [kg/kg steam]
33 // hence
34 ma = m*ms_dot; // [kg/h]
35
36 mprintf('\n The mass of air which will associated
    with this steam is = %f kg\n',ma);
37
38 // There is misprint in book
39
40 // End

```

Scilab code Exa 5.18 pressure and dryness fraction

```

1 clear;
2 clc;
3 disp('Example 5.18');
4
5 // aim : To determine the
6 // (a) final pressure
7 // (b) final dryness fraction of the steam
8
9 // Given values
10 P1 = 130; // initial pressure , [kN/m^2]
11 T1 = 273+75.9; // initial temperature , [K]
12 x1 = .92; // initial dryness fraction
13 T2 = 273+120.2; // final temperature , [K]

```

```

14
15 // solution
16
17 // (a)
18 // from steam table , at 75.9 C
19 Pws = 40; // partial pressure of wet steam [kN/m^2]
20 Pa = P1-Pws; // partial pressure of air , [kN/m^2]
21 vg = 3.99 // specific volume of the wet steam , [m^3/
    kg]
22 // hence
23 V1 = x1*vg; // [m^3/kg]
24 V2 = V1/5; // [m^3/kg]
25 // for air , mass is constant so , Pa*V1/T1=P2*V2/T2,
    also given ,V1/V2=5,so
26 P2 = Pa*V1*T2/(V2*T1); // final pressure ,[kN/m^2]
27
28 // now for steam at 120.2 C
29 Ps = 200; // final partial pressure of steam ,[kN/m
    ^2]
30 // so by dalton 's law total pressure in cylindert
    is
31 Pt = P2+Ps; // [kN/m^2]
32 mprintf('\n (a) The final pressure in the cylinder
    is = %f kN/m^2\n',Pt);
33
34 // (b)
35 // from steam table at 200 kN/m^2
36 vg = .885; // [m^3/kg]
37 // hence
38 x2 = V2/vg; // final dryness fraction of the steam
39 mprintf('\n (b) The final dryness fraction of the
    steam is = %f\n ',x2);
40
41 // End

```

Scilab code Exa 5.19 adiabatic index and change of internal energy

```
1 clear;
2 clc;
3 disp('Example 5.19')
4
5 // aim : To determine the
6 // (a) Gamma,
7 // (b) del_U
8
9 // Given Values
10 P1 = 1400; // [kN/m^2]
11 P2 = 100; // [kN/m^2]
12 P3 = 220; // [kN/m^2]
13 T1 = 273+360; // [K]
14 m = .23; // [kg]
15 cp = 1.005; // [kJ/kg*K]
16
17 // Solution
18 T3 = T1; // since process 1-3 is isothermal
19
20 // (a)
21 // for process 1-3, P1*V1=P3*V3, so
22 V3_by_V1 = P1/P3;
23 // also process 1-2 is adiabatic ,so P1*V1^(Gamma)=
    P2*V2^(Gamma), hence
24 // and process process 2-3 is iso-choric so ,V3=V2
    and
25 V2_by_V1 = V3_by_V1;
26 // hence ,
27 Gamma = log(P1/P2)/log(P1/P3); // heat capacity
    ratio
28
29 mprintf('\n (a) The value of adiabatic index Gamma
    is = %f\n', Gamma);
30
31 // (b)
32 cv = cp/Gamma; // [kJ/kg K]
```

```

33 // for process 2-3, P3/T3=P2/T2, so
34 T2 = P2*T3/P3; // [K]
35
36 // now
37 del_U = m*cv*(T2-T1); // [kJ]
38 mprintf('\n (b) The change in internal energy during
    the adiabatic expansion is U2-U1 = %f kJ (This
    is loss of internal energy)\n', del_U);
39 // End

```

Scilab code Exa 5.20 mass and heat transfer

```

1 clear;
2 clc;
3 disp('Example 5.20');
4
5 // aim : To determine
6 // the mass of oxygen and heat transferred
7
8 // Given values
9 V1 = 300; // [L]
10 P1 = 3.1; // [MN/m^2]
11 T1 = 273+18; // [K]
12 P2 = 1.7; // [MN/m^2]
13 T2 = 273+15; // [K]
14 Gamma = 1.4; // heat capacity ratio
15 // density condition
16 P = .101325; // [MN/m^2]
17 T = 273; // [K]
18 V = 1; // [m^3]
19 m = 1.429; // [kg]
20
21 // hence
22 R = P*V*10^3/(m*T); // [kJ/kg*K]
23 // since volume is constant

```

```

24 V2 = V1; // [L]
25 // for the initial conditions in the cylinder ,P1*V1
    =m1*R*T1
26 m1 = P1*V1/(R*T1); // [kg]
27
28 // after some of the gas is used
29 m2 = P2*V2/(R*T2); // [kg]
30 // The mass of oxygen remaining in cylinder is m2
    kg, so
31 // Mass of oxygen used is
32 m_used = m1-m2; // [kg]
33 mprintf('\n The mass of oxygen used = %f kg\n',
    m_used);
34
35 // for non-flow process ,Q=del_U+W
36 // volume is constant so no external work is done
    so ,Q=del_U
37 cv = R/(Gamma-1); // [kJ/kg*K]
38
39 // heat transfer is
40 Q = m2*cv*(T1-T2); // (kJ)
41 mprintf('\n The amount of heat transferred through
    the cylinder wall is = %f kJ\n',Q);
42
43 // End

```

Scilab code Exa 5.21 work done change of internal energy and heat transfer

```

1 clear;
2 clc;
3 disp('Example 5.21 ');
4
5 // aim : To determine the
6 // (a) work transferred during the compression

```



```

7 // (b) change in internal energy
8 // (c) heat transferred during the compression
9
10 // Given values
11 V1 = .1; // initial volume, [m^3]
12 P1 = 120; // initial pressure, [kN/m^2]
13 P2 = 1200; // final pressure, [kN/m^2]
14 T1 = 273+25; // initial temperature, [K]
15 cv = .72; // [kJ/kg*K]
16 R = .285; // [kJ/kg*K]
17
18 // solution
19
20 // (a)
21 // given process is polytropic with
22 n = 1.2; // polytropic index
23 // hence
24 V2 = V1*(P1/P2)^(1/n); // [m^3]
25 W = (P1*V1-P2*V2)/(n-1); // workdone formula, [kJ]
26 mprintf('\n (a) The work transferred during the
           compression is = %f kJ\n',W);
27
28 // (b)
29 // now mass is constant so,
30 T2 = P2*V2*T1/(P1*V1); // [K]
31 // using, P*V=m*R*T
32 m = P1*V1/(R*T1); // [kg]
33
34 // change in internal energy is
35 del_U = m*cv*(T2-T1); // [kJ]
36 mprintf('\n (b) The change in internal energy is =
           %f kJ\n',del_U);
37
38 // (c)
39 Q = del_U+W; // [kJ]
40 mprintf('\n (c) The heat transferred during the
           compression is = %f kJ\n',Q);
41

```

42 // End

Scilab code Exa 5.22 pressure and specific enthalpy

```
1 clear;
2 clc;
3 disp('Example 5.22');
4
5 // aim : To determine the
6 // (a) new pressure of the air in the receiver
7 // (b) specific enthalpy of air at 15 C
8
9 // Given values
10 V1 = .85; // [m^3]
11 T1 = 15+273; // [K]
12 P1 = 275; // pressure , [kN/m^2]
13 m = 1.7; // [kg]
14 cp = 1.005; // [kJ/kg*K]
15 cv = .715; // [kJ/kg*K]
16
17 // solution
18
19 // (a)
20
21 R = cp-cv; // [kJ/kg*K]
22 // assuming m1 is original mass of the air, using P
   *V=m*R*T
23 m1 = P1*V1/(R*T1); // [kg]
24 m2 = m1+m; // [kg]
25 // again using P*V=m*R*T
26 // P2/P1=(m2*R*T2/V2)/(m1*R*T1/V1); and T1=T2, V1=V2
   , so
27 P2 = P1*m2/m1; // [kN/m^2]
28 mprintf('\n (a) The new pressure of the air in the
   receiver is = %f kN/m^2\n',P2);
```

```

29
30 // (b)
31 // for 1 kg of air , h2-h1=cp*(T1-T0)
32 // and if 0 is chosen as the zero enthalpy , then
33 h = cp*(T1-273); // [kJ/kg]
34 mprintf('\n (b) The specific enthalpy of the air at
15 C is = %f kJ/kg\n',h);
35
36 // End

```

Scilab code Exa 5.23 characteristic gas constant specific heat capacities change of internal energy and work done

```

1 clear;
2 clc;
3 disp('Example 5.23 ');
4
5 // aim : T determine the
6 // (a) characteristic gas constant of the gas
7 // (b) cp,
8 // (c) cv,
9 // (d) del_u
10 // (e) work transfer
11
12 // Given values
13 P = 1; // [bar]
14 T1 = 273+15; // [K]
15 m = .9; // [kg]
16 T2 = 273+250; // [K]
17 Q = 175; // heat transfer , [kJ]
18
19 // solution
20
21 // (a)
22 // using , P*V=m*R*T, given ,

```

```

23 m_by_V = 1.875;
24 // hence
25 R = P*100/(T1*m_by_V);// [kJ/kg*K]
26 mprintf('\n (a) The characteristic gas constant of
    the gas is R = %f kJ/kg K\n',R);
27
28 // (b)
29 // using , Q=m*cp*(T2-T1)
30 cp = Q/(m*(T2-T1));// [kJ/kg K]
31 mprintf('\n (b) The specific heat capacity of the
    gas at constant pressure cp = %f kJ/kg K\n',cp)
    ;
32
33 // (c)
34 // we have , cp-cv=R, so
35 cv = cp-R;// [kJ/kg*K]
36 mprintf('\n (c) The specific heat capacity of the
    gas at constant volume cv = %f kJ/kg K\n',cv);
37
38 // (d)
39 del_U = m*cv*(T2-T1);// [kJ]
40 mprintf('\n (d) The change in internal energy is =
    %f kJ\n',del_U);
41
42 // (e)
43 // using , Q=del_U+W
44 W = Q-del_U;// [kJ]
45 mprintf('\n (e) The work transfer is W = %f kJ\n',
    W);
46
47 // End

```

Scilab code Exa 5.24 work done change of internal energy and heat transfer

```

1 clear;
2 clc;
3 disp('Example 5.24');
4
5 // aim : To determine the
6 // (a) work transfer ,
7 // (b)del_U and,
8 // (c)heat transfer
9
10 // Given values
11 V1 = .15; // [m^3]
12 P1 = 1200; // [kN/m^2]
13 T1 = 273+120; // [K]
14 P2 = 200; // [kN/m^2]
15 cp = 1.006; // [kJ/kg K]
16 cv = .717; // [kJ/kg K]
17
18 // solution
19
20 // (a)
21 // Given,  $PV^{1.32} = \text{constant}$ , so it is polytropic
    process with
22 n = 1.32; // polytropic index
23 // hence
24 V2 = V1*(P1/P2)^(1/n); // [m^3]
25 // now, W
26 W = (P1*V1-P2*V2)/(n-1); // [kJ]
27 fprintf('\n (a) The work transfer is W = %f kJ\n',
    W);
28
29 // (b)
30 R = cp-cv; // [kJ/kg K]
31 m = P1*V1/(R*T1); // gas law, [kg]
32 // also for polytropic process
33 T2 = T1*(P2/P1)^((n-1)/n); // [K]
34 // now for gas,
35 del_U = m*cv*(T2-T1); // [kJ]
36 fprintf('\n (b) The change of internal energy is

```

```

    del_U = %f kJ\n',del_U);
37
38 // (c)
39 Q = del_U+W;// first law of thermodynamics,[kJ]
40 mprintf('\n (c) The heat transfer Q = %f kJ\n',Q);
41
42 // End

```

Scilab code Exa 5.26 volume

```

1 clear;
2 clc;
3 disp('Example 5.26');
4
5 // aim : To determine
6 // the volume of the pressure vessel and the volume
   of the gas before transfer
7
8 // Given values
9
10 P1 = 1400;// initial pressure,[kN/m^2]
11 T1 = 273+85;// initial temperature,[K]
12
13 P2 = 700;// final pressure,[kN/m^2]
14 T2 = 273+60;// final temperature,[K]
15
16 m = 2.7;// mass of the gas passes,[kg]
17 cp = .88;// [kJ/kg]
18 cv = .67;// [kJ/kg]
19
20 // solution
21
22 // steady flow equation is,  $u_1+P_1*V_1+C_1^2/2+Q=u_2+P_2$ 
    $*V_2+C_2^2/2+W$  [1],
23 // given, there is no kinetic energy change and

```

```

    neglecting potential energy term
24 W = 0; // no external work done
25 // so final equation is ,u1+P1*v1+Q=u2    [2]
26 // also u2-u1=cv*(T2-T1)
27 // hence Q=cv*(T2-T1)-P1*v1    [3]
28 // and for unit mass P1*v1=R*T1=(cp-cv)*T1    [4]
29 // so finally
30 Q = cv*(T2-T1)-(cp-cv)*T1; //    [kJ/kg]
31 // so total heat transferred is
32 Q = m*Q; //    [kJ]
33
34 // using eqn [4]
35 v1 = (cp-cv)*T1/P1; //    [m^3/kg]
36 // Total volume is
37 V1 = m*v1; //    [m^3]
38
39 // using ideal gas equation P1*V1/T1=P2*V2/T2
40 V2 = P1*T2*V1/(P2*T1); //    final volume , [m^3]
41
42 mprintf('\n The volume of gas before transfer is =
    %f m^3\n',V1);
43 mprintf('\n The volume of pressure vessel is = %f
    m^3\n',V2);
44
45 // End

```

Chapter 7

Entropy

Scilab code Exa 7.1 specific entropy

```
1 clear;
2 clc;
3 disp('Example 7.1 ');
4
5 // aim : To determine
6 // the specific enthalpy of water
7
8 // Given values
9 Tf = 273+100; // Temperature ,[K]
10
11 // solution
12 // from steam table
13 cp1 = 4.187; // [kJ/kg K]
14 // using equation [8]
15 sf = cp1*log(Tf/273.16); // [kJ/kg*K]
16 mprintf('\n The specific entropy of water is = %f
17         kJ/kg K\n',sf);
18
19 // using steam table
20 sf = 1.307; // [kJ/kg K]
21 mprintf('\n From table The accurate value of sf in
```



```

    this case is = %f kJ/kg K\n',sf);
21
22 // There is small error in book's final value of sf
23
24
25 // End

```

Scilab code Exa 7.2 specific entropy

```

1
2 clear;
3 clc;
4 disp('Example 7.2 ');
5
6 // aim : To determine
7 // the specific entropy
8
9 // Given values
10 P = 2; // pressure , [MN/m^2]
11 x = .8; // dryness fraction
12
13 // solution
14 // from steam table at given pressure
15 Tf = 485.4; // [K]
16 cpl = 4.187; // [kJ/kg K]
17 hfg = 1888.6; // [kJ/kg]
18
19 // (a) finding entropy by calculation
20 s = cpl*log(Tf/273.16)+x*hfg/Tf; // formula for
    entropy calculation
21
22 mprintf('\n (a) The specific entropy of wet steam is
    = %f kJ/kg K\n',s);
23
24 // (b) calculation of entropy using steam table

```

```

25 // from steam table at given pressure
26 sf = 2.447; // [kJ/kg K]
27 sfg = 3.89; // [kJ/kg K]
28 // hence
29 s = sf+x*sfg; // [kJ/kg K]
30
31 mprintf('\n (b) The specific entropy using steam
    table is = %f kJ/kg K\n',s);
32
33 // End

```

Scilab code Exa 7.3 specific entropy

```

1 clear;
2 clc;
3 disp('Example 7.3 ');
4
5 // aim : To determine
6 // the specific entropy of steam
7
8 // Given values
9 P = 1.5; //pressure ,[MN/m^2]
10 T = 273+300; //temperature ,[K]
11
12 // solution
13
14 // (a)
15 // from steam table
16 cpl = 4.187; // [kJ/kg K]
17 Tf = 471.3; // [K]
18 hfg = 1946; // [kJ/kg]
19 cpv = 2.093; // [kJ/kg K]
20
21 // usung equation [2]
22 s = cpl*log(Tf/273.15)+hfg/Tf+cpv*log(T/Tf); // [kJ/

```

```

kg K]
23 mprintf('\\n (a) The specific entropy of steam is =
    %f kJ/kg K\\n',s);
24
25 // (b)
26 // from steam tables
27 s = 6.919; // [kJ/kg K]
28 mprintf('\\n (b) The accurate value of specific
    entropy from steam table is = %f kJ/kg K\\n',s);
29
30 // End

```

Scilab code Exa 7.4 dryness fraction

```

1 clear;
2 clc;
3 disp('Example 7.4 ');
4
5 // aim : To determine
6 // the dryness fraction of steam
7
8 // Given values
9 P1 = 2; // initial pressure, [MN/m^2]
10 t = 350; // temperature, [C]
11 P2 = .28; // final pressure, [MN/m^2]
12
13 // solution
14 // at 2 MN/m^2 and 350 C, steam is superheated
    because the saturation temperature is 212.4 C
15 // From steam table
16 s1 = 6.957; // [kJ/kg K]
17
18 // for isentropic process
19 s2 = s1;
20 // also

```

```

21 sf2 = 1.647; // [kJ/kg K]
22 sfg2 = 5.368; // [kJ/kg K]
23
24 // using
25 // s2 = sf2+x2*sfg2, where x2 is dryness fraction
    of steam
26 // hence
27 x2 = (s2-sf2)/sfg2;
28 mprintf('\n The final dryness fraction of steam is
    x2 = %f\n',x2);
29
30 // End

```

Scilab code Exa 7.5 condition of steam and change in specific entropy

```

1 clear;
2 clc;
3 disp('Example 7.5 ');
4
5 // aim : To determine
6 // the final condition of steam...
7 // the change in specific entropy during hyperbolic
    process
8
9 // Given values
10 P1 = 2; // pressure, [MN/m^2]
11 t = 250; // temperature, [C]
12 P2 = .36; // pressure, [MN/m^2]
13 P3 = .06; // pressure, [MN/m^2]
14
15 // solution
16
17 // (a)
18 // from steam table
19 s1 = 6.545; // [kJ/kg K]

```

```

20 // at .36 MN/m^2
21 sg = 6.930; // [kJ/kg*K]
22
23 sf2 = 1.738; // [kJ/kg K]
24 sfg2 = 5.192; // [kJ/kg K]
25 vg2 = .510; // [m^3]
26
27 // so after isentropic expansion, steam is wet
28 // hence, s2=sf2+x2*sfg2, where x2 is dryness
    fraction
29 // also
30 s2 = s1;
31 // so
32 x2 = (s2-sf2)/sfg2;
33 // and
34 v2 = x2*vg2; // [m^3]
35
36 // for hyperbolic process
37 // P2*v2=P3*v3
38 // hence
39 v3 = P2*v2/P3; // [m^3]
40
41 mprintf('\n (a) From steam table at .06 MN/m^2 steam
    is superheated and has temperature of 100 C with
    specific volume is = %f m^3/kg\n',v3);
42
43 // (b)
44 // at this condition
45 s3 = 7.609; // [kJ/kg*K]
46 // hence
47 change_s23 = s3-sg; // change in specific entropy
    during the hyperbolic process [kJ/kg*K]
48 mprintf('\n (b) The change in specific entropy
    during the hyperbolic process is = %f kJ/kg K\n
    ',change_s23);
49
50 // In the book they have taken sg instead of s2 for
    part (b), so answer is not matching

```

```
51
52 // End
```

Scilab code Exa 7.6 heat transfer and work done

```
1
2 clear;
3 clc;
4 disp('Example 7.6 ');
5
6 // aim : To determine the
7 // (a) heat transfer during the expansion and
8 // (b) work done durind the expansion
9
10 // given values
11 m = 4.5; // mass of steam,[kg]
12 P1 = 3; // initial pressure,[MN/m^2]
13 T1 = 300+273; // initial temperature,[K]
14
15 P2 = .1; // final pressure,[MN/m^2]
16 x2 = .96; // dryness fraction at final stage
17
18 // solution
19 // for state point 1,using steam table
20 s1 = 6.541;// [kJ/kg/K]
21 u1 = 2751;// [kJ/kg]
22
23 // for state point 2
24 sf2 = 1.303;// [kJ/kg/K]
25 sfg2 = 6.056;// [kJ/kg/k]
26 T2 = 273+99.6;// [K]
27 hf2 = 417;// [kJ/kg]
28 hfg2 = 2258;// [kJ/kg]
29 vg2 = 1.694;// [m^3/kg]
30
```

```

31 // hence
32 s2 = sf2+x2*sfg2;// [kJ/kg/k]
33 h2 = hf2+x2*hfg2;// [kJ/kg]
34 u2 = h2-P2*x2*vg2*10^3;// [kJ/kg]
35
36 // Diagram of example 7.6
37 x = [s1 s2];
38 y = [T1 T2];
39 plot2d(x,y);
40 xtitle('Diagram for example 7.6(T vs s)');
41 xlabel('Entropy (kJ/kg K)');
42 ylabel('Temperature (K)');
43
44 x = [s1,s1];
45 y = [0,T1];
46 plot2d(x,y);
47
48 x = [s2,s2];
49 y = [0,T2];
50 plot2d(x,y);
51
52 // (a)
53 // Q_rev is area of T-s diagram
54 Q_rev = (T1+T2)/2*(s2-s1);// [kJ/kg]
55 // so total heat transfer is
56 Q_rev = m*Q_rev;// [kJ]
57
58 // (b)
59 del_u = u2-u1;// change in internal energy , [kJ/kg
]
60 // using 1st law of thermodynamics
61 W = Q_rev-m*del_u;// [kJ]
62
63 mprintf('\n (a) The heat transfer during the
expansion is = %f kJ (received)\n',Q_rev);
64
65 mprintf('\n (b) The work done during the expansion
is = %f kJ\n',W);

```

66
67 // End

Scilab code Exa 7.7 change of entropy and ratio of change of entropy and heat transfer

```
1
2 clear;
3 clc;
4 disp('Example 7.7');
5
6 // aim : To determine the
7 // (a) change of entropy
8 // (b) The approximate change of entropy obtained
   by dividing the heat transferred by the gas by
   the mean absolute temperature during the
   compression
9
10 // Given values
11 P1 = 140; // initial pressure ,[kN/m^2]
12 V1 = .14; // initial volume, [m^3]
13 T1 = 273+25; // initial temperature ,[K]
14 P2 = 1400; // final pressure [kN/m^2]
15 n = 1.25; // polytropic index
16 cp = 1.041; // [kJ/kg K]
17 cv = .743; // [kJ/kg K]
18
19 // solution
20 // (a)
21 R = cp-cv; // [kJ/kg/K]
22 // using ideal gas equation
23 m = P1*V1/(R*T1); // mass of gas ,[kg]
24 // since gas is following law  $P*V^n=constant$  ,so
25 V2 = V1*(P1/P2)^(1/n); // [m^3]
26
```



```

27 // using eqn [9]
28 del_s = m*(cp*log(V2/V1)+cv*log(P2/P1));// [kJ/K]
29 mprintf('\n (a) The change of entropy is = %f kJ/
      K\n',del_s);
30
31 // (b)
32 W = (P1*V1-P2*V2)/(n-1);// polytropic work,[kJ]
33 Gamma = cp/cv;// heat capacity ratio
34 Q = (Gamma-n)/(Gamma-1)*W;// heat transferred ,[kJ]
35
36 // Again using polytropic law
37 T2 = T1*(V1/V2)^(n-1);// final temperature, [K]
38 T_avg = (T1+T2)/2;// mean absolute temperature, [K]
39
40 // so approximate change in entropy is
41 del_s = Q/T_avg;// [kJ/K]
42
43 mprintf('\n (b) The approximate change of entropy
      obtained by dividing the heat transferred by the
      gas by the mean absolute temperature during the
      compression = %f kJ/K\n',del_s);
44
45 // End

```

Scilab code Exa 7.8 change of entropies

```

1 clear;
2 clc;
3 disp('Example 7.8 ');
4
5 // aim : To determine
6 // the change of entropy
7
8 // Given values
9 m = .3;// [kg]

```

```

10 P1 = 350; // [kN/m^2]
11 T1 = 273+35; // [K]
12 P2 = 700; // [kN/m^2]
13 V3 = .2289; // [m^3]
14 cp = 1.006; // [kJ/kg K]
15 cv = .717; // [kJ/kg K]
16
17 // solution
18 // for constant volume process
19 R = cp-cv; // [kJ/kg K]
20 // using PV=mRT
21 V1 = m*R*T1/P1; // [m^3]
22
23 // for constant volume process P/T=constant, so
24 T2 = T1*P2/P1; // [K]
25 s21 = m*cv*log(P2/P1); // formula for entropy change
    for constant volume process
26 mprintf('\n The change of entropy in constant volume
    process is = %f kJ/kg K\n',s21);
27
28 // 'For the above part result given in the book is
    wrong
29
30 V2 = V1;
31 // for constant pressure process
32 T3 = T2*V3/V2; // [K]
33 s32 = m*cp*log(V3/V2); // [kJ/kg K]
34
35 mprintf('\n The change of entropy in constant
    pressure process is = %f kJ/kg K\n',s32);
36
37 // there is misprint in the book's result
38
39 // End

```

Scilab code Exa 7.9 change of entropy

```
1 clear;
2 clc;
3 disp('Example 7.9 ');
4
5 // aim : To determine
6 // the change of entropy
7
8 // Given values
9 P1 = 700; // initial pressure , [kN/m^2]
10 T1 = 273+150; // Temperature ,[K]
11 V1 = .014; // initial volume , [m^3]
12 V2 = .084; // final volume , [m^3]
13
14 // solution
15 // since process is isothermal so
16 T2 = T1;
17 // and using fig.7.10
18 del_s = P1*V1*log(V2/V1)/T1 ; // [kJ/K]
19 mprintf('\n The change of entropy is = %f kJ/kg K
20         \n',del_s);
21 // End
```

Chapter 8

Combustion

Scilab code Exa 8.1 stoichiometric mass

```
1
2 clear;
3 clc;
4 disp('Example 8.1 ');
5
6 // aim : To determine
7 // the stoichiometric mass of air required to burn
8 // 1 kg the fuel
9
10 // Given values
11 C = .72; // mass fraction of C; [kg/kg]
12 H2 = .20; // mass fraction of H2; , [kg/kg]
13 O2 = .08; // mass fraction of O2, [kg/kg]
14 aO2=.232; // composition of oxygen in air
15
16 // solution
17 // for 1kg of fuel
18 mO2 = 8/3*C+8*H2-O2; // mass of O2, [kg]
19
20 // hence stoichiometric mass of O2 required is
21 msO2 = mO2/aO2; // [kg]
```

```

21
22 mprintf(' \n The stoichiometric mass of air required
      to burn 1 kg the fuel should be = %f kg\n',ms02
      );
23
24 // End

```

Scilab code Exa 8.3 stoichiometric mass and composition of products

```

1 clear;
2 clc;
3 disp('Example 8.3 ');
4
5 // aim : To determine
6 // the stoichiometric mass of air
7 // the products of combustion both by mass and as
  percentage
8
9 // Given values
10 C = .82; // mass composition C
11 H2 = .12; // mass composition of H2
12 O2 = .02; // mass composition of O2
13 S = .01; // mass composition of S
14 N2 = .03; // mass composition of N2
15
16 // solution
17 // for 1kg fuel
18 mo2 = 8/3*C+8*H2-O2+S*1; // total mass of O2
  required , [kg]
19 sa = mo2/.232; // stoichimetric air , [kg]
20 mprintf(' \n The stoichiometric mass of air is = %f
      kg/kg fuel\n',sa);
21
22 // for one kg fuel
23 mCO2 = C*11/3; // mass of CO2 produced , [kg]

```

```

24 mH2O = H2*9; // mass of H2O produced , [kg]
25 mSO2 = S*2; // mass of SO2 produce , [kg]
26 mN2 = C*8.84+H2*26.5-02*.768/.232+S*3.3+N2; // mass
    of N2 produced , [kg]
27
28 mt = mCO2+mH2O+mSO2+mN2; // total mass of product , [
    kg]
29
30 x1 = mCO2/mt*100; // %age mass composition of CO2
    produced
31 x2 = mH2O/mt*100; // %age mass composition of H2O
    produced
32 x3 = mSO2/mt*100; // %age mass composition of SO2
    produced
33 x4 = mN2/mt*100; // %age mass composition of N2
    produced
34
35 mprintf('\n CO2 produced = %f kg/kg fuel ,
    percentage composition = %f,\n H2O produced =
    %f kg/kg fuel , percentage composition = %f,\n
    SO2 produced = %f kg/kg fuel , percentage
    composition = %f,\n N2 produced = %f kg/kg
    fuel , percentage composition = %f',mCO2,x1,
    mH2O ,x2 ,mSO2 ,x3 ,mN2 ,x4);
36
37 // End

```

Scilab code Exa 8.4 stoichiometric volume

```

1 clear;
2 clc;
3 disp('Example 8.4');
4
5 // aim : To determine
6 // the stoichiometric volume of air required for

```

