Scilab Textbook Companion for Basic Engineering Thermodynamics by R. Joel[1]

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 1

General Introduction

Scilab code Exa 1.1 Work done

```
clear ;
clc;
disp('Example 1.1');



// Given values
P = 700;    //pressure,[kN/m^2]
V1 = .28;    //initial volume,[m^3]
V2 = 1.68;    //final volume,[m^3]

//solution

W = P*(V2-V1);// // Formula for work done at constant pressure is, [kJ]
mprintf('\n The Work done is = %f MJ\n',W*10^-3);

//End
```

Scilab code Exa 1.2 Volume of the gas

```
clear;
clc;
disp('Example 1.2');



//Given values
P1 = 138;   // initial pressure ,[kN/m^2]
V1 = .112;   //initial volume ,[m^3]
P2 = 690; //  final pressure ,[kN/m^2]
Gama=1.4; //  heat capacity ratio

//  solution

//  since gas is following , PV^1.4=constant ,hence

V2 =V1*(P1/P2)^(1/Gama); //   final volume ,  [m^3]

mprintf('\n The new volume of the gas is = %f m^3\n'
    ,V2)

//End
```

Scilab code Exa 1.3 Work done

```
clear;
clc;
disp('Example 1.3');



//  Given values
P1 = 2070;  //  initial pressure ,  [kN/m^2]
```

```
V1 = .014;  // initial volume,  [m^3]
P2 = 207;  // final pressure, [kN/m^2]
n=1.35;  // polytropic index

// solution

// since gas is following PV^n=constant
// hence

V2 = V1*(P1/P2)^(1/n);  // final volume,  [m^3]

// calculation of workdone

W=(P1*V1-P2*V2)/(1.35-1);  // using work done formula for polytropic process, [kJ]

mprintf('\n The Work done by gas during expansion is = %f kJ\n',W);

//End
```

Scilab code Exa 1.4 Final Pressure and work done

```
clear;
clc;
disp('Example 1.4');



// Given values
P1 = 100;  // initial pressure, [kN/m^2]
V1 = .056;  // initial volume,  [m^3]
V2 = .007;  // final volume,  [m^3]

// To know  P2
```

```
//  since process is hyperbolic so, PV=constant
//  hence

P2 = P1*V1/V2;  //  final pressure, [kN/m^2]

mprintf('\n  The final pressure is  =  %f  kN/m^2\n'
   ,P2);

// calculation of workdone

W = P1*V1*log(V2/V1); //  formula for work done in
   this process, [kJ]

mprintf('\n  Work done on the gas is  =  %f  kJ\n',W
   );

//End
```

Scilab code Exa 1.5 Heat transfer

```
clear;
clc;
disp('Example 1.5');



//  Given values
m = 5; //  mass,  [kg]
t1 = 15; //  inital temperature, [C]
t2 = 100; //  final temperature, [C]
c = 450; //  specific heat capacity, [J/kg K]

//  solution

//  using heat transfer equation,[1]
```

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

//End
```

Scilab code Exa 1.6 Heat transfer

```
clear;
clc;
disp('Example 1.6');


//  Given values
m_cop = 2; //  mass of copper vessel, [kg]
m_wat = 6; //  mass of water, [kg]
c_wat = 4.19; //  specific heat capacity of water,
   [kJ/kg K]

t1 = 20; //  initial temperature, [C]
t2 = 90; //  final temperature, [C]

// From the table of average specific heat
   capacities
c_cop = .390;  // specific heat capacity of copper,[
   kJ/kg k]

// solution
Q_cop = m_cop*c_cop*(t2-t1); //  heat required by
   copper vessel, [kJ]

Q_wat = m_wat*c_wat*(t2-t1); //  heat required by
   water, [kJ]

// since there is no heat loss,so total heat
```

```
transfer is sum of both
Q_total = Q_cop+Q_wat ; //  [kJ]

mprintf(' \n Required heat transfer to accomplish the change  =  %f  kJ\n',Q_total);

//End
```

Scilab code Exa 1.7 Temperature

```

clear;
clc;
disp('Example 1.7');


//  Given values
m = 10; //  mass of iron casting, [kg]
t1 = 200; //  initial temperature, [C]
Q = -715.5; //  [kJ], since heat is lost in this process

// From the table of average specific heat capacities
c = .50; //  specific heat capacity of casting iron, [kJ/kg K]

//  solution
//  using heat equation
//  Q = m*c*(t2-t1)

t2 = t1+Q/(m*c); // [C]

mprintf('\n The final temperature is  t2 =  %f C\n', t2);
```

```

// End
```

Scilab code Exa 1.8 Specific heat capacity

```
clear;
clc;
disp('Example 1.8');



// Given values
m = 4; //  mass of the liquid, [kg]
t1 = 15; //  initial temperature, [C]
t2 = 100; //  final temperature, [C]
Q = 714; //  [kJ],required heat to accomplish this
   change

//  solution
//  using heat equation
//  Q=m*c*(t2-t1)

//  calculation of c
c=Q/(m*(t2-t1)); //  heat capacity, [kJ/kg K]

mprintf('\n The specific heat capacity of the liquid
    is  c =  %f  kJ/kg K\n',c);

//End
```

Scilab code Exa 1.9 Power output and energy rejected

```
clear;
```

```
clc;
disp('Example 1.9');


// Given values
m_dot = 20.4; // mass flowrate of petrol, [kg/h]
c = 43; // calorific value of petrol, [MJ/kg]
n = .2; // Thermal efficiency of engine

// solution
m_dot = 20.4/3600; // [kg/s]
c = 43*10^6; // [J/kg]

// power output
P_out = n*m_dot*c; // [W]

mprintf('\n The power output of the engine is = %f
    kJ\n',P_out*10^-3);

// power rejected

P_rej = m_dot*c*(1-n); // [W]
P_rej = P_rej*60*10^-6; // [MJ/min]

mprintf('\n The energy rejected by the engine is =
    %f MJ/min \n',P_rej);

//End
```

Scilab code Exa 1.10 Thermal efficiency

```
clear;
clc;
disp('Example 1.10');

```

```
// Given values
m_dot = 3.045; // use of coal, [tonne/h]
c = 28; // calorific value of the coal, [MJ/kg]
P_out = 4.1; // output of turbine, [MW]

// solution
m_dot = m_dot*10^3/3600; // [kg/s]

P_in = m_dot*c; // power input by coal, [MW]

n = P_out/P_in; // thermal efficiency formula

mprintf('\n Thermal efficiency of the plant is =
   %f \n',n);

//End
```

Scilab code Exa 1.11 Power output

```
clear;
clc;
disp('Example 1.11');


// Given values
v = 50; // speed, [km/h]
F = 900; // Resistance to the motion of a car

// solution
v = v*10^3/3600; // [m/s]
 Power = F*v; // Power formula, [W]

mprintf('\n The power output of the engine is = %f
```

```
    kW\n',Power*10^-3);

// End
```

Scilab code Exa 1.12 Power output

```

clear;
clc;
disp('Example 1.12');



// Given values
V = 230; // volatage, [volts]
I = 60; // current, [amps]
n_gen = .95; // efficiency of generator
n_eng = .92; // efficiency of engine

// solution

P_gen = V*I; // Power delivered by generator, [W]
P_gen=P_gen*10^-3; // [kW]

P_in_eng=P_gen/n_gen;//Power input from engine,[kW]

P_out_eng=P_in_eng/n_eng;//Power output from engine
    ,[kW]

mprintf('\n The power output from the engine is =
    %f kW\n',P_out_eng);

// End
```

Scilab code Exa 1.13 Current

```
clear;
clc;
disp('Example 1.13');



// Given values
V = 230; // Voltage, [volts]
W = 4; // Power of heater, [kW]

// solution

// using equation P=VI
I = W/V; // current, [K amps]
mprintf('\n The current taken by heater is = %f
   amps \n',I*10^3);

// End
```

Scilab code Exa 1.14 Mass of coal burnt

```
clear;
clc;
disp('Example 1.14');



// Given values
P_out = 500; // output of power station, [MW]
c = 29.5; // calorific value of coal, [MJ/kg]
```

```
r=.28;

//  solution

//  since P represents only 28 percent of energy
   available from coal
P_coal = P_out/r; //  [MW]

m_coal = P_coal/c; //  Mass of coal used, [kg/s]
m_coal = m_coal*3600; //  [kg/h]

//After one hour
m_coal = m_coal*1*10^-3; //  [tonne]
mprintf('\n Mass of coal burnt by the power station
   in 1 hour is  =  %f  tonne \n',m_coal);

//  End
```

Chapter 2

Systems

Scilab code Exa 2.1 Change in total energy

```
clear;
clc;
disp('Example 2.1');



// Given values
Q = 2500; // Heat transferred into the system, [kJ]
W = 1400; // Work transferred from the system, [kJ]

// solution

// since process carried out on a closed system, so using equation [4]
del_E = Q-W; // Change in total energy, [kJ]

mprintf('\n The Change in total energy is, del_E = %f kJ\n',del_E);

if(del_E&gt;0)
```

```
    disp('Since del_E is positive, so there is an increase in total enery')
else
    disp('Since del_E is negative, so there is an decrease in total enery')
end

// There is mistake in the book's results unit

//  End
```

Scilab code Exa 2.2 Heat transferred

```
clear;
clc;
disp('Example 2.2');


//  Given values
del_E = 3500; // Increase in total energy of the system, [kJ]
W = -4200; // Work transfer into the system, [kJ]

//  solution
//  since process carried out on a closed system, so using equation [3]
Q = del_E+W;// [kJ]

mprintf('\n The Heat transfer is, Q =  %f kJ \n',Q);

if(Q&gt;0)
    disp('Since Q&gt;0, so heat is transferred into the system')
else
    disp('Since Q&lt;0, so heat is transferred from
```

```
        the system')
end

// End
```

Scilab code Exa 2.3 Work done

```
clear;
clc;
disp('Example 2.3');



// Given values
Q = -150; // Heat transferred out of the system, [kJ
   /kg]
del_u = -400; // Internal energy decreased ,[kJ/kg]

// solution
// using equation [3],the non flow energy equation
// Q=del_u+W
W = Q-del_u; // [kJ/kg]
mprintf('\n The Work done is, W= %f kJ/kg \n',W);

if(W&gt;0)
      disp('Since W&gt;0, so Work done by the engine
           per kilogram of working substance')
else
    disp('Since &lt;0, so Work done on the engine per
        kilogram of working substance')
end

// End
```

Scilab code Exa 2.4 Power of the system

```
clear;
clc;
disp('Example 2.4');



//  Given values
m_dot = 4; //  fluid flow rate, [kg/s]
Q = -40;  //  Heat loss to the surrounding, [kJ/kg]

//  At inlet
P1 = 600;  // pressure  ,[kn/m^2]
C1 = 220;  // velocity  ,[m/s]
u1 = 2200;  // internal energy,  [kJ/kg]
v1 = .42; // specific volume, [m^3/kg]

//  At outlet
P2 = 150; // pressure, [kN/m^2]
C2 = 145;  // velocity,  [m/s]
u2 = 1650;  // internal energy,  [kJ/kg]
v2 = 1.5;  // specific volume,  [m^3/kg]

//  solution
//  for steady flow energy equation for the open system is given by
//  u1+P1*v1+C1^2/2+Q=u2+P2*v2+C2^2/2+W
//  hence

W = (u1-u2)+(P1*v1-P2*v2)+(C1^2/2-C2^2/2)*10^-3+Q; // [kJ/kg]

mprintf('\n workdone is, W =  %f kJ/kg ',W);
```

```
if(W&gt;0)
      disp('Since W&gt;0, so Power is output from the system')
else
   disp('Since &lt;0, so Power is input to the system')
end

//  Hence

P_out = W*m_dot; // power out put from the system, [kW]
mprintf('\n The power output from the system is  = %f  kW \n',P_out);

//  End
```

Scilab code Exa 2.5 Temperature rise

```
clear;
clc;
disp('Example 2.5');



//  Given values
del_P = 154.45; // pressure difference across the die, [MN/m^2]
rho = 11360; // Density of the lead, [kg/m^3]
c = 130; // specific heat capacity of the lead, [J/kg*K]

//  solution
//  since there is no cooling and no externel work
```

```
   is done, so energy balane becomes
//  P1*V1+U1=P2*V2+U2  ,so
//  del_U=U2-U1=P1*V1-P2*V2

//  also, for temperature rise, del_U=m*c*t, where,
   m is mass; c is specific heat capacity; and t is
   temperature rise

//  Also given that lead is incompressible, so V1=V2
   =V and assuming one m^3 of lead

//  using above equations
t = del_P/(rho*c)*10^6 ;// temperature rise [C]

mprintf('\n The temperature rise of the lead is  =
   %f  C\n',t);

//  End
```

Scilab code Exa 2.6 Area velocity and power

```
clear;
clc;
disp('Example 2.6');


//  Given values
m_dot = 4.5; // mass flow rate of air, [kg/s]
Q = -40; // Heat transfer loss, [kJ/kg]
del_h = -200; // specific enthalpy reduce, [kJ/kg]

C1 = 90; // inlet velocity, [m/s]
v1 = .85; // inlet specific volume, [m^3/kg]

v2 = 1.45; //  exit specific volume, [m^3/kg]
```

```
A2 = .038;  //  exit area of turbine, [m^2]

//  solution

//  part (a)
//  At inlet, by equation[4], m_dot=A1*C1/v1
A1 = m_dot*v1/C1;//inlet area, [m^2]
mprintf('\n (a) The inlet area is, A1 =  %f  m^2 \n',A1);

//  part (b),
//  At outlet, since mass flow rate is same, so m_dot=A2*C2/v2, hence
C2 = m_dot*v2/A2; // Exit velocity,[m/s]
mprintf('\n (b) The exit velocity is, C2 =  %f  m/s \n',C2);

//  part (c)
//  using steady flow equation, h1+C1^2/2+Q=h2+C2^2/2+W
W = -del_h+(C1^2/2-C2^2/2)*10^-3+Q; //  [kJ/kg]

//  Hence power developed is
P = W*m_dot;//  [kW]
mprintf('\n (c) The power developed by the turbine system is  =  %f kW \n',P);

//  End
```

Chapter 4

Steam and two phase systems

Scilab code Exa 4.1 specific enthalpies

```
clear;
clc;
disp('Example 4.1');

//  aim : To determine
//  the enthalpy

//  Given values
P = .50;// Pressure, [MN/m^2]

//  solution

//  From steam tables, at given pressure
hf = 640.1;//  specific liquid enthalpy ,[kJ/kg]
hfg = 2107.4;//  specific enthalpy of evaporation ,[
   kJ/kg]
hg = 2747.5; //  specific enthalpy of dry saturated
   steam ,[kJ/kg]
tf = 151.8; //  saturation temperature,[C]

mprintf('\n The specific liquid enthalpy is  =  %f
```

```
kJ/kg \n',hf);
mprintf('\n The specific enthalpy of evaporation is = %f kJ/kg \n',hfg);
mprintf('\n The specific enthalpy of dry saturated steam is = %f kJ/kg \n',hg);

// End
```

Scilab code Exa 4.2 Saturation temperature and specific enthalpies

```
clear;
clc;
disp('Example 4.2');

// aim : To determine
// saturation temperature and enthalpy

// Given values
P = 2.04;// pressure , [MN/m^2]

// solution
// 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

// calculation of saturation temperature
// from steam table
Table_P_tf = [[2.1,2.0];[214.9,212.4]]; // P in [MN/m^2] and tf in [C]
// using interpolation
tf = interpln(Table_P_tf,2.04);// saturation temperature at given condition
mprintf('\n The Saturation temperature is = %f C \n',tf);
```

```

// calculation of specific liquid enthalpy
//  from steam table
Table_P_hf = [[2.1,2.0];[920.0,908.6]];//  P in [MN/m^2] and hf in [kJ/kg]
// using interpolation
hf = interpln(Table_P_hf,2.04); //  enthalpy at given condition, [kJ/kg]
mprintf('\n The Specific liquid enthalpy is  =  %f kJ/kg \n',hf);

// calculation of specific enthalpy of evaporation
//  from steam table
Table_P_hfg = [[2.1,2.0];[1878.2,1888.6]];//  P in [MN/m^2] and hfg in [kJ/kg]
// using interpolation
hfg = interpln(Table_P_hfg,2.04); //  enthalpy at given condition, [kJ/kg]
mprintf('\n The Specific enthalpy of evaporation is  =  %f kJ/kg \n',hfg);

//  calculation of specific enthalpy of dry saturated steam
//  from steam table
Table_P_hg = [[2.1,2.0];[2798.2,2797.2]];//P in [MN/m^2] and hg in [kJ/kg]
// using interpolation
hg = interpln(Table_P_hg,2.04); //  enthalpy at given condition, [kJ/kg]
mprintf('\n The Specific enthalpy of dry saturated steam is  =  %f kJ/kg \n',hg);

//  End
```

Scilab code Exa 4.3 specific enthalpy

```
clear;
clc;
disp('Example 4.3');

// aim : To determine
// the specific enthalpy

// given values
P = 2; // pressure ,[MN/m^2]
t = 250; // Temperature, [C]
cp = 2.0934; // average value of specific heat
    capacity, [kJ/kg K]

// solution

// looking up steam table it shows that at given
    pressure saturation temperature is 212.4 C,so
tf = 212.4; // [C]
// hence,
Degree_of_superheat = t-tf;// [C]
// from table at given temperature 250 C
h = 2902; // specific enthalpy of steam at 250 C ,[
    kJ/kg]
mprintf('\nThe specific enthalpy of steam at 2 MN/m
    ^2 with temperature 250 C is = %f kJ/kg \n',h)
    ;

// Also from steam table enthalpy at saturation
    temperature is
hf = 2797.2 ;// [kJ/kg]
// so enthalpy at given temperature is
h = hf+cp*(t-tf);// [kJ/kg]

mprintf('\n The specific enthalpy at given T and P
    by alternative path is = %f kJ/kg \n',h);

// End
```

Scilab code Exa 4.4 specific enthalpy

```
clear;
clc;
disp('Example 4.4');

// aim : To determine
// the specific enthalpy of steam

// Given values
P = 2.5;// pressure, [MN/m^2]
t = 320; // temperature, [C]

// solution
// from steam table at given condition the
   saturation temperature of steam is 223.9 C,
   therefore steam is superheated
tf = 223.9;// [C]

// first let's calculate estimated enthalpy
// again from steam table

hg = 2800.9;// enthalpy at saturation temp, [kJ/kg]
cp =2.0934;// specific heat capacity of steam,[kJ/
   kg K]

// so enthalpy at given condition is
h = hg+cp*(t-tf);// [kJ/kg]
mprintf('\n The estimated specific enthalpy is =
   %f kJ/kg \n',h);

// calculation of accurate specific enthalpy
// we need double interpolation for this

```

```
//  first interpolation w.r.t. to temperature
//  At 2 MN/m^2
Table_t_h = [[325,300];[3083,3025]];// where, t in [
   C] and h in [kJ/kg]
h1 = interpln(Table_t_h,320); //  [kJ/kg]

//  at 4 MN/m^2
Table_t_h = [[325,300];[3031,2962]]; //  t in [C]
   and h in [kJ/kg]
h2 = interpln(Table_t_h,320); //  [kJ/kg]

//  now interpolation w.r.t. pressure
Table_P_h = [[4,2];[h2,h1]]; //  where P in NM/m^2
   and h1,h2 in kJ/kg
h = interpln(Table_P_h,2.5);//  [kJ/kg]
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);

//  End
```

Scilab code Exa 4.5 specific enthalpy

```
clear;
clc;
disp('Example 4.5');

// aim : To determine
//  the specific enthalpy

//  Given values
P = 70; //  pressure, [kn/m^2]
x = .85; //  Dryness fraction

// solution
```

```
// from steam table, at given pressure
hf = 376.8;// [kJ/kg]
hfg = 2283.3;// [kJ/kg]

// now using equation [2]
h = hf+x*hfg;// specific enthalpy of wet steam,[kJ/
    kg]

mprintf('\n The specific enthalpy of wet steam is =
      %f kJ/kg \n',h);

// There is minor variation in the book's answer

// End
```

Scilab code Exa 4.8 specific volume

```
clear;
clc;
disp('Example 4.8');