```

        complete combustion of 1 m3 of the gas
7
8 // Given values
9 H2 = .14; // volume fraction of H2
10 CH4 = .02; // volume fraction of CH4
11 CO = .22; // volume fraction of CO
12 CO2 = .05; // volume fraction of CO2
13 O2 = .02; // volume fraction of O2
14 N2 = .55; // volume fraction of N2
15
16 // solution
17 // for 1 m3 of fuel
18 Va = .5*H2+2*CH4+.5*CO-O2; // [m3]
19
20 // stoichiometric air required is
21 Vsa = Va/.21; // [m3]
22
23 mprintf('\n The stoichiometric volume of air
        required for complete combustion is = %f m3/m
        ^3 fuel\n',Vsa);
24
25 // End

```

Scilab code Exa 8.5 volume

```

1 clear;
2 clc;
3 disp('Example 8.5 ');
4
5 // aim : To determine
6 // the volume of the air required
7
8 // Given values
9 H2 = .45; // volume fraction of H2
10 CO = .40; // volume fraction of CO

```

```

11 CH4 = .15; // volume fraction of CH4
12
13 // solution
14 V = 2.38*(H2+CO)+9.52*CH4; // stoichiometric volume of
    air , [m^3]
15
16 mprintf('\n The volume of air required is = %f m
    ^3/m^3 fuel\n',V);
17
18 // Result in the book is misprinted
19
20 // End

```

Scilab code Exa 8.6 stoichiometric volume composition of products

```

1 clear;
2 clc;
3 disp('Example 8.6 ');
4
5 // aim : To determine
6 // the stoichiometric volume of air for the complete
    combustion
7 // the products of combustion
8
9 // given values
10 CH4 = .142; // volumetric composition of CH4
11 CO2 = .059; // volumetric composition of CO2
12 CO = .360; // volumetric composition of CO
13 H2 = .405; // volumetric composition of H2
14 O2 = .005; // volumetric composition of O2
15 N2 = .029; // volumetric composition of N2
16
17 aO2 = .21; // O2 composition into air by volume
18
19 // solution

```



```

20 svO2 = CH4*2+CO*.5+H2*.5-02;// stoichiometric
    volume of O2 required , [m^3/m^3 fuel]
21 svair = svO2/aO2;// stoichiometric volume of air
    required , [m^3/m^3 fuel]
22 mprintf('\n Stoichiometric volume of air required is
    = %f m^3/m^3 fuel\n',svair);
23
24 // for one m^3 fuel
25 vN2 = CH4*7.52+CO*1.88+H2*1.88-02*.79/.21+N2;//
    volume of N2 produced , [m^3]
26 vCO2 = CH4*1+CO2+CO*1;// volume of CO2 produced , [m
    ^3]
27 vH2O = CH4*2+H2*1;// volume of H2O produced , [m^3]
28
29 vt = vN2+vCO2+vH2O;// total volume of product , [m^3]
30
31 x1 = vN2/vt*100;// %age composition of N2 in product
    ,
32 x2 = vCO2/vt*100;// %age composition of CO2 in
    product
33 x3 = vH2O/vt*100;// %age composition of H2O in
    product
34
35 mprintf('\n N2 in products = %fm^3/m^3 fuel ,
    percentage composition = %f,\n CO2 in products
    = %f m^3/m^3 fuel , percentage composition =
    %f,\n H2O in products = %fm^3/m^3 fuel ,
    percentage composition = %f',vN2,x1,vCO2,x2,
    vH2O,x3);
36
37 // End

```

Scilab code Exa 8.7 composition of gases

```
1 clear;
```

```

2  clc;
3  disp('Example 8.7');
4
5  //  aim : To determine
6  //  the percentage analysis of the gas by mass
7
8  //  Given values
9  C02 = 20; // percentage volumetric composition of
      CO2
10 N2 = 70; // percentage volumetric composition of N2
11 O2 = 10; // percentage volumetric composition of O2
12
13 mC02 = 44; // moleculer mas of CO2
14 mN2 = 28; // moleculer mass of N2
15 mO2 = 32; // moleculer mass of O2
16
17 //  solution
18 mgas = C02*mC02+N2*mN2+O2*mO2; // moleculer mass of
      gas
19 m1 = C02*mC02/mgas*100; // percentage composition of
      CO2 by mass
20 m2 = N2*mN2/mgas*100; // percentage composition of N2
      by mass
21 m3 = O2*mO2/mgas*100; // percentage composition of O2
      by mass
22
23 mprintf('\n Mass percentage of CO2 is = %f\n\n
      Mass percentage of N2 is = %f\n\n Mass
      percentage of O2 is = %f\n',m1,m2,m3 )
24
25 // End

```

Scilab code Exa 8.8 composition of gases

```

1  clear;

```

```

2  clc;
3  disp('Example 8.8');
4
5  //  aim : To determine
6  //  the percentage composition of the gas by volume
7
8  //  given values
9  C0 = 30; // %age mass composition of CO
10 N2 = 20; // %age mass composition of N2
11 CH4 = 15; // %age mass composition of CH4
12 H2 = 25; // %age mass composition of H2
13 O2 = 10; // %age mass composition of O2
14
15 mC0 = 28; // molculer mass of CO
16 mN2 = 28; // molculer mass of N2
17 mCH4 = 16; // molculer mass of CH4
18 mH2 = 2; // molculer mass of H2
19 mO2 = 32; // molculer mass of O2
20
21 // solution
22 vg = C0/mC0+N2/mN2+CH4/mCH4+H2/mH2+O2/mO2;
23 v1 = C0/mC0/vg*100; // %age volume composition of CO
24 v2 = N2/mN2/vg*100; // %age volume composition of N2
25 v3 = CH4/mCH4/vg*100; // %age volume composition of
    CH4
26 v4 = H2/mH2/vg*100; // %age volume composition of H2
27 v5 = O2/mO2/vg*100; // %age volume composition of O2
28
29 mprintf(' \n The percentage composition of CO by
    volume is = %f\n, \n The percentage composition
    of N2 by volume is = %f\n \n The percentage
    composition of CH4 by volume is = %f\n \n The
    percentage composition of H2 by volume is = %f\n
    \n The percentage composition of O2by volume is=
    %f ', v1, v2, v3, v4, v5);
30
31 // End

```

Scilab code Exa 8.9 mass of air supplied

```
1 clear;
2 clc;
3 disp('Example 8.9 ');
4
5 // aim : To determine
6 // the mass of air supplied per kilogram of fuel
   burnt
7
8 // given values
9 CO2 = 8.85; // volume composition of CO2
10 CO = 1.2; // volume composition of CO
11 O2 = 6.8; // volume composition of O2
12 N2 = 83.15; // volume composition of N2
13
14 // composition of gases in the fuel oil
15 C = .84; // mass composition of carbon
16 H = .14; // mass composition of hydrogen
17 o2 = .02; // mass composition of oxygen
18
19 mC = 12; // molculer mass of Carbon
20 mCO2 = 44; // molculer mass of CO2
21 mCO = 28; // molculer mass of CO
22 mN2 = 28; // molculer mass of N2
23 mO2 = 32; // molculer mass of O2
24 aO2 = .23; // mass composition of O2 in air
25
26 // solution
27 ma = (8/3*C+8*H-o2)/aO2; // theoretical mass of air /
   kg fuel , [kg]
28
29 mgas = CO2*mCO2+CO*mCO+N2*mN2+O2*mO2; // total mass
   of gas/kg fuel , [kg]
```

```

30 x1 = CO2*mCO2/mgas; // composition of CO2 by mass
31 x2 = CO*mCO/mgas; // composition of CO by mass
32 x3 = O2*mO2/mgas; // composition of O2 by mass
33 x4 = N2*mN2/mgas; // composition of N2 by mass
34
35 m1 = x1*mC/mCO2+x2*mC/mCO; // mass of C/kg of dry
    flue gas, [kg]
36 m2 = C; // mass of C/kg fuel, [kg]
37 mf = m2/m1; // mass of dry flue gas/kg fuel, [kg]
38 mo2 = mf*x3; // mass of excess O2/kg fuel, [kg]
39 mair = mo2/aO2; // mass of excess air/kg fuel, [kg]
40 m = ma+mair; // mass of excess air supplied/kg fuel,
    [kg]
41
42 mprintf('\n The mass of air supplied per/kg of fuel
    burnt is = %f kg\n',m);
43
44 // End

```

Scilab code Exa 8.10 volumetric composition of products

```

1 clear;
2 clc;
3 disp('Example 8.10 ');
4
5 // aim : To determine
6 // volumetric composition of the products of
    combustion
7
8 // given values
9 C = .86; // mass composition of carbon
10 H = .14; // mass composition of hydrogen
11 Ea = .20; // excess air for combustion
12 O2 = .23; // mass composition of O2 in air
13

```

```

14 MC02 = 44; // moleculer mass of CO2
15 MH20 = 18; // moleculer mass of H2O
16 M02 = 32; // moleculer mass of O2
17 MN2 = 28; // moleculer mass of N2,
18
19
20 // solution
21 s02 = (8/3*C+8*H); // stoichiometric O2 required , [kg
    /kg petrol]
22 sair = s02/02; // stoichiometric air required , [kg/kg
    petrol]
23 // for one kg petrol
24 mC02 = 11/3*C; // mass of CO2, [kg]
25 mH20 = 9*H; // mass of H2O, [kg]
26 m02 = Ea*s02; // mass of O2, [kg]
27 mN2 = 14.84*(1+Ea)*(1-02); // mass of N2, [kg]
28
29 mt = mC02+mH20+m02+mN2; // total mass, [kg]
30 // percentage mass composition
31 x1 = mC02/mt*100; // mass composition of CO2
32 x2 = mH20/mt*100; // mass composition of H2O
33 x3 = m02/mt*100; // mass composition of O2
34 x4 = mN2/mt*100; // mass composition of N2
35
36 vt = x1/MC02+x2/MH20+x3/M02+x4/MN2; // total volume
    of petrol
37 v1 = x1/MC02/vt*100; // %age composition of CO2 by
    volume
38 v2 = x2/MH20/vt*100; // %age composition of H2O by
    volume
39 v3 = x3/M02/vt*100; // %age composition of O2 by
    volume
40 v4 = x4/MN2/vt*100; // %age composition of N2 by
    volume
41
42 mprintf(' \nThe percentage composition of CO2 by
    volume is = %f\n, \nThe percentage composition
    of H2O by volume is = %f\n, \nThe percentage

```

```

    composition of O2 by volume is = %f\n,\nThe
    percentage composition of N2 by volume is = %f\n
    n',v1,v2,v3,v4);
43
44 // End

```

Scilab code Exa 8.11 energy carried away

```

1 clear;
2 clc;
3 disp('Example 8.11 ');
4
5 // aim : To determine
6 // the energy carried away by the dry flue gas/kg
   of fuel burned
7
8 // given values
9 C = .78; // mass composition of carbon
10 H2 = .06; // mass composition of hydrogen
11 O2 = .09; // mass composition of oxygen
12 Ash = .07; // mass composition of ash
13 Ea = .50; // excess air for combustion
14 aO2 = .23; // mass composition of O2 in air
15 Tb = 273+20; // boiler house temperature, [K]
16 Tf = 273+320; // flue gas temperature, [K]
17 c = 1.006; // specific heat capacity of dry flue gas,
   [kJ/kg K]
18
19 // solution
20 // for one kg of fuel
21 sO2 = (8/3*C+8*H2); // stoichiometric O2 required, [
   kg/kg fuel]
22 sO2a = sO2-O2; // stoichiometric O2 required from air
   , [kg/kg fuel]
23 sair = sO2a/aO2; // stoichiometric air required, [kg/

```

```

    kg fuel]
24 ma = sair*(1+Ea); // actual air supplied/kg of fuel ,
    [kg]
25 // total mass of flue gas/kg fuel is
26 mf = ma+1; // [kg]
27 mH2 = 9*H2; //H2 produced , [kg]
28 // hence , mass of dry flue gas/kg coal is
29 m = mf-mH2; // [kg]
30 Q = m*c*(Tf-Tb); // energy carried away by flue gas ,
    [kJ]
31 fprintf('\n The energy carried away by the dry flue
    gas/kg is = %f kg\n',Q);
32
33 // End

```

Scilab code Exa 8.12 stoichiometric volume and composition of products

```

1 clear;
2 clc;
3 disp('Example 8.12 ');
4
5 // aim : To determine
6 // (a) the stoichiometric volume of air for the
    complete combustion of 1 m3
7 // (b) the percentage volumetric analysis of the
    products of combustion
8
9 // given values
10 N2 = .018; // volumetric composition of N2
11 CH4 = .94; // volumetric composition of CH4
12 C2H6 = .035; // volumetric composition of C2H6
13 C3H8 = .007; // volumetric composition of C3H8
14 aO2 = .21; // O2 composition in air
15
16 // solution

```



```

17 // (a)
18 // for CH4
19 // CH4 +2 O2= CO2 + 2 H2O
20 sva1 = 2/a02;// stoichiometric volume of air , [m^3/m
    ^3 CH4]
21 svn1 = sva1*(1-a02);// stoichiometric volume of
    nitrogen in the air , [m^3/m^3 CH4]
22
23 // for C2H6
24 // 2 C2H6 +7 O2= 4 CO2 + 6 H2O
25 sva2 = 7/2/a02;// stoichiometric volume of air , [m
    ^3/m^3 C2H6]
26 svn2 = sva2*(1-a02);// stoichiometric volume of
    nitrogen in the air , [m^3/m^3 C2H6]
27
28 // for C3H8
29 // C3H8 +5 O2=3 CO2 + 4 H2O
30 sva3 = 5/a02;// stoichiometric volume of air , [m^3/m
    ^3 C3H8]
31 svn3 = sva3*(1-a02);// stoichiometric volume of
    nitrogen in the air , [m^3/m^3 C3H8]
32
33 Sva = CH4*sva1+C2H6*sva2+C3H8*sva3;// stoichiometric
    volume of air required , [m^3/m^3 gas]
34 mprintf('\n (a) The stoichiometric volume of air for
    the complete combustion = %f m^3m^3 gas\n',Sva
    );
35
36 // (b)
37 // for one m^3 of natural gas
38 vCO2 = CH4*1+C2H6*2+C3H8*3;// volume of CO2 produced
    , [m^3]
39 vH2O = CH4*2+C2H6*3+C3H8*4;// volume of H2O produced
    , [m^3]
40 vN2 = CH4*svn1+C2H6*svn2+C3H8*svn3+N2;// volume of
    N2 produced , [m^3]
41
42 vg = vCO2+vH2O+vN2;// total volume of gas , [m^3]

```

```

43 x1 = vCO2/vg*100; // volume percentage of CO2
    produced
44 x2 = vH2O/vg*100; // volume percentage of H2O
    produced
45 x3 = vN2/vg*100; // volume percentage of N2 produced
46
47 mprintf('\n (b) The percentage volumetric
    composition of CO2 in produced is = %f\n,\n
    The percentage volumetric composition of H2O
    in produced is = %f\n,\n The percentage
    volumetric composition of N2 in produced is =
    %f\n',x1,x2,x3);
48
49 // End

```

Scilab code Exa 8.13 volume and composition by mass

```

1 clear;
2 clc;
3 disp('Example 8.13');
4
5 // aim : To determine
6 // (a) the volume of air taken by the fan
7 // (b) the percentage composition of dry flue gas
8
9 // gien values
10 C = .82; // mass composition of carbon
11 H = .08; // mass composition of hydrogen
12 O = .03; // mass composition of oxygen
13 A = .07; // mass composition of ash
14 mc = .19; // coal uses, [kg/s]
15 ea = .3; // percentage excess air of oxygen in the
    air required for combustion
16 Oa = .23; // percentage of oxygen by mass in the air
17

```

```

18 // solution
19 // (a)
20 P = 100; // air pressure , [kN/m^2]
21 T = 18+273; // air temperature , [K]
22 R = .287; // [kJ/kg K]
23 // basis one kg coal
24 sO2 = 8/3*C+8*H; // stoichiometric O2 required , [kg]
25 aO2 = sO2-.03; // actual O2 required , [kg]
26 tO2 = aO2/Oa; // theoretical O2 required , [kg]
27 Aa = tO2*(1+ea); // actual air supplied , [kg]
28 m = Aa*mc; // Air supplied , [kg/s]
29
30 // now using P*V=m*R*T
31 V = m*R*T/P; // volume of air taken ,[m^3/s]
32 mprintf('\n (a) Volume of air taken by fan is = %f
          m^3/s\n',V);
33
34 // (b)
35 mCO2 = 11/3*C; // mass of CO2 produced , [kg]
36 mO2 = aO2*.3; // mass of O2 produces , [kg]
37 mN2 = Aa*.77; // mass of N2 produced , [[kg]
38 mt = mCO2+mO2+mN2; // total mass , [kg]
39
40 mprintf('\n (b) Percentage mass composition of CO2
          is = %f percent \n',mCO2/mt*100);
41 mprintf('\n      Percentage mass composition of O2 is
          = %f percent\n',mO2/mt*100)
42 mprintf('\n      Percentage mass composition of N2 is
          = %f percent \n',mN2/mt*100)
43
44
45
46 // End

```

Scilab code Exa 8.14 mass and volume

```

1 clear;
2 clc;
3 disp('Example 8.14');
4
5 // aim : To determine
6 // (a) the mass of fuel used per cycle
7 // (b) the actual mass of air taken in per cycle
8 // (c) the volume of air taken in per cycle
9
10 // given values
11 W = 15; // work done, [kJ/s]
12 N = 5; // speed, [rev/s]
13 C = .84; // mass composition of carbon
14 H = .16; // mass composition of hydrogen
15 ea = 1; // percentage excess air supplied
16 CV = 45000; // calorific value of fuel, [kJ/kg]
17 n_the = .3; // thermal efficiency
18 P = 100; // pressure, [kN/m^2]
19 T = 273+15; // temperature, [K]
20 R = .29; // gas constant, [kJ/kg K]
21
22 // solution
23 // (a)
24 E = W*2/N/n_the; // energy supplied, [kJ/cycle]
25 mf = E/CV; // mass of fuel used, [kg]
26 fprintf('\n (a) Mass of fuel used per cycle is =
    %f g\n',mf*10^3);
27
28 // (b)
29 // basis 1 kg fuel
30 mO2 = C*8/3+8*H; // mass of O2 required, [kg]
31 smO2 = mO2/.23; // stoichiometric mass of air, [kg]
32 ma = smO2*(1+ea); // actual mass of air supplied, [kg
    ]
33 m = ma*mf; // mass of air supplied, [kg/cycle]
34 fprintf('\n (b) The mass of air supplied per cycle
    is = %f kg\n',m);
35

```

```

36 // (c)
37 V = m*R*T/P; // volume of air , [m^3]
38 mprintf('\n (c) The volume of air taken in per cycle
        is = %f m^3\n',V);
39
40 // End

```

Scilab code Exa 8.15 mass and composition

```

1 clear;
2 clc;
3 disp('Example 8.15 ');
4
5 // aim : To determine
6 // (a) the mass of coal used per hour
7 // (b) the mass of air used per hour
8 // (c) the percentage analysis of the flue gases by
    mass
9
10 // given values
11 m = 900; // mass of steam boiler generate/h, [kg]
12 x = .96; // steam dryness fraction
13 P = 1400; // steam pressure , [kN/m^2]
14 Tf = 52; // feed water temperature , [C]
15 BE = .71; // boiler efficiency
16 CV = 33000; // calorific value of coal, [kJ/kg]
17 ea = .22; // excess air supply
18 aO2 = .23; // oxygen composition in air
19 c = 4.187; // specific heat capacity of water, [kJ/kg
    K]
20
21 // coal composition
22 C = .83; // mass composition of carbon
23 H2 = .05; // mass composition of hydrogen
24 O2 = .03; // mass composition of oxygen

```

```

25 ash = .09; // mass composition of ash
26
27 // solution
28 // from steam table at pressure P
29 hf = 830.1; // specific enthalpy, [kJ/kg]
30 hfg = 1957.1; // specific enthalpy, [kJ/kg]
31 hg = 2728.8; // specific enthalpy, [kJ/kg]
32
33 // (a)
34 h = hf+x*hfg; // specific enthalpy of steam generated
    by boiler, [kJ/kg]
35 hfw = c*Tf; // specific enthalpy of feed water, [kJ/
    kg]
36 Q = m*(h-hfw); // energy to steam/h, [kJ]
37 Qf = Q/BE; // energy required from fuel/h, [kJ]
38 mc = Qf/CV; // mass of coal/h, [kg]
39 mprintf(' \n (a) The mass of coal used per hour is =
    %f kg \n ', mc);
40
41 // (b)
42 // for one kg coal
43 mO2 = 8/3*C+8*H2+-O2; // actual mass of O2 required,
    [kg]
44 mta = mO2/aO2; // theoretical mass of air, [kg]
45 ma = mta*(1+ea); // mass of air supplied, [kg]
46 mas = ma*mc; // mass of air supplied/h, [kg]
47 mprintf(' \n (b) The mass of air supplied per hour is
    = %f kg \n ', mas);
48
49
50 // (c)
51 // for one kg coal
52 mCO2 = 11/3*C; // mass of CO2 produced, [kg]
53 mH2O = 9*H2; // mass of H2O produced, [kg]
54 mO2 = mO2*ea; // mass of excess O2 in flue gas, [kg]
55 mN2 = ma*(1-aO2); // mass of N2 in flue gas, [kg]
56
57 mt = mCO2+mH2O+mO2+mN2; // total mass of gas

```

```

58 x1 = mCO2/mt*100; // mass percentage composition of
    CO2
59 x2 = mH2O/mt*100; // mass percentage composition of
    H2O
60 x3 = mO2/mt*100; // mass percentage composition of O2
61 x4 = mN2/mt*100; // mass percentage composition of N2
62
63 mprintf('\n (c) The mass percentage composition of
    CO2 = %f,\n      The mass percentage
    composition of H2O = %f,\n      The mass
    percentage composition of O2 = %f,\n      The
    mass percentage composition of N2 = %f',x1,x2,
    x3,x4);
64
65 // mass of coal taken in part (b) is wrong so
    answer is not matching
66
67 // End

```

Scilab code Exa 8.16 volume average molecular mass characteristic gas constant and density

```

1 clear;
2 clc;
3 disp('Example 8.16');
4
5 // aim : To determine
6 // (a) volume of gas
7 // (b) (1) the average molecular mass of air
8 //      (2) the value of R
9 //      (3) the mass of 1 m3 of air at STP
10
11 // given values
12 n = 1; // moles of gas , [kmol]
13 P = 101.32; // standard pressure , [kN/m2]

```

```

14 T = 273; // gas temperature, [K]
15
16 O2 = 21; // percentage volume composition of oxygen
    in air
17 N2 = 79; // percentage volume composition of nitrogen
    in air
18 R = 8.3143; // molar gas constant, [kJ/kg K]
19 mO2 = 32; // molecular mass of O2
20 mN2 = 28; // molecular mass of N2
21
22 // solution
23 // (a)
24 V = n*R*T/P; // volume of gas, [m^3]
25 fprintf('\n (a) The volume of the gas is = %f m^3\n',V);
26
27 // (b)
28 // (1)
29 Mav = (O2*mO2+N2*mN2)/(O2+N2); // average molecular
    mass of air
30 fprintf('\n (b)(1) The average molecular mass of air
    is = %f g/mol\n',Mav);
31
32 // (2)
33 Rav = R/Mav; // characteristic gas constant, [kJ/kg k
    ]
34 fprintf('\n      (2) The value of R is = %f kJ/kg
    K\n',Rav);
35
36 // (3)
37 rho = Mav/V; // density of air, [kg/m^3]
38 fprintf('\n      (3) The mass of one cubic metre of
    air at STP is = %f kg/m^3\n',rho);
39
40 // End

```

Scilab code Exa 8.17 pressures and volume

```
1 clear;
2 clc;
3 disp('Example 8.17');
4
5 // aim : To determine
6 // (a) the partial pressure of each gas in the
   vessel
7 // (b) the volume of the vessel
8 // (c) the total pressure in the gas when
   temperature is raised to 228 C
9
10 // given values
11 M02 = 8; // mass of O2, [kg]
12 MN2 = 7; // mass of N2, [kg]
13 MC02 = 22; // mass of CO2, [kg]
14
15 P = 416; // total pressure in the vessel, [kN/m^2]
16 T = 273+60; // vessel temperature, [K]
17 R = 8.3143; // gas constant, [kJ/kmol K]
18
19 m02 = 32; // molecular mass of O2
20 mN2 = 28; // molecular mass of N2
21 mC02 = 44; // molecular mass of CO2
22
23 // solution
24 // (a)
25 n1 = M02/m02; // moles of O2, [kmol]
26 n2 = MN2/mN2; // moles of N2, [kmol]
27 n3 = MC02/mC02; // moles of CO2, [kmol]
28
29 n = n1+n2+n3; // total moles in the vessel, [kmol]
30 // since, Partial pressure is proportional, so
```

```

31 P1 = n1*P/n; // partial pressure of O2, [kN/m^2]
32 P2 = n2*P/n; // partial pressure of N2, [kN/m^2]
33 P3 = n3*P/n; // partial pressure of CO2, [kN/m^2]
34
35 mprintf('\n (a) The partial pressure of O2 is = %f
           kN/m^2,\n, The partial pressure of N2 is =
           %f kN/m^2,\n The partial pressure of CO2 is
           = %f kN/m^2,\n',P1,P2,P3);
36
37 // (b)
38 // assuming ideal gas
39 V = n*R*T/P; // volume of the container, [m^3]
40 mprintf('\n (b) The volume of the container is =
           %f m^3\n',V);
41
42 // (c)
43 T2 = 273+228; // raised vessel temperature, [K]
44 // so volume of vessel will constant, P/T=constant
45 P2 = P*T2/T; // new pressure in the vessel, [kn/m62]
46 mprintf('\n (c) The new total pressure in the vessel
           is = %f kN/m^2\n',P2);
47
48 // End

```

Scilab code Exa 8.18 mass and velocity

```

1 clear;
2 clc;
3 disp('Example 8.18 ');
4
5 // aim : To determine
6 // the actual mass of air supplied/kg coal
7 // the velocity of flue gas
8
9 // given values

```

```

10 mc = 635; // mass of coal burn/h, [kg]
11 ea = .25; // excess air required
12 C = .84; // mass composition of carbon
13 H2 = .04; // mass composition of hydrogen
14 O2 = .05; // mass composition of oxygen
15 ash = 1-(C+H2+O2); // mass composition of ash
16
17 P1 = 101.3; // pressure, [kN/m^2]
18 T1 = 273; // temperature, [K]
19 V1 = 22.4; // volume, [m^3]
20
21 T2 = 273+344; // gas temperature, [K]
22 P2 = 100; // gas pressure, [kN/m^2]
23 A = 1.1; // cross section area, [m^2]
24 aO2 = .23; // composition of O2 in air
25
26 mCO2 = 44; // molecular mass of carbon
27 mH2O = 18; // molecular mass of hydrogen
28 mO2 = 32; // molecular mass of oxygen
29 mN2 = 28; // molecular mass of nitrogen
30
31 // solution
32 mtO2 = 8/3*C+8*H2-O2; // theoretical O2 required/kg
    coal, [kg]
33 msa = mtO2/aO2; // stoichiometric mass of air
    supplied/kg coal, [kg]
34 mas = msa*(1+ea); // actual mass of air supplied/kg
    coal, [kg]
35
36 m1 = 11/3*C; // mass of CO2/kg coal produced, [kg]
37 m2 = 9*H2; // mass of H2/kg coal produced, [kg]
38 m3 = mtO2*ea; // mass of O2/kg coal produced, [kg]
39 m4 = mas*(1-aO2); // mass of N2/kg coal produced, [kg
    ]
40
41 mt = m1+m2+m3+m4; // total mass, [kg]
42 x1 = m1/mt*100; // %age mass composition of CO2
    produced

```

```

43 x2 = m2/mt*100; // %age mass composition of H2O
    produced
44 x3 = m3/mt*100; // %age mass composition of O2
    produced
45 x4 = m4/mt*100; // %age mass composition of N2
    produced
46
47 vt = x1/mCO2+x2/mH2O+x3/mO2+x4/mN2; // total volume
48 v1 = x1/mCO2/vt*100; // %age volume composition of
    CO2
49 v2 = x2/mH2O/vt*100; // %age volume composition of
    H2O
50 v3 = x3/mO2/vt*100; // %age volume composition of O2
51 v4 = x4/mN2/vt*100; // %age volume composition of N2
52
53 Mav = (v1*mCO2+v2*mH2O+v3*mO2+v4*mN2)/(v1+v2+v3+v4);
    // average molecular mass, [kg/kmol]
54 // since no of moles is constant so PV/T=constant
55 V2 = P1*V1*T2/(P2*T1); // volume, [m^3]
56
57 mp = mt*mc/3600; // mass of product of combustion/s,
    [kg]
58
59 V = V2*mp/Mav; // volume of flowing gas /s, [m^3]
60
61 v = V/A; // velocity of flue gas, [m/s]
62 mprintf('\n The actual mass of air supplied is =
    %f kg/kg coal\n',mas);
63 mprintf('\n The velocity of flue gas is = %f m/s\n
    ',v);
64
65 // End

```

Scilab code Exa 8.19 temperature and density