// aim : To determine
// the specific volume of wet steam

// Given values
P = 1.25; // pressure, [MN/m^2]
x = .9; // dry fraction

// solution
// from steam table at given pressure
vg = .1569;// [m^3/kg]
// hence
v = x*vg; // [m^3/kg]

```

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

// End
```

Scilab code Exa 4.9 specific volume

```
clear;
clc;
disp('Example 4.9');

// aim : To determine
// the specific volume

// Given values
t = 325; // temperature, [C]
P = 2; // pressure, [MN/m^2]

// solution
// from steam table at given t and P
vf = .1321; // [m^3/kg]
tf = 212.4; // saturation temperature, [C]

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);
doh= t-tf; // degree of superheat, [C]
mprintf('\n The degree of superheat is = %f C\n',
   doh);

// End
```

Scilab code Exa 4.10 mass of steam and water

```
clear;
clc;
disp('Example .10');

// aim : To determine
// (a) the mass of steam entering the heater
// (b) the mass of water entering the heater

//  Given values
x = .95;//  Dryness fraction
P = .7;//  pressure,[MN/m^2]
d = 25;//  internal diameter of heater,[mm]
C = 12; //  steam velocity in the pipe,[m/s]

//  solution
//  from steam table at .7 MN/m^2 pressure
hf = 697.1;//  [kJ/kg]
hfg = 2064.9;//  [kJ/kg]
hg = 2762.0; //  [kJ/kg]
vg = .273; //  [m^3/kg]

//  (a)
v = x*vg; //  [m^3/kg]
ms_dot = %pi*(d*10^-3)^2*C*3600/(4*v);//  mass of steam entering, [kg/h]
mprintf('\n (a) The mass of steam entering the heater is  =  %f kg/h \n',ms_dot);

//  (b)
h = hf+x*hfg;//  specific enthalpy of steam entering heater,[kJ/kg]
//  again from steam tables
hf1 = 376.8;//  [kJ/kg] at 90 C
hf2 = 79.8;//  [kJ/kg] at 19 C

//  using energy balance,mw_dot*(hf1-hf2)=ms_dot*(h-hf1)
mw_dot = ms_dot*(h-hf1)/(hf1-hf2);//  mass of water
```

```
entering to heater,[kg/h]

mprintf('\n (b) The mass of water entering the heater is = %f kg/h \n',mw_dot);

// End
```

Scilab code Exa 4.11 change of internal energy

```
clear;
clc;
disp('Example 4.11');

// aim: To determine
// the change of internal energy

// Given values
m = 1.5;// mass of steam,[kg]
P1 = 1;// initial pressure, [MN/m^2]
t = 225;// temperature, [C]
P2 = .28;// final pressure, [MN/m^2]
x = .9;// dryness fraction of steam at P2

// solution

// from steam table at P1
h1 = 2886;// [kJ/kg]
v1 = .2198; // [m^3/kg]
// hence
u1 = h1-P1*v1*10^3;// internal energy [kJ/kg]

// at P2
hf2 = 551.4;// [kJ/kg]
hfg2 = 2170.1;// [kJ/kg]
vg2 = .646; // [m^3/kg]
```

```
//  so
h2 = hf2+x*hfg2;//  [kj/kg]
v2 = x*vg2;//   [m^3/kg]

// now
u2 = h2-P2*v2*10^3;//  [kJ/kg]

//  hence change in specific internal energy is
del_u = u2-u1;//  [kJ/kg]

del_u = m*del_u;//  [kJ];
mprintf('\n The change in internal energy is  =  %f
    kJ \n',del_u);

//  End
```

Scilab code Exa 4.12 dryness fraction

```
clear;
clc;
disp('Example 4.12');

//  aim : To determine
//  the dryness fraction of steam after throttling

//  given values
P1 = 1.4;//  pressure before throttling, [MN/m^2]
x1 = .7;//  dryness fraction before throttling
P2 = .11;//  pressure after throttling, [MN/m^2]

//  solution
//  from steam table
hf1 = 830.1;//  [kJ/kg]
hfg1 = 1957.7;//  [kJ/kg]
h1 = hf1 + x1*hfg1; //  [kJ/kg]
```

```

hf2 = 428.8;//   [kJ/kg]
hfg2 = 2250.8;//   [kJ/kg]

//  now for throttling ,
//  hf1+x1*hfg1=hf2+x2*hfg2; where x2 is dryness fraction after throttling

x2=(h1-hf2)/hfg2; // final dryness fraction

mprintf('\n Dryness fraction of steam after throttling is  = %f \n',x2);

//  End
```

Scilab code Exa 4.13 condition of steam and internal diameter

```
clear;
clc;
disp('Example 4.13');

//  aim : To determine
//  the dryness fraction of steam
//  and the internal diameter of the pipe

//  Given values

//  steam1
P1 = 2;// pressure before throttling , [MN/m^2]
t = 300;//  temperature ,[C]
ms1_dot = 2;// steam flow rate , [kg/s]
P2 = 800;//  pressure after throttling , [kN/m^2]

//  steam2
P = 800;// pressure , [N/m^2]
```

```
x2 = .9;//  dryness fraction
ms2_dot = 5; //  [kg/s]

//  solution
//  (a)
//  from steam table specific enthalpy of steam1 before throttling is
hf1 = 3025;//  [kJ/kg]
//  for throttling process specific enthalpy will same so final specific enthalpy of steam1 is
hf2 = hf1;
// hence
h1 = ms1_dot*hf2;// [kJ/s]

//  calculation of specific enthalpy of steam2
hf2 = 720.9;//  [kJ/kg]
hfg2 = 2046.5;//  [kJ/kg]
//  hence
h2 = hf2+x2*hfg2;//  specific enthalpy, [kJ/kg]
h2 = ms2_dot*h2;//  total enthalpy, [kJ/s]

//  after mixing
m_dot = ms1_dot+ms2_dot;//  total mass of mixture,[kg/s]
h = h1+h2;//  Total enthalpy of the mixture,[kJ/s]
h = h/7;//  [kJ/kg]

//  At pressure 800 N/m^2
hf = 720.9;//  [kJ/kg]
hfg = 2046.5;//  [kJ/kg]
//  so total enthalpy is,hf+x*hfg, where x is dryness fraction of mixture and which is equal to h
//  hence
x = (h-hf)/hfg;// dryness fraction after mixing
mprintf('\n (a) The condition of the resulting mixture is dry with dryness fraction  =  %f \n',x);
```

```
// (b)
// Given
C = 15;// velocity, [m/s]
// from steam table
v = .1255;// [m^/kg]
A = ms1_dot*v/C;// area, [m^2]
// using ms1_dot = A*C/v, where A is cross section area in m^2 and
// A = %pi*d^2/4, where d is diameter of the pipe

// calculation of d
d = sqrt(4*A/%pi); // diameter, [m]

mprintf('\n (b) The internal diameter of the pipe is = %f mm \n',d*1000);

// End
```

Scilab code Exa 4.14 dryness fraction

```
clear;
clc;
disp('Example 4.14');

// aim : To estimate
// the dryness fraction

// Given values
M = 1.8;// mass of condensate, [kg]
m = .2;// water collected, [kg]

// solution
x = M/(M+m);// formula for calculation of dryness fraction using seprating calorimeter
```

```
mprintf(' \n The dryness fraction of the steam entering seprating calorimeter is = %f \n',x);

// End
```

Scilab code Exa 4.15 dryness fraction

```
clear;
clc;
disp('Example 4.15');

// aim : To determine
// the dryness fraction of the steam at 2.2 MN/m^2

// Given values
P1 = 2.2;// [MN/m^2]
P2 = .13;// [MN/m^2]
t2 = 112;// [C]
tf2 = 150;// temperature, [C]

// solution
// from steam table, at 2.2 MN/m^2
// saturated steam at 2 MN/m^2 Pressure
hf1 = 931;// [kJ/kg]
hfg1 = 1870;// [kJ/kg]
hg1 = 2801;// [kJ/kg]

// for superheated steam
// at .1 MN/m^2
hg2 = 2675;// [kJ/kg]
hg2_150 = 2777;// specific enthalpy at 150 C, [kJ/kg]
tf2 = 99.6;// saturation temperature, [C]

```

```
// at .5 MN/m^2
hg3 = 2693;//  [kJ/kg]
hg3_150 = 2773;// specific enthalpy at 150 C, [kJ/kg]
tf3 = 111.4;//  saturation temperature, [C]

Table_P_h1 = [[.1,.5];[hg2,hg3]];// where, P in MN/m^2 and h in [kJ/kg]
hg = interpln(Table_P_h1,.13);//  specific entahlpy at .13 MN/m^2, [kJ/kg]

Table_P_h2 = [[.1,.5];[hg2_150,hg3_150]];//  where, P in MN/m^2 and h in [kJ/kg]
hg_150 = interpln(Table_P_h2,.13);//  specific entahlpy at .13 MN/m^2 and 150 C, [kJ/kg]

Table_P_tf = [[.1,.5];[tf2,tf3]];// where, P in MN/m^2 and h in [kJ/kg]
tf = interpln(Table_P_tf,.13);//  saturation temperature, [C]

//  hence
h2 = hg+(hg_150-hg)/(t2-tf)/(tf2-tf);//  specific enthalpy at .13 MN/m^2 and 112 C, [kJ/kg]

// now since process is throttling so h2=h1
// and h1 = hf1+x1*hfg1, so
x1 = (h2-hf1)/hfg1;// dryness fraction
mprintf(' \n The dryness fraction of steam is  =  %f \n',x1);

// There is a calculation mistake in book so answer is not matching

//  End
```

Scilab code Exa 4.16 minimum dryness fraction

```
clear;
clc;
disp('Example 4.16');

// aim : To determine
// the minimum dryness fraction of steam

// Given values
P1 = 1.8;// testing pressure ,[MN/m^2]
P2 = .11;// pressure after throttling ,[MN/m^2]

// solution
// from steam table
// at .11 MN/m^2 steam is completely dry and
    specific enthalpy is
hg = 2680;// [kJ/kg]

// before throttling steam is wet, so specific
    enthalpy is=hf+x*hfg, where x is dryness fraction
// from steam table
hf = 885;// [kJ/kg]
hfg = 1912;// [kJ/kg]

// now for throttling process ,specific enthalpy
    will same before and after
// hence
x = (hg-hf)/hfg;
mprintf('\n The minimum dryness fraction of steam is
    x = %f \n',x);

// End
```

Scilab code Exa 4.17 mass dryness fraction and heat transfer

```
clear;
clc;
disp('Example 4.17');

//  aim : To determine the
//  (a) mass of steam in the vessel
//  (b) final dryness of the steam
//  (c) amount of heat transferrred during the
    cooling process

//  Given values
V1 = .8;//  [m^3]
P1 = 360;//  [kN/m^2]
P2 = 200;//  [kN/m^2]

//  solution

//  (a)
// at 360 kN/m^2
vg1 = .510;//  [m^3]
m = V1/vg1;//  mass of steam,[kg]
mprintf('\n (a) The mass of steam in the vessel is =
     %f kg\n',m);

//  (b)
//  at 200 kN/m^2
vg2 = .885;// [m^3/kg]
//  the volume remains constant so
x = vg1/vg2;// final dryness fraction
mprintf('\n (b) The final dryness fraction of the
    steam is  =  %f \n',x);

```

```
// (c)
//  at 360 kN/m^2
h1 = 2732.9;// [kJ/kg]
//  hence
u1 = h1-P1*vg1;//  [kJ/kg]

//  at 200 kN/m^2
hf = 504.7;// [kJ/kg]
hfg=2201.6;//[kJ/kg]
//  hence
h2 = hf+x*hfg;// [kJ/kg]
//  now
u2 = h2-P2*vg1;//  [kJ/kg]
//  so
del_u = u2-u1;//  [kJ/kg]
//  from the first law of thermodynamics del_U+W=Q,
W = 0;//  because volume is constant
del_U = m*del_u;//  [kJ]
//  hence
Q = del_U;//  [kJ]
mprintf('\n (c) The amount of heat transferred
   during cooling process is  =  %f kJ \n',Q);

//  End
```

Scilab code Exa 4.18 specific heat

```
clear;
clc;
disp('Example 4.18');

//  aim : To determine
//  the heat received by the steam per kilogram

// Given values
```

```
// initial
P1 = 4;// pressure , [MN/m^2]
x1 = .95; // dryness fraction

// final
t2 = 350;// temperature ,[C]

// solution

// from steam table , at 4 MN/m^2 and x1=.95
hf = 1087.4;// [kJ/kg]
hfg = 1712.9;// [kJ/kg]
// hence
h1 = hf+x1*hfg;// [kJ/kg]

// since pressure is kept constant ant temperature
   is raised so at this condition
h2 = 3095;// [kJ/kg]

// so by energy balance
Q = h2-h1;// Heat received ,[kJ/kg]
mprintf('\n The heat received by the steam is = %f
     kJ/kg \n',Q);

// End
```

Scilab code Exa 4.19 condition of steam

```
clear;
clc;
disp('Example 4.19');

// aim : To determine the condition of the steam
   after
// (a) isothermal compression to half its initial
```

```
volume,heat rejected
// (b) hyperbolic compression to half its initial volume

// Given values
V1 = .3951;// initial volume,[m^3]
P1 = 1.5;// initial pressure,[MN/m^2]

// solution

// (a)
// from steam table, at 1.5 MN/m^2
hf1 = 844.7;// [kJ/kg]
hfg1 = 1945.2;// [kJ/kg]
hg1 = 2789.9;// [kJ/kg]
vg1 = .1317;// [m^3/kg]

// calculation
m = V1/vg1;// mass of steam,[kg]
vg2b = vg1/2;// given,[m^3/kg](vg2b is actual specific volume before compression)
x1 = vg2b/vg1;// dryness fraction
h1 = m*(hf1+x1*hfg1);// [kJ]
Q = m*x1*hfg1;// heat loss,[kJ]
mprintf('\n (a) The Quantity of steam present is = %f kg \n',m);
mprintf('\n     Dryness fraction is = %f \n',x1);
mprintf('\n     The enthalpy is = %f kJ \n',h1);
mprintf('\n     The heat loss is = %f kJ \n',Q);

// (b)
V2 = V1/2;
// Given compression is according to the law PV=Constant,so
P2 = P1*V1/V2;// [MN/m^2]
// from steam table at P2
hf2 = 1008.4;// [kJ/kg]
hfg2 = 1793.9;// [kJ/kg]
```

```
hg2 = 2802.3;//   [kJ/kg]
vg2 = .0666;//   [m^3/kg]

//   calculation
x2 = vg2b/vg2;//   dryness fraction
h2 = m*(hf2+x2*hfg2);//   [kJ]

mprintf('\n (b) The dryness fraction is  =  %f \n',
   x2);
mprintf('\n      The enthalpy is  =  %f kJ\n',h2);

//   End
```

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

```
clear;
clc;
disp('Example 4.20');

//   aim : To determine the
//   (a) mass of steam
//   (b) work transfer
//   (c) change of internal energy
//   (d) heat exchange b/w the steam and surroundings

//   Given values
P1 = 2.1;//   initial pressure,[MN/m^2]
x1 = .9;//   dryness fraction
V1 = .427;//   initial volume,[m^3]
P2 = .7;//   final pressure,[MN/m^2]
//   Given process is polytropic with
n = 1.25; // polytropic index

//   solution
```

```
//  from steam table

//  at 2.1 MN/m^2
hf1 = 920.0;//  [kJ/kg]
hfg1=1878.2;//  [kJ/kg]
hg1=2798.2;//  [kJ/kg]
vg1 = .0949;//  [m^3/kg]

//  and at .7 MN/m^2
hf2 = 697.1;//  [kJ/kg]
hfg2 = 2064.9;//  [kJ/kg]
hg2 = 2762.0;// [kJ/kg]
vg2 = .273;//  [m^3/kg]

//  (a)
v1 = x1*vg1;//  [m^3/kg]
m = V1/v1;//  [kg]
mprintf('\n (a) The mass of steam present is  =  %f kg\n',m);

//  (b)
//  for polytropic process
v2 = v1*(P1/P2)^(1/n);//  [m^3/kg]

x2 = v2/vg2;//  final dryness fraction
//  work transfer
W = m*(P1*v1-P2*v2)*10^3/(n-1);//  [kJ]
mprintf('\n (b) The work transfer is  =  %f  kJ\n',W);

//  (c)
//  initial
h1 = hf1+x1*hfg1;//  [kJ/kg]
u1 = h1-P1*v1*10^3;//  [kJ/kg]

//  final
h2 = hf2+x2*hfg2;//  [kJ/kg]
u2 = h2-P2*v2*10^3;//  [kJ/kg]
```

```
del_U = m*(u2-u1);//  [kJ]
mprintf('\n (c) The change in internal energy is  =
    %f kJ',del_U);
if(del_U<0)
    disp('since del_U<0,so this is loss of internal
       energy')
else
    disp('since del_U>0,so this is gain in internal
       energy')
end

//  (d)
Q = del_U+W;//  [kJ]
mprintf('\n (d) The heat exchange between the steam
   and surrounding is  =  %f  kJ',Q);
if(Q<0)
    disp('since Q<0,so this is loss of heat energy
       to surrounding')
else
    disp('since Q>0,so this is gain in heat energy
       to the steam')
end

// there are minor vairations in the values reported
    in the book

//  End
```

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

```
clear;
clc;
disp('Example 4.21');
```

```
//  aim : To determine the
//  (a) volume occupied by steam
//  (b)(1) final dryness fraction of steam
//        (2) Change of internal energy during
    expansion

//  (a)
//  Given values
P1 = .85;//  [mN/m^2]
x1 = .97;

//  solution
//  from steam table, at .85 MN/m^2,
vg1 = .2268;//  [m^3/kg]
//  hence
v1 = x1*vg1;//  [m^3/kg]
mprintf('\n (a) The volume occupied by 1 kg of steam
     is  =  %f m^3/kg\n',v1);

// (b)(1)
P2 = .17;//  [MN/m^2]
// since process is polytropic process with
n = 1.13; //  polytropic index
// hence
v2 = v1*(P1/P2)^(1/n);// [m^3/kg]

// from steam table at .17 MN/m^2
vg2 = 1.031;// [m^3/kg]
// steam is wet so
x2 = v2/vg2;//  final dryness fraction
mprintf('\n (b)(1) The final dryness fraction of the
     steam is  =  %f \n',x2);

//  (2)
W = (P1*v1-P2*v2)*10^3/(n-1);// [kJ/kg]
//  since process is adiabatic, so
del_u = -W;// [kJ/kg]
```

```
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);
// There are minor variation in the answer

//  End
```

Chapter 5

Gases and single phase systems

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

```
clear;
clc;
disp('Example 5.1');

// aim : To determine
// new pressure exerted on the air and the
   difference in two mercury column level

// Given values
P1 = 765;// atmospheric pressure , [mmHg]
V1 = 20000;// [mm^3]
V2 = 17000;// [mm^3]

// solution

// using boyle's law P*V=constant
// hence
P2 = P1*V1/V2;// [mmHg]
mprintf('\n The new pressure exerted on the air is
   = %f mmHg \n',P2);
```

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

// End
```

Scilab code Exa 5.2 volume

```
clear;
clc;
disp('Example 5.2');

// aim : To determine
// the new volume

// Given values
P1 = 300;// original pressure,[kN/m^2]
V1 = .14;// original volume,[m^3]

P2 = 60;// new pressure after expansion,[kn/m^2]

// solution
// since temperature is constant so using boyle's
   law P*V=constant
V2 = V1*P1/P2;// [m^3]

mprintf('\n The new volume after expansion is = %f
    m^3\n',V2);

// End
```

Scilab code Exa 5.3 volume

```
clear;
clc;
disp('Example 5.3');

//  aim : To determine
//  the new volume of the gas

//  Given values
V1 = 10000;//  [mm^3]
T1 = 273+18;//  [K]
T2 = 273+85;//  [K]

//  solution
//  since pressure exerted on the apparatus is
   constant so using charle's law V/T=constant
//  hence
V2 = V1*T2/T1;//  [mm^3]

mprintf('\n The new volume of the gas trapped in the
    apparatus is  =  %f  mm^3\n',V2);

//  End
```

Scilab code Exa 5.4 temperature

```
clear;
clc;
disp('Example 5.4');

//  aim : To determine
//  the final temperature

//  Given values
```

```
V1 = .2;//  original volume ,[m^3]
T1 = 273+303;// original temperature , [K]
V2 = .1;// final volume , [m^3]

//  solution
//  since pressure is constant , so using charle's
    law V/T=constant
//  hence
T2 = T1*V2/V1;//   [K]
t2 = T2-273;//   [C]
mprintf('\n The final temperature of the gas is  =
    %f  C\n',t2);

//  End
```

Scilab code Exa 5.5 volume

```
clear;
clc;
disp('Example 5.5');

//  aim : To determine
//  the new volume of the gas

//  Given values

//  initial codition
P1 = 140;//   [kN/m^2]
V1 = .1;//    [m^3]
T1 = 273+25;// [K]

//  final condition
P2 = 700;//   [kN/m^2]
T2 = 273+60;//   [K]

```

```
// by charasteristic equation, P1*V1/T1=P2*V2/T2

V2=P1*V1*T2/(T1*P2);// final volume, [m^3]

mprintf('\nThe new volume of the gas is = %f m^3\n',V2);

// End
```

Scilab code Exa 5.6 mass and temperature

```
clear;
clc;
disp('Example 5.6');

// aim : To determine
// the mas of the gas and new temperature

// Given values
P1 = 350;// [kN/m^2]
V1 = .03;// [m^3]
T1 = 273+35;// [K]
R = .29;// Gas constant,[kJ/kg K]

// solution
// using charasteristic equation, P*V=m*R*T
m = P1*V1/(R*T1);// [Kg]
mprintf('\n The mass of the gas present is = %f kg\n',m);

// Now the gas is compressed
P2 = 1050;// [kN/m^2]
V2 = V1;
// since mass of the gas is constant so using, P*V/T=constant
```

```
// hence
T2 = T1*P2/P1// [K]
t2 = T2-273;// [C]

mprintf('\n The new temperature of the gas is = %f C\n',t2);

// End
```

Scilab code Exa 5.7 heat transfer and pressure

```
clear;
clc;
disp('Example 5.7');

// aim : To determine
// the heat transferred to the gas and its final pressure

// Given values
m = 2;// masss of the gas, [kg]
V1 = .7;// volume,[m^3]
T1 = 273+15;// original temperature,[K]
T2 = 273+135;// final temperature,[K]
cv = .72;// specific heat capacity at constant volume,[kJ/kg K]
R = .29;// gas law constant,[kJ/kg K]

// solution
Q = m*cv*(T2-T1);// Heat transferred at constant volume,[kJ]
mprintf('\n The heat transferred to the gas is = %f kJ\n',Q);

// Now, using P1*V1=m*R*T1
```

```
P1 = m*R*T1/V1;//   [kN/m^2]

//   since volume of the system is constant , so P1/T1
   =P2/T2
//   hence
P2 = P1*T2/T1;//   final pressure ,[kN/m^2]
mprintf('\n The final pressure of the gas is  =  %f
    kN/m^2 \n',P2);

//   End
```

Scilab code Exa 5.8 heat transfer and work done

```
clear;
clc;
disp('Example 5.8');

//   aim : To determine
//   the heat transferred from the gas and the work
    done on the gas

//   Given values
P1 = 275;//   pressure ,  [kN/m^2]
V1 = .09;//   volume ,[m^3]
T1 = 273+185;//   initial temperature ,[K]
T2 = 273+15;//   final temperature ,[K]
cp = 1.005;//   specific heat capacity at constant
    pressure ,[kJ/kg K]
R = .29;//   gas law constant ,[kJ/kg K]

//   solution
//   using P1*V1=m*R*T1
m = P1*V1/(R*T1);//   mass of the gas

//   calculation of heat transfer
```

```
Q = m*cp*(T2-T1);//  Heat transferred at constant pressure ,[kJ]
mprintf('\n The heat transferred to the gas is  = %f  kJ\n',Q);

//  calculation of work done
//  Now, since pressure is constant so , V/T=constant
// hence
V2 = V1*T2/T1;//   [m^3]

W = P1*(V2-V1);//  formula for work done at constant pressure ,[kJ]
mprintf('\n Work done on the gas during the process is  =  %f  kJ\n',W);

//  End
```

Scilab code Exa 5.9 pressure

```
clear;
clc;
disp('Example 5.9');

//  aim : To determine
//  the new pressure of the gas

//  Given values
P1 = 300;//  original pressure ,[kN/m^2]
T1 = 273+25;//  original temperature ,[K]
T2 = 273+180;//  final temperature ,[K]

//  solution
//  since gas compressing according to the law ,P*V^1.4=constant
//  so , for polytropic process ,T1/T2=(P1/P2)^((n-1)/n
```

```
),here n=1.4

// hence
P2 = P1*(T2/T1)^((1.4)/(1.4-1));// [kN/m^2]

mprintf('\n The new pressure of the gas is = %f
    kN/m^2\n',P2);

// End
```

Scilab code Exa 5.10 temperature

```
clear;
clc;
disp('Example 5.10');

// aim : To determine
// the new temperature of the gas

// Given values
V1 = .015;// original volume,[m^3]
T1 = 273+285;// original temperature,[K]
V2 = .09;// final volume,[m^3]

// solution
// Given gas is following the law,P*V^1.35=constant
// so process is polytropic with
n = 1.35; // polytropic index

// hence
T2 = T1*(V1/V2)^(n-1);// final temperature, [K]

t2 = T2-273;// [C]

mprintf('\n The new temperature of the gas is = %f
```

```
C \n',t2);

// there is minor error in book's answer

// End
```

Scilab code Exa 5.11 volume pressure and temperature

```
clear;
clc;
disp('Example 5.11');

// aim : To determine the
// (a) original and final volume of the gas
// (b) final pressure of the gas
// (c) final temperature of the gas

// Given values
m = .675;// mass of the gas,[kg]
P1 = 1.4;// original pressure,[MN/m^2]
T1 = 273+280;// original temperature,[K]
R = .287;//gas constant,[kJ/kg K]

// solution

// (a)
// using characteristic equation, P1*V1=m*R*T1
V1 = m*R*T1*10^-3/P1;// [m^3]
// also Given
V2 = 4*V1;// [m^3]
mprintf('\n (a) The original volume of the gas is =
    %f m^3\n',V1);
mprintf('\n and The final volume of the gas is
    = %f m^3\n',V2);

```

```
//  (b)
//  Given that gas is following the law P*V^1.3=constant
//  hence process is polytropic with
n = 1.3; //  polytropic index
P2 = P1*(V1/V2)^n;//  formula for polytropic process,[MN/m^2]
mprintf('\n (b) The final pressure of the gas is  =  %f  kN/m^2\n',P2*10^3);

//  (c)
//  since mass is constant so,using P*V/T=constant
//  hence
T2 = P2*V2*T1/(P1*V1);//  [K]
t2 = T2-273;//  [C]
mprintf('\n (c) The final temperature of the gas is  =  %f C\n',t2);

//  End
```

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

```
clear;
clc;
disp('Example 5.12');

//  aim : T0 determine
//  (a) change in internal nergy of the air
//  (b) work done
//  (c) heat transfer

//  Given values
m = .25;//  mass, [kg]
P1 = 140;//  initial pressure, [kN/m^2]
```

```
V1 = .15;//  initial volume, [m^3]
P2 = 1400;//  final volume, [m^3]
cp = 1.005;//  [kJ/kg K]
cv = .718;//  [kJ/kg K]

//  solution

//  (a)
//  assuming ideal gas
R = cp-cv;//  [kJ/kg K]
//  also, P1*V1=m*R*T1,hence
T1 = P1*V1/(m*R);//  [K]

//  given that process is polytropic with
n = 1.25; //  polytropic index
T2 = T1*(P2/P1)^((n-1)/n);//  [K]

//  Hence, change in internal energy is,
del_U = m*cv*(T2-T1);//  [kJ]
mprintf('\n (a) The change in internal energy of the air is del_U  =  %f  kJ',del_U);
if(del_U>0)
    disp('since del_U >0, so it is gain of internal energy to the air')
else
    disp('since del_U <0, so it is gain of internal energy to the surrounding')
end

//  (b)
W = m*R*(T1-T2)/(n-1);//  formula of work done for polytropic process,[kJ]
mprintf('\n (b) The work done is W =  %f  kJ',W);
if(W>0)
    disp('since W>0, so the work is done by  the air')
else
    disp('since W<0, so the work is done on the air'
```

```
          )
end

//  (c)
Q = del_U+W;//  using 1st law of thermodynamics,[kJ]
mprintf('\n (c) The heat transfer is Q = %f kJ',Q
   );
if(Q>0)
    disp('since Q>0, so the heat is received by  the
        air')
else
    disp('since Q<0, so the heat is rejected by the
       air')
end

//  End
```

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

```
clear;
clc;
disp('Example 5.13');

//  aim : To determine the
//  final volume, work done and the change in
   internal energy

//  Given values
P1 = 700;//  initial pressure,[kN/m^2]
V1 = .015;// initial volume, [m^3]
P2 = 140;//  final pressure, [kN/m^2]
cp = 1.046;//  [kJ/kg K]
cv = .752; //  [kJ/kg K]

//  solution
```

```
Gamma = cp/cv;
// for adiabatic expansion, P*V^gamma=constant, so
V2 = V1*(P1/P2)^(1/Gamma);// final volume, [m^3]
mprintf('\n The final volume of the gas is V2 = %f m^3\n',V2);

// work done
W = (P1*V1-P2*V2)/(Gamma-1);// [kJ]
mprintf('\n The work done by the gas is = %f kJ\n',W);

// for adiabatic process
del_U = -W;// [kJ]
mprintf('\n The change of internal energy is = %f kJ',del_U);
if(del_U>0)
    disp('since del_U >0, so the the gain in internal energy of the gas ')
else
    disp('since del_U <0, so this is a loss of internal energy from the gas')
end

// End
```

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

```
clear;
clc;
disp('Example 5.14');

// aim : To determine the
// (a)heat transfer
// (b)change of internal energy
```

```
//  (c)mass of gas

//   Given values
V1 = .4;//  initial volume, [m^3]
P1 = 100;//  initial pressure, [kN/m^2]
T1 = 273+20;//  temperature, [K]
P2 = 450;//  final pressure,[kN/m^2]
cp = 1.0;//  [kJ/kg K]
Gamma = 1.4; //  heat capacity ratio

//  solution

//  (a)
//  for the isothermal compression,P*V=constant,so
V2 = V1*P1/P2;//  [m^3]
W = P1*V1*log(P1/P2);//  formula of workdone for isothermal process,[kJ]

//  for isothermal process, del_U=0;so
Q = W;
mprintf('\n (a) The heat transferred during compression is Q  =  %f kJ\n',Q);


//  (b)
V3 = V1;
//  for adiabatic expansion
//  also

P3 = P2*(V2/V3)^Gamma;//  [kN/m^2]
W = -(P3*V3-P2*V2)/(Gamma-1);//  work done formula for adiabatic process,[kJ]
//  also, Q=0,so using Q=del_U+W
del_U = -W;//  [kJ]
mprintf('\n (b) The change of the internal energy during the expansion is,del_U  =  %f kJ\n',del_U);

```

```
//  (c)
//  for ideal gas
//  cp-cv=R, and cp/cv=gamma, hence
R = cp*(1-1/Gamma);//  [kj/kg K]

//  now using ideal gas equation
m = P1*V1/(R*T1);//  mass of the gas,[kg]
mprintf('\n (c) The mass of the gas is,m  =  %f  kg\n',m);

// There is calculation mistake in the book


//  End
```

Scilab code Exa 5.15 heat transfer and polytropic heat capacity

```
clear;
clc;
disp('Example 5.15');

//  aim : To determine
//  the heat transferred and polytropic specific heat capacity

//  Given values
P1 = 1;//  initial pressure,  [MN/m^2]
V1 = .003;//  initial volume,  [m^3]
P2 = .1;//  final pressure,[MN/m^2]
cv = .718;//  [kJ/kg*K]
Gamma=1.4;//  heat capacity ratio

//  solution
//  Given process is polytropic with
n = 1.3;//  polytropic index
```

```
//  hence
V2 = V1*(P1/P2)^(1/n);//  final volume,[m^3]
W = (P1*V1-P2*V2)*10^3/(n-1);//  work done,[kJ]
//  so
Q = (Gamma-n)*W/(Gamma-1);//  heat transferred,[kJ]

mprintf('\n The heat received or rejected by the gas during this process is Q = %f kJ',Q);
if(Q>0)
    disp('since Q>0, so heat is received by the gas')
else
    disp('since Q<0, so heat is rejected by the gas')
end

//  now
cn = cv*(Gamma-n)/(n-1);//  polytropic specific heat capacity,[kJ/kg K]
mprintf('\n The polytropic specific heat capacity is cn = %f kJ/kg K\n',cn);

//  End
```

Scilab code Exa 5.16 pressures

```
clear;
clc;
disp('Example 5.16');

//  aim : To determine the
//  (a) initial partial pressure of the steam and air
//  (b) final partial pressure of the steam and air
//  (c) total pressure in the container after
```

```
heating

//  Given values
T1 = 273+39;//  initial temperature,[K]
P1 = 100;//  pressure, [MN/m^2]
T2 = 273+120.2;//  final temperature,[K]

//  solution

//  (a)
//  from the steam tables, the pressure of wet steam at 39 C is
Pw1 = 7;//  partial pressure of wet steam,[kN/m^2]
//  and by Dalton's law
Pa1 = P1-Pw1;//  initial pressure of air, [kN/m^2]

mprintf('\n (a) The initial partial pressure of the steam is  =  %f  kN/m^2',Pw1);
mprintf('\n      The initial partial pressure of the air is  =  %f kN/m^2\n',Pa1);

//  (b)
//  again from steam table, at 120.2 C the pressure of wet steam is
Pw2 = 200;//  [kN/m^2]

//  now since volume is constant so assuming air to be ideal gas so for air  P/T=contant, hence
Pa2 = Pa1*T2/T1 ;//  [kN/m^2]

mprintf(' \n(b) The final partial pressure of the steam is  =  %f kN/m^2',Pw2);
mprintf('\n     The final partial pressure of the air is  =  %f  kN/m^2\n',Pa2);

//  (c)
Pt = Pa2+Pw2;//  using dalton's law, total pressure,[kN/m^2]
```

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

// End
```

Scilab code Exa 5.17 partial pressure and mass

```
clear;
clc;
disp('Example 5.17');

// aim : To determine
// the partial pressure of the air and steam, and
   the mass of the air

// Given values
P1 = 660;// vaccum gauge pressure on condenser [
   mmHg]
P = 765;// atmospheric pressure, [mmHg]
x = .8;// dryness fraction
T = 273+41.5;// temperature,[K]
ms_dot = 1500;// condense rate of steam,[kg/h]
R = .29;// [kJ/kg]

// solution
Pa = (P-P1)*.1334;// absolute pressure,[kN/m^2]
// from steam table, at 41.5 C partial pressure of
   steam is
Ps = 8;// [kN/m^2]
// by dalton's law, partial pressure of air is
Pg = Pa-Ps;// [kN/m^2]

mprintf('\n The partial pressure of the air in the
   condenser is = %f kN/m^2\n',Pg);
mprintf('\n The partial pressure of the steam in the
```

```
    condenser is = %f kN/m^2\n',Ps);

// also
vg = 18.1;// [m^3/kg]
// so
V = x*vg;// [m^3/kg]
// The air associated with 1 kg of the steam will
    occupiy this same volume
// for air, Pg*V=m*R*T, so
m = Pg*V/(R*T);// [kg/kg steam]
// hence
ma = m*ms_dot;// [kg/h]

mprintf('\n The mass of air which will associated
    with this steam is = %f kg\n',ma);

// There is misprint in book

// End
```

Scilab code Exa 5.18 pressure and dryness fraction

```
clear;
clc;
disp('Example 5.18');

// aim : To determine the
// (a) final pressure
// (b) final dryness fraction of the steam

// Given values
P1 = 130;// initial pressure, [kN/m^2]
T1 = 273+75.9;// initial temperature, [K]
x1 = .92;// initial dryness fraction
T2 = 273+120.2;// final temperature, [K]
```

```
// solution

// (a)
// from steam table , at 75.9 C
Pws = 40;// partial pressure of wet steam[kN/m^2]
Pa = P1-Pws;// partial pressure of air , [kN/m^2]
vg = 3.99// specific volume of the wet steam , [m^3/kg]
// hence
V1 = x1*vg;// [m^3/kg]
V2 = V1/5;// [m^3/kg]
// for air , mass is constant so , Pa*V1/T1=P2*V2/T2, also given ,V1/V2=5,so
P2 = Pa*V1*T2/(V2*T1);// final pressure ,[kN/m^2]

// now for steam at 120.2 C
Ps = 200;// final partial pressure of steam ,[kN/m^2]
// so by dalton 's law total pressure in cylindert is
Pt = P2+Ps;// [kN/m^2]
mprintf('\n (a) The final pressure in the cylinder is = %f kN/m^2\n',Pt);

// (b)
// from steam table at 200 kN/m^2
vg = .885;// [m^3/kg]
// hence
x2 = V2/vg;// final dryness fraction of the steam
mprintf('\n (b) The final dryness fraction of the steam is = %f\n ',x2);

// End
```

Scilab code Exa 5.19 adiabatic index and change of internal energy

```
clear;
clc;
disp('Example 5.19')

// aim : To determine the
// (a) Gamma,
// (b) del_U

// Given Values
P1 = 1400;// [kN/m^2]
P2 = 100;// [kN/m^2]
P3 = 220;// [kN/m^2]
T1 = 273+360;// [K]
m = .23;// [kg]
cp = 1.005;// [kJ/kg*K]

// Solution
T3 = T1;// since process 1-3 is isothermal

// (a)
// for process 1-3, P1*V1=P3*V3,so
V3_by_V1 = P1/P3;
// also process 1-2 is adiabatic ,so P1*V1^(Gamma)=P2*V2^(Gamma),hence
// and process process 2-3 is iso-choric so,V3=V2 and
V2_by_V1 = V3_by_V1;
// hence ,
Gamma = log(P1/P2)/log(P1/P3); // heat capacity ratio

mprintf('\n (a) The value of adiabatic index Gamma is = %f\n',Gamma);

// (b)
cv = cp/Gamma;// [kJ/kg K]
```

```
// for process 2-3,P3/T3=P2/T2,so
T2 = P2*T3/P3;// [K]

// now
del_U = m*cv*(T2-T1);// [kJ]
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);
// End
```

Scilab code Exa 5.20 mass and heat transfer

```
clear;
clc;
disp('Example 5.20');

// aim : To determine
// the mass of oxygen and heat transferred

// Given values
V1 = 300;// [L]
P1 = 3.1;// [MN/m^2]
T1 = 273+18;// [K]
P2 = 1.7;// [MN/m^2]
T2 = 273+15;// [K]
Gamma = 1.4; // heat capacity ratio
// density condition
P = .101325;// [MN/m^2]
T = 273;// [K]
V = 1;// [m^3]
m = 1.429;// [kg]

// hence
R = P*V*10^3/(m*T);// [kJ/kg*K]
// since volume is constant
```

```
V2 = V1;// [L]
// for the initial conditions in the cylinder ,P1*V1
   =m1*R*T1
m1 = P1*V1/(R*T1);// [kg]

// after some of the gas is used
m2 = P2*V2/(R*T2);// [kg]
// The mass of oxygen remaining in cylinder is m2
   kg , so
// Mass of oxygen used is
m_used = m1-m2;// [kg]
mprintf('\n The mass of oxygen used = %f kg\n',
   m_used);

// for non-flow process ,Q=del_U+W
// volume is constant so no external work is done
   so ,Q=del_U
cv = R/(Gamma-1);// [kJ/kg*K]

// heat transfer is
Q = m2*cv*(T1-T2);// (kJ)
mprintf('\n The amount of heat transferred through
   the cylinder wall is = %f kJ\n',Q);

// End
```