```

1 clear;
2 clc;
3 disp('Example 8.19');
4
5 // aim : To determine
6 // (a) the temperature of the gas after compression
7 // (b) the density of the air-gas mixture
8
9 // given values
10 CO = 26; // %age volume composition of CO
11 H2 = 16; // %age volume composition of H2
12 CH4 = 7; // %age volume composition of CH4
13 N2 = 51; // %age volume composition of N2
14
15 P1 = 103; // gas pressure , [kN/m^2]
16 T1 = 273+21; // gas temperature , [K]
17 rv = 7; // volume ratio
18
19 aO2 = 21; // %age volume composition of O2 in the air
20 c = 21; // specific heat capacity of diatomic gas , [
    kJ/kg K]
21 cCH4 = 36; // specific heat capacity of CH4, [kJ/kg K
    ]
22 R = 8.3143; // gas constant , [kJ/kg K]
23
24 mCO = 28; // moleculer mass of carbon
25 mH2 = 2; // moleculer mass of hydrogen
26 mCH4 = 16; // moleculer mas of methane
27 mN2 = 28; // moleculer mass of nitrogen
28 mO2 = 32; // moleculer mass of oxygen
29
30 // solution
31 // (a)
32 Cav = (CO*c+H2*c+CH4*cCH4+N2*c+100*2*c)/(100+200); //
    heat capacity , [kJ/kg K]
33
34 Gama = (Cav+R)/Cav; // heat capacity ratio
35 // rv = V1/V2

```

```

36 // process is polytropic , so
37 T2 = T1*(rv)^(Gama-1); // final tempearture , [K]
38 mprintf('\n (a) The temperature of the gas after
      compression is = %f C\n',T2-273);
39
40 // (b)
41
42 Mav = (C0*mC0+H2*mH2+CH4*mCH4+N2*mN2+42*mO2+158*mN2)
      /(100+200)
43
44 // for 1 kmol of gas
45 V = R*T1/P1; // volume of one kmol of gas , [m^3]
46 // hence
47 rho = Mav/V; // density of gas , [kg/m^3]
48
49 mprintf('\n (b) The density of air-gas mixture is =
      %f kg/m^3\n',rho);
50
51 // End

```

Scilab code Exa 8.20 stoichiometric equation

```

1 clear;
2 clc;
3 disp('Example 8.20 ');
4
5 // aim : to determine
6 // stoichiometric equation for combustion of
  hydrogen
7
8 // solution
9 // equation with algebraic coefficient is
10 //  $H_2+aO_2+79/21*aN_2=bH_2O+79/21*aN_2$ 
11 // by equating coefficients
12 b = 1;

```

```

13 a = b/2;
14 // so equation becomes
15 // 2 H2+ O2+3.76 N2=2 H2O+3.76 N2
16 disp('The required stoichiometric equation is = ')
    ;
17 disp('2 H2+ O2+3.76 N2 = 2 H2O+3.76 N2');
18
19 // End

```

Scilab code Exa 8.22 gravimetric composition

```

1 clear;
2 clc;
3 disp('Example 8.22 ');
4
5 // aim : To determine
6 // the percentage gravimetric analysis of the total
   products of combustion
7
8 // given values
9 CO = 12; // %age volume composition of CO
10 H2 = 41; // %age volume composition of H2
11 CH4 = 27; // %age volume composition of CH4
12 O2 = 2; // %age volume composition of O2
13 CO2 = 3; // %age volume composition of CO2
14 N2 = 15; // %age volume composition of N2
15
16 mCO2 = 44; // moleculer mass of CO2, [kg/kmol]
17 mH2O = 18; // moleculer mass of H2O, [kg/kmol]
18 mO2 = 32; // moleculer mass of O2, [kg/kmol]
19 mN2 = 28; // moleculer mass of N2, [kg/kmol]
20
21 ea = 15; // %age excess air required
22 aO2 = 21; // %age air composition in the air
23

```

```

24 // solution
25 // combustion equation by no. of moles
26 // 12CO + 41H2 + 27CH4 + 2O2 + 3CO2 + 15N2 + aO2
    +79/21*aN2 = bCO2 + dH2O + eO2 + 15N2 +79/21*aN2
27 // equating C coefficient
28 b = 12+27+3; // [mol]
29 // equating H2 coefficient
30 d = 41+2*27; // [mol]
31 // O2 required is 15 % extra ,so
32 // e/(e-a)=.15 so e=.13a
33 // equating O2 coefficient
34 // 2+3+a=b+d/2 +e
35
36 a = (b+d/2-5)/(1-.13);
37 e = .13*a; // [mol]
38
39 // gravimetric analysis of product
40 v1 = b*mCO2; // gravimetric volume of CO2
41 v2 = d*mH2O ; // gravimetric volume of H2O
42 v3 = e*mO2; // gravimetric volume of O2
43 v4 = 15*mN2 +79/21*a*mN2; // gravimetric volume of N2
44
45 vt = v1+v2+v3+v4; // total
46 x1 = v1/vt*100; // percentage gravimetric of CO2
47 x2 = v2/vt*100; // percentage gravimetric of H2O
48 x3 = v3/vt*100; // percentage gravimetric of O2
49 x4 = v4/vt*100; // percentage gravimetric of N2
50
51 mprintf('\n Percentage gravimetric composition of
    CO2 = %f\n ,\n Percentage gravimetric
    composition of H2O = %f\n\n Percentage
    gravimetric composition of O2 = %f\n\n
    Percentage gravimetric composition of N2 = %f\n
    ',x1,x2,x3,x4);
52
53 // End

```

Scilab code Exa 8.23 mass and volumetric efficiency

```
1 clear;
2 clc;
3 disp('Example 8.23 ');
4
5 // aim : To determine
6 // (a) the actual quantity of air supplied/kg of
   fuel
7 // (b) the volumetric efficiency of the engine
8
9 // given values
10 d = 300*10^-3; // bore ,[m]
11 L = 460*10^-3; // stroke ,[m]
12 N = 200; // engine speed , [rev/min]
13
14 C = 87; // %age mass composition of Carbon in the
   fuel
15 H2 = 13; // %age mass composition of H2 in the fuel
16
17 mc = 6.75; // fuel consumption , [kg/h]
18
19 CO2 = 7; // %age composition of CO2 by volume
20 O2 = 10.5; // %age composition of O2 by volume
21 N2 = 7; // %age composition of N2 by volume
22
23 mC = 12; // moleculer mass of CO2, [kg/kmol]
24 mH2 = 2; // moleculer mass of H2, [kg/kmol]
25 mO2 = 32; // moleculer mass of O2, [kg/kmol]
26 mN2 = 28; // moleculer mass of N2, [kg/kmol]
27
28 T = 273+17; // atmospheric temperature , [K]
29 P = 100; // atmospheric pressure , [kn/m^2]
30 R = .287; // gas constant , [kJ/kg k]
```

```

31
32 // solution
33 // (a)
34 // combustion equation by no. of moles
35 //  $87/12 C + 13/2 H_2 + a O_2 + 79/21*a N_2 = b CO_2 + d$ 
     $H_2O + eO_2 + f N_2$ 
36 // equating coefficient
37 b = 87/12; // [mol]
38 a = 22.7; // [mol]
39 e = 10.875; // [mol]
40 f = 11.8*b; // [mol]
41 // so fuel side combustion equation is
42 //  $87/12 C + 13/2 H_2 + 22.7 O_2 + 85.5 N_2$ 
43 mair = ( 22.7*mO2 +85.5*mN2)/100; // mass of air/kg
    fuel, [kg]
44 mprintf('\n (a) The mass of actual air supplied per
    kg of fuel is = %f kg\n',mair);
45
46 // (b)
47 m = mair*mc/60; // mass of air/min, [kg]
48 V = m*R*T/P; // volumetric flow of air/min, [m^3]
49 SV = %pi/4*d^2*L*N/2; // swept volume/min, [m^3]
50
51 VE = V/SV; // volumetric efficiency
52 mprintf('\n (b) The volumetric efficiency of the
    engine is = %fpercent\n',VE*100);
53
54 // End

```

Scilab code Exa 8.24 mass of air

```

1 clear;
2 clc;
3 disp('Example 8.24 ');
4

```

```

5 // aim : To determine
6 // the mass of air supplied/kg of fuel burnt
7
8 // given values
9 // gas composition in the fuel
10 C = 84; // %age mass composition of Carbon in the
    fuel
11 H2 = 14; // %age mass composition of H2 in the fuel
12 O2f = 2; // %age mass composition of O2 in the fuel
13
14 // exhaust gas composition
15 CO2 = 8.85; // %age composition of CO2 by volume
16 CO = 1.2; // %age composition of CO by volume
17 O2 = 6.8; // %age composition of O2 by volume
18 N2 = 83.15; // %age composition of N2 by volume
19
20 mC = 12; // molecular mass of CO2, [kg/kmol]
21 mH2 = 2; // molecular mass of H2, [kg/kmol]
22 mO2 = 32; // molecular mass of O2, [kg/kmol]
23 mN2 = 28; // molecular mass of N2, [kg/kmol]
24
25 // solution
26 // combustion equation by no. of moles
27 // 84/12 C + 14/2 H2 + 2/32 O2 + a O2 + 79.3/20.7*a N2
    = b CO2 + d CO + e O2 + f N2 + g H2
28 // equating coefficient and given condition
29 b = 6.16; // [mol]
30 a = 15.14; // [mol]
31 d = .836; // [mol]
32 f = 69.3*d; // [mol]
33 // so fuel side combustion equation is
34 // 84/12 C + 14/2 H2 + 2/32 O2 + 15.14 O2 + 85.5 N2
35 mair = ( a*mO2 + f*mN2)/100; // mass of air/kg fuel, [
    kg]
36 mprintf(' \n The mass of air supplied per kg of fuel
    is = %f kg \n ', mair);
37
38 // End

```


Chapter 9

Heat transfer

Scilab code Exa 9.1 interface temperature

```
1 clear;
2 clc;
3 disp('Example 9.1 ');
4
5 // aim : To determine
6 // the heat loss per hour through the wall and
   interface temperature
7
8 // Given values
9 x1 = .25; // thickness of brick ,[m]
10 x2 = .05; // thickness of concrete ,[m]
11 t1 = 30; // brick face temperature ,[C]
12 t3 = 5; // concrete face temperature ,[C]
13 l = 10; // length of the wall , [m]
14 h = 5; // height of the wall , [m]
15 k1 = .69; // thermal conductivity of brick ,[W/m/K]
16 k2 = .93; // thermal conductivity of concrete ,[W/m/K]
17
18 // solution
19 A = l*h; // area of heat transfer ,[m^2]
20 Q_dot = A*(t1-t3)/(x1/k1+x2/k2); // heat transferred ,
```

```

    [J/s]
21
22 // so heat loss per hour is
23 Q = Q_dot*3600*10^-3; // [kJ]
24 mprintf('\n The heat lost per hour is = %f kJ\n',
    Q);
25
26 // interface temperature calculation
27 // for the brick wall, Q_dot=k1*A*(t1-t2)/x1;
28 // hence
29 t2 = t1-Q_dot*x1/k1/A; // [C]
30 mprintf('\n The interface temperature is = %f C\n',
    ,t2);
31
32 // End

```

Scilab code Exa 9.2 thickness of lagging

```

1 clear;
2 clc;
3 disp('Example 9.2 ');
4
5 // aim : To determine
6 // the minimum
7 // thickness of the lagging required
8
9 // Given values
10 r1 = 75/2; // external radius of the pipe ,[mm]
11 L = 80; // length of the pipe ,[m]
12 m_dot = 1000; // flow of steam , [kg/h]
13 P = 2; // pressure , [MN/m^2]
14 x1 = .98; // inlet dryness fraction
15 x2 = .96; // outlet dryness fraction
16 k = .08; // thermal conductivity of pipe , [W/m/K]
17 t2 = 27; // outside temperature ,[C]

```

```

18
19 // solution
20 // using steam table at 2 MN/m^2 the enthalpy of
    evaporation of steam is ,
21 hfg = 1888.6; // [kJ/kg]
22 // so heat loss through the pipe is
23 Q_dot = m_dot*(x1-x2)*hfg/3600; // [kJ]
24
25 // also from steam table saturation temperature of
    steam at 2 MN/m^2 is ,
26 t1 = 212.4; // [C]
27 // and for thick pipe , Q_dot=k*2*%pi*L*(t1-t2)/log(
    r2/r1)
28 // hence
29 r2 = r1*exp(k*2*%pi*L*(t1-t2)*10^-3/Q_dot); // [mm]
30
31 t = r2-r1; // thickness , [mm]
32
33 mprintf('\n The minimum thickness of the lagging
    required is = %f mm\n',t);
34
35 // End

```

Scilab code Exa 9.3 heat lost and interface temperature

```

1 clear;
2 clc;
3 disp('Example 9.3 ');
4
5 // aim : To determine the
6 // (a) heat loss per hour
7 // (b) interface temperature og lagging
8
9 // Given values
10 r1 = 50; // radius of steam main , [mm]

```

```

11 r2 = 90; // radius with first lagging , [mm]
12 r3 = 115; // outside radius of steam main with
    lagging , [mm]
13 k1 = .07; // thermal conductivity of 1st lagging , [W/m
    /K]
14 k2 = .1; // thermal conductivity of 2nd lagging , [W/m
    /K]
15 P = 1.7; // steam pressure , [MN/m^2]
16 t_superheat = 30; // superheat of steam , [K]
17 t3 = 24; // outside temperature of the lagging , [C]
18 L = 20; // length of the steam main , [m]
19
20 // solution
21 // (a)
22 // using steam table saturation temperature of
    steam at 1.7 MN/m^2 is
23 t_sat = 204.3; // [C]
24 // hence
25 t1 = t_sat+t_superheat; // temperature of steam , [C]
26
27 Q_dot = 2*pi*L*(t1-t3)/(log(r2/r1)/k1+log(r3/r2)/k2
    ); // heat loss , [W]
28 // heat loss in hour is
29 Q = Q_dot*3600*10^-3; // [kJ]
30
31 fprintf('\n (a) The heat lost per hour is = %f kJ\
    n', Q);
32
33 // (b)
34 // using Q_dot=2*pi*k1*(t1-t1)/log(r2/r1)
35 t2 = t1-Q_dot*log(r2/r1)/(2*pi*k1*L); // interface
    temperature of lagging , [C]
36
37 fprintf('\n (b) The interface temperature of the
    lagging is = %f C\n', t2);
38
39 // There is some calculation mistake in the book so
    answer is not matching

```



```
40
41 // End
```

Scilab code Exa 9.4 energy emitted

```
1 clear;
2 clc;
3 disp('Example 9.4');
4
5 // aim : To determine
6 // the energy emitted from the surface
7
8 // Given values
9 h = 3; // height of surface , [m]
10 b = 4; // width of surface , [m]
11 epsilon_s = .9; // emissivity of the surface
12 T = 273+600; // surface temperature ,[K]
13 sigma = 5.67*10^-8; // [W/m^2/K^4]
14
15 // solution
16 As = h*b; // area of the surface , [m^2]
17
18 Q_dot = epsilon_s*sigma*As*T^4*10^-3; // energy
    emitted , [kW]
19
20 mprintf('\n The energy emitted from the surface is
    = %f kW\n',Q_dot);
21
22 // End
```

Scilab code Exa 9.5 Rate of heat transfer

```
1 clear;
```

```

2  clc;
3  disp('Example 9.5 ');
4
5  //  aim : To determine
6  //  the rate of energy transfer between furnace and
    the sphere and its direction
7
8  //  Given values
9  l = 1.25; // internal side of cubical furnace , [m]
10 ti = 800+273; // internal surface temperature of the
    furnace ,[K]
11 r = .2; // sphere radius , [m]
12 epsilon = .6; // emissivity of sphere
13 ts = 300+273; // surface temperature of sphere , [K]
14 sigma = 5.67*10^-8; // [W/m^2/K^4]
15
16 //  Solution
17 Af = 6*l^2; // internal surface area of furnace , [m
    ^2]
18 As = 4 *%pi*r^2; // surface area of sphere , [m^2]
19
20 //  considering internal furnace to be black
21 Qf = sigma*Af*ti^4*10^-3; // [kW]
22
23 //  radiation emitted by sphere is
24 Qs = epsilon*sigma*As*ts^4*10^-3; // [kW]
25
26 //  Hence transfer of energy is
27 Q = Qf-Qs; // [kW]
28
29 mprintf(' \n The transfer of energy will be from
    furnace to sphere and transfer rate is = %f kW \
    n ',Q);
30
31 //  There is some calculation mistake in the book
    so answer is not matching
32
33 //  End

```

Scilab code Exa 9.6 overall heat transfer coefficient and heat lost

```
1 clear;
2 clc;
3 disp('Example 9.6 ');
4
5 // aim : To determine
6 // the overall transfer coefficient and the heat
   loss per hour
7
8 // Given values
9 x1 = 25*10^-3; // Thickness of insulating board, [m]
10 x2 = 75*10^-3; // Thickness of fibreglass, [m]
11 x3 = 110*10^-3; // Thickness of brickwork, [m]
12 k1 = .06; // Thermal conductivity of insulating board
   , [W/m K]
13 k2 = .04; // Thermal conductivity of fibreglass, [W/m
   K]
14 k3 = .6; // Thermal conductivity of brickwork, [W/m K
   ]
15 Us1 = 2.5; // surface heat transfer coefficient of
   the inside wall, [W/m^2 K]
16 Us2 = 3.1; // surface heat transfer coefficient of
   the outside wall, [W/m^2 K]
17 ta1 = 27; // internal ambient temperature, [C]
18 ta2 = 10; // external ambient temperature, [C]
19 h = 6; // height of the wall, [m]
20 l = 10; // length of the wall, [m]
21
22 // solution
23 U = 1/(1/Us1+x1/k1+x2/k2+x3/k3+1/Us2); // overall
   heta transfer coefficient, [W/m^2 K]
24
25 A = l*h; // area, [m^2]
```

```

26
27 Q_dot = U*A*(ta1-ta2); // heat loss [W]
28
29 // so heat loss per hour is
30 Q = Q_dot*3600*10^-3; // [kJ]
31 mprintf('\n The overall heat transfer coefficient
    for the wall is = %f W/m^2 K\n',U);
32 mprintf('\n The heat loss per hour through the wall
    is = %f kJ\n',Q);
33
34 // End

```

Scilab code Exa 9.7 heat lost and surface temperature of lagging

```

1 clear;
2 clc;
3 disp('Example 9.7 ');
4
5 // aim : To determine
6 // the heat loss per hour and the surface
    temperature of the lagging
7
8 // Given values
9 r1 = 75*10^-3; // External radiou of the pipe , [m]
10 t_l1 = 40*10^-3; // Thickness of lagging1 , [m]
11 t_l2 = t_l1;
12 k1 = .07; // thermal conductivity of lagging1 , [W/m K
    ]
13 k2 = .1; // thermal conductivity of lagging2 , [W/m K]
14 Us = 7; // surface transfer coefficient for outer
    surface , [W/m^2 K]
15 L = 50; // length of the pipe , [m]
16 ta = 27; // ambient temperature , [C]
17 P = 3.6; // wet steam pressure , [MN/m^2]
18

```

```

19 // solution
20 // from steam table saturation temperature of the
    steam at given pressure is ,
21 t1 = 244.2; // [C]
22 r2 = r1+t_l1; // radius of pipe with lagging1 , [m]
23 r3 = r2+t_l2; // radius of pipe with both the
    lagging , [m]
24
25 R1 = log(r2/r1)/(2*pi*L*k1); // resistance due to
    lagging1 , [C/W]
26 R2 = log(r3/r2)/(2*pi*L*k2); // resistance due to
    lagging2 , [C/W]
27 R3 = 1/(Us*2*pi*r3*L); // ambient resistance , [C/W]
28
29 // hence overall resistance is ,
30 Req = R1+R2+R3; // [C/W]
31 tdf = t1-ta; // temperature driving force , [C]
32 Q_dot = tdf/Req; // rate of heat loss , [W]
33 // so heat loss per hour is ,
34 Q = Q_dot*3600*10^-3; // heat loss per hour , [kJ]
35
36 // using eqn [3]
37 t3 = ta+Q_dot*R3; // surface temperature of the
    lagging , [C]
38
39 fprintf('\n The heat loss per hour is = %f kJ\n',
    Q);
40 fprintf('\n The surface temperature of the lagging
    is = %f C\n',t3);
41
42 // there is minor variation in the answer
43
44 // End

```

Chapter 10

Steam plant

Scilab code Exa 10.1 equivalent evaporation

```
1 clear;
2 clc;
3 disp('Example 10.1 ');
4
5 // aim : To determine
6 // the equivalent evaporation
7
8 // Given
9 P = 1.4; // [MN/m^2]
10 m = 8; // mass of water, [kg]
11 T1 = 39; // entering temperature, [C]
12 T2 = 100; // [C]
13 x = .95; // dryness fraction
14
15 // solution
16 hf = 830.1; // [kJ/kg]
17 hfg = 1957.7; // [kJ/kg]
18 // steam is wet so specific enthalpy of steam is
19 h = hf+x*hfg; // [kJ/kg]
20
21 // at 39 C
```

```

22 h1 = 163.4; // [kJ/kg]
23 // hence
24 q = h-h1; // [kJ/kg]
25 Q = m*q; // [kJ]
26
27 evap = Q/2256.9; // equivalent evaporation [kg steam
    /(kg coal)]
28
29 mprintf('\n The equivalent evaporation, from and at
    100 C is = %f kg steam/kg coal\n ',evap);
30
31 // End

```

Scilab code Exa 10.2 mass fraction of enthalpy drop and heat transfer

```

1 clear;
2 clc;
3 disp('Example 10.2');
4
5 // aim : To determine
6 // the mass of oil used per hour and the fraction
    of enthalpy drop through the turbine
7 // heat transfer available per kilogram of exhaust
    steam
8
9 // Given values
10 ms_dot = 5000; // generation of steam, [kg/h]
11 P1 = 1.8; // generated steam pressure, [MN/m^2]
12 T1 = 273+325; // generated steam temperature, [K]
13 Tf = 273+49.4; // feed temperature, [K]
14 neta = .8; // efficiency of boiler plant
15 c = 45500; // calorific value, [kJ/kg]
16 P = 500; // turbine generated power, [kW]
17 Pt = .18; // turbine exhaust pressure, [MN/m^2]
18 x = .98; // dryness fraction of steam

```

```

19
20 // solution
21 // using steam table at 1.8 MN/m^2
22 hf1 = 3106; // [kJ/kg]
23 hg1 = 3080; // [kJ/kg]
24 // so
25 h1 = hf1-neta*(hf1-hg1); // [kJ/kg]
26 // again using steam table specific enthalpy of
    feed water is
27 hwf = 206.9; // [kJ/kg]
28 h_rais = ms_dot*(h1-hwf); // energy to raise steam, [
    kJ]
29
30 h_fue = h_rais/neta; // energy from fuel per hour, [
    kJ]
31 m_oil = h_fue/c; // mass of fuel per hour, [kg]
32
33 // from steam table at exhaust
34 hf = 490.7; // [kJ/kg]
35 hfg = 2210.8; // [kJ/kg]
36 // hence
37 h = hf+x*hfg; // [kJ/kg]
38 // now
39 h_drop = (h1-h)*ms_dot/3600; // specific enthalpy
    drop in turbine [kJ]
40 f = P/h_drop; // fraction ofenthalpy drop converted
    into work
41 // heat transfer available in exhaust is
42 Q = h-hwf; // [kJ/kg]
43 mprintf('\n The mass of oil used per hour is = %f
    kg\n',m_oil);
44 mprintf('\n The fraction of the enthalpy drop
    through the turbine that is converted into useful
    work is = %f\n',f);
45 mprintf('\n The heat transfer available in exhaust
    steam above 49.4 C is = %f kJ/kg\n',Q);
46
47 // End

```

Scilab code Exa 10.3 efficiency equivalent evaporation and coal consumption

```
1 clear;
2 clc;
3 disp('Example 10.3');
4
5 // aim : To determine
6 // (a) the thermal efficiency of the boiler
7 // (b) the equivalent evaporation of the boiler
8 // (c) the new coal consumption
9
10 // given values
11 ms_dot = 5400; // steam feed rate, [kg/h]
12 P = 750; // steam pressure, [kN/m^2]
13 x = .98; // steam dryness fraction
14 Tf1 = 41.5; // feed water temperature, [C]
15 CV = 31000; // calorific value of coal used in the
    boiler, [kJ/kg]
16 mc1 = 670; // rate of burning of coal/h, [kg]
17 Tf2 = 100; // increased water temperature, [C]
18
19 // solution
20 // (a)
21 SRC = ms_dot/mc1; // steam raised/kg coal, [kg]
22 hf = 709.3; // [kJ/kg]
23 hfg = 2055.5; // [kJ/kg]
24 h1 = hf+x*hfg; // specific enthalpy of steam raised,
    [kJ/kg]
25 // from steam table
26 hfw = 173.9; // specific enthalpy of feed water, [kJ/
    kg]
27 EOB = SRC*(h1-hfw)/CV; // efficiency of boiler
28 mprintf('\n (a) The thermal efficiency of the boiler
```

```

        is = %f percent\n',EOB*100);
29
30 // (b)
31 he = 2256.9;// specific enthalpy of evaporation, [kJ
    /kg]
32 Ee = SRC*(h1-hfw)/he;// equivalent evaporation[kg/kg
    coal]
33 mprintf('\n (b) The equivalent evaporation of boiler
    is = %f kg/kg coal\n',Ee);
34
35 // (c)
36 hw = 419.1;// specific enthalpy of feed water at 100
    C, [kJ/kg]
37 Eos = ms_dot*(h1-hw);// energy of steam under new
    condition, [kJ/h]
38 neb = EOB+.05;// given condition new efficiency of
    boiler if 5%more than previous
39 Ec = Eos/neb;// energy from coal, [kJ/h]
40 mc2 = Ec/CV;// mass of coal used per hour in new
    condition, [kg]
41 mprintf('\n (c) Mass of coal used in new condition
    is = %f kg\n',mc2);
42 mprintf('\n          The saving in coal per hour is =
    %f kg\n',mc1-mc2);
43
44 // End

```

Scilab code Exa 10.4 heat transfer and volume

```

1 clear;
2 clc;
3 disp('Example 10.4');
4
5 // aim : To determine the
6 // (a) Heat transfer in the boiler

```

```

7 // (b) Heat transfer in the superheater
8 // (c) Gas used
9
10 // given values
11 P = 100; // boiler operating pressure , [bar]
12 Tf = 256; // feed water temperature , [C]
13 x = .9; // steam dryness fraction .
14 Th = 450; // superheater exit temperature , [C]
15 m = 1200; // steam generation/h, [tonne]
16 TE = .92; // thermal efficiency
17 CV = 38; // calorific value of fuel , [MJ/m^3]
18
19 // solution
20 // (a)
21 // from steam table
22 hw = 1115.4; // specific enthalpy of feed water , [kJ/
    kg]
23 // for wet steam
24 hf = 1408; // specific enthalpy , [kJ/kg]
25 hg = 2727.7; // specific enthalpy , [kJ/kg]
26 // so
27 h = hf+x*(hg-hf); // total specific enthalpy of wet
    steam , [kJ/kg]
28 // hence
29 Qb = m*(h-hw); // heat transfer/h for wet steam , [MJ]
30 fprintf('\n (a) The heat transfer/h in producing wet
    steam in the boiler is = %f MJ\n',Qb);
31
32 // (b)
33 // again from steam table
34 // specific enthalpy of superheated stem at given
    condition is ,
35 hs = 3244; // [kJ/kg]
36
37 Qs = m*(hs-h); // heat transfer/h in superheater , [MJ
    ]
38 fprintf('\n (b) The heat transfer/h in superheater
    is = %f MJ\n',Qs);

```

```

39
40 // (c)
41 V = (Qb+Qs)/(TE*CV); // volume of gs used/h, [m^3]
42 mprintf('\n (c) The volume of gas used/h is = %f m
      ^3\n',V);
43
44 // There is calculation mistake in the book so our
      answer is not matching
45
46 // End

```

Scilab code Exa 10.5 flow rate

```

1 clear;
2 clc;
3 disp('Example 10.5 ');
4
5 //aim : To determine
6 // the flow rate of cooling water
7
8 //Given values
9 P=24; //pressure , [kN/m^2]
10 ms_dot=1.8; //steam condense rate ,[tonne/h]
11 x=.98; //dryness fraction
12 T1=21; //entrance temperature of cooling water,[C]
13 T2=57; //outlet temperature of cooling water,[C]
14
15 //solution
16 //at 24 kN/m^2, for steam
17 hfg=2616.8; //[kJ/kg]
18 hf1=268.2; //[kJ/kg]
19 //hence
20 h1=hf1+x*(hfg-hf1); //[kJ/kg]
21
22 //for cooling water

```

```

23 hf3=238.6; //[kJ/kg]
24 hf2=88.1; //[kJ/kg]
25
26 //using equation [3]
27 //ms_dot*(hf3-hf2)=mw_dot*(h1-hf1), so
28 mw_dot=ms_dot*(h1-hf1)/(hf3-hf2); //[tonne/h]
29 disp('tonne/h',mw_dot,'The flow rate of the cooling
      water is =')
30
31 //End

```

Scilab code Exa 10.6 energy supplied dryness fraction and Rankine efficiency

```

1 clear;
2 clc;
3 disp('Example 10.6');
4
5 // aim : To determine
6 // (a) the energy supplied in the boiler
7 // (b) the dryness fraction of the steam entering
      the condenser
8 // (c) the rankine efficiency
9
10 // given values
11 P1 = 3.5; // steam entering pressure , [MN/m^2]
12 T1 = 273+350; // entering temperature , [K]
13 P2 = 10; //steam exhaust pressure , [kN/m^2]
14
15 // solution
16 // (a)
17 // from steam table , at P1 is ,
18 hf1 = 3139; // [kJ/kg]
19 hg1 = 3095; // [kJ/kg]
20 h1 = hf1-1.5/2*(hf1-hg1);

```