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

```
clear;
clc;
disp('Example 5.21');

// aim : To determine the
// (a) work transferred during the compression
```

```
//  (b) change in internal energy
//  (c) heat transferred during the compression

//  Given values
V1 = .1;//  initial volume, [m^3]
P1 = 120;//  initial pressure, [kN/m^2]
P2 = 1200; // final pressure, [kN/m^2]
T1 = 273+25;//  initial temperature, [K]
cv = .72;//  [kJ/kg*K]
R = .285;//  [kJ/kg*K]

//  solution

//  (a)
//  given process is polytropic with
n = 1.2;  // polytropic index
//  hence
V2 = V1*(P1/P2)^(1/n);//  [m^3]
W = (P1*V1-P2*V2)/(n-1);//  workdone formula, [kJ]
mprintf('\n (a) The work transferred during the
   compression is  =  %f  kJ\n',W);

//  (b)
//  now mass is constant so,
T2 = P2*V2*T1/(P1*V1);//  [K]
//  using, P*V=m*R*T
m = P1*V1/(R*T1);//  [kg]

//  change in internal energy is
del_U = m*cv*(T2-T1);//  [kJ]
mprintf('\n (b) The change in internal energy is  =
    %f  kJ\n',del_U);

//  (c)
Q = del_U+W;//  [kJ]
mprintf('\n (c) The heat transferred during the
   compression is  =  %f  kJ\n',Q);
```

```
// End
```

Scilab code Exa 5.22 pressure and specific enthalpy

```
clear;
clc;
disp('Example 5.22');

// aim : To determine the
// (a) new pressure of the air in the receiver
// (b) specific enthalpy of air at 15 C

// Given values
V1 = .85;// [m^3]
T1 = 15+273;// [K]
P1 = 275;// pressure,[kN/m^2]
m = 1.7;// [kg]
cp = 1.005;// [kJ/kg*K]
cv = .715;// [kJ/kg*K]

// solution

// (a)

R = cp-cv;// [kJ/kg*K]
// assuming m1 is original mass of the air, using P*V=m*R*T
m1 = P1*V1/(R*T1);// [kg]
m2 = m1+m;// [kg]
// again using P*V=m*R*T
// P2/P1=(m2*R*T2/V2)/(m1*R*T1/V1); and T1=T2,V1=V2, so
P2 = P1*m2/m1;// [kN/m^2]
mprintf('\n (a) The new pressure of the air in the receiver is = %f kN/m^2\n',P2);
```

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

// End
```

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

```
clear;
clc;
disp('Example 5.23');

// aim : T determine the
// (a) characteristic gas constant of the gas
// (b) cp,
// (c) cv,
// (d) del_u
// (e) work transfer

// Given values
P = 1;// [bar]
T1 = 273+15;// [K]
m = .9;// [kg]
T2 = 273+250;// [K]
Q = 175;// heat transfer,[kJ]

// solution

// (a)
// using, P*V=m*R*T, given,
```

```
m_by_V = 1.875;
// hence
R = P*100/(T1*m_by_V);// [kJ/kg*K]
mprintf('\n (a) The characteristic gas constant of the gas is R = %f kJ/kg K\n',R);

// (b)
// using , Q=m*cp*(T2-T1)
cp = Q/(m*(T2-T1));// [kJ/kg K]
mprintf('\n (b) The specific heat capacity of the gas at constant pressure cp = %f kJ/kg K\n',cp);

// (c)
// we have , cp-cv=R, so
cv = cp-R;// [kJ/kg*K]
mprintf('\n (c) The specific heat capacity of the gas at constant volume cv = %f kJ/kg K\n',cv);

// (d)
del_U = m*cv*(T2-T1);// [kJ]
mprintf('\n (d) The change in internal energy is = %f kJ\n',del_U);

// (e)
// using , Q=del_U+W
W = Q-del_U;// [kJ]
mprintf('\n (e) The work transfer is W = %f kJ\n',W);

// End
```

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

```
clear;
clc;
disp('Example 5.24');

// aim : To determine the
// (a) work transfer,
// (b)del_U and,
// (c)heat transfer

// Given values
V1 = .15;// [m^3]
P1 = 1200;// [kN/m^2]
T1 = 273+120;// [K]
P2 = 200;// [kN/m^2]
cp = 1.006;//[kJ/kg K]
cv = .717;// [kJ/kg K]

// solution

// (a)
// Given, PV^1.32=constant, so it is polytropic process with
n = 1.32;// polytropic index
// hence
V2 = V1*(P1/P2)^(1/n);// [m^3]
// now, W
W = (P1*V1-P2*V2)/(n-1);// [kJ]
mprintf('\n (a) The work transfer is W = %f kJ\n', W);

// (b)
R = cp-cv;// [kJ/kg K]
m = P1*V1/(R*T1);// gas law,[kg]
// also for polytropic process
T2 = T1*(P2/P1)^((n-1)/n);// [K]
// now for gas,
del_U = m*cv*(T2-T1);// [kJ]
mprintf('\n (b) The change of internal energy is
```

```
del_U = %f kJ\n',del_U);

// (c)
Q = del_U+W;// first law of thermodynamics,[kJ]
mprintf('\n (c) The heat transfer Q = %f kJ\n',Q);

// End
```

Scilab code Exa 5.26 volume

```
clear;
clc;
disp('Example 5.26');

// aim : To determine
// the volume of the pressure vessel and the volume of the gas before transfer

// Given values

P1 = 1400;// initial pressure,[kN/m^2]
T1 = 273+85;// initial temperature,[K]

P2 = 700;// final pressure,[kN/m^2]
T2 = 273+60;// final temperature,[K]

m = 2.7;// mass of the gas passes,[kg]
cp = .88;// [kJ/kg]
cv = .67;// [kJ/kg]

// solution

// steady flow equation is, u1+P1*V1+C1^2/2+Q=u2+P2*V2+C2^2/2+W [1],
// given, there is no kinetic energy change and
```

```
    neglecting potential energy term
W = 0;// no external work done
//  so final equation is,u1+P1*v1+Q=u2    [2]
// also u2-u1=cv*(T2-T1)
// hence Q=cv*(T2-T1)-P1*v1     [3]
//  and for unit mass P1*v1=R*T1=(cp-cv)*T1   [4]
//  so finally
Q = cv*(T2-T1)-(cp-cv)*T1;//  [kJ/kg]
//  so total heat transferred is
Q = m*Q;//  [kJ]

//  using eqn [4]
v1 = (cp-cv)*T1/P1;//  [m^3/kg]
//  Total volume is
V1 = m*v1;//  [m^3]

//  using ideal gas equation P1*V1/T1=P2*V2/T2
V2 = P1*T2*V1/(P2*T1);//  final volume,[m^3]

mprintf('\n The volume of gas before transfer is  =
    %f  m^3\n',V1);
mprintf('\n The volume of pressure vessel is  =  %f
    m^3\n',V2);

//  End
```

Chapter 7

Entropy

Scilab code Exa 7.1 specific entropy

```
clear;
clc;
disp('Example 7.1');

// aim : To determine
// the specific enthalpy of water

// Given values
Tf = 273+100;// Temperature,[K]

// solution
// from steam table
cpl = 4.187;// [kJ/kg K]
// using equation [8]
sf = cpl*log(Tf/273.16);// [kJ/kg*K]
mprintf('\n The specific entropy of water is = %f
    kJ/kg K\n',sf);

// using steam table
sf = 1.307;// [kJ/kg K]
mprintf('\n From table The accurate value of sf in
```

```
    this case is = %f kJ/kg K\n',sf);

// There is small error in book's final value of sf


// End
```

Scilab code Exa 7.2 specific entropy

```

clear;
clc;
disp('Example 7.2');

// aim : To determine
// the specific entropy

// Given values
P = 2;// pressure ,[MN/m^2]
x = .8;// dryness fraction

// solution
// from steam table at given pressure
Tf = 485.4;// [K]
cpl = 4.187;// [kJ/kg K]
hfg = 1888.6;// [kJ/kg]

// (a) finding entropy by calculation
s = cpl*log(Tf/273.16)+x*hfg/Tf;// formula for
    entropy calculation

mprintf('\n (a) The specific entropy of wet steam is
     = %f kJ/kg K\n',s);

// (b) calculation of entropy using steam table
```

```
// from steam table at given pressure
sf = 2.447;// [kJ/kg K]
sfg = 3.89;// [kJ/kg K]
// hence
s = sf+x*sfg;// [kJ/kg K]

mprintf('\n (b) The specific entropy using steam
   table is = %f kJ/kg K\n',s);

// End
```

Scilab code Exa 7.3 specific entropy

```
clear;
clc;
disp('Example 7.3');

// aim : To determine
// the specific entropy of steam

// Given values
P = 1.5;//pressure,[MN/m^2]
T = 273+300;//temperature,[K]

// solution

// (a)
// from steam table
cpl = 4.187;// [kJ/kg K]
Tf = 471.3;// [K]
hfg = 1946;// [kJ/kg]
cpv = 2.093;// [kJ/kg K]

// usung equation [2]
s = cpl*log(Tf/273.15)+hfg/Tf+cpv*log(T/Tf);// [kJ/
```

```
    kg K]
mprintf('\n (a) The specific entropy of steam is =
    %f kJ/kg K\n',s);

// (b)
// from steam tables
s = 6.919;// [kJ/kg K]
mprintf('\n (b) The accurate value of specific
   entropy from steam table is = %f kJ/kg K\n',s);

// End
```

Scilab code Exa 7.4 dryness fraction

```
clear;
clc;
disp('Example 7.4');

// aim : To determine
// the dryness fraction of steam

// Given values
P1 = 2;// initial pressure, [MN/m^2]
t = 350;// temperature, [C]
P2 = .28;// final pressure, [MN/m^2]

// solution
// at 2 MN/m^2 and 350 C,steam is superheated
   because the saturation temperature is 212.4 C
// From steam table
s1 = 6.957;// [kJ/kg K]

// for isentropic process
s2 = s1;
// also
```

```
sf2 = 1.647;//  [kJ/kg K]
sfg2 = 5.368;//  [kJ/kg K]

//  using
//  s2 = sf2+x2*sfg2 , where x2 is dryness fraction
    of steam
//  hence
x2 = (s2-sf2)/sfg2;
mprintf('\n The final dryness fraction of steam is
   x2  =  %f\n',x2);

//  End
```

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

```
clear;
clc;
disp('Example 7.5');

//  aim : To determine
//  the  final condition of steam...
//  the change in specific entropy during hyperbolic
     process

//  Given values
P1 = 2;//  pressure, [MN/m^2]
t = 250;//  temperature, [C]
P2 = .36;//  pressure, [MN/m^2]
P3 = .06;//  pressure, [MN/m^2]

//  solution

//  (a)
//  from steam table
s1 = 6.545;//  [kJ/kg K]
```

```
//  at .36 MN/m^2
sg = 6.930;//  [kJ/kg*K]

sf2 = 1.738;//  [kJ/kg K]
sfg2 = 5.192;//  [kJ/kg K]
vg2 = .510;//  [m^3]

//  so after isentropic expansion, steam is wet
//  hence, s2=sf2+x2*sfg2, where x2 is dryness fraction
//  also
s2 = s1;
//  so
x2 = (s2-sf2)/sfg2;
//  and
v2 = x2*vg2;//  [m^3]

//  for  hyperbolic process
//  P2*v2=P3*v3
//  hence
v3 = P2*v2/P3;//  [m^3]

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);

//  (b)
//  at this condition
s3 = 7.609;//  [kJ/kg*K]
//  hence
change_s23 = s3-sg;//  change in specific entropy during the hyperblic process[kJ/kg*K]
mprintf('\n (b) The change in specific entropy during the hyperbolic process is  =  %f kJ/kg K\n',change_s23);

// In the book they have taken sg instead of s2 for part (b), so answer is not matching
```

```

// End
```

Scilab code Exa 7.6 heat transfer and work done

```

clear;
clc;
disp('Example 7.6');

// aim : To determine the
// (a) heat transfer during the expansion and
// (b) work done durind the expansion

// given values
m = 4.5; // mass of steam ,[kg]
P1 = 3; // initial pressure ,[MN/m^2]
T1 = 300+273; // initial temperature ,[K]

P2 = .1; // final pressure ,[MN/m^2]
x2 = .96; // dryness fraction at final stage

// solution
// for state point 1,using steam table
s1 = 6.541;// [kJ/kg/K]
u1 = 2751;// [kJ/kg]

 // for state point 2
 sf2 = 1.303;// [kJ/kg/K]
 sfg2 = 6.056;// [kJ/kg/k]
 T2 = 273+99.6;// [K]
 hf2 = 417;// [kJ/kg]
 hfg2 = 2258;// [kJ/kg]
 vg2 = 1.694;// [m^3/kg]

```

```
// hence
s2 = sf2+x2*sfg2;// [kJ/kg/k]
h2 = hf2+x2*hfg2;// [kJ/kg]
u2 = h2-P2*x2*vg2*10^3;// [kJ/kg]

// Diagram of example 7.6
x = [s1 s2];
y = [T1 T2];
plot2d(x,y);
xtitle('Diagram for example 7.6(T vs s)');
xlabel('Entropy (kJ/kg K)');
ylabel('Temperature (K)');

x = [s1,s1];
y = [0,T1];
plot2d(x,y);

x = [s2,s2];
y = [0,T2];
plot2d(x,y);

// (a)
// Q_rev is area of T-s diagram
Q_rev = (T1+T2)/2*(s2-s1);// [kJ/kg]
// so total heat transfer is
Q_rev = m*Q_rev;// [kJ]

// (b)
del_u = u2-u1;// change in internal energy, [kJ/kg
   ]
// using 1st law of thermodynamics
W = Q_rev-m*del_u;// [kJ]

mprintf('\n (a) The heat transfer during the
   expansion is = %f kJ (received)\n',Q_rev);

mprintf('\n (b) The work done during the expansion
   is = %f kJ\n',W);
```

```

// End
```

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

```

clear;
clc;
disp('Example 7.7');

// aim : To determine the
// (a) change of entropy
// (b) The approximate change of entropy obtained
    by dividing the heat transferred by the gas by
    the mean absolute temperature during the
    compression

// Given values
P1 = 140;// initial pressure,[kN/m^2]
V1 = .14;// initial volume, [m^3]
T1 = 273+25;// initial temperature,[K]
 P2 = 1400;// final pressure [kN/m^2]
 n = 1.25; // polytropic index
 cp = 1.041;// [kJ/kg K]
 cv = .743;// [kJ/kg K]

 // solution
 // (a)
 R = cp-cv;// [kJ/kg/K]
 // using ideal gas equation
 m = P1*V1/(R*T1);// mass of gas,[kg]
 // since gas is following law P*V^n=constant ,so
 V2 = V1*(P1/P2)^(1/n);// [m^3]

```

```
// using eqn [9]
del_s = m*(cp*log(V2/V1)+cv*log(P2/P1));// [kJ/K]
mprintf('\n (a) The change of entropy is = %f kJ/
   K\n',del_s);

// (b)
W = (P1*V1-P2*V2)/(n-1);// polytropic work,[kJ]
Gamma = cp/cv;// heat capacity ratio
Q = (Gamma-n)/(Gamma-1)*W;// heat transferred,[kJ]

// Again using polytropic law
T2 = T1*(V1/V2)^(n-1);// final temperature, [K]
T_avg = (T1+T2)/2;// mean absolute temperature, [K]

// so approximate change in entropy is
del_s = Q/T_avg;// [kJ/K]

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);

// End
```

Scilab code Exa 7.8 change of entropies

```
clear;
clc;
disp('Example 7.8');

// aim : To determine
// the change of entropy

// Given values
m = .3;// [kg]
```

```
P1 = 350;//  [kN/m^2]
T1 = 273+35;//  [K]
P2 = 700;//  [kN/m^2]
V3 = .2289;//  [m^3]
cp = 1.006;//  [kJ/kg K]
cv = .717;//  [kJ/kg K]

//  solution
//  for constant volume process
R = cp-cv;//  [kJ/kg K]
//  using PV=mRT
V1 = m*R*T1/P1;//  [m^3]

//  for constant volume process P/T=constant,so
T2 = T1*P2/P1;//  [K]
s21 = m*cv*log(P2/P1);//  formula for entropy change for constant volume process
mprintf('\n The change of entropy in constant volume process is  =  %f  kJ/kg K\n',s21);

// 'For the above part result given in the book is wrong

V2 = V1;
// for constant pressure process
T3 = T2*V3/V2;//  [K]
s32 = m*cp*log(V3/V2);//  [kJ/kg K]

mprintf('\n The change of entropy in constant pressure process is  =  %f  kJ/kg K\n',s32);

// there is misprint in the book's result

// End
```

Scilab code Exa 7.9 change of entropy

```
clear;
clc;
disp('Example 7.9');

// aim : To determine
// the change of entropy

// Given values
P1 = 700;// initial pressure, [kN/m^2]
T1 = 273+150;// Temperature ,[K]
V1 = .014;// initial volume, [m^3]
V2 = .084;// final volume, [m^3]

// solution
// since process is isothermal so
T2 = T1;
// and using fig.7.10
del_s = P1*V1*log(V2/V1)/T1 ;// [kJ/K]
mprintf('\n The change of entropy is = %f kJ/kg K
   \n',del_s);

// End
```

Chapter 8

Combustion

Scilab code Exa 8.1 stoichiometric mass

```

clear;
clc;
disp('Example 8.1');

//  aim : To determine
//   the stoichiometric mass of air required to burn
    1 kg the fuel

//  Given values
C = .72;//  mass fraction of C; [kg/kg]
H2 = .20;//  mass fraction of H2;, [kg/kg]
O2 = .08;//  mass fraction of O2, [kg/kg]
aO2=.232;//  composition of oxygen in air

//  solution
//  for 1kg of fuel
mO2  = 8/3*C+8*H2-O2;//  mass of O2, [kg]

//  hence stoichiometric mass of O2 required is
msO2  = mO2/aO2;// [kg]
```

```

mprintf('\n The stoichiometric mass of air required
    to burn 1 kg the fuel should be =  %f  kg\n',msO2
    );

//  End
```

Scilab code Exa 8.3 stoichiometric mass and composition of products

```
clear;
clc;
disp('Example 8.3');

//  aim : To determine
//  the stoichiometric mass of air
//  the products of combustion both by mass and as
    percentage

//  Given values
C = .82;// mass composition C
H2 = .12;// mass composition of H2
O2 = .02;// mass composition of O2
S = .01;// mass composition of S
N2 = .03;// mass composition of N2

 //  solution
//  for 1kg fuel
mo2 = 8/3*C+8*H2-O2+S*1;// total mass of  O2
    required , [kg]
sa = mo2/.232;// stoichimetric  air , [kg]
mprintf('\n The stoichiometric mass of air is  =  %f
     kg/kg fuel\n',sa);

// for one kg fuel
mCO2 = C*11/3;// mass of CO2 produced , [kg]
```

```
mH2O = H2*9;// mass of H2O produced, [kg]
mSO2 = S*2;// mass of SO2 produce, [kg]
mN2 = C*8.84+H2*26.5-O2*.768/.232+S*3.3+N2;// mass of N2 produced, [kg]

mt = mCO2+mH2O+mSO2+mN2;// total mass of product, [kg]

x1 = mCO2/mt*100;// %age mass composition of CO2 produced
x2 = mH2O/mt*100;// %age mass composition of H2O produced
x3 = mSO2/mt*100;// %age mass composition of SO2 produced
x4 = mN2/mt*100;// %age mass composition of N2 produced

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);

// End
```

Scilab code Exa 8.4 stoichiometric volume

```
clear;
clc;
disp('Example 8.4');

// aim : To determine
// the stoichiometric volume of air required for
```

```
   complete combution of 1 m^3 of the gas

// Given values
H2 = .14;// volume fraction of H2
CH4 = .02;// volume fraction of CH4
CO = .22;// volume fraction of CO
CO2 = .05;// volume fraction of CO2
O2 = .02;// volume fraction of O2
N2 = .55;// volume fraction of N2

// solution
// for 1 m^3 of fuel
Va = .5*H2+2*CH4+.5*CO-O2;// [m^3]

// stoichiometric air required is
Vsa = Va/.21;// [m^3]

mprintf('\n The stoichiometric volume of air
   required for complete combustion is = %f m^3/m
   ^3 fuel\n',Vsa);

// End
```

Scilab code Exa 8.5 volume

```
clear;
clc;
disp('Example 8.5');

// aim : To determine
// the volume of the air required

// Given values
H2 = .45;// volume fraction of H2
CO = .40;// volume fraction of CO
```

```
CH4 = .15;// volume fraction of CH4

//  solution
V = 2.38*(H2+CO)+9.52*CH4;// stoichimetric volume of air , [m^3]

mprintf('\n The volume of air required is  =  %f  m^3/m^3 fuel\n',V);