```

21 // at Point 3
22 h3 = 191.8; // [kJ/kg]
23 Es = h1-h3; // energy supplied , [kJ/kg]
24 mprintf('\n (a) The energy supplied in boiler/kg
    steam is = %f kJ/kg\n',Es);
25
26 // (b)
27 // at P1
28 sf1 = 6.960; // [kJ/kg K]
29 sg1 = 6.587; // [kJ/kg K]
30 s1 = sf1-1.5/2*(sf1-sg1); // [kJ/kg K]
31 // at P2
32 sf2 = .649; // [kJ/kg K]
33 sg2 = 8.151; // [kJ/kg K]
34 // s2=sf2+x2(sg2-sf2)
35 // theoretically expansion through turbine is
    isentropic so s1=s2
36 // hence
37 s2 = s1;
38 x2 = (s2-sf2)/(sg2-sf2); // dryness fraction
39 mprintf('\n (b) The dryness fraction of steam
    entering the condenser is = %f \n',x2);
40
41 // (c)
42 // at point 2
43 hf2 = 191.8; // [kJ/kg]
44 hfg2 = 2392.9; // [kJ/kg]
45 h2 = hf2+x2*hfg2; // [kJ/kg]
46 Re = (h1-h2)/(h1-h3); // rankine efficiency
47 mprintf('\n (c) The Rankine efficiency is = %f
    percent\n',Re*100);
48
49 // End

```

Scilab code Exa 10.7 Rankine efficiency and specific work done

```

1 clear;
2 clc;
3 disp('Example 10.7');
4
5 // aim : To determine
6 // the specific work done and compare this with
   that obtained when determining the rankine
   efficiency
7
8 // given values
9 P1 = 1000; // steam entering pressure , [kN/m^2]
10 x1 = .97; // steam entering dryness fraction
11 P2 = 15; // steam exhaust pressure , [kN/m^2]
12 n = 1.135; // polytropic index
13
14 // solution
15 // (a)
16 // from steam table , at P1 is
17 hf1 = 762.6; // [kJ/kg]
18 hfg1 = 2013.6; // [kJ/kg]
19 h1 = hf1+hfg1; // [kJ/kg]
20
21 sf1 = 2.138; // [kJ/kg K]
22 sg1 = 6.583; // [kJ/kg K]
23 s1 = sf1+x1*(sg1-sf1); // [kJ/kg K]
24
25 // at P2
26 sf2 = .755; // [kJ/kg K]
27 sg2 = 8.009; // [kJ/kg K]
28 // s2 = sf2+x2(sg2-sf2)
29 // since expansion through turbine is isentropic so
   s1=s2
30 // hence
31 s2 = s1;
32 x2 = (s2-sf2)/(sg2-sf2); // dryness fraction
33
34 // at point 2
35 hf2 = 226.0; // [kJ/kg]

```

```

36  hfg2 = 2373.2; // [kJ/kg]
37  h2 = hf2+x2*hfg2; // [kJ/kg]
38
39  // at Point 3
40  h3 = 226.0; // [kJ/kg]
41
42  // (a)
43  Re = (h1-h2)/(h1-h3); // rankine efficiency
44  mprintf('\n (a) The Rankine efficiency is = %f
           percent\n',Re*100);
45
46  // (b)
47  vg1 = .1943; // specific volume at P1, [m^3/kg]
48  vg2 = 10.02; // specific volume at P2, [m^3/kg]
49  V1 = x1*vg1; // [m^3/kg]
50  V2 = x2*vg2; // [m^3/kg]
51
52  W1 = n/(n-1)*(P1*V1-P2*V2); // specific work done, [
           kJ/kg]
53
54  // from rankine cycle
55  W2 = h1-h2; // [kJ/kg]
56  mprintf('\n (b) The specific work done is = %f kJ/
           kg\n',W1);
57  mprintf('\n           The specific work done (from rankine
           ) is = %f kJ/kg\n',W2);
58
59  // there is calculation mistake in the book so our
           answer is not matching
60
61  // End

```

Scilab code Exa 10.8 Rankine efficiency steam consumption and Carnot efficiency


```

1  clear;
2  clc;
3  disp('Example 10.8');
4
5  //  aim : To determine
6  //  (a) the rankine efficiency
7  //  (b) the specific steam consumption
8  //  (c) the carnot efficiency of the cycle
9
10 //  given values
11 P1 = 1100; // steam entering pressure , [kN/m^2]
12 T1 = 273+250; // steam entering temperature , [K]
13 P2 = 280; // pressure at point 2, [kN/m^2]
14 P3 = 35; // pressure at point 3, [kN/m^2]
15
16 //  solution
17 //  (a)
18 //  from steam table , at P1  and T1 is
19 hf1 = 2943; // [kJ/kg]
20 hg1 = 2902; // [kJ/kg]
21 h1 = hf1-.1*(hf1-hg1); // [kJ/kg]
22
23 sf1 = 6.926; // [kJ/kg K]
24 sg1 = 6.545; // [kJ/kg K]
25 s1 = sf1-.1*(sf1-sg1); // [kJ/kg K]
26
27 //  at P2
28 sf2 = 1.647; // [kJ/kg K]
29  sg2 = 7.014; // [kJ/kg K]
30 //  s2=sf2+x2(sg2-sf2)
31 //  since expansion through turbine is isentropic so
    s1=s2
32 //  hence
33  s2  =  s1;
34  x2 = (s2-sf2)/(sg2-sf2); //  dryness fraction
35
36 //  at point 2
37  hf2 = 551.4; // [kJ/kg]

```

```

38  hfg2 = 2170.1; // [kJ/kg]
39  h2 = hf2+x2*hfg2; // [kJ/kg]
40  vg2 = .646; // [m^3/kg]
41  v2 = x2*vg2; // [m^3/kg]
42
43  // by Fig10.20.
44  A6125 = h1-h2; // area of 6125, [kJ/kg]
45  A5234 = v2*(P2-P3); // area 5234, [kJ/kg]
46  W = A6125+A5234; // work done
47  hf = 304.3; // specific enthalpy of water at
      condenser pressuer, [kJ/kg]
48  ER = h1-hf; // energy received, [kJ/kg]
49  Re = W/ER; // rankine efficiency
50  mprintf('\n (a) The rankine efficiency is = %f
      percent\n',Re*100);
51
52  // (b)
53  kWh = 3600; // [kJ]
54  SSC = kWh/W; // specific steam consumption, [kJ/kWh]
55  mprintf('\n (b) The specific steam consumption is =
      %f kJ/kWh\n',SSC);
56
57  // (c)
58  // from steam table
59  T3 = 273+72.7; // temperature at point 3
60  CE = (T1-T3)/T1; // carnot efficiency
61  mprintf('\n (c) The carnot efficiency of the cycle
      is = %f percent\n',CE*100);
62
63  // End

```

Scilab code Exa 10.9 power and thermal efficiency

```

1  clear;
2  clc;

```

```

3 disp('Example 10.9');
4
5 // aim : To determine
6 // (a) the theoretical power of steam passing
   through the turbine
7 // (b) the thermal efficiency of the cycle
8 // (c) the thermal efficiency of the cycle assuming
   there is no reheat
9
10 // given values
11 P1 = 6; // initial pressure , [MN/m^2]
12 T1 = 450; // initial temperature , [C]
13 P2 = 1; // pressure at stage 1, [MN/m^2]
14 P3 = 1; // pressure at stage 2, [MN/m^2]
15 T3 = 370; // temperature , [C]
16 P4 = .02; // pressure at stage 3, [MN/m^2]
17 P5 = .02; // pressure at stage 4, [MN/m^2]
18 T5 = 320; // temperature , [C]
19 P6 = .02; // pressure at stage 5, [MN/m^2]
20 P7 = .02; // final pressure , [MN/m^2]
21
22 // solution
23 // (a)
24 // using Fig 10.21
25 h1 = 3305; // specific enthalpy , [kJ/kg]
26 h2 = 2850; // specific enthalpy , [kJ/kg]
27 h3 = 3202; // specific enthalpy , [kJ/kg]
28 h4 = 2810; // specific enthalpy , [kJ/kg]
29 h5 = 3115; // specific enthalpy , [kJ/kg]
30 h6 = 2630; // specific enthalpy , [kJ/kg]
31 h7 = 2215; // specific enthalpy , [kJ/kg]
32 W = (h1-h2)+(h3-h4)+(h5-h6); // specific work through
   the turbine , [kJ/kg]
33 mprintf('\n (a) The theoretical power/kg steam/s is
   = %f kW\n',W);
34
35 // (b)
36 // from steam table

```

```

37 hf6 = 251.5; // [kJ/kg]
38
39 TE1 = ((h1-h2)+(h3-h4)+(h5-h6))/((h1-hf6)+(h3-h2)+(
      h5-h4)); // thermal efficiency
40 mprintf('\n (b) The thermal efficiency of the cycle
      is = %f percent\n',TE1*100);
41
42 // (c)
43 // if there is no heat
44 hf7 = hf6;
45 TE2 = (h1-h7)/(h1-hf7); // thermal efficiency
46 mprintf('\n (c) The thermal efficiency of the cycle
      if there is no heat is = %f percent\n',TE2*100)
      ;
47
48 // End

```

Scilab code Exa 10.10 mass and thermal efficiency

```

1 clear;
2 clc;
3 disp('Example 10.10 ');
4
5 // aim : To determine
6 // (a) the mass of steam bled to each feed heater in
      kg/kg of supply steam
7 // (b) the thermal efficiency of the arrangement
8
9 // given values
10 P1 = 7; // steam initial pressure , [MN/m^2]
11 T1 = 273+500; // steam initil temperature , [K]
12 P2 = 2; // pressure at stage 1, [MN/m^2]
13 P3 = .5; // pressure at stage 2, [MN/m^2]
14 P4 = .05; // condenser pressure , [MN/m^2]
15 SE = .82; // stage efficiency of turbine

```

```

16
17 // solution
18 // from the enthalpy-entropy chart(Fig10.23) values
    of specific enthalpies are
19 h1 = 3410;// [kJ/kg]
20 h2_prim = 3045;// [kJ/kg]
21 // h1-h2=SE*(h1-h2_prim), so
22 h2 = h1-SE*(h1-h2_prim);// [kJ/kg]
23
24 h3_prim = 2790;// [kJ/kg]
25 // h2-h3=SE*(h2-h3_prim), so
26 h3 = h2-SE*(h2-h3_prim);// [kJ/kg]
27
28 h4_prim = 2450;// [kJ/kg]
29 // h3-h4 = SE*(h3-h4_prim), so
30 h4 = h3-SE*(h3-h4_prim);// [kJ/kg]
31
32 // from steam table
33 // @ 2 MN/m^2
34 hf2 = 908.6;// [kJ/kg]
35 // @ .5 MN/m^2
36 hf3 = 640.1;// [kJ/kg]
37 // @ .05 MN/m^2
38 hf4 = 340.6;// [kJ/kg]
39
40 // (a)
41 // for feed heater1
42 m1 = (hf2-hf3)/(h2-hf3);// mass of bled steam, [kg/
    kg supplied steam]
43 // for feed heater2
44 m2 = (1-m1)*(hf3-hf4)/(h3-hf4);//
45 mprintf('\\n (a) The mass of steam bled in feed
    heater 1 is = %f kg/kg supply steam\\n',m1);
46 mprintf('\\n      The mass of steam bled in feed
    heater 2 is = %f kg/kg supply steam\\n',m2);
47
48 // (b)
49 W = (h1-h2)+(1-m1)*(h2-h3)+(1-m1-m2)*(h3-h4);//

```

```

    theoretical work done, [kJ/kg]
50 Eb = h1-hf2; // energy input in the boiler, [kJ/kg]
51 TE1 = W/Eb; // thermal efficiency
52 mprintf('\n (b) The thermal efficiency of the
    arrangement is = %f percent\n',TE1*100);
53
54 // If there is no feed heating
55 hf5 = hf4;
56 h5_prim = 2370; // [kJ/kg]
57 // h1-h5 = SE*(h1-h5_prim), so
58 h5 = h1-SE*(h1-h5_prim); // [kJ/kg]
59 Ei = h1-hf5; //energy input, [kJ/kg]
60 W = h1-h5; // theoretical work, [kJ/kg]
61 TE2 = W/Ei; // thermal efficiency
62 mprintf('\n          The thermal efficiency if there is
    no feed heating is = %f percent\n',TE2*100);
63
64 // End

```

Chapter 11

The steam engine

Scilab code Exa 11.1 bore stroke and speed

```
1 clear;
2 clc;
3 disp('Example 11.1 ')
4
5 // aim : To determine the
6 // (a) bore of the cylinder
7 // (b) piston stroke
8 // (c) speed of the engine
9
10 // Given values
11 P_req = 60; // power required to develop, [kW]
12 P = 1.25; // boiler pressure, [MN/m^2]
13 Pb = .13; // back pressure, [MN/m^2]
14 cut_off = .3; // [stroke]
15 k = .82; // diagram factor
16 n = .78; // mechanical efficiency
17 LN = 3; // mean piston speed, [m/s]
18
19 // solution
20 // (a)
21 r = 1/cut_off; // expansion ratio
```

```

22 Pm = P/r*(1+log(r))-Pb;// mean effective pressure , [
    MN/m^2]
23 P_ind = P_req/n;// Actual indicated power developed ,
    [kW]
24 P_the = P_ind/k;// Theoretical indicated power
    developed , [kW]
25
26 // using indicated_power=Pm*LN*A
27 // Hence
28 A = P_the/(Pm*LN)*10^-3;// piston area ,[m^2]
29 d = sqrt(4*A/%pi)*10^3;// bore ,[mm]
30 mprintf('\n (a) The bore of the cylinder is = %f
    mm\n',d);
31
32 // (b)
33 // given that stroke is 1.25 times bore
34 L = 1.25*d;// [mm]
35 mprintf('\n (b) The piston stroke is = %f mm\n',L)
    ;
36
37 // (c)
38 // LN=mean piston speed , where L is stroke in meter
    and N is 2*rev/s,(since engine is double_acting)
39 // hence
40 rev_per_sec = LN/(2*L*10^-3);// [rev/s]
41
42 rev_per_min = rev_per_sec*60;// [rev/min]
43 mprintf('\n (c) The speed of the engine is = %f
    rev/min\n',rev_per_min);
44
45 // End

```

Scilab code Exa 11.2 diameter and stroke

```
1 clear;
```



```

2  clc;
3  disp('Example 11.2')
4
5  //  aim : To determine the
6  //  (a) the diameter of the cylinder
7  //  (b) piston stroke
8  //  (c) actual steam consumption and indicated
    thermal efficiency
9
10 //  Given values
11 P = 900;// inlet pressure , [kN/m^2]
12 Pb = 140;// exhaust pressure , [kN/m^2]
13 cut_off = .4;// [stroke]
14 k = .8;// diagram factor
15 rs = 1.2;// stroke to bore ratio
16 N = 4;// engine speed , [rev/s]
17 ip = 22.5;// power output from the engine , [kW]
18
19 // solution
20 // (a)
21 r = 1/cut_off;// expansion ratio
22 Pm = P/r*(1+log(r))-Pb;// mean effective pressure , [
    kN/m^2]
23 Pm = Pm*k;// actual mean effective pressure , [kN/m
    ^2]
24
25 // using ip=Pm*L*A*N
26 // and L=r*d; where L is stroke and d is bore
27 d = (ip/(Pm*rs*pi/4*2*N))^(1/3);// diameter of the
    cylinder , [m]
28
29 mprintf('\\n (a) The diameter of the cylinder is =
    %f mm\\n',d*1000);
30
31 // (b)
32 L = rs*d;// stroke , [m]
33 mprintf('\\n (b) The piston stroke is = %f mm\\n',L
    *1000);

```

```

34
35 // (c)
36 SV = %pi/4*d^2*L;// stroke volume, [m^3]
37 V = SV*cut_off*2*240*60;// volume of steam consumed
    per hour, [m^3]
38 v = .2148;// specific volume at 900 kN/m^2, [m^3/kg]
39 SC = V/v;// steam consumed/h, [kg]
40 ASC = 1.5*SC;// actual steam consumption/h, [kg]
41 mprintf('\n (c) The actual steam consumption/h is =
    %f kg\n',ASC);
42
43 m_dot = ASC/3600;// steam consumption,[kg/s]
44 // from steam table
45 hg = 2772.1;// specific enthalpy of inlet steam, [kJ
    /kg]
46 hfe = 458.4;// specific liquid enthalpy at exhaust
    pressure, [kJ/kg]
47
48 ITE = ip/(m_dot*(hg-hfe));// indicated thermal
    efficiency
49 mprintf('\n      The indicated thermal efficiency is
    = %f percent\n',ITE*100);
50
51 // End

```

Scilab code Exa 11.3 diagram factor and indicated thermal efficiency

```

1 clear;
2 clc;
3 disp('Example 11.3');
4
5 // aim : To determine
6 // (a) the diagram factor
7 // (b) the indicated thermal efficiency of the
    engine

```

```

8
9 // given values
10 d = 250*10^-3; // cylinder diameter , [m]
11 L = 375*10^-3; // length of stroke , [m]
12 P = 1000; // steam pressure , [kPa]
13 x = .96; // dryness fraction of steam
14 Pb = 55; // exhaust pressure , [kPa]
15 r = 6; // expansion ratio
16 ip = 45; // indicated power developed , [kW]
17 N = 3.5; // speed of engine , [rev/s]
18 m = 460; // steam consumption , [kg/h]
19
20 // solution
21 // (a)
22 Pm = P/r*(1+log(r))-Pb; // [kN/m^3]
23 A = %pi*(d)^2/4; // area , [m^2]
24 tip = Pm*L*A*N*2; // theoretical indicated power , [kW
    ]
25 k = ip/tip; // diagram factor
26 fprintf('\n (a) The diagram factor is = %f\n',k);
27
28 // (b)
29 // from steam table at 1 MN/m^2
30 hf = 762.6; // [kJ/kg]
31 hfg = 2013.6; // [kJ/kg]
32 // so
33 h1 = hf+x*hfg; // specific enthalpy of steam at 1MN/m
    ^2, [kJ/kg]
34 // minimum specific enthalpy in engine at 55 kPa
35 hf = 350.6; // [kJ/kg]
36 // maximum energy available in engine is
37 h = h1-hf; // [kJ/kg]
38 ITE = ip/(m*h/3600)*100; // indicated thermal
    efficiency
39 fprintf('\n (b) The indicated thermal efficiency is
    = %f percent\n ',ITE);
40
41 // End

```

Scilab code Exa 11.4 steam consumption

```
1 clear;
2 clc;
3 disp('Example 11.4');
4
5 // aim : To determine
6 // steam consumption
7
8 // given values
9 P1 = 11; // power, [kW]
10 m1 = 276; // steam use/h when developing power P1, [kW
    ]
11 ip = 8; // indicated power output, [kW]
12 B = 45; // steam used/h at no load, [kg]
13
14 // solution
15 // using graph of Fig.11.9
16 A = (m1-B)/P1; // slop of line, [kg/kWh]
17 W = A*ip+B; // output, [kg/h]
18 mprintf('\n The steam consumption is = %f kg/h\n
    ',W);
19
20 // End
```

Scilab code Exa 11.5 pressure power output and steam consumption

```
1 clear;
2 clc;
3 disp('Example 11.5');
4
```

```

5 // aim : To determine
6 // (a) the intermediate pressure
7 // (b) the indicated power output
8 // (c) the steam consumption of the engine
9
10 // given values
11 P1 = 1400; // initial pressure , [kN/m^2]
12 x = .9; // dryness fraction
13 P5 = 35; // exhaust pressure
14 k = .8; // diagram factor of low-pressure cylinder
15 L = 350*10^-3; // stroke of both the cylinder , [m]
16 dhp = 200*10^-3; // diameter of high pressure
    cylinder , [m]
17 dlp = 300*10^-3; // diameter of low-pressure cylinder
    , [m]
18 N = 300; // engine speed , [rev/min]
19
20 // solution
21 // taking reference Fig.11.13
22 Ahp = %pi/4*dhp^2; // area of high-pressure cylinder ,
    [m^2]
23 Alp = %pi/4*dlp^2; // area of low-pressure cylinder ,
    [m^2]
24 // for equal initial piston loads
25 // (P1-P7)Ahp=(P7-P5)Alp
26 def f(' [x]=f(P7) ', 'x=(P1-P7)*Ahp-(P7-P5)*Alp ');
27 P7 = fsolve(0,f); // intermediate pressure , [kN/m^2]
28 mprintf('\n (a) The intermediate pressure is = %f
    kN/m^2\n ',P7);
29
30 // (b)
31 V6 = Ahp*L; // volume of high-pressure cylinder , [m
    ^3]
32 P2 = P1;
33 P6 = P7;
34 // using P2*V2=P6*V6
35 V2 = P6*V6/P2; // [m^3]
36 V1 = Alp*L; // volume of low-pressure cylinder , [m^3]

```

```

37 R = V1/V2; // expansion ratio
38 Pm = P1/R*(1+log(R))-P5; // effective pressure of low
    -pressure cylinder, [kn/m^2]
39 Pm = k*Pm; // actual effective pressure, [kN/m^2]
40 ip = Pm*L*Alp*N*2/60; // indicated power, [kW]
41 mprintf('\n (b) The indicated power is = %f kW\n',
    ip);
42
43 // (c)
44 COV = V1/ R; // cut-off volume in high-pressure
    cylinder, [m^3]
45 V = COV*N*2*60; // volume of steam admitted/h
46 // from steam table
47 vg = .1407; // [m^3/kg]
48 AV = x*vg; // specific volume of admission steam, [m
    ^3/kg]
49 m = V/AV; // steam consumption, [kg/h]
50 mprintf('\n (c) The steam consumption of the engine
    is = %f kg/h\n',m);
51
52 // End

```

Scilab code Exa 11.6 power output diameter and intermediate pressure

```

1 clear;
2 clc;
3 disp('Example 11.6 ');
4
5 // aim : To determine
6 // (a) the indicated power output
7 // (b) the diameter of high-pressure cylinder of the
    engine
8 // (c) the intermediate pressure
9
10 // given values

```

```

11 P = 1100; // initial pressure , [kN/m^2]
12 Pb = 28; // exhaust pressure
13 k = .82; // diagram factor of low-pressure cylinder
14 L = 600*10^-3; // stroke of both the cylinder , [m]
15 dlp = 600*10^-3; // diameter of low-pressure cylinder
    , [m]
16 N = 4; // engine speed , [rev/s]
17 R = 8; // expansion ratio
18
19 // solution
20 // taking reference Fig.11.13
21 // (a)
22 Pm = P/R*(1+log(R))-Pb; // effective pressure of low-
    pressure cylinder , [kN/m^2]
23 Pm = k*Pm; // actual effective pressure , [kN/m^2]
24 Alp = %pi/4*dlp^2; // area of low-pressure cylinder ,
    [m^2]
25 ip = Pm*L*Alp*N*2; // indicated power , [kW]
26 mprintf('\n (a) The indicated power is = %f kW\n',
    ip);
27
28 // (b)
29 // work done by both cylinder is same as area of
    diagram
30 w = Pm*Alp*L; // [kJ]
31 W = w/2; // work done/cylinder , [kJ]
32 V2 = Alp*L/8; // volume , [m^3]
33 P2 = P; // [kN/m^2]
34 // using area  $A_{1267} = P_2 * V_2 * \log(V_6/V_2) = W$ 
35 V6 = V2*exp(W/(P2*V2)); // intermediate volume , [m^3]
36 // using  $A_{hp} * L = \frac{\pi}{4} * d_{hp}^2 * L = V_6$ 
37 dhp = sqrt(V6*4/L/%pi); // diameter of high-pressure
    cylinder , [m]
38 mprintf('\n (b) The diameter of high-pressure
    cylinder is = %f mm\n', dhp*1000);
39
40 // (c)
41 // using  $P_2 * V_2 = P_6 * V_6$ 

```

```

42 P6 = P2*V2/V6; // intermediate pressure, [kN/m^2]
43 mprintf('\n (c) The intermediate opressure is = %f
         kN/m^2\n',P6);
44
45 // End

```

Scilab code Exa 11.7 speed and diameter

```

1 clear;
2 clc;
3 disp('Example 11.7');
4
5 // aim : To determine
6 // (a) The speed of the engine
7 // (b) the diameter of the high pressure cylinder
8
9 // given values
10 ip = 230; // indicated power, [kW]
11 P = 1400; // admission pressure, [kN/m^2]
12 Pb = 35; // exhaust pressure, [kN/m^2]
13 R = 12.5; // expansion ratio
14 d1 = 400*10^-3; // diameter of low pressure cylinder,
    [m]
15 L = 500*10^-3; // stroke of both the cylinder, [m]
16 k = .78; // diagram factor
17 rv = 2.5; // expansion ratio of high pressure
    cylinder
18
19 // solution
20 // (a)
21 Pm = P/R*(1+log(R))-Pb; // mean effective pressure in
    low pressure cylinder, [kN/m^2]
22 ipt = ip/k; // theoretical indicated power, [kw]
23 // using ip=Pm*L*A*N
24 A = %pi/4*d1^2; // area, [m^2]

```



```

25 N = ipt/(Pm*L*A*2); // speed , [rev/s]
26 mprintf('\n (a) The engine speed is = %f rev/s\n',
    ,N);
27
28 // (b)
29 V1 = A*L; // volume of low pressure cylinder , [m^3]
30 COV = V1/R; // cutt off volume of hp cylinder , [m^3]
31 V = COV*rv; // total volume , [m^3]
32
33 // V = %pi/4*d^2*L, so
34 d = sqrt(4*V/%pi/L); // diameter of high pressure
    cylinder , [m]
35 mprintf('\n (b) The diameter of the high pressure
    cylinder is = %f mm\n',d*1000);
36
37 // End

```

Scilab code Exa 11.8 mean effective pressures diagram factor and indicated power

```

1 clear;
2 clc;
3 disp('Example 11.8 ');
4
5 // aim : To determine
6 // (a) the actual and hypothetical mean effective
    pressures referred to the low-pressure cylinder
7 // (b) the overall diagram factor
8 // (c) the indicated power
9
10 // given values
11 P = 1100; // steam supply pressure , [kN/m^2]
12 Pb = 32; // back pressure , [kN/m^2]
13 d1 = 300*10^-3; // cylinder1 diameter , [m]
14 d2 = 600*10^-3; // cylinder2 diameter , [m]

```

```

15 L = 400*10^-3; // common stroke of both cylinder , [m]
16
17 A1 = 12.5; // average area of indicated diagram for
    HP, [cm^2]
18 A2 = 11.4; // average area of indicated diagram for
    LP, [cm^2]
19
20 P1 = 270; // indicator calibration , [kN/m^2/ cm]
21 P2 = 80; // spring calibration , [kN/m^2/ cm]
22 N = 2.7; // engine speed , [rev/s]
23 l = .75; // length of both diagram , [m]
24
25 // solution
26 // (a)
27 // for HP cylinder
28 Pmh = P1*A1/7.5; // [kN/m^2]
29 F = Pmh*%pi/4*d1^2; // force on HP, [kN]
30 PmH = Pmh*(d1/d2)^2; // pressure referred to LP
    cylinder , [kN/m^2]
31 PmL = P2*A2/7.5; // pressure for LP cylinder , [kN/m
    ^2]
32 PmA = PmH+PmL; // actual effective pressure referred
    to LP cylinder , [kN/m^2]
33
34 Ah = %pi/4*d1^2; // area of HP cylinder , [m^2]
35 Vh = Ah*L; // volume of HP cylinder , [m^3]
36 CVh = Vh/3; // cut-off volume of HP cylinder , [m^3]
37 A1 = %pi/4*d2^2; // area of LP cylinder , [m^2]
38 V1 = A1*L; // volume of LP cylinder , [m^3]
39
40 R = V1/CVh; // expansion ratio
41 Pm = P/R*(1+log(R))-Pb; // hypothetical mean
    effective pressure referred to LP cylinder , [kN/m
    ^2]
42
43 mprintf('\n (a) The actual mean effective pressure
    referred to LP cylinder is = %f kN/m^2\n', PmA);
44 mprintf('\n          The hypothetical mean effective

```

```

    pressure referred to LP cylinder is = %f kN/m
    ^2\n',Pm);
45
46 // (a)
47 ko = PmA/Pm;// overall diagram factor
48 mprintf('\n (b) The overall diagram factor is = %f
    \n',ko);
49
50 // (c)
51 ip = PmA*L*A1*N*2;// indicated power, [kW]
52 mprintf('\n (c) The indicated power is = %f kW\n',
    ip);
53
54 // End

```

Scilab code Exa 11.9 mean effective pressures diagram factor and percentage of power developed in each cylinder

```

1 clear;
2 clc;
3 disp('Example 11.9 ');
4
5 // aim : To determine
6 // (a) the actual and hypothetical mean effective
    pressures referred to the low-pressure cylinder
7 // (b) the overall diagram factor
8 // (c) the percentage of the total indicated power
    developed in each cylinder
9
10 // given values
11 P = 1400;// steam supply pressure, [kN/m^2]
12 Pb = 20;// back pressure, [kN/m^2]
13 Chp = .6;// cut-off in HP cylinder, [stroke]
14 dh = 300*10^-3;// HP diameter, [m]
15 di = 500*10^-3;// IP diameter, [m]

```

```

16 dl = 900*10^-3; // LP diameter , [m]
17
18 Pm1 = 590; // actual pressure of HP cylinder , [kN/m
    ^2]
19 Pm2 = 214; // actual pressure of IP cylinder , [kN/m
    ^2]
20 Pm3 = 88; // actual pressure of LP cylinder , [kN/m^2]
21
22 // solution
23 // (a)
24 // for HP cylinder
25 PmH = Pm1*(dh/dl)^2; // PmH referred to LP cylinder ,
    [kN/m^2]
26 // for IP cylinder
27 PmI = Pm2*(di/dl)^2; // PmI referred to LP cylinder ,
    [kN/m^2]
28 PmA = PmH+PmI+Pm3; // actual mean effective pressure
    referred to LP cylinder , [kN/m^2]
29
30 R = dl^2/(dh^2*Chp); // expansion ratio
31 Pm = P/R*(1+log(R))-Pb; // hypothetical mean
    effective pressure referred to LP cylinder , [kN/m
    ^2]
32
33 mprintf('\n (a) The actual mean effective pressure
    referred to LP cylinder is = %f kN/m^2\n',PmA)
    ;
34 mprintf('\n          The hypothetical mean effective
    pressure referred to LP cylinder is = %f kN/m
    ^2\n',Pm);
35
36 // (b)
37 ko = PmA/Pm; // overall diagram factor
38 mprintf('\n (b) The overall diagram factor is = %f
    \n',ko);
39
40 // (c)
41 HP = PmH/PmA*100; // %age of indicated power

```

```
developed in HP
42 IP = PmI/PmA*100; // %age of indicated power
developed in IP
43 LP = Pm3/PmA*100; // %age of indicated power
developed in LP
44 mprintf('\\n (c) The pecentage of the total indicated
power developed in HP cylinder is = %f percent
\\n',HP);
45 mprintf('\\n The percentage of the total indicated
power developed in IP cylinder is = %f percent
\\n',IP);
46 mprintf('\\n The percentage of the total indicated
power developed in LP cylinder is = %f
percent\\n',LP);
47
48 // End
```

Chapter 12

Nozzle

Scilab code Exa 12.1 area and Mach number

```
1 clear;
2 clc;
3 disp('Example 12.1 ');
4
5 // aim : To determine the
6 // (a) throat area
7 // (b) exit area
8 // (c) Mach number at exit
9
10 // Given values
11 P1 = 3.5; // inlet pressure of air , [MN/m^2]
12 T1 = 273+500; // inlet temperature of air , [MN/m^2]
13 P2 = .7; // exit pressure , [MN/m^2]
14 m_dot = 1.3; // flow rate of air , [kg/s]
15 Gamma = 1.4; // heat capacity ratio
16 R = .287; // [kJ/kg K]
17
18 // solution
19 // given expansion may be considered to be adiabatic
    and to follow the law  $PV^{\text{Gamma}}=\text{constant}$ 
20 // using ideal gas law
```

```

21 v1 = R*T1/P1*10^-3; // [m^3/kg]
22 Pt = P1*(2/(Gamma+1))^(Gamma/(Gamma-1)); // critical
    pressure , [MN/m^2]
23
24 // velocity at throat is
25 Ct = sqrt(2*Gamma/(Gamma-1)*P1*10^6*v1*(1-(Pt/P1)
    ^(((Gamma-1)/Gamma)))); // [m/s]
26 vt = v1*(P1/Pt)^(1/Gamma); // [m^3/kg]
27 // using m_dot/At=Ct/vt
28 At = m_dot*vt/Ct*10^6; // throat area , [mm^2]
29 mprintf('\n (a) The throat area is = %f mm^2\n',At
    );
30
31 // (b)
32 // at exit
33 C2 = sqrt(2*Gamma/(Gamma-1)*P1*10^6*v1*(1-(P2/P1)
    ^(((Gamma-1)/Gamma)))); // [m/s]
34 v2 = v1*(P1/P2)^(1/Gamma); // [m^3/kg]
35 A2 = m_dot*v2/C2*10^6; // exit area , [mm^2]
36
37 mprintf('\n (b) The exit area is = %f mm^2\n',A2)
    ;
38
39 // (c)
40 M = C2/Ct;
41 mprintf('\n (c) The Mach number at exit is = %f\n'
    ,M);
42
43 // End

```

Scilab code Exa 12.2 increases in pressure temperature and internal energy

```

1 clear;
2 clc;

```

```

3 disp('Example 12.2');
4
5 // aim : To determine the increases in pressure ,
   temperature and internal energy per kg of air
6
7 // Given values
8 T1 = 273; // [K]
9 P1 = 140; // [kN/m^2]
10 C1 = 900; // [m/s]
11 C2 = 300; // [m/s]
12 cp = 1.006; // [kJ/kg K]
13 cv = .717; // [kJ/kg K]
14
15 // solution
16 R = cp-cv; // [kJ/kg K]
17 Gamma = cp/cv; // heat capacity ratio
18 // for frictionless adiabatic flow,  $(C2^2-C1^2)/2=$ 
   Gamma/(Gamma-1)*R*(T1-T2)
19
20 T2 =T1-(((C2^2-C1^2)*(Gamma-1)/(2*Gamma*R))*10^-3; //
   [K]
21 T_inc = T2-T1; // increase in temperature [K]
22
23 P2 = P1*(T2/T1)^(Gamma/(Gamma-1)); // [MN/m^2]
24 P_inc = (P2-P1)*10^-3; // increase in pressure , [MN/m
   ^2]
25
26 U_inc = cv*(T2-T1); // Increase in internal energy
   per kg, [kJ/kg]
27 mprintf('\n The increase in pressure is = %f MN/m
   ^2\n',P_inc);
28 mprintf('\n Increase in temperature is = %f K\n',
   T_inc);
29 mprintf('\n Increase in internal energy is = %f
   kJ/kg\n',U_inc);
30
31 // there is minor variation in result
32

```


33 // End

Scilab code Exa 12.3 throat area and degree of undercooling

```
1 clear;
2 clc;
3 disp('Example 12.3');
4
5 // aim : To determine the
6 // (a) throat and exit areas
7 // (b) degree of undercooling at exit
8 // Given values
9 P1 = 2; // inlet pressure of air, [MN/m^2]
10 T1 = 273+325; // inlet temperature of air, [MN/m^2]
11 P2 = .36; // exit pressure, [MN/m^2]
12 m_dot = 7.5; // flow rate of air, [kg/s]
13 n = 1.3; // polytropic index
14
15 // solution
16 // (a)
17 // using steam table
18 v1 = .132; // [m^3/kg]
19 // given expansion following law  $PV^n = \text{constant}$ 
20
21 Pt = P1*(2/(n+1))^(n/(n-1)); // critical pressure, [
    MN/m^2]
22
23 // velocity at throat is
24 Ct = sqrt(2*n/(n-1)*P1*10^6*v1*(1-(Pt/P1)^((n-1)/n)
    )); // [m/s]
25 vt = v1*(P1/Pt)^(1/n); // [m^3/kg]
26 // using  $m_{\dot{}}/A_t = C_t/v_t$ 
27 At = m_dot*v_t/Ct*10^6; // throat area, [mm^2]
28 mprintf('\n (a) The throat area is = %f mm^2\n', At
    );
```

```

29
30 // at exit
31 C2 = sqrt(2*n/(n-1)*P1*10^6*v1*(1-(P2/P1)^((n-1)/n)
    )); // [m/s]
32 v2 = v1*(P1/P2)^(1/n); // [m^3/kg]
33 A2 = m_dot*v2/C2*10^6; // exit area, [mm^2]
34
35 mprintf('\n      The exit area is = %f mm^2\n',A2
    );
36
37 // (b)
38 T2 = T1*(P2/P1)^((n-1)/n); //outlet temperature, [K]
39 t2 = T2-273; // [C]
40 // at exit pressure saturation temperature is
41 ts = 139.9; // saturation temperature, [C]
42 Doc = ts-t2; // Degree of undercooling, [C]
43 mprintf('\n (b) The Degree of undercooling at exit
    is = %f C\n',Doc);
44
45 // There is some calculation mistake in the book so
    answer is not matching
46
47 // End

```

Scilab code Exa 12.4 velocities and areas

```

1 clear;
2 clc;
3 disp('Example 12.4');
4
5 // aim : To determine the
6 // (a) throat and exit velocities
7 // (b) throat and exit areas
8
9 // Given values

```

```

10 P1 = 2.2; // inlet pressure , [MN/m^2]
11 T1 = 273+260; // inlet temperature , [K]
12 P2 = .4; // exit pressure , [MN/m^2]
13 eff = .85; // efficiency of the nozzle after throat
14 m_dot = 11; // steam flow rate in the nozzle , [kg/s]
15
16 // solution
17 // (a)
18 // assuming steam is following same law as previous
   question 12.3
19 Pt = .546*P1; // critical pressure , [MN/m^2]
20 // from Fig. 12.6
21 h1 = 2940; // [kJ/kg]
22 ht = 2790; // [kJ/kg]
23
24 Ct = sqrt(2*(h1-ht)*10^3); // [m/s]
25
26 // again from Fig. 12.6
27 h2_prime = 2590; // [kJ/kg]
28 // using eff = (ht-h2)/(ht-h2_prime)
29
30 h2 = ht-eff*(ht-h2_prime); // [kJ/kg]
31
32 C2 = sqrt(2*(h1-h2)*10^3); // [m/s]
33
34 // (b)
35 // from chart
36 vt = .16; // [m^3/kg]
37 v2 = .44; // [m^3/kg]
38 // using m_dot*v=A*C
39 At = m_dot*vt/Ct*10^6; // throat area , [mm^2]
40
41 A2 = m_dot*v2/C2*10^6; // throat area , [mm^2]
42
43 mprintf('\n (a) The throat velocity is = %f m/s\n'
   ,Ct);
44 mprintf('\n          The exit velocity is = %f m/s\n'
   ,C2);

```

```
45 mprintf('\\n (b) The throat area is = %f mm^2\\n',  
    At);  
46 mprintf('\\n      The throat area is = %f mm^2\\n',  
    A2);  
47  
48 // End
```

Chapter 13

Steam turbines

Scilab code Exa 13.1 power developed and kinetic energy

```
1 clear;
2 clc;
3 disp('Example 13.1 ');
4
5 // aim : To determine
6 // the power developed for a steam flow of 1 kg/s
   at the blades and the kinetic energy of the steam
   finally leaving the wheel
7
8 // Given values
9 alfa = 20; // blade angle, [degree]
10 Cai = 375; // steam exit velocity in the nozzle, [m/s]
11 U = 165; // blade speed, [m/s]
12 loss = .15; // loss of velocity due to friction
13
14 // solution
15 // using Fig13.12,
16 Cvw = 320; // change in velocity of whirl, [m/s]
17 cae = 132.5; // absolute velocity at exit, [m/s]
18 Pds = U*Cvw*10^-3; // Power developed for steam flow
   of 1 kg/s, [kW]
```

```

19 Kes = cae^2/2*10^-3; // Kinetic energy change of
    steam , [kW/kg]
20
21 mprintf('\n The power developed for a steam flow of
    1 kg/s is = %f kW\n',Pds)
22 mprintf('\n The energy of steam finally leaving the
    wheel is = %f kW/kg\n',Kes);
23
24 // End

```

Scilab code Exa 13.2 angle of blade work done diagram efficiency and end thrust

```

1 clear;
2 clc;
3 disp('Example 13.2');
4
5 // aim : To determine
6 // (a) the entry angle of the blades
7 // (b) the work done per kilogram of steam per
    second
8 // (c) the diagram efficiency
9 // (d) the end-thrust per kilogram of steam per
    second
10
11 // given values
12 Cai = 600; // steam velocity , [m/s]
13 sia = 25; // steam inlet angle with blade , [degree]
14 U = 255; // mean blade speed , [m/s]
15 sea = 30; // steam exit angle with blade , [degree]
16
17 // solution
18 // (a)
19 // using Fig.13.13(diagram for example 13.2)
20 eab = 41.5; // entry angle of blades , [degree]

```

```

21 mprintf(' \n (a) The angle of blades is = %f
    degree \n', eab);
22
23 // (b)
24 Cwi_plus_Cwe = 590; // velocity of whirl, [m/s]
25 W = U*(Cwi_plus_Cwe); // work done on the blade, [W/kg
    ]
26 mprintf(' \n (b) The work done on the blade is = %f
    kW/kg \n', W*10^-3);
27
28 // (c)
29 De = 2*U*(Cwi_plus_Cwe)/Cai^2; // diagram efficiency
30 mprintf(' \n (c) The diagram efficiency is = %f
    percent \n', De*100);
31
32 // (d)
33 // again from the diagram
34 Cfe_minus_Cfi = -90; // change in velocity of flow, [m
    /s]
35 Eth = Cfe_minus_Cfi; // end-thrust, [N/kg s]
36 mprintf(' \n (d) The End-thrust is = %f N/kg', Eth)
    ;
37
38 // End

```

Scilab code Exa 13.3 power output and diagram efficiency

```

1 clear;
2 clc;
3 disp('Example 13.3');
4
5 // aim : To determine
6 // (a) the power output of the turbine
7 // (b) the diagram efficiency
8

```

```

 9 // given values
10 U = 150; // mean blade speed , [m/s]
11 Cai1 = 675; // nozzle speed , [m/s]
12 na = 20; // nozzle angle , [degree]
13 m_dot = 4.5; // steam flow rate , [kg/s]
14
15 // solution
16 // from Fig. 13.15(diagram 13.3)
17 Cw1 = 915; // [m/s]
18 Cw2 = 280; // [m/s]
19
20 // (a)
21 P = m_dot*U*(Cw1+Cw2); // power of turbine ,[W]
22 mprintf('\n (a) The power of turbine is = %f kW\n'
          ,P*10^-3);
23
24 // (b)
25 De = 2*U*(Cw1+Cw2)/Cai1^2; // diagram efficiency
26 mprintf('\n (b) The diagram efficiency is = %f
          percent\n',De*100);
27
28 // End

```

Scilab code Exa 13.4 power output specific enthalpy drop and increase in relative velocity

```

1 clear;
2 clc;
3 disp('Example 13.4 ');
4
5 // aim : To determine
6 // (a) the power output of the stage
7 // (b) the specific enthalpy drop in the stage
8 // (c) the percentage increase in relative velocity
    in the moving blades due to expansion in the

```



```

        bladse
9
10 // given values
11 N = 50; // speed, [m/s]
12 d = 1; // blade ring diameter, [m]
13 nai = 50; // nozzle inlet angle, [degree]
14 nae = 30; // nozzle exit angle, [degree]
15 m_dot = 600000; // steam flow rate, [kg/h]
16 se = .85; // stage efficiency
17
18 // solution
19 // (a)
20 U = %pi*d*N; // mean blade speed, [m/s]
21 // from Fig. 13.17(diagram 13.4)
22 Cwi_plus_Cwe = 444; // change in whirl speed, [m/s]
23 P = m_dot*U*Cwi_plus_Cwe/3600; // power output of the
    stage, [W]
24 mprintf('\n (a) The power output of the stage is =
    %f MW\n',P*10^-6);
25
26 // (b)
27 h = U*Cwi_plus_Cwe/se; // specific enthalpy, [J/kg]
28 mprintf('\n (b) The specific enthalpy drop in the
    stage is = %f kJ/kg\n ',h*10^-3);
29
30 // (c)
31 // again from diagram
32 Cri = 224; // [m/s]
33 Cre = 341; // [m/s]
34 Iir = (Cre-Cri)/Cri; // increase in relative velocity
35 mprintf('\n (c) The increase in relative velocity is
    = %f percent\n',Iir*100);
36
37 // End

```

Scilab code Exa 13.5 blade height power developed and specific enthalpy drop

```

1  clear;
2  clc;
3  disp('Example 13.5 ');
4
5  // aim : To determine
6  // (a) the blade height of the stage
7  // (b) the power developed in the stage
8  // (c) the specific enthalpy drop at the stage
9
10 // given values
11 U = 60; // mean blade speed, [m/s]
12 P = 350; // steam pressure, [kN/m^2]
13 T = 175; // steam temperature, [C]
14 nai = 30; // stage inlet angle, [degree]
15 nae = 20; // stage exit angle, [degree]
16
17 // solution
18 // (a)
19 m_dot = 13.5; // steam flow rate, [kg/s]
20 // at given T and P
21 v = .589; // specific volume, [m^3/kg]
22 // given H=d/10, so
23 H = sqrt(m_dot*v/(%pi*10*60)); // blade height, [m]
24 mprintf('\n (a) The blade height at this stage is =
           %f mm\n',H*10^3);
25
26 // (b)
27 Cwi_plus_Cwe = 270; // change in whirl speed, [m/s]
28 P = m_dot*U*(Cwi_plus_Cwe); // power developed, [W]
29 mprintf('\n (b) The power developed is = %f kW\n',
           ,P*10^-3);
30
31 // (c)
32 s = .85; // stage efficiency
33 h = U*Cwi_plus_Cwe/s; // specific enthalpy, [J/kg]

```

```
34 mprintf('\\n (a) The specific enthalpy drop in the  
    stage is = %f kJ/kg',h*10^-3);  
35  
36 // End
```

Chapter 14

Air and gas compressors

Scilab code Exa 14.1 free air delivered volumetric efficiency temperature cycle power and isothermal efficiency

```
1 clear;
2 clc;
3 disp(' Example 14.1 ');
4
5 // aim : To determine
6 // (a) the free air delivered
7 // (b) the volumetric efficiency
8 // (c) the air delivery temperature
9 // (d) the cycle power
10 // (e) the isothermal efficiency
11
12 // given values
13 d = 200*10^-3; // bore , [m]
14 L = 300*10^-3; // stroke , [m]
15 N = 500; // speed , [rev/min]
16 n = 1.3; // polytropic index
17 P1 = 97; // intake pressure , [kN/m^2]
18 T1 = 273+20; // intake temperature , [K]
19 P3 = 550; // compression pressure , [kN/m^2]
20
```

```

21 // solution
22 // (a)
23 P4 = P1;
24 P2 = P3;
25 Pf = 101.325; // free air pressure, [kN/m^2]
26 Tf = 273+15; // free air temperature, [K]
27 SV = %pi/4*d^2*L; // swept volume, [m^3]
28 V3 = .05*SV; // [m^3]
29 V1 = SV+V3; // [m^3]
30 V4 = V3*(P3/P4)^(1/n); // [m^3]
31 ESV = (V1-V4)*N; // effective swept volume/min, [m^3]
32 // using PV/T=constant
33 Vf = P1*ESV*Tf/(Pf*T1); // free air delivered, [m^3/
    min]
34 fprintf('\n (a) The free air delivered is = %f m
    ^3/min\n', Vf);
35
36 // (b)
37 VE = Vf/(N*(V1-V3)); // volumetric efficiency
38 fprintf('\n (b) The volumetric efficiency is = %f
    percent\n', VE*100);
39
40 // (c)
41 T2 = T1*(P2/P1)^((n-1)/n); // free air temperature,
    [K]
42 fprintf('\n (c) The air delivery temperature is =
    %f C\n', T2-273);
43
44 // (d)
45 CP = n/(n-1)*P1*(V1-V4)*((P2/P1)^((n-1)/n)-1)*N/60;
    // cycle power, [kW]
46 fprintf('\n (d) The cycle power is = %f kW\n', CP
    );
47
48 // (e)
49 // neglecting clearance
50 W = n/(n-1)*P1*V1*((P2/P1)^((n-1)/n)-1)
51 Wi = P1*V1*log(P2/P1); // isothermal efficiency

```

```

52 IE = Wi/W; // isothermal efficiency
53 mprintf('\n (e) The isothermal efficiency neglecting
    clearance is = %f percent\n',IE*100);
54
55 // End

```

Scilab code Exa 14.2 intermediate pressure volume and cycle power

```

1 clear;
2 clc;
3 disp(' Example 14.2 ');
4
5 // aim : To determine
6 // (a) the intermediate pressure
7 // (b) the total volume of each cylinder
8 // (c) the cycle power
9
10 // given values
11 v1 = .2; // air intake , [m^3/s]
12 P1 = .1; // intake pressure , [MN/m^2]
13 T1 = 273+16; // intake temperature , [K]
14 P3 = .7; // final pressure , [MN/m^2]
15 n = 1.25; // compression index
16 N = 10; // speed , [rev/s]
17
18 // solution
19 // (a)
20 P2 = sqrt(P1*P3); // intermediate pressure , [MN/m^2]
21 mprintf('\n (a) The intermediate pressure is = %f
    MN/m^2\n',P2);
22
23 // (b)
24 V1 = v1/N; // total volume , [m^3]
25 // since intercooling is perfect so 2 lie on the
    isothermal through1 , P1*V1=P2*V2

```

```

26 V2 = P1*V1/P2; // volume, [m^3]
27 mprintf('\n (b) The total volume of the HP cylinder
    is = %f litres\n', V2*10^3);
28
29 // (c)
30 CP = 2*n/(n-1)*P1*v1*((P2/P1)^((n-1)/n)-1); // cycle
    power, [MW]
31 mprintf('\n (c) The cycle power is = %f MW\n',
    CP*10^3);
32
33 // there is calculation mistake in the book so
    answer is not matching
34
35 // End

```

Scilab code Exa 14.3 intermediate pressures effective swept volume temperature and work done

```

1 clear;
2 clc;
3 disp(' Example 14.3 ');
4
5 // aim : To determine
6 // (a) the intermediate pressures
7 // (b) the effective swept volume of the LP cylinder
8 // (c) the temperature and the volume of air
    delivered per stroke at 15 bar
9 // (d) the work done per kilogram of air
10
11 // given values
12 d = 450*10^-3; // bore , [m]
13 L = 300*10^-3; // stroke , [m]
14 c1 = .05; // clearance
15 P1 = 1; // intake pressure , [bar]
16 T1 = 273+18; // intake temperature , [K]

```

```

17 P4 = 15; // final delivery pressure , [bar]
18 n = 1.3; // compression and expansion index
19 R = .29; // gas constant , [kJ/kg K]
20
21 // solution
22 // (a)
23 k=(P4/P1)^(1/3);
24 // hence
25 P2 = k*P1; // intermediare pressure , [bar]
26 P3 = k*P2; // intermediate pressure , [bar]
27
28 mprintf('\n (a) The intermediate pressure is P2 =
    %f bar\n',P2);
29 mprintf('\n      The intermediate pressure is P3=
    %f bar\n',P3);
30
31 // (b)
32 SV = %pi*d^2/4*L; // swept volume of LP cylinder , [m
    ^3]
33 // hence
34 V7 = c1*SV; // volume , [m^3]
35 V1 = SV+V7; // volume , [m^3]
36 // also
37 P7 = P2;
38 P8 = P1;
39 V8 = V7*(P7/P8)^(1/n); // volume , [m^3]
40 ESV = V1-V8; // effective swept volume of LP cylinder
    , [m^3]
41
42 mprintf('\n (b) The effective swept volume of the LP
    cylinder is = %f litres\n',ESV*10^3);
43
44 // (c)
45 T9 = T1;
46 P9 = P3;
47 T4 = T9*(P4/P9)^((n-1)/n); // delivery temperature , [
    K]
48 // now using P4*(V4-V5)/T4=P1*(V1-V8)/T1

```



```

49 V4_minus_V5 = P1*T4*(V1-V8)/(P4*T1); // delivery
    volume, [m^3]
50
51 mprintf('\n (c) The delivery temperature is = %f C
    \n',T4-273);
52 mprintf('\n          The delivery volume is = %f
    litres\n',V4_minus_V5*10^3);
53
54 // (d)
55
56 W = 3*n*R*T1*((P2/P1)^((n-1)/n)-1)/(n-1); // work
    done/kg ,[kJ]
57 mprintf('\n (d) The work done per kilogram of air is
    = %f kJ\n',W);
58
59 // End

```

Scilab code Exa 14.4 pressure temperature and energy

```

1 clear;
2 clc;
3 disp(' Example 14.4 ');
4
5 // aim : To determine
6 // (a) the final pressure and temperature
7 // (b) the energy required to drive the compressor
8
9 // given values
10 rv = 5; // pressure compression ratio
11 m_dot = 10; // air flow rate, [kg/s]
12 P1 = 100; // initial pressure, [kN/m^2]
13 T1 = 273+20; // initial temperature, [K]
14 n_com = .85; // isentropic efficiency of compressor
15 Gama = 1.4; // heat capacity ratio
16 cp = 1.005; // specific heat capacity, [kJ/kg K]

```

```

17
18 // solution
19 // (a)
20 T2_prim = T1*(rv)^((Gama-1)/Gama); // temperature
    after compression , [K]
21 // using isentropic efficiency=(T2_prim-T1)/(T2-T1)
22 T2 = T1+(T2_prim-T1)/n_com; // final temperature , [K
    ]
23 P2 = rv*P1; // final pressure , [kN/m^2]
24 mprintf('\n (a) The final temperature is = %f C\n
    ',T2-273);
25 mprintf('\n (b) The final pressure is = %f kN/m
    ^2\n',P2);
26
27 // (b)
28 E = m_dot*cp*(T1-T2); // energy required , [kW]
29 mprintf('\n (b) The energy required to drive the
    compressor is = %f kW',E);
30 if(E<0)
31     disp('The negative sign indicates energy input')
    ;
32 else
33     disp('The positive sign indicates energy output'
    );
34 end
35
36 // End

```

Scilab code Exa 14.5 power developed

```

1 clear;
2 clc;
3 disp(' Example 14.5 ');
4
5 // aim : To determine

```

```

6 // the power absorbed in driving the compressor
7
8 // given values
9 FC = .68; // fuel consumption rate, [kg/min]
10 P1 = 93; // initial pressure, [kN/m^2]
11 P2 = 200; // final pressure, [kN/m^2]
12 T1 = 273+15; // initial temperature, [K]
13 d = 1.3; // density of mixture, [kg/m^3]
14 n_com = .82; // isentropic efficiency of compressor
15 Gama = 1.38; // heat capacity ratio
16
17 // solution
18 R = P1/(d*T1); // gas constant, [kJ/kg K]
19 // for mixture
20 cp = Gama*R/(Gama-1); // heat capacity, [kJ/kg K]
21 T2_prim = T1*(P2/P1)^((Gama-1)/Gama); // temperature
    after compression, [K]
22 // using isentropic efficiency=(T2_prim-T1)/(T2-T1)
23 T2 = T1+(T2_prim-T1)/n_com; // final temperature, [K
    ]
24 m_dot = FC*15/60; // given condition, [kg/s]
25 P = m_dot*cp*(T2-T1); // power absorbed by compressor
    , [kW]
26 mprintf('\n The power absorbed by compressor is =
    %f kW\n',P);
27
28 // End

```

Scilab code Exa 14.6 power

```

1 clear;
2 clc;
3 disp(' Example 14.6 ');
4
5 // aim : To determine

```

```

6 // the power required to drive the blower
7
8 // given values
9 m_dot = 1; // air capacity, [kg/s]
10 rp = 2; // pressure ratio
11 P1 = 1*10^5; // intake pressure, [N/m^2]
12 T1 = 273+70; // intake temperature, [K]
13 R = .29; // gas constant, [kJ/kg k]
14
15 // solution
16 V1_dot = m_dot*R*T1/P1*10^3; // [m^3/s]
17 P2 = rp*P1; // final pressure, [n/m^2]
18 P = V1_dot*(P2-P1); // power required, [W]
19 mprintf('\n The power required to drive the blower
        is = %f kW\n',P*10^-3);
20
21 // End

```

Scilab code Exa 14.7 power

```

1 clear;
2 clc;
3 disp(' Example 14.7 ');
4
5 // aim : To determine
6 // the power required to drive the vane pump
7
8 // given values
9 m_dot = 1; // air capacity, [kg/s]
10 rp = 2; // pressure ratio
11 P1 = 1*10^5; // intake pressure, [N/m^2]
12 T1 = 273+70; // intake temperature, [K]
13 Gama = 1.4; // heat capacity ratio
14 rv = .7; // volume ratio
15

```

```

16 // solution
17 V1 = .995; // intake pressure (as given previous
           // question), [m^3/s]
18 // using  $P_1 V_1^\gamma = P_2 V_2^\gamma$ , so
19 P2 = P1*(1/rv)^\gamma; // pressure, [N/m^2]
20 V2 = rv*V1; // volume, [m^3/s]
21 P3 = rp*P1; // final pressure, [N/m^2]
22 P = \gamma/(\gamma-1)*P1*V1*((P2/P1)^((\gamma-1)/\gamma)-1)+
           V2*(P3-P2); // power required, [W]
23 fprintf('\n The power required to drive the vane
           // pump is = %f kW\n', P*10^-3);
24
25 // End

```

Scilab code Exa 14.8 power temperature and pressure

```

1 clear;
2 clc;
3 disp(' Example 14.8 ');
4
5 // aim : To determine
6 // the total temperature and pressure of the
           // mixture
7
8 // given values
9 rp = 2.5; // static pressure ratio
10 FC = .04; // fuel consumption rate, [kg/min]
11 P1 = 60; // inlet pressure, [kN/m^2]
12 T1 = 273+5; // inlet temperature, [K]
13 n_com = .84; // isentropic efficiency of compressor
14 \gamma = 1.39; // heat capacity ratio
15 C2 = 120; // exit velocity from compressor, [m/s]
16 rm = 13; // air-fuel ratio
17 cp = 1.005; // heat capacity ratio
18

```