// Result in the book is misprinted

// End
```

Scilab code Exa 8.6 stoichiometric volume composition of products

```
clear;
clc;
disp('Example 8.6');

// aim : To determine
// the stoichiometric volume of air for the complete combustion
// the products of combustion

// given values
CH4 = .142;// volumetric composition of CH4
CO2 = .059;// volumetric composition of CO2
CO = .360;// volumetric composition of CO
H2 = .405;// volumetric composition of H2
O2 = .005;// volumetric composition of O2
N2 = .029;// volumetric composition of N2

aO2 = .21;// O2 composition into air by volume

//  solution
```

```
svO2 = CH4*2+CO*.5+H2*.5-O2;// stroichiometric volume of O2 required, [m^3/m^3 fuel]
svair = svO2/aO2;// stroichiometric volume of air required, [m^3/m^3 fuel]
mprintf('\n Stoichiometric volume of air required is = %f m^3/m^3 fuel\n',svair);

// for one m^3 fuel
vN2 = CH4*7.52+CO*1.88+H2*1.88-O2*.79/.21+N2;// volume of N2 produced, [m^3]
vCO2 = CH4*1+CO2+CO*1;// volume of CO2 produced, [m^3]
vH2O = CH4*2+H2*1;// volume of H2O produced, [m^3]

vt = vN2+vCO2+vH2O;// total volume of product, [m^3]

x1 = vN2/vt*100;// %age composition of N2 in product,
x2 = vCO2/vt*100;// %age composition of CO2 in product
x3 = vH2O/vt*100;// %age composition of H2O in product

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);

// End
```

Scilab code Exa 8.7 composition of gases

```
clear;
```

```
clc;
disp('Example 8.7');

// aim : To determine
// the percentage analysis of the gas by mass

// Given values
CO2 = 20;// percentage volumetric composition of CO2
N2 = 70;// percentage volumetric composition of N2
O2 = 10;// percentage volumetric composition of O2

mCO2 = 44;// moleculer mas of CO2
mN2 = 28;// moleculer mass of N2
mO2 = 32;// moleculer mass of O2

// solution
mgas = CO2*mCO2+N2*mN2+O2*mO2;// moleculer mass of gas
m1 = CO2*mCO2/mgas*100;// percentage composition of CO2 by mass
m2 = N2*mN2/mgas*100;// percentage composition of N2 by mass
m3 = O2*mO2/mgas*100;// percentage composition of O2 by mass

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 )

// End
```

Scilab code Exa 8.8 composition of gases

```
clear;
```

```
clc;
disp('Example 8.8');

//  aim : To determine
//  the percentage composition of the gas by volume

//  given values
CO = 30;// %age mass composition of CO
N2 = 20;// %age mass composition of N2
CH4 = 15;// %age mass composition of CH4
H2 = 25;// %age mass composition of H2
O2 = 10;// %age mass composition of O2

mCO = 28;// molculer mass of CO
mN2 = 28;// molculer mass of N2
mCH4 = 16;// molculer mass of CH4
mH2 = 2;// molculer mass of H2
mO2 = 32;// molculer mass of O2

// solution
vg = CO/mCO+N2/mN2+CH4/mCH4+H2/mH2+O2/mO2;
v1 = CO/mCO/vg*100;// %age volume composition of CO
v2 = N2/mN2/vg*100;// %age volume composition of N2
v3 = CH4/mCH4/vg*100;// %age volume composition of
   CH4
v4 = H2/mH2/vg*100;// %age volume composition of H2
v5 = O2/mO2/vg*100;// %age volume composition of O2

mprintf('\n The percentage composition of CO by
   volume is  =  %f\n,\nThe percentage composition
   of N2 by volume is  =  %f\n\nThe percentage
   composition of CH4 by volume is  =  %f\n\nThe
   percentage composition of H2 by volume is  =  %f\
   n\nThe percentage composition of O2by volume is=
   %f',v1,v2,v3,v4,v5);

// End
```

Scilab code Exa 8.9 mass of air supplied

```
clear;
clc;
disp('Example 8.9');

// aim : To determine
// the mass of air supplied per kilogram of fuel
   burnt

// given values
CO2 = 8.85;// volume composition of CO2
CO = 1.2;//  volume composition of CO
O2 = 6.8;//  volume composition of O2
N2 = 83.15;//  volume composition of N2

// composition of gases in the fuel oil
C = .84;// mass composition of carbon
H = .14;// mass composition of hydrogen
o2 = .02;// mass composition of oxygen

mC = 12;// moleculer mass of Carbon
mCO2 = 44;// molculer mass of CO2
mCO = 28;// molculer mass of CO
mN2 = 28;// molculer mass of N2
mO2 = 32;// molculer mass of O2
aO2 = .23;// mass composition of O2 in air

// solution
ma = (8/3*C+8*H-o2)/aO2;// theoretical mass of air/
   kg fuel, [kg]

mgas = CO2*mCO2+CO*mCO+N2*mN2+O2*mO2;//  total mass
   of gas/kg fuel, [kg]
```

```
x1 = CO2*mCO2/mgas;//  composition of CO2 by mass
x2 = CO*mCO/mgas;// composition of CO by mass
x3 = O2*mO2/mgas;//  composition of O2 by mass
x4 = N2*mN2/mgas;//  composition of N2 by mass

m1 = x1*mC/mCO2+x2*mC/mCO;// mass of C/kg of dry
    flue gas, [kg]
m2 = C;// mass of C/kg fuel, [kg]
mf = m2/m1;// mass of dry flue gas/kg fuel, [kg]
mo2 = mf*x3;// mass of excess O2/kg fuel, [kg]
mair = mo2/aO2;// mass of excess air/kg fuel, [kg]
m = ma+mair;// mass of excess air supplied/kg fuel,
    [kg]

mprintf('\n The mass of air supplied per/kg of fuel
    burnt is = %f kg\n',m);

// End
```

Scilab code Exa 8.10 volumetric composition of products

```
clear;
clc;
disp('Example 8.10');

// aim : To determine
// volumetric composition of the products of
    combustion

// given values
C = .86;//  mass composition of carbon
H = .14;// mass composition of hydrogen
Ea = .20;//  excess air for combustion
O2 = .23;// mass composition of O2 in air

```

```
MCO2 = 44;// moleculer mass of CO2
MH2O = 18;// moleculer mass of H2O
MO2 = 32;// moleculer mass of O2
MN2 = 28;// moleculer mass of N2,


// solution
sO2 = (8/3*C+8*H);// stoichiometric O2 required , [kg/kg petrol]
sair = sO2/O2;// stoichiometric air required , [kg/kg petrol]
// for one kg petrol
mCO2 = 11/3*C;// mass of CO2,[kg]
mH2O = 9*H;// mass of H2O, [kg]
mO2 = Ea*sO2;// mass of O2, [kg]
mN2 = 14.84*(1+Ea)*(1-O2);// mass of N2, [kg]

mt = mCO2+mH2O+mO2+mN2;// total mass, [kg]
// percentage mass composition
x1 = mCO2/mt*100;// mass composition of CO2
x2 = mH2O/mt*100;// mass composition of H2O
x3 = mO2/mt*100;// mass composition of O2
x4 = mN2/mt*100;// mass composition of N2

vt = x1/MCO2+x2/MH2O+x3/MO2+x4/MN2;// total volume of petrol
v1 = x1/MCO2/vt*100;// %age composition of CO2 by volume
v2 = x2/MH2O/vt*100;// %age composition  of H2O by volume
v3 = x3/MO2/vt*100;// %age composition of O2 by volume
v4 = x4/MN2/vt*100;// %age composition of N2 by volume

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',v1,v2,v3,v4);

// End
```

Scilab code Exa 8.11 energy carried away

```
clear;
clc;
disp('Example 8.11');

// aim : To determine
// the energy carried away by the dry flue gas/kg of fuel burned

// given values
C = .78;// mass composition of carbon
H2 = .06;// mass composition of hydrogen
O2 = .09;// mass composition of oxygen
Ash = .07;// mass composition of ash
Ea = .50;// excess air for combustion
aO2 = .23;// mass composition of O2 in air
Tb = 273+20;// boiler house temperature, [K]
Tf = 273+320;// flue gas temperature, [K]
c = 1.006;// specific heat capacity of dry flue gas, [kJ/kg K]

// solution
// for one kg of fuel
sO2 = (8/3*C+8*H2);// stoichiometric O2 required, [kg/kg fuel]
sO2a = sO2-O2;// stoichiometric O2 required from air, [kg/kg fuel]
sair = sO2a/aO2;// stoichiometric air required, [kg/
```

```
kg fuel]
ma = sair*(1+Ea);// actual air supplied/kg of fuel, [kg]
// total mass of flue gas/kg fuel is
mf = ma+1;// [kg]
mH2 = 9*H2;//H2 produced, [kg]
// hence, mass of dry flue gas/kg coall is
m = mf-mH2;// [kg]
Q = m*c*(Tf-Tb);// energy carried away by flue gas, [kJ]
mprintf('\n The energy carried away by the dry flue gas/kg is = %f kg\n',Q);

// End
```

Scilab code Exa 8.12 stoichiometric volume and composition of products

```
clear;
clc;
disp('Example 8.12');

// aim : To determine
// (a) the stoichiometric volume of air for the complete combustion of 1 m^3
// (b) the percentage volumetric analysis of the products of combustion

// given values
N2 = .018;// volumetric composition of N2
CH4 = .94;// volumetric composition of CH4
C2H6 = .035;// volumetric composition of C2H6
C3H8 = .007;// volumetric composition of C3H8
aO2 = .21;// O2 composition in air

// solution
```

```
// (a)
// for CH4
// CH4 +2 O2= CO2 + 2 H2O
sva1 = 2/aO2;// stoichiometric volume of air, [m^3/m^3 CH4]
svn1 = sva1*(1-aO2);// stoichiometric volume of nitrogen in the air, [m^3/m^3 CH4]

// for C2H6
// 2 C2H6 +7 O2= 4 CO2 + 6 H2O
sva2 = 7/2/aO2;// stoichiometric volume of air, [m^3/m^3 C2H6]
svn2 = sva2*(1-aO2);// stoichiometric volume of nitrogen in the air, [m^3/m^3 C2H6]

// for C3H8
// C3H8 +5 O2=3 CO2 + 4 H2O
sva3 = 5/aO2;// stoichiometric volume of air, [m^3/m^3 C3H8]
svn3 = sva3*(1-aO2);// stoichiometric volume of nitrogen in the air, [m^3/m^3 C3H8]

Sva = CH4*sva1+C2H6*sva2+C3H8*sva3;// stoichiometric volume of air required, [m^3/m^3 gas]
mprintf('\n (a) The stoichiometric volume of air for the complete combustion = %f m^3m^3 gas\n',Sva);

// (b)
// for one m^3 of natural gas
vCO2 = CH4*1+C2H6*2+C3H8*3;// volume of CO2 produced, [m^3]
vH2O = CH4*2+C2H6*3+C3H8*4;// volume of H2O produced, [m^3]
vN2 = CH4*svn1+C2H6*svn2+C3H8*svn3+N2;// volume of N2 produced, [m^3]

vg = vCO2+vH2O+vN2;// total volume of gas, [m^3]
```

```
x1 = vCO2/vg*100;// volume percentage of CO2 produced
x2 = vH2O/vg*100;// volume percentage of H2O produced
x3 = vN2/vg*100;// volume percentage of N2 produced

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);

// End
```

Scilab code Exa 8.13 volume and composition by mass

```
clear;
clc;
disp('Example 8.13');

// aim : To determine
// (a) the volume of air taken by the fan
// (b) the percentage composition of dry flue gas

// gien values
C = .82;// mass composition of carbon
H = .08;// mass composition of hydrogen
 O = .03;// mass composition of oxygen
 A = .07;// mass composition of ash
mc = .19;// coal uses, [kg/s]
 ea = .3;// percentage excess air of oxygen in the air required for combustion
Oa = .23;// percentage of oxygen by mass in the air

```

```
 // solution
 // (a)
 P = 100;// air pressure, [kN/m^2]
 T = 18+273;// air temperature, [K]
 R = .287;// [kJ/kg K]
 // basis one kg coal
 sO2 = 8/3*C+8*H;// stoichiometric O2 required, [kg]
 aO2 = sO2-.03;// actual O2 required, [kg]
tO2 = aO2/Oa;// theoretical O2 required, [kg]
Aa = tO2*(1+ea);// actual air supplied, [kg]
m = Aa*mc;// Air supplied, [kg/s]

// now using P*V=m*R*T
V = m*R*T/P;// volume of air taken ,[m^3/s]
mprintf('\n (a) Volume of air taken by fan is = %f m^3/s\n',V);

// (b)
mCO2 = 11/3*C;// mass of CO2 produced, [kg]
mO2 = aO2*.3;// mass of O2 produces, [kg]
mN2 = Aa*.77;// mass of N2 produced, [[kg]
mt = mCO2+mO2+mN2;// total mass, [kg]

mprintf('\n (b) Percentage mass composition of CO2 is = %f percent \n',mCO2/mt*100);
mprintf('\n     Percentage mass composition of O2 is = %f percent\n',mO2/mt*100)
mprintf('\n     Percentage mass composition of N2 is = %f percent \n',mN2/mt*100)



// End
```

Scilab code Exa 8.14 mass and volume

```
clear;
clc;
disp('Example 8.14');

// aim : To determine
// (a) the mass of fuel used per cycle
// (b) the actual mass of air taken in per cycle
// (c) the volume of air taken in per cycle

// given values
W = 15;// work done, [kJ/s]
N = 5;// speed, [rev/s]
C = .84;// mass composition of carbon
H = .16;// mass composition of hydrogen
ea = 1;// percentage excess air supplied
CV = 45000;// calorificvalue of fuel, [kJ/kg]
n_the = .3;// thermal efficiency
P = 100;// pressuer, [kN/m^2]
T = 273+15;// temperature, [K]
R = .29;// gas constant, [kJ/kg K]

// solution
// (a)
E = W*2/N/n_the;// energy supplied, [kJ/cycle]
mf = E/CV;// mass of fuell used, [kg]
mprintf('\n (a) Mass of fuel used per cycle is =
    %f g\n',mf*10^3);

// (b)
// basis 1 kg fuel
mO2 = C*8/3+8*H;// mass of O2 requirea, [kg]
smO2 = mO2/.23;// stoichiometric mass of air, [kg]
ma = smO2*(1+ea);// actual mass of air supplied, [kg
    ]
m = ma*mf;// mass of air supplied, [kg/cycle]
mprintf('\n (b) The mass of air supplied per cycle
    is = %f kg\n',m);

```

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

// End
```

Scilab code Exa 8.15 mass and composition

```
clear;
clc;
disp('Example 8.15');

// aim : To determine
// (a) the mass of coal used per hour
// (b) the mass of air used per hour
// (c) the percentage analysis of the flue gases by
    mass

// given values
m = 900;// mass of steam boiler generate/h, [kg]
x = .96;// steam dryness fraction
P = 1400;// steam pressure , [kN/m^2]
Tf = 52;// feed water temperature , [C]
BE = .71;// boiler efficiency
CV = 33000;// calorific value of coal , [kJkg[
ea = .22;// excess air supply
aO2 = .23;// oxygen composition in air
c = 4.187;// specific heat capacity of water , [kJ/kg
    K]

// coal composition
C = .83;// mass composition of carbon
H2 = .05;// mass composition of hydrogen
O2 = .03;// mass composition of oxygen
```

```
ash = .09;// mass composition of ash

// solution
// from steam table at pressure P
hf = 830.1;// specific enthalpy , [kJ/kg]
hfg = 1957.1;// specific enthalpy , [kJ/kg]
hg = 2728.8;// specific enthalpy , [kJ/kg]

// (a)
h = hf+x*hfg;// specific enthalpy of steam generated
    by boiler , [kJ/kg]
hfw = c*Tf;// specific enthalpy of feed water , [kJ/
    kg]
Q = m*(h-hfw);// energy to steam/h, [kJ]
Qf = Q/BE;// energy required from fuel/h, [kJ]
mc = Qf/CV;// mass of coal/h,[kg]
mprintf('\n (a) The mass of coal used per hour is  =
     %f kg\n',mc);

// (b)
// for one kg coal
mO2 = 8/3*C+8*H2+-O2;// actual mass of O2 required ,
    [kg]
mta = mO2/aO2;// theoretical mass of air , [kg]
ma = mta*(1+ea);// mass of air supplied , [kg]
mas = ma*mc;// mass of air supplied/h, [kg]
mprintf('\n (b) The mass of air supplied per hour is
     =  %f kg\n',mas);


// (c)
// for one kg coal
mCO2 = 11/3*C;// mass of CO2 produced , [kg]
mH2O = 9*H2;// mass of H2O produced , [kg]
mO2 = mO2*ea;// mass of excess O2 in flue gas , [kg]
mN2 = ma*(1-aO2);// mass of N2 in flue gas , [kg]

mt = mCO2+mH2O+mO2+mN2;// total mass of gas
```

```
x1 = mCO2/mt*100;// mass percentage composition of
    CO2
x2 = mH2O/mt*100;// mass percentage composition of
    H2O
x3 = mO2/mt*100;// mass percentage composition of O2
x4 = mN2/mt*100;// mass percentage composition of N2

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);

//  mass of coal taken in part (b) is wrong so
    answer is not matching

//  End
```

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

```
clear;
clc;
disp('Example 8.16');

// aim : To determine
// (a) volume of gas
// (b) (1) the average molecular mass of air
//       (2) the value of R
//       (3) the mass of 1 m^3 of air at STP

// given values
n = 1;// moles of gas, [kmol]
P = 101.32;// standard pressure, [kN/m^2]
```

```
T = 273;// gas tempearture, [K]

O2 = 21;// percentage volume composition of oxygen in air
N2 = 79;// percentage volume composition of nitrogen in air
R = 8.3143;// molar gas constant, [kJ/kg K]
mO2 = 32;// moleculer mass of O2
mN2 = 28;// moleculer mass of N2

// solution
// (a)
V = n*R*T/P;// volume of gas, [m^3]
mprintf('\n (a) The volume of the gas is = %f m^3\n',V);

// (b)
//(1)
Mav = (O2*mO2+N2*mN2)/(O2+N2);// average moleculer mass of air
mprintf('\n (b)(1) The average moleculer mass of air is = %f g/mol\n',Mav);

// (2)
Rav = R/Mav;// characteristic gas constant, [kJ/kg k]
mprintf('\n     (2) The value of R is = %f  kJ/kg K\n',Rav);

// (3)
rho = Mav/V;// density of air, [kg/m^3]
mprintf('\n     (3) The mass of one cubic metre of air at STP is = %f  kg/m^3\n',rho);

//  End
```

Scilab code Exa 8.17 pressures and volume

```
clear;
clc;
disp('Example 8.17');

// aim : To determine
// (a) the partial pressure of each gas in the vessel
// (b) the volume of the vessel
// (c)  the total pressure in the gas when temperature is raised to228 C

// given values
MO2 = 8;//  mass of O2, [kg]
MN2 = 7;//  mass of N2, [kg]
MCO2 = 22;//  mass of CO2, [kg]

P = 416;// total pressure in the vessel, [kN/m^2]
T = 273+60;// vessel temperature, [K]
R = 8.3143;// gas constant, [kJ/kmol K]

mO2 = 32;// molculer mass of O2
mN2 = 28;// molculer mass of N2
mCO2 = 44;// molculer mass of CO2

// solution
// (a)
n1 = MO2/mO2;// moles of O2, [kmol]
n2 = MN2/mN2;// moles of N2, [kmol]
n3 = MCO2/mCO2;// moles of CO2, [kmol]

n = n1+n2+n3;// total moles in the vessel, [kmol]
// since,Partial pressure is proportinal, so
```

```
P1 = n1*P/n;// partial pressure of O2, [kN/m^2]
P2 = n2*P/n;// partial pressure of N2, [kN/m^2]
P3 = n3*P/n;// partial pressure of CO2, [kN/m^2]

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);

// (b)
// assuming ideal gas
V = n*R*T/P;// volume of the container, [m^3]
mprintf('\n (b) The volume of the container is =
   %f m^3\n',V);

// (c)
T2 = 273+228;// raised vessel temperature, [K]
// so volume of vessel will constant , P/T=constant
P2 = P*T2/T;// new pressure in the vessel , [kn/m62]
mprintf('\n (c) The new total pressure in the vessel
    is = %f kN/m^2\n',P2);

// End
```

Scilab code Exa 8.18 mass and velocity

```
clear;
clc;
disp('Example 8.18');

// aim : To determine
// the actual mass of air supplied/kg coal
// the velocity of flue gas

// given values
```

```
mc = 635;// mass of coal burn/h, [kg]
ea = .25;// excess air required
C = .84;// mass composition of carbon
H2 = .04;// mass composition of hydrogen
O2 = .05;// mass composition of oxygen
ash = 1-(C+H2+O2);// mass composition of ash

P1 = 101.3;// pressure, [kJn/m^2]
T1 = 273;// temperature, [K]
V1 = 22.4;// volume, [m^3]

T2 = 273+344;// gas temperature, [K]
P2 = 100;// gas pressure, [kN/m^2]
A = 1.1;// cross section area, [m^2]
aO2 = .23;// composition of O2 in air

mCO2 = 44;// moleculer mass of carbon
mH2O = 18;// molecular mass of hydrogen
mO2 = 32;// moleculer mas of oxygen
mN2 = 28;// moleculer mass of nitrogen

// solution
mtO2 = 8/3*C+8*H2-O2;// theoretical O2 required/kg coal, [kg]
msa= mtO2/aO2;// stoichiometric mass of  air supplied/kg coal, [kg]
mas = msa*(1+ea);// actual mass of air supplied/kg coal, [kg]

m1 = 11/3*C;// mass of CO2/kg coal produced, [kg]
m2 = 9*H2;// mass of H2/kg coal produced, [kg]
m3 = mtO2*ea;// mass of O2/kg coal produced, [kg]
m4 = mas*(1-aO2);// mass of N2/kg coal produced, [kg]

mt = m1+m2+m3+m4;// total mass, [kg]
x1 = m1/mt*100;// %age mass composition of CO2 produced
```

```
x2 = m2/mt*100;// %age mass composition of H2O produced
x3 = m3/mt*100;// %age mass composition of O2 produced
x4 = m4/mt*100;// %age mass composition of N2 produced

vt = x1/mCO2+x2/mH2O+x3/mO2+x4/mN2;// total volume
v1 = x1/mCO2/vt*100;// %age volume composition of CO2
v2 = x2/mH2O/vt*100;// %age volume composition of H2O
v3 = x3/mO2/vt*100;// %age volume composition of O2
v4 = x4/mN2/vt*100;// %age volume composition of N2

Mav = (v1*mCO2+v2*mH2O+v3*mO2+v4*mN2)/(v1+v2+v3+v4);// average moleculer mass, [kg/kmol]
// since no of moles is constant so PV/T=constant
V2 = P1*V1*T2/(P2*T1);//volume, [m^3]

mp = mt*mc/3600;// mass of product of combustion/s, [kg]

V = V2*mp/Mav;// volume of flowing gas /s,[m^3]

v = V/A;// velocity of flue gas, [m/s]
mprintf('\n The actual mass of air supplied is = %f kg/kg coal\n',mas);
mprintf('\n The velocity of flue gas is = %f m/s\n',v);

// End
```

Scilab code Exa 8.19 temperature and density

```
clear;
clc;
disp('Example 8.19');

// aim : To determine
// (a) the temperature of the gas after compression
// (b) the density of the air-gas mixture

// given values
CO = 26;// %age volume composition of CO
H2 = 16;// %age volume composition of H2
CH4 = 7;// %age volume composition of CH4
N2 = 51;// %age volume composition of N2

P1 = 103;// gas pressure, [kN/m^2]
T1 = 273+21;// gas temperature, [K]
rv = 7;// volume ratio

aO2 = 21;// %age volume composition of O2 in the air
c = 21;// specific heat capacity of diatomic gas, [kJ/kg K]
cCH4 = 36;// specific heat capacity of CH4, [kJ/kg K]
R = 8.3143;// gas constant, [kJ/kg K]

mCO = 28;// moleculer mass of carbon
mH2 = 2;// molecular mass of hydrogen
mCH4 = 16;// moleculer mas of methane
mN2 = 28;// moleculer mass of nitrogen
mO2 = 32;// moleculer mass of oxygen

// solution
// (a)
Cav = (CO*c+H2*c+CH4*cCH4+N2*c+100*2*c)/(100+200);// heat capacity, [kJ/kg K]

Gama = (Cav+R)/Cav;// heat capacity ratio
// rv = V1/V2
```

```
// process is polytropic , so
T2 = T1*(rv)^(Gama-1);// final tempearture , [K]
mprintf('\n (a) The temperature of the gas after compression is = %f C\n',T2-273);

// (b)

Mav = (CO*mCO+H2*mH2+CH4*mCH4+N2*mN2+42*mO2+158*mN2)/(100+200)

// for 1 kmol of gas
V = R*T1/P1;// volume of one kmol of gas , [m^3]
// hence
rho = Mav/V;// density of gas , [kg/m^3]

mprintf('\n (b) The density of air-gas mixture is = %f kg/m^3\n',rho);

// End
```

Scilab code Exa 8.20 stoichiometric equation

```
clear;
clc;
disp('Example 8.20');

// aim : to determine
// stoichiometric equation for combustion of hydrogen

// solution
// equation with algebric coefficient is
// H2+aO2+79/21*aN2=bH2O+79/21*aN2
// by equating coefficients
b = 1;
```

```
a = b/2;
// so equation becomes
// 2 H2+ O2+3.76 N2=2 H2O+3.76 N2
disp('The required stoichiometric equation is  =  ')
    ;
disp('2 H2+ O2+3.76 N2 = 2 H2O+3.76 N2');

// End
```

Scilab code Exa 8.22 gravimetric composition

```
clear;
clc;
disp('Example 8.22');

// aim : To determine
// the percentage gravimetric analysis of the total
    products of combustion

// given values
CO = 12;//  %age volume composition of CO
H2 = 41;//  %age volume composition of H2
CH4 = 27;//  %age volume composition of CH4
O2 = 2;//  %age volume composition of O2
CO2 = 3;//  %age volume composition of CO2
N2 = 15;//  %age volume composition of N2

mCO2 = 44;// moleculer mass of CO2,[kg/kmol]
mH2O = 18;// moleculer mass of H2O, [kg/kmol]
mO2 = 32;// moleculer mass of O2, [kg/kmol]
mN2 = 28;// moleculer mass of N2, [kg/kmol]

ea = 15;// %age excess air required
aO2 = 21;// %age air composition in the air

```

```
// solution
// combustion equation by no. of moles
// 12CO + 41H2 + 27CH4 + 2O2 + 3CO2 + 15N2 + aO2 +79/21*aN2 = bCO2 + dH2O + eO2 + 15N2 +79/21*aN2
// equating C coefficient
b = 12+27+3;// [mol]
// equatimg H2 coefficient
d = 41+2*27;// [mol]
// O2 required is 15 % extra,so
// e/(e-a)=.15 so e=.13a
// equating O2 coefficient
// 2+3+a=b+d/2 +e

a = (b+d/2-5)/(1-.13);
e = .13*a;// [mol]

// gravimetric analysis of product
v1 =  b*mCO2;// gravimetric volume of CO2
v2 =  d*mH2O ;// gravimetric volume of H2O
v3 = e*mO2;// gravimetric volume of O2
v4 = 15*mN2 +79/21*a*mN2;// gravimetric volume of N2

vt = v1+v2+v3+v4;// total
x1 = v1/vt*100;// percentage gravimetric of CO2
x2 = v2/vt*100;// percentage gravimetric of H2O
x3 = v3/vt*100;// percentage gravimetric of O2
x4 = v4/vt*100;// percentage gravimetric of N2

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);

//  End
```

Scilab code Exa 8.23 mass and volumetric efficiency

```
clear;
clc;
disp('Example 8.23');

//  aim : To determine
// (a) the actual quantity of air supplied/kg of
    fuel
// (b) the volumetric efficiency of the engine

// given values
d = 300*10^-3;// bore ,[m]
L = 460*10^-3;// stroke ,[m]
N = 200;// engine speed , [rev/min]

C = 87;//  %age mass composition of Carbon in the
    fuel
H2 = 13;//  %age mass composition of H2 in the fuel

mc = 6.75;// fuel consumption , [kg/h]

CO2 = 7;// %age composition of CO2 by volume
O2 = 10.5;// %age composition of O2 by volume
N2 = 7;// %age composition of N2 by volume

mC = 12;// moleculer mass of CO2,[kg/kmol]
mH2 = 2;// moleculer mass of H2, [kg/kmol]
mO2 = 32;// moleculer mass of O2, [kg/kmol]
mN2 = 28;// moleculer mass of N2, [kg/kmol]

T = 273+17;// atmospheric temperature , [K]
P = 100;// atmospheric pressure , [kn/m^2]
R =.287;// gas constant , [kJ/kg k]
```

```
// solution
// (a)
// combustion equation by no. of moles
// 87/12 C + 13/2 H2 + a O2+79/21*a N2 = b CO2 + d
   H2O + eO2 + f N2
// equating coefficient
b = 87/12;// [mol]
a = 22.7;// [mol]
e = 10.875;// [mol]
f = 11.8*b;// [mol]
// so fuel side combustion equation is
// 87/12 C + 13/2 H2 +22.7 O2 +85.5 N2
mair = ( 22.7*mO2 +85.5*mN2)/100;// mass of air/kg
   fuel, [kg]
mprintf('\n (a) The mass of actual air supplied per
   kg of fuel is = %f kg\n',mair);

// (b)
m = mair*mc/60;// mass of air/min, [kg]
V = m*R*T/P;// volumetric flow of air/min, [m^3]
SV = %pi/4*d^2*L*N/2;// swept volume/min, [m^3]

VE = V/SV;// volumetric efficiency
mprintf('\n (b) The volumetric efficiency of the
   engine is = %fpercent\n',VE*100);

// End
```

Scilab code Exa 8.24 mass of air

```
clear;
clc;
disp('Example 8.24');

```

```
// aim : To determine
//  the mass of air supplied/kg of fuel burnt

// given values
// gas composition in the fuel
C = 84;//  %age mass composition of Carbon in the fuel
H2 = 14;//  %age mass composition of H2 in the fuel
O2f = 2;// %age mass composition of O2 in the fuel

// exhaust gas composition
CO2 = 8.85;// %age composition of CO2 by volume
CO = 1.2// %age composition of CO by volume
O2 = 6.8;// %age composition of O2 by volume
N2 = 83.15;// %age composition of N2 by volume

mC = 12;// moleculer mass of CO2,[kg/kmol]
mH2 = 2;// moleculer mass of H2, [kg/kmol]
mO2 = 32;// moleculer mass of O2, [kg/kmol]
mN2 = 28;// moleculer mass of N2, [kg/kmol]

// solution
// combustion equation by no. of moles
// 84/12 C + 14/2 H2 +2/32 O2 + a O2+79.3/20.7*a N2 = b CO2 + d CO2+  eO2 + f N2 +g H2
// equating  coefficient and given condition
b = 6.16;// [mol]
a = 15.14;// [mol]
d = .836;// [mol]
f = 69.3*d;// [mol]
// so fuel side combustion equation is
// 84/12 C + 14/2 H2 +2/32 O2 +  15.14 O2 +85.5 N2
mair = ( a*mO2 +f*mN2)/100;// mass of air/kg fuel, [kg]
mprintf('\n The mass of air supplied per kg of fuel is  =  %f  kg\n',mair);

//  End
```

Chapter 9

Heat transfer

Scilab code Exa 9.1 interface temperature

```
clear;
clc;
disp('Example 9.1');

//  aim : To determine
//  the heat loss per hour through the wall and interface temperature

//  Given values
x1 = .25;// thickness of brick,[m]
x2 = .05;// thickness of concrete,[m]
t1 = 30;// brick face temperature,[C]
t3 = 5;// concrete face temperature,[C]
l = 10;// length of the wall, [m]
h = 5;// height of the wall, [m]
k1 = .69;// thermal conductivity of brick,[W/m/K]
k2 = .93;// thermal conductivity of concrete,[W/m/K]

//  solution
A = l*h;// area of heat transfer,[m^2]
Q_dot = A*(t1-t3)/(x1/k1+x2/k2);// heat transferred,
```

```
[J/s]

//  so heat loss per hour is
Q = Q_dot*3600*10^-3;// [kJ]
mprintf('\n The heat lost per hour is  =  %f  kJ\n',Q);

//  interface temperature calculation
//   for  the brick wall, Q_dot=k1*A*(t1-t2)/x1;
//  hence
t2 = t1-Q_dot*x1/k1/A;// [C]
mprintf('\n The interface temperature is  =  %f C\n',t2);

//  End
```

Scilab code Exa 9.2 thickness of lagging

```
clear;
clc;
disp('Example 9.2');

//  aim : To determine
//  the minimum
//  thickness of the lagging required

//  Given values
r1 = 75/2;// external radious of the pipe,[mm]
L = 80;// length of the pipe,[m]
m_dot = 1000;// flow of steam, [kg/h]
P = 2;// pressure, [MN/m^2]
x1 = .98;// inlet dryness fraction
x2 = .96;// outlet dryness fraction
k = .08;// thermal conductivity of of pipe, [W/m/K]
t2 = 27;// outside temperature,[C]
```

```

//  solution
//  using steam table  at 2 MN/m^2 the enthalpy of evaporation of steam is ,
hfg = 1888.6;// [kJ/kg]
//  so heat loss through the pipe is
Q_dot = m_dot*(x1-x2)*hfg/3600;// [kJ]

// also from steam table saturation temperature of steam at 2 MN/m^2 is ,
t1 = 212.4;// [C]
// and for thick pipe , Q_dot=k*2*%pi*L*(t1-t2)/log(r2/r1)
// hence
r2 = r1*exp(k*2*%pi*L*(t1-t2)*10^-3/Q_dot);// [mm]

t = r2-r1;// thickness , [mm]

mprintf('\n The minimum thickness of the lagging required is  =  %f  mm\n',t);

//  End
```

Scilab code Exa 9.3 heat lost and interface temperature

```
clear;
clc;
disp('Example 9.3');

//  aim : To determine the
//  (a) heat loss per hour
//   (b) interface temperature og lagging

// Given values
r1 = 50; // radious of steam main,[mm]
```

```
r2 = 90;// radious with first lagging ,[mm]
r3 = 115;// outside radious os steam main with
    lagging ,[mm]
k1 = .07;// thermal conductivity of 1st lagging ,[W/m
    /K]
k2 = .1;// thermal conductivity of 2nd lagging , [W/m
    /K]
P = 1.7;// steam pressure ,[MN/m^2]
t_superheat = 30;// superheat of steam , [K]
t3 = 24;// outside temperature of the lagging ,[C]
L = 20;// length of the steam main ,[m]

//  solution
//  (a)
//  using steam table saturation temperature of
    steam at 1.7 MN/m^2 is
t_sat = 204.3;// [C]
// hence
t1 = t_sat+t_superheat;// temperature of steam ,[C]

Q_dot = 2*%pi*L*(t1-t3)/(log(r2/r1)/k1+log(r3/r2)/k2
    );// heat loss ,[W]
//  heat loss in hour is
Q = Q_dot*3600*10^-3;// [kJ]

mprintf('\n (a) The heat lost per hour is  =  %f kJ\
    n',Q);

// (b)
//  using Q_dot=2*%pi*k1*(t1-t1)/log(r2/r1)
t2 = t1-Q_dot*log(r2/r1)/(2*%pi*k1*L);// interface
    temperature of lagging ,[C]

mprintf('\n (b) The interface temperature of the
    lagging is  =  %f C\n',t2);

//  There is some calculation mistake in the book so
     answer is not matching
```

```
// End
```

Scilab code Exa 9.4 energy emitted

```
clear;
clc;
disp('Example 9.4');

// aim : To determine
// the energy emetted from the surface

// Given values
h = 3;// height of surface, [m]
b = 4;// width of surface, [m]
epsilon_s = .9;// emissivity of the surface
T = 273+600;// surface temperature ,[K]
sigma = 5.67*10^-8;// [W/m^2/K^4]

// solution
As = h*b;// area of the surface, [m^2]

Q_dot = epsilon_s*sigma*As*T^4*10^-3;// energy
    emitted, [kW]

mprintf('\n The energy emitted from the surface is
    = %f kW\n',Q_dot);

// End
```

Scilab code Exa 9.5 Rate of heat transfer

```
clear;
```

```
clc;
disp('Example 9.5');

// aim : To determine
// the rate of energy transfer between furnace and the sphere and its direction

// Given values
l = 1.25;// internal side of cubical furnace, [m]
ti = 800+273;// internal surface temperature of the furnace,[K]
r = .2;// sphere radious, [m]
epsilon = .6;// emissivity of sphere
ts = 300+273;// surface temperature of sphere, [K]
sigma = 5.67*10^-8;// [W/m^2/K^4]

// Solution
Af = 6*l^2;// internal surface area of furnace, [m^2]
As =4 *%pi*r^2;// surface area of sphere, [m^2]

// considering internal furnace to be black
Qf = sigma*Af*ti^4*10^-3;// [kW]

// radiation emitted by sphere is
Qs = epsilon*sigma*As*ts^4*10^-3; // [kW]

// Hence transfer of energy is
Q = Qf-Qs;// [kW]

mprintf('\n The transfer of energy will be from furnace to sphere and transfer rate is = %f kW\n',Q);

// There is some calculation mistake in the book so answer is not matching

// End
```

Scilab code Exa 9.6 overall heat transfer coefficient and heat lost

```
clear;
clc;
disp('Example 9.6');

//  aim : To determine
//  the overall transfer coefficient and the heat
    loss per hour

//  Given values
x1 = 25*10^-3;// Thickness of insulating board, [m]
x2 = 75*10^-3;// Thickness of fibreglass, [m]
x3 = 110*10^-3;// Thickness of brickwork, [m]
k1 = .06;// Thermal conductivity of insulating board
    , [W/m K]
k2 = .04;// Thermal conductivity of fibreglass, [W/m
    K]
k3 = .6;// Thermal conductivity of brickwork, [W/m K
    ]
Us1 = 2.5;//  surface heat transfer coefficient of
    the inside wall,[W/m^2 K]
Us2 = 3.1;//  surface heat transfer coefficient of
    the outside wall,[W/m^2 K]
ta1 = 27;// internal ambient temperature, [C]
ta2 = 10;// external ambient temperature, [C]
h = 6;// height of the wall, [m]
l = 10;// length of the wall, [m]

//  solution
U = 1/(1/Us1+x1/k1+x2/k2+x3/k3+1/Us2);// overall
    heta transfer coefficient,[W/m^2 K]

A = l*h;// area ,[m^2]
```

```
Q_dot = U*A*(ta1-ta2);// heat loss [W]

// so heat loss per hour is
Q = Q_dot*3600*10^-3;// [kJ]
mprintf('\n The overall heat transfer coefficient for the wall is = %f W/m^2 K\n',U);
mprintf('\n The heat loss per hour through the wall is = %f kJ\n',Q);

// End
```

Scilab code Exa 9.7 heat lost and surafce temperature of lagging

```
clear;
clc;
disp('Example 9.7');

// aim : To determine
// the heat loss per hour and the surface temperature of the lagging

// Given values
r1 = 75*10^-3;// External radiou of the pipe, [m]
t_l1 = 40*10^-3;// Thickness of lagging1, [m]
t_l2 = t_l1;
k1 = .07;// thermal conductivity of lagging1, [W/m K]
k2 = .1;// thermal conductivity of lagging2, [W/m K]
Us = 7;// surface transfer coefficient for outer surface, [W/m^2 K]
L = 50;// length of the pipe, [m]
ta = 27;// ambient temperature, [C]
P = 3.6;// wet steam pressure, [MN/m^2]