```

19 // solution
20 P2 = rp*P1;// given condition , [kN/m^2]
21 T2_prim = T1*(P2/P1)^((Gama-1)/Gama);// temperature
    after compression , [K]
22 // using isentropic efficiency=(T2_prim-T1)/(T2-T1)
23 T2 = T1+(T2_prim-T1)/n_com;// final temperature , [K
    ]
24 m_dot = FC*(rm+1);// mass of air-fuel mixture , [kg/s
    ]
25 P = m_dot*cp*(T2-T1);// power to drive compressor , [
    kW]
26 mprintf('\n The power required to drive compressor
    is = %f kW\n',P);
27
28 Tt2 = T2+C2^2/(2*cp*10^3);// total temperature ,[K]
29 Pt2 = P2*(Tt2/T2)^(Gama/(Gama-1));// total pressure ,
    [kN/m^2]
30 mprintf('\n The temperature in the engine is = %f
    C\n',Tt2-273);
31 mprintf('\n The pressure in the engine cylinder is
    = %f kN/m^2\n',Pt2);
32
33 // There is calculation mistake in the book
34
35
36 // End

```

Chapter 15

Ideal gas power cycles

Scilab code Exa 15.1 thermal efficiency

```
1 clear;
2 clc;
3 disp('Example 15.1 ');
4
5 // aim : To determine
6 // the thermal efficiency of the cycle
7
8 // given values
9 T1 = 273+400; // temperature limit , [K]
10 T3 = 273+70; // temperature limit , [K]
11
12 // solution
13 // using equation [15] of section 15.3
14 n_the = (T1-T3)/T1*100; // thermal efficiency
15 mprintf('\n The thermal efficiency of the cycle is
    = %f percent\n',n_the);
16
17 // End
```

Scilab code Exa 15.2 volume ratios and thermal efficiency

```
1 clear;
2 clc;
3 disp('Example 15.2');
4
5 // aim : To determine
6 // (a) the volume ratios of the isothermal and
7 //       adiabatic processes
8 // (b) the thermal efficiency of the cycle
9
10 // given values
11 T1 = 273+260; // temperature, [K]
12 T3 = 273+21; // temperature, [K]
13 er = 15; // expansion ratio
14 Gama = 1.4; // heat capacity ratio
15
16 // solution
17 // (a)
18 T2 = T1;
19 T4 = T3;
20 // for adiabatic process
21 rva = (T1/T4)^(1/(Gama-1)); // volume ratio of
22 //       adiabatic
23 rvi = er/rva; // volume ratio of isothermal
24 mprintf('\n (a) The volume ratio of the adiabatic
25 //       process is = %f\n',rva);
26 mprintf('\n       The volume ratio of the isothermal
27 //       process is = %f\n',rvi);
28
29 // (b)
30 n_the = (T1-T4)/T1*100; // thermal efficiency
31 mprintf('\n (b) The thermal efficiency of the cycle
32 //       is = %f percent\n',n_the);
33
34 // End
```

Scilab code Exa 15.3 pressure volume temperature thermal efficiency work done and work ratio

```
1 clear;
2 clc;
3 disp('Example 15.3');
4
5 // aim : To determine
6 // (a) the pressure , volume and temperature at each
    corner of the cycle
7 // (b) the thermal efficiency of the cycle
8 // (c) the work done per cycle
9 // (d) the work ratio
10
11 // given values
12 m = 1; // mass of air , [kg]
13 P1 = 1730; // initial pressure of carnot engine , [kN/
    m^2]
14 T1 = 273+300; // initial temperature , [K]
15 R = .29; // [kJ/kg K]
16 Gama = 1.4; // heat capacity ratio
17
18 // solution
19 // taking reference Fig. 15.15
20 // (a)
21 // for the isothermal process 1-2
22 // using ideal gas law
23 V1 = m*R*T1/P1; // initial volume , [m^3]
24 T2 = T1;
25 V2 = 3*V1; // given condition
26 // for isothermal process , P1*V1=P2*V2, so
27 P2 = P1*(V1/V2); // [MN/m^2]
28 // for the adiabatic process 2-3
29 V3 = 6*V1; // given condition
```

```

30 T3 = T2*(V2/V3)^(Gama-1);
31 // also for adiabatic process , P2*V2^Gama=P3*V3^Gama
    , so
32 P3 = P2*(V2/V3)^Gama;
33 // for the isothermal process 3-4
34 T4 = T3;
35 // for both adiabatic processes , the temperataure
    ratio is same,
36 // T1/T4 = T2/T3=(V4/V1)^(Gama-1)=(V3/V2)^(Gama-1),
    so
37 V4 = 2*V1;
38 // for isothermal process , 3-4, P3*V3=P4*V4, so
39 P4 = P3*(V3/V4);
40 disp(' (a) At line 1 ');
41 mprintf('\n V1 = %f m^3, t1 = %f C, P1 = %f
    kN/m^2\n',V1,T1-273,P1);
42
43 disp('At line 2');
44 mprintf('\n V2 = %f m^3, t2 = %f C, P2 = %f
    kN/m^2\n',V2,T2-273,P2);
45
46 disp('At line 3');
47 mprintf('\n V3 = %f m^3, t3 = %f C, P3 = %f
    kN/m^2\n',V3,T3-273,P3);
48
49
50 disp('At line 4');
51 mprintf('\n V4 = %f m^3, t4 = %f C, P4 = %f
    kN/m^2\n',V4,T4-273,P4);
52
53
54 // (b)
55 n_the = (T1-T3)/T1;// thermal efficiency
56 mprintf('\n (b) The thermal efficiency of the cycle
    is = %f percent\n',n_the*100);
57
58 // (c)
59 W = m*R*T1*log(V2/V1)*n_the;// work done, [J]

```

```

60 mprintf('\n (c) The work done per cycle is = %f
      kJ\n',W);
61
62 // (d)
63 wr = (T1-T3)*log(V2/V1)/(T1*log(V2/V1)+(T1-T3)/(Gama
      -1));// work ratio
64 mprintf('\n (d) The work ratio is = %f\n',wr);
65
66 // there is calculation mistake in the book so
      answer is not matching
67
68 // End

```

Scilab code Exa 15.4 pressure volume temperature heat work done thermal efficiency carnot efficiency work ratio and mean effective pressure

```

1 clear;
2 clc;
3 disp('Example 15.4');
4
5 // aim : To determine
6 // (a) the pressure , volume and temperature at cycle
      state points
7 // (b) the heat received
8 // (c) the work done
9 // (d) the thermal efficiency
10 // (e) the carnot efficiency
11 // (f) the work ration
12 // (g) the mean effective pressure
13
14 // given values
15 ro = 8;// overall volume ratio;
16 rv = 6;// volume ratio of adiabatic compression
17 P1 = 100;// initial pressure , [kN/m^2]
18 V1 = .084;// initial volume, [m^3]

```

```

19 T1 = 273+28; // initial temperature, [K]
20 Gama = 1.4; // heat capacity ratio
21 cp = 1.006; // specific heat capacity, [kJ/kg K]
22
23 // solution
24 // taking reference Fig. 15.18
25 // (a)
26 V2 = V1/rv; // volume at stage2, [m^3]
27 V4 = ro*V2; // volume at stage 4; [m^3]
28 // using PV^(Gama)=constant for process 1-2
29 P2 = P1*(V1/V2)^(Gama); // pressure at stage2, [kN/m
    ^2]
30 T2 = T1*(V1/V2)^(Gama-1); // [K]
31
32 P3 = P2; // pressure at stage 3, [kN/m^2]
33 V3 = V4/rv; // volume at stage 3, [m^3]
34 // since pressure is constant in process 2-3, so
    using V/T=constant, so
35 T3 = T2*(V3/V2); // temperature at stage 3, [K]
36
37 // for process 1-4
38 T4 = T1*(V4/V1); // temperature at stage4, [K]
39 P4 = P1; // pressure at stage4, [kN/m^2]
40
41 mprintf('\n (a) P1 = %f kN/m^2, V1 = %f m^3,
    t1 = %f C,\n P2 = %f kN/m^2,
    V2 = %f m^3, t2 = %f C,\n P3 =
    %f kN/m^2, V3 = %f m^3, t3 = %f C,\n
    P4 = %f kN/m^2, V4 = %f m^3,
    t4 = %f C\n', P1, V1, T1-273, P2, V2, T2-273, P3
    , V3, T3-273, P4, V4, T4-273);
42
43 // (b)
44 R = cp*(Gama-1)/Gama; // gas constant, [kJ/kg K]
45 m = P1*V1/(R*T1); // mass of gas, [kg]
46 Q = m*cp*(T3-T2); // heat received, [kJ]
47 mprintf('\n (b) The heat received is = %f kJ\n', Q)
    ;

```

```

48
49 // (c)
50 W = P2*(V3-V2)-P1*(V4-V1)+((P3*V3-P4*V4)-(P2*V2-P1*
      V1))/(Gama-1);// work done, [kJ]
51 mprintf('\n (c) The work done is = %f kJ\n',W);
52
53 // (d)
54 TE = 1-T1/T2;// thermal efficiency
55 mprintf('\n (d) The thermal efficiency is = %f
      percent\n',TE*100);
56
57 // (e)
58 CE = (T3-T1)/T3;// carnot efficiency
59 mprintf('\n (e) The carnot efficiency is = %f
      percent\n',CE*100);
60
61 // (f)
62 PW = P2*(V3-V2)+(P3*V3-P4*V4)/(Gama-1);// positive
      work done, [kj]
63 WR = W/PW;// work ratio
64 mprintf('\n (f) The work ratio is = %f\n',WR);
65
66 // (g)
67 Pm = W/(V4-V2);// mean effective pressure, [kN/m^2]
68 mprintf('\n (g) The mean effective pressure is =
      %f kN/m^2\n',Pm);
69
70 // there is minor variation in answer reported in
      the book
71
72 // End

```

Scilab code Exa 15.5 thermal efficiency and specific fuel consumption

```
1 clear;
```

```

2  clc;
3  disp('Example 15.5 ');
4
5  // aim : To determine
6  // (a) the actual thermal efficiency of the turbine
7  // (b) the specific fuel consumption of the turbine
   in kg/kWh
8
9  // given values
10 P2_by_P1 = 8;
11 n_tur = .6; // ideal turbine thermal efficiency
12 c = 43*10^3; // calorific value of fuel, [kJ/kg]
13 Gama = 1.4; // heat capacity ratio
14
15 // solution
16 // (a)
17 rv = P2_by_P1;
18 n_tur_ide = 1-1/(P2_by_P1)^((Gama-1)/Gama); // ideal
   thermal efficiency
19 ate = n_tur_ide*n_tur; // actual thermal efficiency
20 mprintf(' \n (a) The actual thermal efficiency of the
   turbine is = %f percent \n', ate*100);
21
22 // (b)
23 ewf = c*ate; // energy to work fuel, [kJ/kg]
24 kWh = 3600; // energy equivalent, [kJ]
25 sfc = kWh/ewf; // specific fuel consumption, [kg/kWh]
26 mprintf(' \n (b) The specific fuel consumption of the
   turbine is = %f kg/kWh', sfc);
27
28 // End

```

Scilab code Exa 15.6 relative efficiency

```

1  clear;

```

```

2  clc;
3  disp('Example 15.6 ');
4
5  // aim : To determine
6  // the relative efficiency of the engine
7
8  // given values
9  d = 80; // bore, [mm]
10 l = 85; // stroke, [mm]
11 V1 = .06*10^6; // clearance volume, [mm^3]
12 ate = .22; // actual thermal efficiency of the engine
13 Gama = 1.4; // heat capacity ratio
14
15 // solution
16 sv = %pi*d^2/4*l; // stroke volume, [mm^3]
17 V2 = sv+V1; // [mm^3]
18 rv = V2/V1;
19 ite = 1-(1/rv)^(Gama-1); // ideal thermal efficiency
20 re = ate/ite; // relative thermal efficiency
21 mprintf(' \n The relative efficiency of the engine is
           = %f percent \n ',re*100);
22
23 // End

```

Scilab code Exa 15.7 pressure volume temperature heat thermal efficiency
work done mean effective pressure

```

1  clear;
2  clc;
3  disp('Example 15.7 ');
4
5  // aim : To determine
6  // (a) the pressure, volume and temperature at each
       cycle process change points
7  // (b) the heat transferred to air

```

```

8 // (c) the heat rejected by the air
9 // (d) the ideal thermal efficiency
10 // (e) the work done
11 // (f) the mean effective pressure
12
13 // given values
14 m = 1; // mass of air, [kg]
15 rv = 6; // volume ratio of adiabatic compression
16 P1 = 103; // initial pressure, [kN/m^2]
17 T1 = 273+100; // initial temperature, [K]
18 P3 = 3450; // maximum pressure, [kN/m^2]
19 Gama = 1.4; // heat capacity ratio
20 R = .287; // gas constant, [kJ/kg K]
21
22 // solution
23 // taking reference Fig. 15.20
24 // (a)
25 // for point 1
26 V1 = m*R*T1/P1; // initial volume, [m^3]
27
28 // for point 2
29 V2 = V1/rv; // volume at point 2, [m^3]
30 // using  $PV^{(\text{Gama})}=\text{constant}$  for process 1-2
31 P2 = P1*(V1/V2)^(Gama); // pressure at point 2, [kN/
m^2]
32 T2 = T1*(V1/V2)^(Gama-1); // temperature at point 2, [
K]
33
34 // for point 3
35 V3 = V2; // volume at point 3, [m^3]
36 // since volume is constant in process 2-3, so
using P/T=constant, so
37 T3 = T2*(P3/P2); // temperature at stage 3, [K]
38
39 // for point 4
40 V4 = V1; // volume at point 4, [m^3]
41 P4 = P3*(V3/V4)^Gama; // pressure at point 4, [kN/m
^2]

```



```

42 // again since volume is constant in process 4-1 ,
    so using P/T=constant , so
43 T4 = T1*(P4/P1); // temperature at point 4, [K]
44
45 mprintf('\n (a) P1 = %f kN/m^2, V1 = %f m^3,
           t1 = %f C,\n P2 = %f kN/m^2,
           V2 = %f m^3, t2 = %f C,\n P3 = %f
           kN/m^2, V3 = %f m^3, t3 = %f C,\n
           P4 = %f kN/m^2, V4 = %f m^3,
           t4 = %f C\n',P1,V1,T1-273,P2,V2,T2-273,P3,V3,T3
           -273,P4,V4,T4-273);
46
47 // (b)
48 cv = R/(Gama-1); // specific heat capacity, [kJ/kg K
    ]
49 Q23 = m*cv*(T3-T2); // heat transferred, [kJ]
50 mprintf('\n (b) The heat transferred to the air is
           = %f kJ\n',Q23);
51
52 // (c)
53 Q34 = m*cv*(T4-T1); // heat rejected by air, [kJ]
54 mprintf('\n (c) The heat rejected by the air is =
           %f kJ\n',Q34);
55
56 // (d)
57 TE = 1-Q34/Q23; // ideal thermal efficiency
58 mprintf('\n (d) The ideal thermal efficiency is =
           %f percent\n',TE*100);
59
60 // (e)
61 W = Q23-Q34; // work done ,[kJ]
62 mprintf('\n (e) The work done is = %f kJ\n',W);
63
64 // (f)
65 Pm = W/(V1-V2); // mean effective pressure, [kN/m^2]
66 mprintf('\n (f) The mean effefctive pressure is =
           %f kN/m^2\n',Pm);
67

```

68 // End

Scilab code Exa 15.8 pressure volume temperature thermal efficiency theoretical output mean effective pressure and Carnot efficiency

```
1 clear;
2 clc;
3 disp('Example 15.8');
4
5 // aim : To determine
6 // (a) the pressure , volume and temperature at cycle
   state points
7 // (b) the thermal efficiency
8 // (c) the theoretical output
9 // (d) the mean effective pressure
10 // (e) the carnot efficiency
11
12 // given values
13 rv = 9; // volume ratio
14 P1 = 101; // initial pressure , [kN/m^2]
15 V1 = .003; // initial volume, [m^3]
16 T1 = 273+18; // initial temperature, [K]
17 P3 = 4500; // maximum pressure , [kN/m^2]
18 N = 3000;
19 cp = 1.006; // specific heat capacity at constant
   pressure , [kJ/kg K]
20 cv = .716; // specific heat capacity at constant
   volume, [kJ/kg K]
21
22 // solution
23 // taking reference Fig. 15.20
24 // (a)
25 // for process 1-2
26 Gama = cp/cv; // heat capacity ratio
27 R = cp-cv; // gas constant , [kJ/kg K]
```

```

28 V2 = V1/rv;// volume at stage2 , [m^3]
29 // using PV^(Gama)=constant for process 1-2
30 P2 = P1*(V1/V2)^(Gama);// pressure at stage2 ,. [kN/m
    ^2]
31 T2 = T1*(V1/V2)^(Gama-1);// [K]
32
33 // for process 2-3
34 V3 = V2;// volume at stage 3, [m^3]
35 // since volume is constant in process 2-3 , so
    using P/T=constant , so
36 T3 = T2*(P3/P2);// temperature at stage 3, [K]
37
38 // for process 3-4
39 V4 = V1;// volume at stage 4
40 // using PV^(Gama)=constant for process 3-4
41 P4 = P3*(V3/V4)^(Gama);// pressure at stage2 ,. [kN/m
    ^2]
42 T4 = T3*(V3/V4)^(Gama-1);// temperature at stage
    4,[K]
43
44 mprintf('\n (a) P1 = %f kN/m^2, V1 = %f m^3,
    t1 = %f C,\n P2 = %f kN/m^2,
    V2 = %f m^3, t2 = %f C,\n P3 = %f
    kN/m^2, V3 = %f m^3, t3 = %f C,\n
    P4 = %f kN/m^2, V4 = %f m^3,
    t4 = %f C\n',P1,V1,T1-273,P2,V2,T2-273,P3,V3,T3
    -273,P4,V4,T4-273);
45
46 // (b)
47 TE = 1-(T4-T1)/(T3-T2);// thermal efficiency
48 mprintf('\n (b) The thermal efficiency is = %f
    percent\n',TE*100);
49
50 // (c)
51 m = P1*V1/(R*T1);// mass os gas , [kg]
52 W = m*cv*((T3-T2)-(T4-T1));// work done, [kJ]
53 Wt = W*N/60;// workdone per minute, [kW]
54 mprintf('\n (c) The theoretical output is = %f

```

```

    kW\n',Wt);
55
56 // (d)
57 Pm = W/(V1-V2); // mean effective pressure, [kN/m^2]
58 mprintf('\n (g) The mean effeective pressure is =
    %f kN/m^2\n',Pm);
59
60 // (e)
61 CE = (T3-T1)/T3; // carnot efficiency
62 mprintf('\n (e) The carnot efficiency is = %f
    percent\n',CE*100);
63
64
65 // End

```

Scilab code Exa 15.9 pressure volume temperature work done thermal efficiency work ratio mean effective pressure and Carnot efficiency

```

1 clear;
2 clc;
3 disp('Example 15.9');
4
5 // aim : To determine
6 // (a) the pressure and temperature at cycle process
    change points
7 // (b) the work done
8 // (c) the thermal efficiency
9 // (d) the work ratio
10 // (e) the mean effective pressure
11 // (f) the carnot efficiency
12
13
14 // given values
15 rv = 16; // volume ratio of compression
16 P1 = 90; // initial pressure , [kN/m^2]

```

```

17 T1 = 273+40; // initial temperature, [K]
18 T3 = 273+1400; // maximum temperature, [K]
19 cp = 1.004; // specific heat capacity at constant
    pressure, [kJ/kg K]
20 Gama = 1.4; // heat capacity ratio
21
22 // solution
23 cv = cp/Gama; // specific heat capacity at constant
    volume, [kJ/kg K]
24 R = cp-cv; // gas constant, [kJ/kg K]
25 // for one kg of gas
26 V1 = R*T1/P1; // initial volume, [m^3]
27 // taking reference Fig. 15.22
28 // (a)
29 // for process 1-2
30 // using  $PV^{(\text{Gama})}=\text{constant}$  for process 1-2
31 // also  $rv = V1/V2$ 
32 P2 = P1*(rv)^(Gama); // pressure at stage2, . [kN/m^2]
33 T2 = T1*(rv)^(Gama-1); // temperature at stage 2, [K]
34
35 // for process 2-3
36 P3 = P2; // pressure at stage 3, [kN/m^2]
37 V2 = V1/rv; // [m^3]
38 // since pressure is constant in process 2-3, so
    using  $V/T=\text{constant}$ , so
39 V3 = V2*(T3/T2); // volume at stage 3, [m^3]
40
41 // for process 1-4
42 V4 = V1; // [m^3]
43 P4 = P3*(V3/V4)^(Gama)
44 // since in stage 1-4 volume is constant, so  $P/T=$ 
    constant,
45 T4 = T1*(P4/P1); // temperature at stage 4, [K]
46
47 mprintf(' \n (a) P1 = %f kN/m^2,          t1 =
    %f C, \n      P2 = %f kN/m^2,          t2 = %f C
    , \n          P3 = %f kN/m^2,          t3 = %f C, \n
    P4 = %f kN/m^2,          t4 = %f C \n ',

```

```

    P1 , T1 - 273 , P2 , T2 - 273 , P3 , T3 - 273 , P4 , T4 - 273 );
48
49 // (b)
50 W = cp*(T3-T2)-cv*(T4-T1); // work done, [kJ]
51 mprintf('\n (b) The work done is = %f kJ\n',W);
52
53 // (c)
54 TE = 1-(T4-T1)/((T3-T2)*Gama); // thermal efficiency
55 mprintf('\n (c) The thermal efficiency is = %f
    percent\n',TE*100);
56
57 // (d)
58 PW = cp*(T3-T2)+R*(T3-T4)/(Gama-1); // positive work
    done
59 WR = W/PW; // work ratio
60 mprintf('\n (d) The work ratio is = %f\n',WR);
61
62 // (e)
63 Pm = W/(V1-V2); // mean effective pressure, [kN/m^2]
64 mprintf('\n (e) The mean effefctive pressure is =
    %f kN/m^2\n',Pm);
65
66 // (f)
67 CE = (T3-T1)/T3; // carnot efficiency
68 mprintf('\n (f) The carnot efficiency is = %f
    percent\n',CE*100);
69
70 // value of t2 printed in the book is incorrect
71
72 // End

```

Scilab code Exa 15.10 maximum temperature and thermal efficiency

```

1 clear;
2 clc;

```

```

3 disp('Example 10');
4
5 // aim : To determine
6 // (a) the maximum temperature attained during the
   cycle
7 // (b) the thermal efficiency of the cycle
8
9 // given value
10 rva =7.5;// volume ratio of adiabatic expansion
11 rvc =15;// volume ratio of compression
12 P1 = 98;// initial pressure , [kn/m^2]
13 T1 = 273+44;// initial temperature , [K]
14 P4 = 258;// pressure at the end of the adiabatic
   expansion , [kN/m^2]
15 Gama = 1.4;// heat capacity ratio
16
17 // solution
18 // by seeing diagram
19 // for process 4-1, P4/T4=P1/T1
20 T4 = T1*(P4/P1);// [K]
21 // for process 3-4
22 T3 = T4*(rva)^(Gama-1);
23 mprintf('\n (a) The maximum temperature during the
   cycle is = %f C\n',T3-273);
24
25 // (b)
26
27 // for process 1-2,
28 T2 = T1*(rvc)^(Gama-1);// [K]
29 n_the = 1-(T4-T1)/((Gama)*(T3-T2));// thermal
   efficiency
30 mprintf('\n (b) The thermal efficiency of the cycle
   is = %f percent\n',n_the*100);
31
32 // End

```

Scilab code Exa 15.11 thermal efficiency and indicated power

```
1 clear;
2 clc;
3 disp('Example 15.11');
4
5 // aim : To determine
6 // (a) the thermal efficiency of the cycle
7 // (b) the indicated power of the cycle
8
9 // given values
10 // taking basis one second
11 rv = 11; // volume ratio
12 P1 = 96; // initial pressure , [kN/m^2]
13 T1 = 273+18; // initial temperature, [K]
14 Gama = 1.4; // heat capacity ratio
15
16 // solution
17 // taking reference Fig. 15.24
18 // (a)
19 Beta = 2; // ratio of V3 and V2
20 TE = 1-(Beta^(Gama)-1)/((rv^(Gama-1))*Gama*(Beta-1))
    ; // thermal efficiency
21 mprintf('\n (a) the thermal efficiency of the cycle
    is = %f percent\n ',TE*100);
22
23 // (b)
24 // let V1-V2=.05, so
25 V2 = .05*.1; // [m^3]
26 // from this
27 V1 = rv*V2; // [m^3]
28 V3 = Beta*V2; // [m^3]
29 V4 = V1; // [m^3]
30 P2 = P1*(V1/V2)^(Gama); // [kN/m^2]
```



```

31 P3 = P2; // [kn/m^2]
32 P4=P3*(V3/V4)^(Gama); // [kN/m^2]
33 // indicated power
34 W = P2*(V3-V2)+((P3*V3-P4*V4)-(P2*V2-P1*V1))/(Gama
    -1); // indicated power, [kW]
35 mprintf('\n (c) The indicated power of the cycle is
    = %f kW\n',W);
36
37 // End

```

Scilab code Exa 15.12 pressures and temperatures

```

1 clear;
2 clc;
3 disp('Example 15.12');
4
5 // aim : To determine
6 // (a) the pressure and temperature at the end of
    compression
7 // (b) the pressure and temperature at the end of
    the constant volume process
8 // (c) the temperature at the end of constant
    pressure process
9
10 // given values
11 P1 = 103; // initial pressure, [kN/m^2]
12 T1 = 273+22; // initial temperature, [K]
13 rv = 16; // volume ratio of the compression
14 Q = 244; // heat added, [kJ/kg]
15 Gama = 1.4; // heat capacity ratio
16 cv = .717; // heat capacity, [kJ/kg k]
17
18 // solution
19 // taking reference as Fig.15.26
20 // (a)

```

```

21 // for compression
22 // rv = V1/V2
23 P2 = P1*(rv)^Gama; // pressure at end of compression ,
    [kN/m^2]
24 T2 = T1*(rv)^(Gama-1); // temperature at end of
    compression , [K]
25 fprintf('\n (a) The pressure at the end of
    compression is = %f MN/m^2\n',P2*10^-3);
26 fprintf('\n      The temperature at the end of
    compression is = %f C\n',T2-273);
27
28 // (b)
29 // for constant volume process ,
30 // Q = cv*(T3-T2), so
31 T3 = T2+Q/cv; // temperature at the end of constant
    volume, [K]
32
33 // so for constant volume, P/T=constant, hence
34 P3 = P2*(T3/T2); // pressure at the end of constant
    volume process, [kN/m^2]
35 fprintf('\n (b) The pressure at the end of constant
    volume process is = %f MN/m^2\n ',P3*10^-3);
36 fprintf('\n      The temperature at the end of
    constant volume process is = %f C\n',T3-273);
37
38 // (c)
39 S = rv-1; // stroke
40 // assuming
41 V3 = 1; // [volume]
42 //so
43 V4 = V3+S*.03; // [volume]
44 // also for constant process V/T=constant, hence
45 T4 = T3*(V4/V3); // temperature at the end of
    constant pressure process, [k]
46 fprintf('\n (c) The temperature at the end of
    constant pressure process is = %f C\n',T4-273);
47
48 // End

```

Scilab code Exa 15.13 pressure volume temperature work done thermal efficiency heat work ratio mean effective pressure and Carnot efficiency

```
1 clear;
2 clc;
3 disp('Example 15.13');
4
5 // aim : To determine
6 // (a) the pressure , volume and temperature at cycle
   process change points
7 // (b) the net work done
8 // (c) the thermal efficiency
9 // (d) the heat received
10 // (e) the work ratio
11 // (f) the mean effective pressure
12 // (g) the carnot efficiency
13
14
15 // given values
16 rv = 15; // volume ratio
17 P1 = 97*10^-3; // initial pressure , [MN/m^2]
18 V1 = .084; // initial volume , [m^3]
19 T1 = 273+28; // initial temperature , [K]
20 T4 = 273+1320; // maximum temperature , [K]
21 P3 = 6.2; // maximum pressure , [MN/m^2]
22 cp = 1.005; // specific heat capacity at constant
   pressure , [kJ/kg K]
23 cv = .717; // specific heat capacity at constant
   volume , [kJ/kg K]
24
25 // solution
26 // taking reference Fig. 15.27
27 // (a)
28 R = cp-cv; // gas constant , [kJ/kg K]
```