```

```
//  solution
//  from steam table saturation temperature of the steam at given pressure is,
t1 =  244.2;// [C]
r2 = r1+t_l1;// radious of pipe with lagging1,[m]
r3 = r2+t_l2;// radious of pipe with both the lagging, [m]

R1 = log(r2/r1)/(2*%pi*L*k1);// resistance due to lagging1,[C/W]
R2 = log(r3/r2)/(2*%pi*L*k2);// resistance due to lagging2,[C/W]
R3 = 1/(Us*2*%pi*r3*L);// ambient resistance, [C/W]

//  hence overall resistance is,
Req = R1+R2+R3;// [C/W]
tdf = t1-ta;// temperature driving force, [C]
Q_dot = tdf/Req;// rate of heat loss, [W]
//  so heat loss per hour is,
Q = Q_dot*3600*10^-3;// heat loss per hour, [kJ]

//  using eqn [3]
t3 = ta+Q_dot*R3;// surface temperature of the lagging, [C]

mprintf('\n The heat loss per hour is  =  %f  kJ\n',Q);
mprintf('\n The surface temperature of the lagging is  =  %f C\n',t3);

//  there is minor variation in the answer

//  End
```

Chapter 10

Steam plant

Scilab code Exa 10.1 equivalent evaporation

```
clear;
clc;
disp('Example 10.1');

// aim : To determine
// the equivalent evaporation

// Given
P = 1.4;// [MN/m^2]
m = 8;// mass of water,[kg]
T1 = 39;// entering temperature,[C]
T2 = 100;// [C]
x = .95;//dryness fraction

// solution
hf = 830.1;// [kJ/kg]
hfg = 1957.7;// [kJ/kg]
// steam is wet so specific enthalpy of steam is
h = hf+x*hfg;// [kJ/kg]

// at 39 C
```

```
h1 = 163.4;//   [kJ/kg]
//   hence
q = h-h1;//   [kJ/kg]
Q = m*q;//   [kJ]

evap = Q/2256.9;//   equivalent evaporation[kg steam
    /(kg coal)]

mprintf('\n The equivalent evaporation, from and at
    100 C is  =  %f  kg steam/kg coal\n ',evap);

// End
```

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

```
clear;
clc;
disp('Example 10.2');

// aim : To determine
//  the mass of oil used per hour and the fraction
    of enthalpy drop through the turbine
//  heat transfer available per kilogram of exhaust
    steam

//  Given values
ms_dot = 5000;// generation of steam, [kg/h]
P1 = 1.8;// generated steam pressure, [MN/m^2]
T1 = 273+325;// generated steam temperature, [K]
Tf = 273+49.4;// feed temperature, [K]
neta = .8;// efficiency of boiler plant
c = 45500;// calorific value, [kJ/kg]
P = 500;// turbine generated power, [kW]
Pt = .18;// turbine exhaust pressure, [MN/m^2]
x = .98;// dryness farction of steam
```

```
// solution
// using steam table at 1.8 MN/m^2
hf1 = 3106;// [kJ/kg]
hg1 = 3080;// [kJ/kg]
// so
h1 = hf1-neta*(hf1-hg1);// [kJ/kg]
// again using steam table specific enthalpy of
   feed water is
hwf = 206.9;// [kJ/kg]
h_rais = ms_dot*(h1-hwf);// energy to raise steam, [
   kJ]

h_fue = h_rais/neta;// energy from fuel per hour, [
   kJ]
m_oil = h_fue/c;// mass of fuel per hour, [kg]

// from steam table at exhaust
hf = 490.7;// [kJ/kg]
hfg = 2210.8;// [kJ/kg]
// hence
h = hf+x*hfg;// [kJ/kg]
// now
h_drop = (h1-h)*ms_dot/3600;// specific enthalpy
   drop in turbine [kJ]
f = P/h_drop;// fraction ofenthalpy drop converted
   into work
// heat transfer available in exhaust is
Q = h-hwf;// [kJ/kg]
mprintf('\n The mass of oil used per hour is = %f
    kg\n',m_oil);
mprintf('\n The fraction of the enthalpy drop
   through the turbine that is converted into useful
    work is = %f\n',f);
mprintf('\n The heat transfer available in exhaust
   steam above 49.4 C is = %f kJ/kg\n',Q);

// End
```

Scilab code Exa 10.3 efficiency equivalent evaporation and coal consumption

```
clear;
clc;
disp('Example 10.3');

// aim : To determine
// (a) the thermal efficiency of the boiler
// (b) the equivalent evaporation of the boiler
// (c) the new coal consumption

// given values
ms_dot = 5400;// steam feed rate, [kg/h]
P = 750;// steam pressure, [kN/m^2]
x = .98;// steam dryness fraction
Tf1 = 41.5;// feed water temperature, [C]
CV = 31000;// calorific value of coal used in the boiler, [kJ/kg]
mc1 = 670;// rate of burning of coal/h, [kg]
Tf2 = 100;// increased water temperature, [C]

// solution
// (a)
SRC = ms_dot/mc1;// steam raised/kg coal, [kg]
hf = 709.3;// [kJ/kg]
hfg = 2055.5;// [kJ/kg]
h1 = hf+x*hfg;// specific enthalpy of steam raised, [kJ/kg]
// from steam table
hfw = 173.9;// specific enthalpy of feed water, [kJ/kg]
EOB = SRC*(h1-hfw)/CV;// efficiency of boiler
mprintf('\n (a) The thermal efficiency of the boiler
```

```
    is = %f percent\n',EOB*100);

// (b)
he = 2256.9;// specific enthalpy of evaporation, [kJ
    /kg]
Ee = SRC*(h1-hfw)/he;// equivalent evaporation[kg/kg
    coal]
mprintf('\n (b) The equivalent evaporation of boiler
    is = %f kg/kg coal\n',Ee);

// (c)
hw = 419.1;// specific enthalpy of feed water at 100
    C, [kJ/kg]
Eos = ms_dot*(h1-hw);// energy of steam under new
    condition, [kJ/h]
neb = EOB+.05;// given condition new efficiency of
    boiler if 5%more than previous
Ec = Eos/neb;// energy from coal, [kJ/h]
mc2 = Ec/CV;// mass of coal used per hour in new
    condition, [kg]
mprintf('\n (c) Mass of coal used in new condition
    is = %f kg\n',mc2);
mprintf('\n      The saving in coal per hour is =
    %f kg\n',mc1-mc2);

// End
```

Scilab code Exa 10.4 heat transfer and volume

```
clear;
clc;
disp('Example 10.4');

// aim : To determine the
// (a) Heat transfer in the boiler
```

```
//    (b) Heat transfer in the superheater
//   (c) Gas used

//   given values
P = 100;// boiler operating pressure, [bar]
Tf = 256;// feed water temperature, [C]
x = .9;// steam dryness fraction.
Th = 450;// superheater exit temperature, [C]
m = 1200;// steam generation/h, [tonne]
TE = .92;// thermal efficiency
CV = 38;// calorific value of fuel, [MJ/m^3]

// solution
// (a)
// from steam table
hw = 1115.4;// specific enthalpy of feed water, [kJ/kg]
// for wet steam
hf = 1408;// specific enthalpy, [kJ/kg]
hg = 2727.7;// specific enthalpy, [kJ/kg]
//   so
h = hf+x*(hg-hf);// total specific enthalpy of wet steam, [kJ/kg]
//   hence
Qb = m*(h-hw);// heat transfer/h for wet steam, [MJ]
mprintf('\n (a) The heat transfer/h in producing wet steam in the boiler is = %f MJ\n',Qb);

// (b)
// again from steam table
// specific enthalpy of superheated stem at given condition is,
hs = 3244;// [kJ/kg]

Qs = m*(hs-h);// heat transfer/h in superheater, [MJ]
mprintf('\n (b) The heat transfer/h in superheater is = %f MJ\n',Qs);
```

```
// (c)
V = (Qb+Qs)/(TE*CV);// volume of gs used/h, [m^3]
mprintf('\n (c) The volume of gas used/h is  =  %f m
   ^3\n',V);

//  There is calculation mistake in the book so our
   answer is not matching

//  End
```

Scilab code Exa 10.5 flow rate

```
clear;
clc;
disp('Example 10.5');

//aim : To determine
// the flow rate of cooling water

//Given values
P=24;//pressure, [kN/m^2]
ms_dot=1.8;//steam condense rate,[tonne/h]
x=.98;//dryness fraction
T1=21;//entrance temperature of cooling water,[C]
T2=57;//outlet temperature of cooling water,[C]

//solution
//at 24 kN/m^2, for steam
hfg=2616.8;//[kJ/kg]
hf1=268.2;//[kJ/kg]
//hence
h1=hf1+x*(hfg-hf1);//[kJ/kg]

//for cooling water
```

```
hf3=238.6;//[kJ/kg]
hf2=88.1;//[kJ/kg]

//using equation [3]
//ms_dot*(hf3-hf2)=mw_dot*(h1-hf1),so
mw_dot=ms_dot*(h1-hf1)/(hf3-hf2);//[tonne/h]
disp('tonne/h',mw_dot,'The flow rate of the cooling
    water is =')

//End
```

Scilab code Exa 10.6 energy supplied dryness fraction and Rankine efficiency

```
clear;
clc;
disp('Example 10.6');

//  aim : To determine
//  (a) the energy supplied in the boiler
//  (b) the dryness fraction of the steam entering
    the condenser
//  (c) the rankine efficiency

//  given values
P1 = 3.5;// steam entering pressure, [MN/m^2]
T1 = 273+350;// entering temperature, [K]
P2 = 10;//steam exhaust pressure, [kN/m^2]

// solution
//  (a)
//  from steam table, at P1 is,
hf1 = 3139;// [kJ/kg]
hg1 = 3095;// [kJ/kg]
h1 = hf1-1.5/2*(hf1-hg1);
```

```
// at Point 3
h3 = 191.8;// [kJ/kg]
Es = h1-h3;// energy supplied , [kJ/kg]
mprintf('\n (a) The energy supplied in boiler/kg
   steam is  =  %f kJ/kg\n',Es);

// (b)
// at P1
sf1 = 6.960;// [kJ/kg K]
sg1 = 6.587;// [kJ/kg K]
s1 = sf1-1.5/2*(sf1-sg1);// [kJ/kg K]
// at P2
sf2 = .649;// [kJ/kg K]
 sg2 = 8.151;// [kJ/kg K]
 // s2=sf2+x2(sg2-sf2)
 // theoretically expansion through turbine is
    isentropic so s1=s2
 // hence
 s2 = s1;
 x2 = (s2-sf2)/(sg2-sf2);// dryness fraction
 mprintf('\n (b) The dryness fraction of steam
    entering the condenser is =  %f \n',x2);

 // (c)
 // at point 2
 hf2 = 191.8;// [kJ/kg]
 hfg2 = 2392.9;// [kJ/kg]
 h2 = hf2+x2*hfg2;// [kJ/kg]
 Re = (h1-h2)/(h1-h3);// rankine efficiency
 mprintf('\n (c) The Rankine efficiency is  =  %f
    percent\n',Re*100);

 //  End
```

Scilab code Exa 10.7 Rankine efficiency and specific work done

```
clear;
clc;
disp('Example 10.7');

// aim : To determine
//  the specific work done and compare this with
   that obtained when determining the rankine
   effficiency

// given values
P1 = 1000;// steam entering pressure, [kN/m^2]
x1 = .97;// steam entering dryness fraction
P2 = 15;//steam exhaust pressure, [kN/m^2]
n = 1.135;// polytropic index

// solution
// (a)
// from steam table, at P1 is
hf1 = 762.6;// [kJ/kg]
hfg1 = 2013.6;// [kJ/kg]
h1 = hf1+hfg1; // [kJ/kg]

sf1 = 2.138;// [kJ/kg K]
sg1 = 6.583;// [kJ/kg K]
s1 = sf1+x1*(sg1-sf1);// [kJ/kg K]

// at P2
sf2 = .755;// [kJ/kg K]
 sg2 = 8.009;// [kJ/kg K]
// s2 = sf2+x2(sg2-sf2)
// since expansion through turbine is isentropic so
   s1=s2
 // hence
 s2 = s1;
 x2 = (s2-sf2)/(sg2-sf2);// dryness fraction

  // at point 2
 hf2 = 226.0;// [kJ/kg]
```

```
hfg2 = 2373.2;// [kJ/kg]
h2 = hf2+x2*hfg2;// [kJ/kg]

// at Point 3
h3 = 226.0;// [kJ/kg]

// (a)
Re = (h1-h2)/(h1-h3);// rankine efficiency
mprintf('\n (a) The Rankine efficiency is = %f
    percent\n',Re*100);

// (b)
vg1 = .1943;// specific volume at P1, [m^3/kg]
vg2 = 10.02;// specific volume at P2, [m^3/kg]
V1 = x1*vg1;// [m^3/kg]
V2 = x2*vg2;// [m^3/kg]

W1 = n/(n-1)*(P1*V1-P2*V2);// specific work done, [
    kJ/kg]

// from rankine cycle
W2 = h1-h2;// [kJ/kg]
mprintf('\n (b) The specific work done is = %f kJ/
    kg\n',W1);
mprintf('\n     The specific work done (from rankine
    ) is = %f kJ/kg\n',W2);

// there is calculation mistake in the book so our
    answer is not matching

// End
```

Scilab code Exa 10.8 Rankine efficiency steam consumption and Carnot efficiency

```
clear;
clc;
disp('Example 10.8');

//  aim : To determine
//  (a) the rankine fficiency
//  (b) the specific steam consumption
//  (c) the carnot efficiency of the cycle

// given values
P1 = 1100;// steam entering pressure, [kN/m^2]
T1 = 273+250;// steam entering temperature, [K]
P2 = 280;// pressure at point 2, [kN/m^2]
P3 = 35;// pressure at point 3, [kN/m^2]

// solution
// (a)
// from steam table, at P1  and T1 is
hf1 = 2943;// [kJ/kg]
hg1 = 2902;// [kJ/kg]
h1 = hf1-.1*(hf1-hg1); // [kJ/kg]

sf1 = 6.926;// [kJ/kg K]
sg1 = 6.545;// [kJ/kg K]
s1 = sf1-.1*(sf1-sg1);// [kJ/kg K]

// at P2
sf2 = 1.647;// [kJ/kg K]
 sg2 = 7.014;// [kJ/kg K]
// s2=sf2+x2(sg2-sf2)
// since expansion through turbine is isentropic so
   s1=s2
 // hence
 s2  = s1;
 x2 = (s2-sf2)/(sg2-sf2);// dryness fraction

 // at point 2
 hf2 = 551.4;// [kJ/kg]
```

```
hfg2 = 2170.1;// [kJ/kg]
h2 = hf2+x2*hfg2;// [kJ/kg]
vg2 = .646;// [m^3/kg]
v2 = x2*vg2;// [m^3/kg]

// by Fig10.20.
A6125 = h1-h2;// area of 6125, [kJ/kg]
A5234 = v2*(P2-P3);// area 5234, [kJ/kg]
W = A6125+A5234;// work done
hf = 304.3;// specific enthalpy of water at
    condenser pressuer, [kJ/kg]
ER = h1-hf;// energy received, [kJ/kg]
Re = W/ER;// rankine efficiency
mprintf('\n (a) The rankine efficiency is = %f
    percent\n',Re*100);

// (b)
kWh = 3600;// [kJ]
SSC = kWh/W;// specific steam consumption, [kJ/kWh]
mprintf('\n (b) The specific steam consumption is =
     %f kJ/kWh\n',SSC);

// (c)
// from steam table
T3 = 273+72.7;// temperature at point 3
CE = (T1-T3)/T1;// carnot efficiency
mprintf('\n (c) The carnot efficiency of the cycle
   is = %f percent\n',CE*100);

// End
```

Scilab code Exa 10.9 power and thermal efficiency

```
clear;
clc;
```

```
disp('Example 10.9');

// aim : To determine
// (a) the theoretical power of steam passing through the turbine
// (b) the thermal efficiency of the cycle
// (c) the thermal efficiency of the cycle assuming there is no reheat

// given values
P1 = 6;// initial pressure, [MN/m^2]
T1 = 450;// initial temperature, [C]
P2 = 1;// pressure at stage 1, [MN/m^2]
P3 = 1;// pressure at stage 2, [MN/m^2]
T3 = 370;// temperature, [C]
P4 = .02;// pressure at stage 3, [MN/m^2]
P5 = .02;// pressure at stage 4, [MN/m^2]
T5 = 320;// temperature, [C]
P6 = .02;// pressure at stage 5, [MN/m^2]
P7 = .02;// final pressure , [MN/m^2]

// solution
// (a)
// using Fig 10.21
h1 = 3305;// specific enthalpy, [kJ/kg]
h2 = 2850;// specific enthalpy, [kJ/kg]
h3 = 3202;// specific enthalpy, [kJ/kg]
h4 = 2810;// specific enthalpy, [kJ/kg]
h5 = 3115;// specific enthalpy, [kJ/kg]
h6 = 2630;// specific enthalpy, [kJ/kg]
h7 = 2215;// specific enthalpy, [kJ/kg]
W = (h1-h2)+(h3-h4)+(h5-h6);// specific work through the turbine, [kJ/kg]
mprintf('\n (a) The theoretical power/kg steam/s is = %f kW\n',W);

// (b)
// from steam table
```

```
hf6 = 251.5;// [kJ/kg]

TE1 = ((h1-h2)+(h3-h4)+(h5-h6))/((h1-hf6)+(h3-h2)+(h5-h4));// thermal efficiency
mprintf('\n (b) The thermal efficiency of the cycle is = %f percent\n',TE1*100);

// (c)
// if there is no heat
hf7 = hf6;
TE2 = (h1-h7)/(h1-hf7);// thermal efficiency
mprintf('\n (c) The thermal efficiency of the cycle if there is no heat is = %f percent\n',TE2*100);

// End
```

Scilab code Exa 10.10 mass and thermal efficiency

```
clear;
clc;
disp('Example 10.10');

// aim : To determine
// (a) the mass of steam bled to each feed heater in kg/kg of supply steam
// (b) the thermal efficiency of the arrangement

// given values
P1 = 7;// steam initial pressure, [MN/m^2]
T1 = 273+500;// steam initil temperature, [K]
P2 = 2;// pressure at stage 1, [MN/m^2]
P3 = .5;// pressure at stage 2, [MN/m^2]
P4 = .05;// condenser pressure,[MN/m^2]
SE = .82;// stage efficiency of turbine
```

```
// solution
// from the enthalpy-entropy chart(Fig10.23) values of specific enthalpies are
h1 = 3410;// [kJ/kg]
h2_prim = 3045;// [kJ/kg]
// h1-h2=SE*(h1-h2_prim), so
h2 = h1-SE*(h1-h2_prim);// [kJ/kg]

h3_prim = 2790;// [kJ/kg]
// h2-h3=SE*(h2-h3_prim), so
h3 = h2-SE*(h2-h3_prim);// [kJ/kg]

h4_prim = 2450;// [kJ/kg]
// h3-h4 = SE*(h3-h4_prim), so
h4 = h3-SE*(h3-h4_prim);// [kJ/kg]

// from steam table
// @ 2 MN/m^2
hf2 = 908.6;// [kJ/kg]
// @ .5 MN/m^2
hf3 = 640.1;// [kJ/kg]
// @ .05 MN/m^2
hf4 = 340.6;// [kJ/kg]

// (a)
// for feed heater1
m1 = (hf2-hf3)/(h2-hf3);// mass of bled steam, [kg/kg supplied steam]
// for feed heater2
m2 = (1-m1)*(hf3-hf4)/(h3-hf4);//
mprintf('\n (a) The mass of steam bled in feed heater 1 is = %f kg/kg supply steam\n',m1);
mprintf('\n      The mass of steam bled in feed heater 2 is = %f kg/kg supply steam\n',m2);

// (b)
W = (h1-h2)+(1-m1)*(h2-h3)+(1-m1-m2)*(h3-h4);//
```

```
theoretical work done, [kJ/kg]
Eb = h1-hf2;// energy input in the boiler, [kJ/kg]
TE1 = W/Eb;// thermal efficiency
mprintf('\n (b) The thermal efficiency of the arrangement is = %f percent\n',TE1*100);

// If there is no feed heating
hf5 = hf4;
h5_prim = 2370;// [kJ/kg]
// h1-h5 = SE*(h1-h5_prim), so
h5 = h1-SE*(h1-h5_prim);// [kJ/kg]
Ei = h1-hf5;//energy input, [kJ/kg]
W = h1-h5;// theoretical work, [kJ/kg]
TE2 = W/Ei;// thermal efficiency
mprintf('\n      The thermal efficiency if there is no feed heating is = %f percent\n',TE2*100);

// End
```