```

29 Gama = cp/cv;// heat capacity ratio
30 // for process 1-2
31 V2 = V1/rv;// volume at stage2 , [m^3]
32 // using PV^(Gama)=constant for process 1-2
33 P2 = P1*(V1/V2)^(Gama);// pressure at stage2 ,. [MN/m
    ^2]
34 T2 = T1*(V1/V2)^(Gama-1);// temperature at stage 2,
    [K]
35
36 // for process 2-3
37 // since volumee is constant in process 2-3 , so
    using P/T=constant , so
38 T3 = T2*(P3/P2);// volume at stage 3, [K]
39 V3 = V2;// volume at stage 3, [MN/m^2]
40
41 // for process 3-4
42 P4 = P3;// pressure at stage 4, [m^3]
43 // since in stage 3-4 P is constant, so V/T=constant
    ,
44 V4 = V3*(T4/T3);// temperature at stage 4,[K]
45
46 // for process 4-5
47 V5 = V1;// volume at stage 5, [m^3]
48 P5 = P4*(V4/V5)^(Gama);// pressure at stage5 ,. [MN/m
    ^2]
49 T5 = T4*(V4/V5)^(Gama-1);// temperature at stage 5,
    [K]
50
51 mprintf( '\n (a)  P1 = %f kN/m^2,    V1 = %f m^3,
    t1 = %f C,\n          P2 = %f MN/m^2,
    V2 = %f m^3,          t2 = %f C,\n          P3 =
    %f MN/m^2,    V3 = %f m^3,          t3 = %f C
    ,\n          P4 = %f MN/m^2,    V4 = %f m^3,
    t4 = %f C,\n          P5 = %fkN/m^2,    V5
    = %fm^3,          t5 = %fC\n',P1*10^3,V1,T1
    -273,P2,V2,T2-273,P3,V3,T3-273,P4,V4,T4-273,P5
    *10^3,V5,T5-273);

```

52

```

53
54 // (b)
55 W = (P3*(V4-V3)+((P4*V4-P5*V5)-(P2*V2-P1*V1))/(Gama
      -1))*10^3;// work done, [kJ]
56 mprintf('\n (b) The net work done is = %f kJ\n',W)
      ;
57
58 // (c)
59 TE = 1-(T5-T1)/((T3-T2)+Gama*(T4-T3));// thermal
      efficiency
60 mprintf('\n (c) The thermal efficiency is = %f
      percent\n',TE*100);
61
62 // (d)
63 Q = W/TE;// heat received, [kJ]
64 mprintf('\n (d) The heat received is = %f kJ\n',Q)
      ;
65
66 // (e)
67 PW = P3*(V4-V3)+(P4*V4-P5*V5)/(Gama-1)
68 WR = W*10^-3/PW;// work ratio
69 mprintf('\n (f) The work ratio is = %f\n',WR);
70
71 // (e)
72 Pm = W/(V1-V2);// mean effective pressure, [kN/m^2]
73 mprintf('\n (e) The mean effective pressure is =
      %f kN/m^2\n',Pm);
74
75 // (f)
76 CE = (T4-T1)/T4;// carnot efficiency
77 mprintf('\n (f) The carnot efficiency is = %f
      percent\n',CE*100);
78
79 // End

```

Scilab code Exa 15.14 thermal efficiency heat work done work ratio and mean effective pressure

```

1  clear;
2  clc;
3  disp('Example 15.14');
4
5  // aim : To determine
6  // (a)  the thermal efficiency
7  // (b)  the heat received
8  // (c)  the heat rejected
9  // (d)  the net work
10 // (e)  the work ratio
11 // (f)  the mean effective pressure
12 // (g)  the carnot efficiency
13
14
15 // given values
16 P1 = 101; // initial pressure , [kN/m^2]
17 V1 = 14*10^-3; // initial volume, [m^3]
18 T1 = 273+15; // initial temperature, [K]
19 P3 = 1850; // maximum pressure , [kN/m^2]
20 V2 = 2.8*10^-3; // compressed volume, [m^3]
21 Gama = 1.4; // heat capacity
22 R = .29; // gas constant , [kJ/kg k]
23
24 // solution
25 // taking reference Fig. 15.29
26 // (a)
27 // for process 1-2
28 // using  $PV^{(\text{Gama})}=\text{constant}$  for process 1-2
29 P2 = P1*(V1/V2)^(Gama); // pressure at stage2 ,. [MN/m
    ^2]
30 T2 = T1*(V1/V2)^(Gama-1); // temperature at stage 2,
    [K]
31
32 // for process 2-3
33 // since volumee is constant in process 2-3 , so

```

```

    using P/T=constant , so
34 T3 = T2*(P3/P2); // volume at stage 3, [K]
35
36 // for process 3-4
37 P4 = P1;
38 T4 = T3*(P4/P3)^((Gama-1)/Gama); // temperature
39
40 TE = 1-Gama*(T4-T1)/(T3-T2); // thermal efficiency
41 mprintf('\n (a) The thermal efficiency is = %f
    percent\n', TE*100);
42
43 // (b)
44 cv = R/(Gama-1); // heat capacity at constant volume
    , [kJ/kg k]
45 m = P1*V1/(R*T1); // mass of gas, [kg]
46 Q1 = m*cv*(T3-T2); // heat received, [kJ/cycle]
47 mprintf('\n (b) The heat received is = %f kJ/cycle
    \n', Q1);
48
49 // (c)
50 cp = Gama*cv; // heat capacity at constant at
    constant pressure, [kJ/kg K]
51 Q2 = m*cp*(T4-T1); // heat rejected, [kJ/cycle]
52 mprintf('\n (c) The heat rejected is = %f kJ/cycle
    \n', Q2);
53
54 // (d)
55 W = Q1-Q2; // net work, [kJ/cycle]
56 mprintf('\n (d) The net work is = %f kJ/cycle\n',
    W);
57
58 // (e)
59 // pressure is constant for process 1-4, so V/T=
    constant
60 V4 = V1*(T4/T1); // volume, [m^3]
61 V3 = V2; // for process 2-3
62 P4 = P1; // for process 1-4
63 PW = (P3*V3-P1*V1)/(Gama-1); // positive work done, [

```

```

        kJ/cycle]
64 WR = W/PW;// work ratio
65 mprintf('\n (e) The work ratio is = %f\n',WR);
66
67 // (f)
68 Pm = W/(V4-V2);// mean effective pressure , [kN/m^2]
69 mprintf('\n (f) The mean effefctive pressure is =
        %f kN/m^2\n',Pm);
70
71 // (g)
72 CE = (T3-T1)/T3;// carnot efficiency
73 mprintf('\n (g) The carnot efficiency is = %f
        percent\n',CE*100);
74
75 // there is minor variation in answer reported in
        the book
76
77 // End

```

Scilab code Exa 15.15 work done and thermal efficiency

```

1 clear;
2 clc;
3 disp('Example 15.15 ');
4
5 // aim : To determine
6 // (a) the net work done
7 // (b) the ideal thermal efficiency
8 // (c) the thermal efficiency if the process of
        generation is not included
9
10 // given values
11 P1 = 110;// initial pressure , [kN/m^2]
12 T1 = 273+30;// initial temperature , [K]
13 V1 = .05;// initial volume , [m^3]

```



```

14 V2 = .005; // volume, [m^3]
15 T3 = 273+700; // temperature, [m^3]
16 R = .289; // gas constant, [kJ/kg K]
17 cv = .718; // heat capacity, [kJ/kg K]
18
19 // solution
20 // (a)
21 m = P1*V1/(R*T1); // mass, [kg]
22 W = m*R*(T3-T1)*log(V1/V2); // work done, [kJ]
23 mprintf('\n (a) The net work done is = %f kJ\n',W)
    ;
24
25 // (b)
26 n_the = (T3-T1)/T3; // ideal thermal efficiency
27 mprintf('\n (b) The ideal thermal efficiency is =
    %f percent\n',n_the*100);
28
29 // (c)
30 V4 = V1;
31 V3 = V2;
32 T4 = T3;
33 T2 = T1;
34
35 Q_rej = m*cv*(T4-T1)+m*R*T1*log(V1/V2); // heat
    rejected
36 Q_rec = m*cv*(T3-T2)+m*R*T3*log(V4/V3); // heat
    received
37
38 n_th = (1-Q_rej/Q_rec); // thermal efficiency
39 mprintf('\n (c) the thermal efficiency if the
    process of regeneration is not included is = %f
    percent\n',n_th*100);
40
41 // End

```

Scilab code Exa 15.16 maximum temperature work done and thermal efficiency

```

1  clear;
2  clc;
3  disp('Example 15.16 ');
4
5  // aim : To determine
6  // (a) the maximum temperature
7  // (b) the net work done
8  // (c) the ideal thermal efficiency
9  // (d) the thermal efficiency if the process of
    regeneration is not included
10
11 // given values
12 P1 = 100; // initial pressure , [kN/m^2)
13 T1 = 273+20; // initial temperature , [K]
14 V1 = .08; // initial volume , [m^3]
15 rv = 5; // volume ratio
16 R = .287; // gas constant , [kJ/kg K]
17 cp = 1.006; // heat capacity , [kJ/kg K]
18 V3_by_V2 = 2;
19
20 // solution
21 // (a)
22 // using Fig.15.33
23 // process 1-2 is isothermal
24 T2 = T1;
25 // since process 2-3 is isobaric , so V/T=constant
26 T3 = T2*(V3_by_V2); // maximum temperature , [K]
27 mprintf('\n (a) The maximum temperature is = %f C\
    n', T3-273);
28
29 // (b)
30 m = P1*V1/(R*T1); // mass , [kg]
31 W = m*R*(T3-T1)*log(rv); // work done , [kJ]
32 mprintf('\n (b) The net work done is = %f kJ\n', W
    );

```

```

33
34 // (c)
35 TE = (T3-T1)/T3; // ideal thermal efficiency
36 mprintf('\n (c) The ideal thermal efficiency is =
    %f percent\n',TE*100);
37
38 // (d)
39 T4 = T3;
40 T2 = T1;
41
42 Q_rej = m*cp*(T4-T1)+m*R*T1*log(rv); // heat rejected
43 Q_rec = m*cp*(T3-T2)+m*R*T3*log(rv); // heat received
44
45 n_th = (1-Q_rej/Q_rec); // thermal efficiency
46 mprintf('\n (d) the thermal efficiency if the
    process of regeneration is not included is = %f
    percent\n',n_th*100);
47
48 // End

```

Scilab code Exa 15.17 work done and thermal efficiency

```

1 clear;
2 clc;
3 disp('Example 15.17 ');
4
5 // aim : To determine
6 // (a) the net work done
7 // (b) the thermal efficiency
8
9 // given values
10 m = 1; // mass of air , [kg]
11 T1 = 273+230; // initial temperature , [K]
12 P1 = 3450; // initial pressure , [kN/m^2]
13 P2 = 2000; // pressure , [kN/m^2]

```

```

14 P3 = 140; // pressure , [kN/m^2]
15 P4 = P3;
16 Gama = 1.4; // heat capacity ratio
17 cp = 1.006; // heat capacity , [kJ/kg k]
18
19 // solution
20 T2 =T1; // isothermal process 1-2
21 // process 2-3 and 1-4 are adiabatic so
22 T3 = T2*(P3/P2)^((Gama-1)/Gama); // temperature , [K]
23 T4 = T1*(P4/P1)^((Gama-1)/Gama); // [K]
24 R = cp*(Gama-1)/Gama; // gas constant , [kJ/kg K]
25 Q1 = m*R*T1*log(P1/P2); // heat received , [kJ]
26 Q2 = m*cp*(T3-T4); // heat rejected
27
28 //hence
29 W = Q1-Q2; // work done
30 mprintf('\n (a) The net work done is = %f kJ\n',W)
    ;
31
32 // (b)
33 TE = 1-Q2/Q1; // thermal efficiency
34 mprintf('\n (b) The thermal efficiency is = %f
    percent\n',TE*100);
35
36 // End

```

Scilab code Exa 15.18 thermal efficiency and Carnot efficiency

```

1 clear;
2 clc;
3 disp('Example 15.18 ');
4
5 // aim : To determine
6 // thermal efficiency
7 // carnot efficiency

```

```

8
9 // given values
10 rv = 5; // volume ratio
11 Gama = 1.4; // heat capacity ratio
12
13 // solution
14 // under given condition
15
16 TE = 1-(1/Gama*(2-1/rv^(Gama-1)))/(1+2*((Gama-1)/
    Gama)*log(rv/2)); // thermal efficiency
17 mprintf('\n The thermal efficiency is = %f percent
    \n',TE*100);
18
19 CE = 1-1/(2*rv^(Gama-1)); // carnot efficiency
20 mprintf('\n The carnot efficiency is = %f \n',CE
    *100);
21
22 // End

```

Chapter 16

Internal combustion engines

Scilab code Exa 16.1 power output thermal efficiency and work ratio

```
1 clear;
2 clc;
3 disp('Example 16.1 ');
4
5 // aim : To determine
6 // (a) the net power output of the turbine plant if
7 //       the turbine is coupled to the compressor
8 // (b) the thermal efficiency of the plant
9 // (c) the work ratio
10
11 // Given values
12 P1 = 100; // inlet pressure of compressor, [kN/m^2]
13 T1 = 273+18; // inlet temperature, [K]
14 P2 = 8*P1; // outlet pressure of compressor, [kN/m^2]
15 n_com = .85; // isentropic efficiency of compressor
16 T3 = 273+1000; // inlet temperature of turbine, [K]
17 P3 = P2; // inlet pressure of turbine, [kN/m^2]
18 P4 = 100; // outlet pressure of turbine, [kN/m^2]
19 n_tur = .88; // isentropic efficiency of turbine
20 m_dot = 4.5; // air mass flow rate, [kg/s]
21 cp = 1.006; // [kJ/kg K]
```

```

21 Gamma = 1.4; // heat capacity ratio
22
23 // (a)
24 // For the compressor
25 T2_prime = T1*(P2/P1)^((Gamma-1)/Gamma); // [K]
26 T2 = T1+(T2_prime-T1)/n_com; // exit pressure of
    compressor, [K]
27
28 // for turbine
29 T4_prime = T3*(P4/P3)^((Gamma-1)/Gamma); // [K]
30 T4 = T3-(T3-T4_prime)*n_tur; // exit temperature of
    turbine, [K]
31
32 P_output = m_dot*cp*((T3-T4)-(T2-T1)); // [kW]
33 mprintf('\n (a) The net power output is = %f kW\n
    ',P_output);
34
35 // (b)
36 n_the = ((T3-T4)-(T2-T1))/(T3-T2)*100; // thermal
    efficiency
37 mprintf('\n (b) The thermal efficiency of the plant
    is = %f percent\n',n_the);
38
39 // (c)
40 P_pos = m_dot*cp*(T3-T4); // Positive cycle work, [kW
    ]
41
42 W_ratio = P_output/P_pos; // work ratio
43 mprintf('\n (c) The work ratio is = %f\n',W_ratio)
44
45 // End

```

Scilab code Exa 16.2 pressure ratio work output thermal efficiency work ratio and Carnot efficiency

```

1  clear;
2  clc;
3  disp('Example 16.2');
4
5  // aim : To determine
6  // (a) the pressure ratio which will give the maximum
       net work output
7  // (b) the maximum net specific work output
8  // (c) the thermal efficiency at maximum work output
9  // (d) the work ratio at maximum work output
10 // (e) the carnot efficiency within the cycle
       temperature limits
11
12 // Given values
13 // taking the reference as Fig.16.35
14 T3 = 273+1080; // [K]
15 T1 = 273+10; // [K]
16 cp = 1.007; // [kJ/kg K]
17 Gamma = 1.41; // heat capacity ratio
18
19 // (a)
20 r_pmax = (T3/T1)^((Gamma)/(Gamma-1)); // maximum
       pressure ratio
21 // for maximum net work output
22 r_p = sqrt(r_pmax);
23 mprintf('\n (a) The pressure ratio which give the
       maximum network output is = %f\n',r_p);
24
25 // (b)
26 T2 = T1*(r_p)^((Gamma-1)/Gamma); // [K]
27 // From equation [23]
28 T4 = T2;
29 W_max = cp*((T3-T4)-(T2-T1)); // Maximum net specific
       work output , [kJ/kg]
30
31 mprintf('\n (b) The maximum net specific work output
       is = %f kJ/kg\n',W_max);
32

```



```

33 // (c)
34 W = cp*(T3-T2);
35 n_the = W_max/W; // thermal efficiency
36 mprintf('\n (c) The thermal efficiency at maximum
    work output is = %f percent\n ',n_the*100);
37
38 // (d)
39 // From the equation [26]
40 W_ratio = n_the; // Work ratio
41 mprintf('\n (d) The work ratio at maximum work
    output is = %f\n ',W_ratio);
42
43 // (e)
44 n_carnot = (T3-T1)/T3*100; // carnot efficiency
45 mprintf('\n (e) The carnot efficiency within the
    cycle temperature limits is = %f percent\n ',
    n_carnot);
46
47 // End

```

Scilab code Exa 16.3 power output temperature thermal efficiency and work ratio

```

1  clc;
2  disp('Example 16.3 ');
3
4  // aim : To determine
5  // (a) the net power output of the plant
6  // (b) the exhaust temperature from the heat
    exchanger
7  // (c) the thermal efficiency of the plant
8  // (d) the thermal efficiency of the plant if there
    were no heat exchanger
9  // (e) the work ratio
10

```

```

11 // Given values
12 T1 = 273+15; // temperature, [K]
13 P1 = 101; // pressure, [kN/m^2]
14 P2 = 6*P1; // [kN/m^2]
15 eff = .65; // effectiveness of the heat exchanger,
16 T3 = 273+870; // temperature, [K]
17 P4 = 101; // [kN/m^2]
18 n_com = .85; // efficiency of compressor,
19 n_tur = .80; // efficiency of turbine
20 m_dot = 4; // mass flow rate, [kg/s]
21 Gama = 1.4; // heat capacity ratio
22 cp = 1.005; // [kJ/kg K]
23
24 // solution
25 // (a)
26 // For compressor
27 T2_prim = T1*(P2/P1)^((Gama-1)/Gama); // [K]
28
29 // using n_com = (T2_prim-T1)/(T2-T1)
30
31 T2 = T1+(T2_prim-T1)/n_com
32 // For turbine
33 P3 = P2;
34 T4_prim = T3*(P4/P3)^((Gama-1)/Gama); // [K]
35
36 T4=T3-n_tur*(T3-T4_prim); // [K]
37 P_out = m_dot*cp*((T3-T4)-(T2-T1)); // net power
    output, [kW]
38 mprintf('\\n (a) The net power output of the plant is
    = %f kW\\n',P_out);
39
40 // (b)
41 mtd = T4-T2; // maximum temperature drop for heat
    transfer, [K]
42 atd = eff*mtd; // actual temperature, [K]
43 et = T4-atd; // Exhaust temperature from heat
    exchanger, [K]
44 t6 = et-273; // [C]

```

```

45 mprintf('\n (b) The exhaust temperature from the
    heat exchanger is = %f C\n',t6);
46
47 // (c)
48 T5 = T2+atd;// [K]
49 n_the = ((T3-T4)-(T2-T1))/(T3-T5)*100;// thermal
    efficiency
50 mprintf('\n (c) The thermal efficiency of the plant
    is = %f percent\n',n_the);
51
52 // (d)
53 // with no heat exchanger
54 n_the = ((T3-T4)-(T2-T1))/(T3-T2)*100;// thermal
    efficiency without heat exchanger
55 mprintf('\n (d) The thermal efficiency of the plant
    if there wereno heat exchanger is = %f percent
    \n',n_the);
56
57 // (e)
58 P_pos = m_dot*cp*(T3-T4);// positive cycle work;// [
    kW]
59 w_rat = P_out/P_pos;// work ratio
60 mprintf('\n (e) The work ratio is = %f\n',w_rat)
61
62 // End

```

Scilab code Exa 16.4 pressure temperature power output thermal efficiency work ratio and Carnot efficiency

```

1 clear;
2 clc;
3 disp('Example 16.4');
4
5 // aim : To determine
6 // (a) the pressure and temperature as the air

```

```

leaves the compressor turbine
7 // (b) the power output from the free power turbine
8 // (c) the thermal efficiency of the plant
9 // (d) the work ratio
10 // (e) the carnot efficiency within the cycle
    temperature limits
11
12 // Given values
13 T1 = 273+19; // temperature , [K]
14 P1 = 100; // pressure , [kN/m^2]
15 P2 = 8*P1; // [kN/m^2]
16 P3 = P2; // [kN/m^2]
17 T3 = 273+980; // temperature , [K]
18 n_com = .85; // efficiency of rotary compressor
19 P5 = 100; // [kN/m^2]
20 n_cum = .88; // isentropic efficiency of combustion
    chamber compressor ,
21 n_tur = .86; // isentropic efficiency of turbine
22 m_dot = 7; // mass flow rate of air , [kg/s]
23 Gama = 1.4; // heat capacity ratio
24 cp = 1.006; // [kJ/kg K]
25
26 // solution
27 // (a)
28 // For compressor
29 T2_prim = T1*(P2/P1)^((Gama-1)/Gama); // [K]
30
31 T2 = T1+(T2_prim-T1)/n_com; // temperature , [K]
32
33 // for compressor turbine
34 // T3-T4 = T2-T1, because compressor turbine power=
    compressor power so
35 T4 = T3-(T2-T1); // turbine exit temperature , [K]
36 T4_prim = T3-(T3-T4)/n_cum; // [K]
37
38 // For turbine
39 // T4_prim = T3*(P4/P3)^((Gama-1)/Gama)
40 P4 = P3*(T4_prim/T3)^(Gama/(Gama-1)); // exit air

```

```

    pressure of air , [kN/m^2]
41
42 mprintf('\\n (a) The temperature as the air leaves
    the compressor turbine is = %f C\\n',T4-273);
43 mprintf('\\n      The pressure as the air leaves the
    compressor turbine is = %f kN/m^2\\n',P4);
44
45 // (b)
46 T5_prim = T4*(P5/P4)^((Gama-1)/Gama); // [K]
47
48
49 T5 = T4-n_tur*(T4-T5_prim); // temperature , [K]
50
51 P0 = m_dot*cp*(T4-T5); // power output
52 mprintf('\\n (b) The power output from the free power
    turbine is = %f kW\\n',P0);
53
54 // (c)
55
56 n_the = (T4-T5)/(T3-T2)*100; // thermal efficiency
57 mprintf('\\n (c) The thermal efficiency of the plant
    is = %f percent\\n',n_the);
58
59 // (d)
60
61 WR = (T4-T5)/(T3-T5); // work ratio
62 mprintf('\\n (d) The work ratio is = %f\\n',WR);
63
64 // (e)
65 CE = (T3-T1)/T3; // carnot efficiency
66 mprintf('\\n (e) The carnot efficiency is = %f
    percent\\n',CE*100);
67
68 // End

```

Scilab code Exa 16.5 pressure temperature and power developed

```
1 clear;
2 clc;
3 disp('Example 16.5 ');
4
5 // aim : To determine
6 // (a) the pressure and temperature of the air
   compression
7 // (b) the power developed by the gas turbine
8 // (c) the temperature and pressure of the
   airentering the exhaust jet as it leaves the gas
   turbine
9
10 // Given values
11 T1 = 273-22.4; // temperature , [K]
12 P1 = 470; // pressure , [bar]
13 P2 = 30*P1; // [kN/m^2]
14 P3 = P2; // [kN/m^2]
15 T3 = 273+960; // temperature , [K]
16 r = 1.25; // ratio of turbine power to compressor
   power
17 n_tur = .86; // isentropic efficiency of turbine
18 m_dot = 80; // mass flow rate of air , [kg/s]
19 Gama = 1.41; // heat capacity ratio
20 cp = 1.05; // [kJ/kg K]
21
22 // solution
23 // (a)
24 // For compressor
25 T2_prim = T1*(P2/P1)^((Gama-1)/Gama); // [K]
26 // using n_tur=(T2_prim-T1)/(T2-T1)
27 T2 = T1+(T2_prim-T1)/n_tur; // temperature , [K]
28
29 mprintf('\n (a) The pressure of the air after
   compression is = %f bar\n',P2);
30
31 mprintf('\n           The temperature of the air after
```

```

        compression is = %f C\n',T2-273);
32
33 // (b)
34 Td = r*(T2-T1); // temperature drop in turbine, [K]
35 P0 = m_dot*cp*Td; // power output, [kW]
36 mprintf('\n (b) The power developed by the gas
        turbine is = %f MW\n',P0*10^-3);
37
38 // (c)
39 t3 = T3-273; // [C]
40 t4 = t3-Td; // temeperature of air leaving turbine,[
        K]
41 Tdi = Td/n_tur; // isentropic temperature drop, [K]
42 T4_prim = t3-Tdi+273; // temperature, [K]
43 // using T4_prim=T3*(P4/P3)^((Gama-1)/Gama)
44 P4 = P3*(T4_prim/T3)^(Gama/(Gama-1)); // exit air
        pressure of air, [kN/m^2]
45
46 mprintf('\n (c) The air pressure as it leaves the
        gas turbine is = %f bar\n',P4);
47
48 // Result in the book is not matching because they
        have taken pressure in mbar but in in question
        it is given in bar
49
50 // End

```

Scilab code Exa 16.6 mass theoretical output and thermal efficiency

```

1 clc;
2 disp('Example 16.6 ');
3
4 // aim : To determine
5 // (a) the mass of fuel oil used by the gas turbine
6 // (b) the mass flow of steam from the boiler

```

```

7 // (c) the theoretical output from the steam turbine
8 // (d) the overall theoretical thermal efficiency of
  the plant
9
10 // given values
11 Po = 150; // generating plant output, [MW]
12 n_the1 = .35; // thermal efficiency
13 CV = 43; // calorific value of fuel, [MJ]
14 me = 400; // flow rate of exhaust gas, [kg/s]
15 T = 90; // boiler exit temperature, [C]
16 T1 = 550; // exhaust gas temperature, [C]
17 P2 = 10; // steam generation pressure, [MN/m^2]
18 T2 = 450; // boiler exit temperature, [C]
19 Tf = 140; // feed water temperature, [C]
20 n_tur = .86; // turbine efficiency
21 P3 = .5; // exhaust temperature, [MN/m^2]
22 n_boi = .92; // boiler thermal efficiency
23 cp = 1.1; // heat capacity, [kJ/kg]
24
25
26 // solution
27 // (a)
28 ER = Po*3600/n_the1; // energy requirement from the
  fuel, [MJ/h]
29 mf = ER/CV*10^-3; // fuel required, [tonne/h]
30 mprintf(' \n (a) The mass of fuel oil used by the gas
  is = %f tonne/h \n',mf);
31
32 // (b)
33
34 ET = me*cp*(T1-T)*3600*n_boi; // energy transferred
  to steam, [kJ/h]
35 // from steam table
36 h1 = 3244; // specific enthalpy, [kJ/kg]
37 hf = 588.5; // specific enthalpy, [kJ/kg]
38 ERR = h1-hf; // energy required to raise steam, [kJ/
  kg]
39 ms = ET/ERR*10^-3; // mass flow of steam, [tonne/h]

```



```

40 mprintf('\\n (b) The mass flow rate of steam from
    the boiler is = %f tonne/h\\n',ms);
41
42 // again from steam table
43 s1 = 6.424;// specific entropy, [kJ/kg K]
44 sf2 = 1.86;// specific entropy, [kJ/kg K]
45 sg2 = 6.819;// specific entropy, [kJ/kg K]
46
47 hf2 = 640.1;// specific enthalpy,[kJ/kg]
48 hg2 = 2747.5;// specific enthalpy, [kJ/kg]
49 // for ths process s1=s2=sf2+x2*(sg2-sf2)
50 s2 = s1;
51 // hence
52 x2 = (s2-sf2)/(sg2-sf2);// dryness fraction
53
54 h2_prim = hf2+x2*(hg2-hf2);// specific enthalpy of
    steam, [kJ/kg]
55
56 T0 = n_tur*(h1-h2_prim);//theoretical steam turbine
    output, [kJ/kg]
57 T0t = T0*ms/3600;// total theoretical steam turbine
    output, [MW]
58
59 mprintf('\\n (c) The theoretical output from the
    steam turbine is = %f MW\\n',T0t);
60
61 // (d)
62 n_tho = (Po+T0t)*n_the1/Po;// overall theoretical
    thermal efficiency
63 mprintf('\\n (d) The overall thermal efficiency is =
    %f percent\\n',n_tho*100);
64
65 // End

```

Chapter 17

Engine and plant trials

Scilab code Exa 17.1 indicated and brake output mechanical efficiency and energy balance

```
1 clear;
2 clc;
3 disp('Example 17.1 ');
4
5 // aim : To determine
6 // the indicated and brake output and the mechanical
7 // efficiency
8 // draw up an overall energy balance and as % age
9 // given values
10 h = 21; // height of indicator diagram, [mm]
11 ic = 27; // indicator calibration, [kN/m^2 per mm]
12 sv = 14*10^-3; // swept volume of the cylinder; , [m^3]
13 N = 6.6; // speed of engine, [rev/s]
14 ebl = 77; // effective brake load, [kg]
15 ebr = .7; // effective brake radius, [m]
16 fc = .002; // fuel consumption, [kg/s]
17 CV = 44000; // calorific value of fuel, [kJ/kg]
18 cwc = .15; // cooling water circulation, [kg/s]
19 Ti = 38; // cooling water inlet temperature, [C]
```

```

20 To = 71; // cooling water outlet temperature, [C]
21 c = 4.18; // specific heat capacity of water, [kJ/kg]
22 eeg = 33.6; // energy to exhaust gases, [kJ/s]
23 g = 9.81; // gravitational acceleration, [m/s^2]
24
25 // solution
26 PM = ic*h; // mean effective pressure, [kN/m^2]
27 LA = sv; // swept volume of the cylinder, [m^3]
28 ip = PM*LA*N/2; // indicated power, [kW]
29 T = ebl*g*ebr; // torque, [N*m]
30 bp = 2*pi*N*T; // brake power, [W]
31 n_mech = bp/ip*10^-3; // mechanical efficiency
32 mprintf('\n The Indicated power is = %f kW\n', ip);
33 mprintf('\n The Brake power is = %f kW\n', bp
    *10^-3);
34 mprintf('\n The mechanical efficiency is = %f
    percent\n', n_mech);
35
36 ef = CV*fc; // energy from fuel, [kJ/s]
37 eb = bp*10^-3; // energy to brake power, [kJ/s]
38 ec = cwc*c*(To-Ti); // energy to coolant, [kJ/s]
39 es = ef-(eb+ec+eeg); // energy to surrounding, [kJ/s]
40
41 disp('Energy can be tabulated as :-');
42 disp('
    ');
43 disp('
    kJ/s                Percentage    ')
44 disp('
    ');
45 mprintf('\n Energy from fuel
    %f                %f\n
    Energy to brake power
    %f                %f\n
    Energy to coolant
    %f                %f\n

```

```

Energy to exhaust          %f
          %f\n Energy to surroundings ,etc
.          %f          %f\n',ef,ef/ef
*100,eb,eb/ef*100,ec,ec/ef*100,eeg,eeg/ef*100,es,
es/ef*100);
46
47 // End

```

Scilab code Exa 17.2 brake and indicated power mechanical efficiency steam consumption and energy balance

```

1 clear;
2 clc;
3 disp('Example 17.2');
4
5 // aim : To determine
6 // (a) bp
7 // (b) ip
8 // (c) mechanical efficiency
9 // (d) indicated thermal efficiency
10 // (e) brake specific steam consumption
11 // (f) draw up complete energy account for the test
    one-minute basis taking 0 C as datum
12
13 // given values
14 d = 200*10^-3; // cylinder diameter, [mm]
15 L = 250*10^-3; // stroke, [mm]
16 N = 5; // speed, [rev/s]
17 r = .75/2; // effective radius of brake wheel, [m]
18 Ps = 800; // stop valve pressure, [kN/m^2]
19 x = .97; // dryness fraction of steam
20 BL = 136; // brake load, [kg]
21 SL = 90; // spring balance load, [N]
22 PM = 232; // mean effective pressure, [kN/m^2]
23 Pc = 10; // condenser pressure, [kN/m^2]

```

```

24 m_dot = 3.36; // steam consumption, [kg/min]
25 CC = 113; // condenser cooling water, [kg/min]
26 Tr = 11; // temperature rise of condenser cooling
    water, [K]
27 Tc = 38; // condensate temperature, [C]
28 C = 4.18; // heat capacity of water, [kJ/kg K]
29 g = 9.81; // gravitational acceleration, [m/s^2]
30
31 // solution
32 // from steam table
33 // at 800 kN/m^2
34 tf1 = 170.4; // saturation temperature, [C]
35 hf1 = 720.9; // [kJ/kg]
36 hfg1 = 2046.5; // [kJ/kg]
37 hg1 = 2767.5; // [kJ/kg]
38 vg1 = .2403; // [m^3/kg]
39
40 // at 10 kN/m^2
41 tf2 = 45.8; // saturation temperature, [C]
42 hf2 = 191.8; // [kJ/kg]
43 hfg2 = 2392.9; // [kJ/kg]
44 hg2 = 2584.8; // [kJ/kg]
45 vg2 = 14.67; // [m^3/kg]
46
47 // (a)
48 T = (BL*g-SL)*r; // torque, [Nm]
49 bp = 2*pi*N*T*10^-3; // brake power, [W]
50 fprintf('\n (a) The brake power is = %f kW\n', bp
    );
51
52 // (b)
53 A = pi*d^2/4; // area, [m^2]
54 ip = PM*L*A*N*2; // double-acting so*2, [kW]
55 fprintf('\n (b) The indicated power is = %f kW\n',
    ip);
56
57 // (c)
58 n_mec = bp/ip; // mechanical efficiency

```

```

59 mprintf('\\n (c) The mechanical efficiency is = %f
    percent\\n',n_mec*100);
60
61 // (d)
62 h = hf1+x*hf2; // [kJ/kg]
63 hf = hf2;
64 ITE = ip/((m_dot/60)*(h-hf)); // indicated thermal
    efficiency
65 mprintf('\\n (d) The indicated thermal efficiency is
    = %f percent\\n',ITE*100);
66 // (e)
67 Bsc=m_dot*60/bp; // brake specific steam consumption,
    [kg/kWh]
68 mprintf('\\n (e) The brake steam consumption is =
    %f kg/kWh\\n',Bsc);
69
70 // (f)
71 // energy balance reckoned from 0 C
72 Es = m_dot*h; // energy supplied, [kJ]
73 Eb = bp*60; // energy to bp, [kJ]
74 Ecc = CC*C*Tr; // energy to condensate cooling water,
    [kJ]
75 Ec = m_dot*C*Tc; // energy to condensate, [kJ]
76 Ese = Es-Eb-Ecc-Ec; // energy to surrounding, etc, [kJ
    ]
77
78 mprintf('\\n (f) Energy supplied/min is = %f kJ\\n'
    ,Es);
79
80 mprintf('\\n    Energy to bp/min is = %f kJ\\n',Eb)
    ;
81 mprintf('\\n    Energy to condenser cooling water/min
    is = %f kJ\\n',Ecc);
82 mprintf('\\n    Energy to condensate/min is = %f kJ
    \\n',Ec);
83 mprintf('\\n    Energy to surrounding, etc/min is =
    %f kJ\\n',Ese);
84

```

```
85 // answer in the book is misprinted
86
87 // End
```

Scilab code Exa 17.3 brake power fuel consumption thermal efficiency and energy balance

```
1 clear;
2 clc;
3 disp('Example 17.3');
4
5 // aim : To determine
6 // (a) the brake power
7 // (b) the brake specific fuel consumption
8 // (c) the indicated thermal efficiency
9 // (d) the energy balance, expressing the various
    items
10
11 // given values
12 t = 30; // duration of trial, [min]
13 N = 1750; // speed of engine, [rev/min]
14 T = 330; // brake torque, [Nm]
15 mf = 9.35; // fuel consumption, [kg]
16 CV = 42300; // calorific value of fuel, [kJ/kg]
17 cwc = 483; // jacket cooling water circulation, [kg]
18 Ti = 17; // inlet temperature, [C]
19 To = 77; // outlet temperature, [C]
20 ma = 182; // air consumption, [kg]
21 Te = 486; // exhaust temperature, [C]
22 Ta = 17; // atmospheric temperature, [C]
23 n_mec = .83; // mechanical efficiency
24 c = 1.25; // mean specific heat capacity of exhaust
    gas, [kJ/kg K]
25 C = 4.18; // specific heat capacity, [kJ/kg K]
26
```

```

27 // solution
28 // (a)
29 bp = 2*pi*N*T/60*10^-3; // brake power, [kW]
30 mprintf('\n (a) The Brake power is = %f kW\n',bp)
    ;
31
32 // (b)
33 bsf = mf*2/bp; //brake specific fuel consumption, [kg
    /kWh]
34 mprintf('\n (b) The brake specific fuel consumption
    is = %f kg/kWh\n',bsf);
35
36 // (c)
37 ip = bp/n_mec; // indicated power, [kW]
38 ITE = ip/(2*mf*CV/3600); // indicated thermal
    efficiency
39 mprintf('\n (c) The indicated thermal efficiency is
    = %f percent\n',ITE*100);
40
41 // (d)
42 // taking basis one minute
43 ef = CV*mf/30; // energy from fuel, [kJ]
44 eb = bp*60; // energy to brake power, [kJ]
45 ec = cwc/30*C*(To-Ti); // energy to cooling water, [kJ
    ]
46 ee = (ma+mf)/30*c*(Te-Ta); // energy to exhaust, [kJ]
47 es = ef-(eb+ec+ee); // energy to surrounding, etc, [kJ]
48
49 mprintf('\n (d) Energy from fuel is = %f kJ\n',ef)
    ;
50 mprintf('\n      Energy to brake power is = %f kJ\
    n',eb);
51 mprintf('\n      Energy to cooling water is = %f
    kJ\n',ec);
52 mprintf('\n      Energy to exhaust is = %f kJ\n',
    ee);
53 mprintf('\n      Energy to surrounding, etc is =
    %f kJ\n',es);

```



```
54
55 // End
```

Scilab code Exa 17.4 indicated power and mechanical efficiency

```
1 clear;
2 clc;
3 disp('Example 17.4');
4
5 // aim : To determine
6 // (a) the indicated power of the engine
7 // (b) the mechanical efficiency of the engine
8
9 // given values
10 bp = 52; // brake power output, [kW]
11 bp1 = 40.5; // brake power of cylinder cut1, [kW]
12 bp2 = 40.2; // brake power of cylinder cut2, [kW]
13 bp3 = 40.1; // brake power of cylinder cut3, [kW]
14 bp4 = 40.6; // brake power of cylinder cut4, [kW]
15 bp5 = 40.7; // brake power of cylinder cut5, [kW]
16 bp6 = 40.0; // brake power of cylinder cut6, [kW]
17
18 // sollution
19 ip1 = bp-bp1; // indicated power of cylinder cut1, [
    kW]
20 ip2 = bp-bp2; // indicated power of cylinder cut2, [
    kW]
21 ip3 = bp-bp3; // indicated power of cylinder cut3, [
    kW]
22 ip4 = bp-bp4; // indicated power of cylinder cut4, [
    kW]
23 ip5 = bp-bp5; // indicated power of cylinder cut5, [
    kW]
24 ip6 = bp-bp6; // indicated power of cylinder cut6, [
    kW]
```

```

25
26 ip = ip1+ip2+ip3+ip4+ip5+ip6; // indicated power of
    engine ,[kW]
27 mprintf('\n (a) The indicated power of the engine is
    = %f kW\n',ip);
28
29 // (b)
30 n_mec = bp/ip; // mechanical efficiency
31 mprintf('\n (b) The mechanical efficiency of the
    engine is = %f percent\n',n_mec*100);
32
33 // End

```

Scilab code Exa 17.5 brake power indicated power mechanical efficiency and energy balance

```

1 clear;
2 clc;
3 disp('Example 17.5 ');
4
5 // aim : To determine
6 // the brake power, indicated power and mechanical
    efficiency
7 // draw up an energy balance and as % age of the
    energy supplied
8
9 // given values
10 N = 50; // speed , [rev/s]
11 BL = 267; // break load .,[N]
12 BL1 = 178; // break load of cylinder cut1 , [N]
13 BL2 = 187; // break load of cylinder cut2 , [N]
14 BL3 = 182; // break load of cylinder cut3 , [N]
15 BL4 = 182; // break load of cylinder cut4 , [N]
16
17 FC = .568/130; // fuel consumption , [L/s]

```

```

18 s = .72; // specific gravity of fuel
19 CV = 43000; // calorific value of fuel, [kJ/kg]
20
21 Te = 760; // exhaust temperature, [C]
22 c = 1.015; // specific heat capacity of exhaust gas,
    [kJ/kg K]
23 Ti = 18; // cooling water inlet temperature, [C]
24 To = 56; // cooling water outlet temperature, [C]
25 mw = .28; // cooling water flow rate, [kg/s]
26 Ta = 21; // ambient temperature, [C]
27 C = 4.18; // specific heat capacity of cooling water,
    [kJ/kg K]
28
29 // solution
30 bp = BL*N/455; // brake power of engine, [kW]
31 bp1 = BL1*N/455; // brake power of cylinder cut1, [kW
    ]
32 i1 = bp-bp1; // indicated power of cylinder cut1, [kW
    ]
33 bp2 = BL2*N/455; // brake power of cylinder cut2, [kW
    ]
34 i2 = bp-bp2; // indicated power of cylinder cut2, [kW
    ]
35 bp3 = BL3*N/455; // brake power of cylinder cut3, [kW
    ]
36 i3 = bp-bp3; // indicated power of cylinder cut3, [kW
    ]
37 bp4 = BL4*N/455; // brake power of cylinder cut4, [kW
    ]
38 i4 = bp-bp4; // indicated power of cylinder cut4, [kW
    ]
39
40 ip = i1+i2+i3+i4; // indicated power of engine, [kW]
41 n_mec = bp/ip; // mechanical efficiency
42
43 mprintf('\n The Brake power is = %f kW\n',bp);
44 mprintf('\n The Indicated power is = %f kW\n',ip);
45 mprintf('\n The mechanical efficiency is = %f

```

```

    percent\n',n_mec*100);
46
47 mf = FC*s; // mass of fuel/s, [kg]
48 ef = CV*mf; // energy from fuel/s, [kJ]
49 me = 15*mf; // mass of exhaust/s, [kg], (given in
    condition)
50 ee = me*c*(Te-Ta); // energy to exhaust/s, [kJ]
51 ec = mw*C*(To-Ti); // energy to cooling water/s, [kJ]
52 es = ef-(ee+ec+bp); // energy to surrounding, etc/s, [
    kJ]
53
54 disp('Energy can be tabulated as :-');
55 disp('
    ');
56 disp('
    kJ/s                Percentage    ')
57 disp('
    ');
58 mprintf('\n Energy from fuel
           %f                %f\n
    Energy to brake power          %f
           %f\n Energy to exhaust
           %f                %f\n
    Energy to coolant              %f
           %f\n Energy to surroundings, etc.
           %f                %f\n', ef, ef/ef
    *100, bp, bp/ef*100, ee, ee/ef*100, ec, ec/ef*100, es, es
    /ef*100);
59
60 // there is minor variation in the result reported
    in the book
61 // End

```

Scilab code Exa 17.6 brake power fuel consumption and thermal efficiency

```
1 clear;
2 clc;
3 disp('Example 17.6');
4
5 // aim : To determine
6 // (a) the break power of engine
7 // (b) the fuel consumption of the engine
8 // (c) the brake thermal efficiency of the engine
9
10 // given values
11 d = 850*10^-3; // bore , [m]
12 L = 2200*10^-3; // stroke , [m]
13 PMb = 15; // BMEP of cylinder , [bar]
14 N = 95/60; // speed of engine , [rev/s]
15 sfc = .2; // specific fuel oil consumption , [kg/kWh]
16 CV = 43000; // calorific value of the fuel oil , [kJ/
    kg]
17
18 // solution
19 // (a)
20 A = %pi*d^2/4; // area , [m^2]
21 bp = PMb*L*A*N*8/10; // brake power , [MW]
22 mprintf('\n (a) The brake power is = %f MW\n', bp)
    ;
23
24 // (b)
25 FC = bp*sfc; // fuel consumption , [kg/h]
26 mprintf('\n (b) The fuel consumption is = %f
    tonne/h\n', FC);
27
28 // (c)
29 mf = FC/3600; // fuel used , [kg/s]
```

```
30  n_the = bp/(mf*CV); // brake thermal efficiency
31  mprintf('\n (c) The brake thermal efficiency is =
        %f percent\n', n_the*100);
32
33  // End
```

Chapter 18

Refrigeration

Scilab code Exa 18.1 coefficient of performance mass flow and cooling water requirement

```
1 clear;
2 clc;
3 disp('Example 18.1 ');
4
5 // aim : To determine
6 // (a) the coefficient of performance
7 // (b) the mass flow of the refrigerant
8 // (c) the cooling water required by the condenser
9
10 // given values
11 P1 = 462.47; // pressure limit , [kN/m^2]
12 P3 = 1785.90; // pressure limit , [kN/m^2]
13 T2 = 273+59; // entering saturation temperature , [K]
14 T5 = 273+32; // exit temperature of condenser , [K]
15 d = 75*10^-3; // bore , [m]
16 L = d; // stroke , [m]
17 N = 8; // engine speed , [rev/s]
18 VE = .8; // volumetric efficiency
19 cpL = 1.32; // heat capacity of liquid , [kJ/kg K]
20 c = 4.187; // heat capacity of water , [kJ/kg K]
```

```

21
22 // solution
23 // from given table
24 // at P1
25 h1 = 231.4; // specific enthalpy , [kJ/kg]
26 s1 = .8614; // specific entropy , [ kJ/kg K]
27 v1 = .04573; // specific volume , [m^3/kg]
28
29 // at P3
30 h3 = 246.4; // specific enthalpy , [kJ/kg]
31 s3 = .8093; // specific entropy , [ kJ/kg K]
32 v3 = .04573; // specific volume , [m^3/kg]
33 T3= 273+40; // saturation temperature , [K]
34 h4 = 99.27; // specific enthalpy , [kJ/kg]
35 // (a)
36 s2 = s1; // specific entropy , [kJ/kg k]
37 // using s2=s3+cpv*log (T2/T3)
38 cpv = (s2-s3)/log(T2/T3); // heat capacity , [kj/kg k]
39
40 // from Fig.18.8
41 T4 = T3;
42 h2 = h3+cpv*(T2-T3); // specific enthalpy , [kJ/kg]
43 h5 = h4-cpL*(T4-T5); // specific enthalpy , [kJ/kg]
44 h6 = h5;
45 COP = (h1-h6)/(h2-h1); // coefficient of performance
46 mprintf('\n (a) The coefficient of performance of
the refrigerator is = %f\n',COP);
47
48 // (b)
49 SV = %pi/4*d^2*L; // swept volume of compressor/rev ,
[m^3]
50 ESV = SV*VE*N*3600; // effective swept volume/h, [m
^3]
51 m = ESV/v1; // mass flow of refrigerant/h,[kg]
52 mprintf('\n (b) The mass flow of refrigerant/h is =
%f kg\n',m);
53
54 // (c)

```



```

55 dT = 12; // temperature limit , [C]
56 Q = m*(h2-h5); // heat transfer in condenser/h, [kJ]
57 // using Q=m_dot*c*dT, so
58 m_dot = Q/(c*dT); // mass flow of water required , [kg
/h]
59 mprintf('\n (c) The mass flow of water required is
= %f kg/h\n',m_dot);
60
61 // End

```

Scilab code Exa 18.2 mass flow dryness fraction power and ratio of heat transfer

```

1 clear;
2 clc;
3 disp('Example 18.2');
4
5 // aim : To determine
6 // (a) the mass flow of R401
7 // (b) the dryness fraction of R401 at the entry to
the evaporator
8 // (c) the power of driving motor
9 // (d) the ratio of heat transferred from condenser
to the power required to the motor
10
11 // given values
12 P1 = 411.2; // pressure limit , [kN/m^2]
13 P3 = 1118.9; // pressure limit , [kN/m^2]
14 Q = 100*10^3; // heat transfer from the condenser , [kJ
/h]
15 T2 = 273+60; // entering saturation temperature , [K]
16
17 // given
18 // from given table
19 // at P1

```

```

20 h1 = 409.3; // specific enthalpy , [kJ/kg]
21 s1 = 1.7431; // specific entropy , [ kJ/kg K]
22
23 // at P3
24 h3 = 426.4; // specific enthalpy , [kJ/kg]
25 s3 = 1.7192; // specific entropy , [ kJ/kg K]
26 T3 = 273+50; // saturation temperature , [K]
27 h4 = 265.5; // specific enthalpy , [kJ/kg]
28 // (a)
29 s2 = s1; // specific entropy , [kJ/kg k]
30 // using s2=s3+cpv*log(T2/T3)
31 cpv = (s2-s3)/log(T2/T3); // heat capacity , [kj/kg k]
32
33 // from Fig.18.8
34 h2 = h3+cpv*(T2-T3); // specific enthalpy , [kJ/kg]
35 Qc = h2-h4; // heat transfer from condenser , [kJ/kg]
36 mR401 = Q/Qc; // mass flow of R401 , [kg]
37 fprintf('\n (a) The mass flow of R401 is = %f kg/
    h\n',mR401);
38
39 // (b)
40 hf1 = 219; // specific enthalpy , [kJ/kg]
41 h5 = h4;
42 // using h5=hf1+s5*(h1-hf1) ,so
43 x5 = (h5-hf1)/(h1-hf1); // dryness fraction
44 fprintf('\n (b) The dryness fraction of R401 at the
    entry to the evaporator is = %f\n',x5);
45
46 // (c)
47 P = mR401*(h2-h1)/3600/.7; // power to driving motor ,
    [kW]
48 fprintf('\n (c) The power to driving motor is =
    %f kW\n',P);
49
50 // (d)
51 r = Q/3600/P; // ratio
52 fprintf('\n (d) The ratio of heat transferred from
    condenser to the power required to the motor is

```

```
    = %f : 1\n',r);  
53  
54 // End
```

Chapter 19

Psychrometry

Scilab code Exa 19.1 moisture content

```
1 clear;
2 clc;
3 disp('Example 19.1 ');
4
5 // aim : To compare the moisture content and the
6 // true specific volumes of atmosphere air
7 // (a) temperature is 12 C and the air is saturated
8 // (b) temperature is 31 C and air is .75 saturated
9
10 // Given values
11 P_atm = 101.4; // atmospheric pressure , [kN/m^2]
12 R = .287; // [kJ/kg K]
13
14 // solution
15 // (a)
16 T = 273+12; // air temperature , [K]
17 // From steam table at 12 C
18 p = 1.4; // [kN/m^2]
19 vg = 93.9; // [m^3/kg]
20 pa = P_atm-p; // partial pressure of the dry air , [kN
21 // /m^2]
```

```

20 va = R*T/pa; // [m^3/kg]
21
22 mw = va/vg; // mass of water vapor in the air, [kg]
23 v = va/(1+mw); // specific volume of humid air, [m^3/
    kg]
24
25 mprintf('\n (a) The mass of water vapor in the humid
    air is = %f kg\n',mw);
26 mprintf('\n      The specific volume of humid air is
    = %f m^3/kg\n',v);
27
28 // (b)
29 x = .75; // dryness fraction
30 T = 273+31; // air temperature, [K]
31 // From steam table
32 p = 4.5; // [kN/m^2]
33 vg = 31.1; // [m^3/kg]
34 pa = P_atm-p; // [kN/m^2]
35 va = R*T/pa; // [m^3/kg]
36 mw1= va/vg; // mass of water vapor in the air, [kg]
37 mw_actual = mw1*x; // actual mass of vapor, [kg]
38 v = va/(1+mw_actual); // true specific volume of
    humid air, [m^3/kg]
39
40 mprintf('\n (b) The mass of water vapor in the humid
    air is = %f kg\n',mw1);
41 mprintf('\n      The specific volume of humid air is
    = %f m^3/kg\n',v);
42
43 ewv = mw_actual/mw ;
44 mprintf('\n On the warm day the air contains %f
    times the mass of water vapor as on the cool day
    \n',ewv);
45
46 // End

```

Scilab code Exa 19.2 partial pressures specific humidity and composition

```
1 clear;
2 clc;
3 disp('Example 19.2');
4
5 // aim : To determine
6 // (a) the partial pressures of the vapor and the
    dry air
7 // (b) the specific humidity of the mixture
8 // (c) the composition of the mixture
9
10 // Given values
11 phi = .65; // Relative humidity
12 T = 2733+20; // temperature, [K]
13 p = 100; // barometric pressure, [kN/m^2]
14
15 // solution
16 // (a)
17 // From the steam table at 20 C
18 pg = 2.34; // [kN/m^2]
19 ps = phi*pg; // partial pressure of vapor, [kN/m^2]
20 pa = p-ps; // partial pressure of dry air, [kN/m^2]
21 mprintf('\n (a) The partial pressure of vapor is =
    %f kN/m^2\n',ps);
22 mprintf('\n      The partial pressure of dry air is
    = %f kN/m^2\n',pa);
23
24 // (b)
25 // from equation [15]
26 omega = .622*ps/(p-ps); // specific humidity of the
    mixture
27 mprintf('\n (b) The specific humidity of the mixture
    is = %f kg/kg dry air\n',omega);
```

```

28
29 // (c)
30 // using eqn [1] from section 19.2
31 y = 1/(1+omega); // composition of the mixture
32 mprintf('\n (c) The composition of the mixture is =
        %f\n',y);
33
34 // End

```

Scilab code Exa 19.3 specific humidity dew point degree of superheat mass of condensate

```

1 clear;
2 clc;
3 disp('Example 19.3 ');
4
5 // aim : To determine
6 // (a) the specific humidity
7 // (b) the dew point
8 // (c) the degree of superheat of the superheated
    vapor
9 // (d) the mass of condensate formed per kg of dry
    air if the moist air is cooled to 12 C
10
11 // Given values
12 t = 25; // C
13 T = 273+25; // moist air temperature , [K]
14 phi = .6; // relative humidity
15 p = 101.3; // barometric pressure , [kN/m^2]
16 R = .287; // [kJ/kg K]
17
18 // solution
19 // (a)
20 // From steam table at 25 C
21 pg = 3.17; // [kN/m^2]

```

```

22 ps = phi*pg;// partial pressure of the vapor, [kN/m
    ^2]
23 omega = .622*ps/(p-ps);// the specific humidity of
    air
24
25 fprintf('\n (a) The specific humidity is = %f kg/
    kg air\n',omega);
26
27 // (b)
28 // Dew point is saturated temperature at ps is ,
29 t_dew = 16+2*(1.092-1.817)/(2.062-1.817);// [C]
30 fprintf('\n (b) The dew point is = %f C\n',t_dew);
31
32 // (c)
33 Dos = t-t_dew;// degree of superheat, [C]
34 fprintf('\n (c) The degree of superheat is = %f C\
    n',Dos);
35
36 // (d)
37 // at 25 C
38 pa = p-ps;// [kN/m^2]
39 va = R*T/pa;// [m^3/kg]
40 // at 16.69 C
41 vg = 73.4-(73.4-65.1)*.69/2;// [m^3/kg]
42 ms1= va/vg;
43 // at 12 C
44 vg = 93.8;// [m^3/kg]
45 ms2 = va/vg;
46
47 m = ms1-ms2;// mas of condensate
48 fprintf('\n (d) The mass of condensate is = %f kg
    /kg dry air\n',m);
49
50 // there is calculation mistake in the book so
    answer is no matching
51
52 // End

```

Scilab code Exa 19.4 volume mass and heat transfer

```
1 clear;
2 clc;
3 disp(' Example 19.4 ');
4
5 // aim : To determine
6 // (a) the volume of external saturated air
7 // (b) the mass of air
8 // (c) the heat transfer
9 // (d) the heat transfer required by the combined
    water vapour
10
11 // given values
12 Vb = 56000; // volume of building , [m^3]
13 T2 = 273+20; // temperature of air in the building , [K
    ]
14 phi = .6; // relative humidity
15 T1 = 8+273; // external air saturated temperature , [K
    ]
16 p0 = 101.3; // atmospheric pressure , [kN/m^2]
17 cp = 2.093; // heat capacity of saturated steam , [kJ/
    kg K]
18 R = .287; // gas constant , [kJ/kg K]
19
20 // solution
21 // from steam table at 20 C saturation pressure of
    steam is ,
22 pg = 2.34; // [kN/m^2]
23
24 // (a)
25 pvap = phi*pg; // partial pressure of vapor , [kN/m^2]
26 P = p0-pvap; // partial pressure of air , [kN/m^2]
27 V = 2*Vb; // air required , [m^3]
```

```

28 // at 8 C saturation pressure ia
29 pvap = 1.072; // [kN/m^2]
30 P2 = p0-pvap; // partial pressure of entry at 8 C, [
    kN/m^2]
31
32 // using P1*V1/T1=P2*V2/T2;
33 V2 = P*V*T1/(T2*P2); // air required at 8 C, [m^3/h]
34 mprintf('\n (a) The volume of air required is = %f
    m^3/h\n',V2);
35
36 // (b)
37 // assuming
38 pg = 1.401; // pressure , [kN/m^2]
39 Tg = 273+12; // [K]
40 vg = 93.8; // [m^3/kg]
41 // at constant pressure
42 v = vg*T2/Tg; // volume [m^3/kg]
43 mv = V/v; // mass of vapor in building at 20 C, [kg/h
    ]
44 // from steam table at 8 C
45 vg2 = 121; // [m^3/kg]
46 mve = V2/vg2; // mass of vapor supplied with
    saturated entry air , [kg/h]
47 mw = mv-mve; // mass of water added, [kg/h]
48 mprintf('\n (b) The mass of water added is = %f
    kg/h\n',mw);
49
50 // (c)
51 // for perfect gas
52 m = P2*V2/(R*T1); // [kg/h]
53 Cp = .287; // heat capacity , [kJ/kg K]
54 Q = m*Cp*(T2-T1); // heat transfer by dry air , [kJ/h]
55 mprintf('\n (c) The heat transfer required by dry
    air is = %f MJ/h\n',Q*10^-3);
56
57 // (d)
58 // from steam table
59 h1 = 2516.2; // specific enthalpy of saturated vapor

```

```

        at 8 C,[kJ/kg]
60 hs = 2523.6;// specific enthalpy of saturated vapor
    at 20 C, [kJ/kg]
61 h2 = hs+cp*(T2-T1);// specific enthalpy of vapor at
    20 c, [kJ/kg]
62 Q1 = mve*(h2-h1);// heat transfer required for vapor
    , [kJ]
63
64 // again from steam table
65 hf1 = 33.6;// [kJ/kg]
66 hg3 = 2538.2;// [kJ/kg]
67 Q2 = mw*(hg3-hf1);// heat transfer required for
    water, [kJ/h]
68 Qt = Q1+Q2;// total heat transfer, [kJ/h]
69 mprintf('\\n (d) The heat transferred required for
    vapor+supply water is = %f MJ/h\\n',Qt*10^-3);
70
71 // there is minor variation in the answer reported
    in the book
72
73 // End

```