Chapter 11

The steam engine

Scilab code Exa 11.1 bore stroke and speed

```
clear;
clc;
disp('Example 11.1')

//  aim : To determine the
// (a) bore of the cylinder
// (b) piston stroke
// (c) speed of the engine

//  Given values
P_req = 60;// power required to develop, [kW]
P = 1.25;// boiler pressure, [MN/m^2]
Pb = .13;// back pressure, [MN/m^2]
cut_off = .3;// [stroke]
k = .82;// diagram factor
n = .78;// mechanical efficiency
LN = 3;// mean piston speed, [m/s]

// solution
// (a)
r = 1/cut_off;// expansion ratio
```

```
Pm = P/r*(1+log(r))-Pb;// mean effective pressure, [MN/m^2]
P_ind = P_req/n;// Actual indicated power developed, [kW]
P_the = P_ind/k;// Theoretical indicated power developed, [kW]

//  using indicated_power=Pm*LN*A
//  Hence
A = P_the/(Pm*LN)*10^-3;// piston area,[m^2]
d = sqrt(4*A/%pi)*10^3;// bore ,[mm]
mprintf('\n (a) The bore of the cylinder is  =  %f mm\n',d);

// (b)
// given that stroke is 1.25 times bore
L = 1.25*d;// [mm]
mprintf('\n (b) The piston stroke is  =  %f mm\n',L);

// (c)
// LN=mean piston speed, where L is stroke in meter and N is 2*rev/s,(since engine is double_acting)
//  hence
rev_per_sec = LN/(2*L*10^-3);// [rev/s]

rev_per_min = rev_per_sec*60;// [rev/min]
mprintf('\n (c) The speed of the engine is  =  %f rev/min\n',rev_per_min);

//  End
```

Scilab code Exa 11.2 diameter and stroke

```
clear;
```

```
clc;
disp('Example 11.2')

//  aim : To determine the
//  (a) the diameter of the cylinder
//  (b) piston stroke
//  (c) actual steam consumption and indicated thermal efficiency

//  Given values
P = 900;// inlet pressure, [kN/m^2]
Pb = 140;//  exhaust pressure, [kN/m^2]
cut_off =.4;// [stroke]
k = .8;// diagram factor
rs = 1.2;// stroke to bore ratio
N = 4;// engine speed, [rev/s]
ip = 22.5;// power output from the engine, [kW]

// solution
// (a)
r = 1/cut_off;// expansion ratio
Pm = P/r*(1+log(r))-Pb;// mean effective pressure, [kN/m^2]
Pm = Pm*k;// actual mean effective pressure, [kN/m^2]

// using ip=Pm*L*A*N
// and L=r*d; where L is stroke and d is bore
d = (ip/(Pm*rs*%pi/4*2*N))^(1/3);// diameter of the cylinder, [m]

mprintf('\n (a) The diameter of the cylinder is  =  %f  mm\n',d*1000);

// (b)
L = rs*d;// stroke, [m]
mprintf('\n (b) The piston stroke is  =  %f  mm\n',L*1000);
```

```

// (c)
SV = %pi/4*d^2*L;// stroke volume, [m^3]
V = SV*cut_off*2*240*60;// volume of steam consumed
    per hour, [m^3]
v = .2148;// specific volume at 900 kN/m^2, [m^3/kg]
SC = V/v;// steam consumed/h, [kg]
ASC = 1.5*SC;// actual steam consumption/h, [kg]
mprintf('\n (c) The actual steam consumption/h is  =
    %f kg\n',ASC);

m_dot = ASC/3600;// steam consumption,[kg/s]
// from steam table
hg = 2772.1;// specific enthalpy of inlet steam, [kJ
    /kg]
hfe = 458.4;// specific liquid enthalpy at exhaust
    pressure, [kJ/kg]

ITE = ip/(m_dot*(hg-hfe));// indicated thermal
    efficiency
mprintf('\n     The indicated thermal efficiency is
    = %f percent\n',ITE*100);

// End
```

Scilab code Exa 11.3 diagram factor and indicated thermal efficiency

```
clear;
clc;
disp('Example 11.3');

// aim : To determine
// (a) the diagram factor
// (b) the indicated thermal efficiency of the
    engine
```

```

// given values
d = 250*10^-3;// cylinder diameter, [m]
L = 375*10^-3;// length of stroke, [m]
P = 1000;// steam pressure , [kPa]
x = .96;// dryness fraction of steam
Pb = 55;// exhaust pressure, [kPa]
r = 6;// expansion ratio
ip = 45;// indicated power developed, [kW]
N = 3.5;// speed of engine, [rev/s]
m = 460;// steam consumption, [kg/h]

// solution
// (a)
Pm = P/r*(1+log(r))-Pb;// [kN/m^3]
A = %pi*(d)^2/4;// area, [m^2]
tip = Pm*L*A*N*2;// theoretical indicated power, [kW]
k = ip/tip;// diagram factor
mprintf('\n (a) The diagram factor is = %f\n',k);

// (b)
// from steam table at 1 MN/m^2
hf = 762.6;// [kJ/kg]
hfg = 2013.6;// [kJ/kg]
// so
h1 = hf+x*hfg;// specific enthalpy of steam at 1MN/m^2, [kJ/kg]
// minimum specific enthalpy in engine at 55 kPa
hf = 350.6;// [kJ/kg]
// maximum energy available in engine is
h = h1-hf;// [kJ/kg]
ITE = ip/(m*h/3600)*100;// indicated thermal efficiency
mprintf('\n (b) The indicated thermal efficiency is = %f percent\n ',ITE);

// End
```

Scilab code Exa 11.4 steam consumption

```
clear;
clc;
disp('Example 11.4');

// aim : To determine
// steam consumption

// given values
P1 = 11;// power, [kW]
m1 = 276;// steam use/h when developing power P1,[kW
    ]
ip = 8;// indicated power output, [kW]
B = 45;// steam used/h at no load, [kg]

// solution
// using graph of Fig.11.9
A = (m1-B)/P1;// slop of line, [kg/kWh]
W = A*ip+B;// output, [kg/h]
mprintf('\n The steam consumption is = %f kg/h\n
    ',W);

// End
```

Scilab code Exa 11.5 pressure power output and steam consumption

```
clear;
clc;
disp('Example 11.5');

```

```
//  aim : To determine
// (a) the intermediate pressure
// (b) the indicated power output
// (c) the steam consumption of the engine

// given values
P1 = 1400;// initial pressure, [kN/m^2]
x = .9;// dryness fraction
P5 = 35;// exhaust pressure
k = .8;// diagram factor of low-pressure cylindaer
L = 350*10^-3;// stroke of both the cylinder, [m]
dhp = 200*10^-3;// diameter of high pressure cylinder, [m]
dlp = 300*10^-3;// diameter of low-pressure cylinder, [m]
N = 300;// engine speed, [rev/min]

// solution
// taking reference Fig.11.13
Ahp = %pi/4*dhp^2;// area of high-pressure cylinder, [m^2]
Alp = %pi/4*dlp^2;// area of low-pressure cylinder, [m^2]
// for equal initial piston loads
// (P1-P7)Ahp=(P7-P5)Alp
deff('[x]=f(P7)','x=(P1-P7)*Ahp-(P7-P5)*Alp');
P7 = fsolve(0,f);// intermediate pressure, [kN/m^2]
mprintf('\n (a) The intermediate pressure is = %f kN/m^2\n ',P7);

// (b)
V6 = Ahp*L;// volume of high-pressure cylinder, [m^3]
P2 = P1;
P6 = P7;
// using P2*V2=P6*V6
V2 = P6*V6/P2; // [m^3]
V1 = Alp*L;// volume of low-pressure cylinder, [m^3]
```

```
R = V1/V2;// expansion ratio
Pm = P1/R*(1+log(R))-P5;// effective pressure of low
    -pressure cylinder, [kn/m^2]
Pm = k*Pm;// actual effective pressure, [kN/m^2]
ip = Pm*L*Alp*N*2/60;// indicated power, [kW]
mprintf('\n (b) The indicated power is  =  %f kW\n',
    ip);

// (c)
COV = V1/ R;// cut-off  volume in high-pressure
    cylinder, [m^3]
V = COV*N*2*60;// volume of steam admitted/h
// from steam table
vg = .1407;// [m^3/kg]
AV = x*vg;// specific volume of admission steam, [m
    ^3/kg]
m = V/AV;// steam consumption, [kg/h]
mprintf('\n (c) The steam consumption of the engine
    is  =  %f  kg/h\n',m);

//  End
```

Scilab code Exa 11.6 power output diameter and intermediate pressure

```
clear;
clc;
disp('Example 11.6');

// aim : To determine
// (a) the indicated power output
// (b) the diameter of high-pressure cylinder of the
     engine
// (c) the intermediate pressure

// given values
```

```
P = 1100;// initial pressure, [kN/m^2]
Pb = 28;// exhaust pressure
k = .82;// diagram factor of low-pressure cylindaer
L = 600*10^-3;// stroke of both the cylinder, [m]
dlp = 600*10^-3;// diameter of low-pressure cylinder, [m]
N = 4;// engine speed, [rev/s]
R = 8;// expansion ratio

// solution
// taking reference Fig.11.13
// (a)
Pm = P/R*(1+log(R))-Pb;// effective pressure of low-pressure cylinder, [kn/m^2]
Pm = k*Pm;// actual effective pressure, [kN/m^2]
Alp = %pi/4*dlp^2;// area of low-pressure cylinder, [m^2]
ip = Pm*L*Alp*N*2;// indicated power, [kW]
mprintf('\n (a) The indicated power is = %f kW\n',ip);

// (b)
// work done by both cylinder is same as area of diagram
w = Pm*Alp*L;// [kJ]
W = w/2;// work done/cylinder, [kJ]
V2 = Alp*L/8;// volume, [m63]
P2 = P;// [kN/m^2]
//  using area A1267=P2*V2*log(V6/V2)=W
V6 = V2*exp(W/(P2*V2));// intermediate volume, [m^3]
// using Ahp*L=%pi/4*dhp^2*L=V6
dhp = sqrt(V6*4/L/%pi);// diameter of high-pressure cylinder, [m]
mprintf('\n (b) The diameter of high-pressure cylinder is = %f  mm\n',dhp*1000);

// (c)
// using P2*V2=P6*V6
```

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

//  End
```

Scilab code Exa 11.7 speed and diameter

```
clear;
clc;
disp('Example 11.7');

// aim : To determine
// (a) The speed of the engine
// (b) the diameter of the high pressure cylinder

// given values
ip = 230;// indicated power, [kW]
P = 1400;// admission pressure, [kN/m^2]
Pb = 35;// exhaust pressure, [kN/m^2]
R = 12.5;// expansion ratio
d1 = 400*10^-3;// diameter of low pressure cylinder, [m]
L = 500*10^-3;// stroke of both the cylinder, [m]
k = .78;// diagram factor
rv = 2.5;// expansion ratio of high pressure cylinder

// solution
// (a)
Pm = P/R*(1+log(R))-Pb;// mean effective pressure in low pressure cylinder, [kN/m^2]
ipt = ip/k;// theoretical indicated power, [kw]
// using ip=Pm*L*A*N
A = %pi/4*d1^2;// area , [m^2]
```

```
N = ipt/(Pm*L*A*2);// speed, [rev/s]
mprintf('\n (a) The engine speed is = %f rev/s\n'
    ,N);

// (b)
V1 = A*L;// volume of low pressure cylinder, [m^3]
COV = V1/R;// cutt off volume of hp cylinder, [m^3]
V = COV*rv;// total volume, [m^3]

// V = %pi/4*d^2*L, so
d = sqrt(4*V/%pi/L);// diameter of high pressure
    cylinder, [m]
mprintf('\n (b) The diameter of the high pressure
    cylinder is = %f mm\n',d*1000);

// End
```

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

```
clear;
clc;
disp('Example 11.8');

// aim : To determine
// (a) the actual and hypothetical mean effective
    pressures referred to the low-pressure cylinder
// (b) the overall diagram factor
// (c) the indicated power

// given values
P = 1100;// steam supply pressure, [kN/m^2]
Pb = 32;// back pressure, [kN/m^2]
d1 = 300*10^-3;// cylinder1 diameter, [m]
d2 = 600*10^-3;// cylinder2 diameter, [m]
```

```
L = 400*10^-3;// common stroke of both cylinder, [m]

A1 = 12.5;//  average area of indicated diagram for HP, [cm^2]
A2 = 11.4;//  average area of indicated diagram for LP, [cm^2]

P1 = 270;// indicator calibration, [kN/m^2/ cm]
P2 = 80;// spring calibration, [kN/m^2/ cm]
N = 2.7;// engine speed, [rev/s]
l = .75;// length of both diagram, [m]

// solution
// (a)
// for HP cylinder
Pmh = P1*A1/7.5;// [kN/m^2]
F = Pmh*%pi/4*d1^2;// force on HP, [kN]
PmH = Pmh*(d1/d2)^2;// pressure referred to LP cylinder, [kN/m^2]
PmL = P2*A2/7.5;// pressure for LP cylinder, [kN/m^2]
PmA = PmH+PmL;// actual effective pressure referred to LP cylinder, [kN/m^2]

Ah = %pi/4*d1^2;// area of HP cylinder, [m^2]
Vh = Ah*L;// volume of HP cylinder, [m^3]
CVh = Vh/3;// cut-off volume of HP cylinder, [m^3]
Al = %pi/4*d2^2;// area of LP cylinder, [m^2]
Vl = Al*L;// volume of LP cylinder, [m^3]

R = Vl/CVh;// expansion ratio
Pm = P/R*(1+log(R))-Pb;// hypothetical mean effective pressure referred to LP cylinder, [kN/m^2]

mprintf('\n (a) The actual mean effective pressure referred to LP cylinder is  =  %f kN/m^2\n',PmA);
mprintf('\n      The hypothetical mean effective
```

```
pressure referred to LP cylinder is = %f kN/m
    ^2\n',Pm);

// (a)
ko = PmA/Pm;// overall diagram factor
mprintf('\n (b) The overall diagram factor is = %f
    \n',ko);

// (c)
ip = PmA*L*Al*N*2;// indicated power, [kW]
mprintf('\n (c) The indicated power is = %f kW\n',
    ip);

// End
```

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

```
clear;
clc;
disp('Example 11.9');

// aim : To determine
// (a) the actual and hypothetical mean effective
    pressures referred to the low-pressure cylinder
// (b) the overall diagram factor
// (c) the pecentage of the total indicated power
    developed in each cylinder

// given values
P = 1400;// steam supply pressure, [kN/m^2]
Pb = 20;// back pressure, [kN/m^2]
Chp = .6;// cut-off in HP cylinder, [stroke]
dh = 300*10^-3;// HP diameter, [m]
di = 500*10^-3;// IP diameter, [m]
```

```
dl = 900*10^-3;// LP diameter, [m]

Pm1 = 590;// actual pressure of HP cylinder, [kN/m^2]
Pm2 = 214;// actual pressure of IP cylinder, [kN/m^2]
Pm3 = 88;// actual pressure of LP cylinder, [kN/m^2]

// solution
// (a)
// for HP cylinder
PmH = Pm1*(dh/dl)^2;// PmH referred to LP cylinder, [kN/m^2]
// for IP cylinder
PmI = Pm2*(di/dl)^2;// PmI referred to LP cylinder, [kN/m^2]
PmA = PmH+PmI+Pm3;// actual mean effective pressure referred to LP cylinder, [kN/m^2]

R = dl^2/(dh^2*Chp);// expansion ratio
Pm = P/R*(1+log(R))-Pb;// hypothetical mean effective pressure referred to LP cylinder, [kN/m^2]

mprintf('\n (a) The actual mean effective pressure referred to LP cylinder is = %f kN/m^2\n',PmA);
mprintf('\n     The hypothetical mean effective pressure referred to LP cylinder is = %f kN/m^2\n',Pm);

// (b)
ko = PmA/Pm;// overall diagram factor
mprintf('\n (b) The overall diagram factor is = %f\n',ko);

// (c)
HP = PmH/PmA*100;// %age of indicated power
```

```
developed in HP
IP = PmI/PmA*100; // %age of indicated power developed in IP
LP = Pm3/PmA*100; // %age of indicated power developed in LP
mprintf('\n (c) The pecentage of the total indicated power developed in HP cylinder is  =  %f percent \n',HP);
mprintf('\n      The pecentage of the total indicated power developed in IP cylinder is  =  %f percent \n',IP);
mprintf('\n      The pecentage of the total indicated power developed in LP cylinder is  =  %f percent\n',LP);

//    End
```

Chapter 12

Nozzle

Scilab code Exa 12.1 area and Mach number

```
clear;
clc;
disp('Example 12.1');

//  aim : To determine the
//  (a) throat area
//   (b) exit area
//   (c) Mach number at exit

// Given values
P1 = 3.5;// inlet pressure of air , [MN/m^2]
T1 = 273+500;// inlet temperature of air , [MN/m^2]
P2 = .7;// exit pressure , [MN/m^2]
m_dot = 1.3;// flow rate of air , [kg/s]
Gamma = 1.4;// heat capacity ratio
R = .287;// [kJ/kg K]

// solution
// given expansion may be considered to be adiabatic
    and to follow the law PV^Gamma=constant
// using ideal gas law
```

```
v1 = R*T1/P1*10^-3;// [m^3/kg]
Pt = P1*(2/(Gamma+1))^(Gamma/(Gamma-1));// critical pressure, [MN/m^2]

// velocity at throat is
Ct = sqrt(2*Gamma/(Gamma-1)*P1*10^6*v1*(1-(Pt/P1)^(((Gamma-1)/Gamma))));// [m/s]
vt = v1*(P1/Pt)^(1/Gamma);// [m^3/kg]
// using m_dot/At=Ct/vt
At = m_dot*vt/Ct*10^6;// throat area, [mm^2]
mprintf('\n (a) The throat area is = %f mm^2\n',At);

// (b)
// at exit
C2 = sqrt(2*Gamma/(Gamma-1)*P1*10^6*v1*(1-(P2/P1)^(((Gamma-1)/Gamma))));// [m/s]
v2 = v1*(P1/P2)^(1/Gamma);// [m^3/kg]
A2 = m_dot*v2/C2*10^6;// exit area, [mm^2]

mprintf('\n (b) The exit area is = %f mm^2\n',A2);

// (c)
M = C2/Ct;
mprintf('\n (c) The Mach number at exit is = %f\n',M);

// End
```

Scilab code Exa 12.2 increases in pressure temperature and internal energy

```
clear;
clc;
```

```
disp('Example 12.2');

// aim : To determine the increases in pressure, temperature and internal energy per kg of air

// Given values
T1 = 273;// [K]
P1 = 140;// [kN/m^2]
C1 = 900;// [m/s]
C2 = 300;// [m/s]
cp = 1.006;// [kJ/kg K]
cv =.717;// [kJ/kg K]

// solution
R = cp-cv;// [kJ/kg K]
Gamma = cp/cv;// heat capacity ratio
// for frictionless adiabatic flow, (C2^2-C1^2)/2= Gamma/(Gamma-1)*R*(T1-T2)

T2 =T1-((C2^2-C1^2)*(Gamma-1)/(2*Gamma*R))*10^-3; // [K]
T_inc = T2-T1;// increase in temperature [K]

P2 = P1*(T2/T1)^(Gamma/(Gamma-1));// [MN/m^2]
P_inc = (P2-P1)*10^-3;// increase in pressure,[MN/m^2]

U_inc = cv*(T2-T1);// Increase in internal energy per kg,[kJ/kg]
mprintf('\n The increase in pressure is = %f MN/m^2\n',P_inc);
mprintf('\n Increase in temperature is = %f K\n',T_inc);
mprintf('\n Increase in internal energy is = %f kJ/kg\n',U_inc);

// there is minor variation in result
```

```
// End
```

Scilab code Exa 12.3 throat area and degree of undercooling

```
clear;
clc;
disp('Example 12.3');

// aim : To determine the
//  (a) throat and exit areas
//   (b) degree of undercooling at exit
// Given values
P1 = 2;// inlet pressure of air, [MN/m^2]
T1 = 273+325;// inlet temperature of air, [MN/m^2]
P2 = .36;// exit pressure, [MN/m^2]
m_dot = 7.5;// flow rate of air, [kg/s]
n = 1.3;// polytropic index

// solution
// (a)
//  using steam table
v1 = .132;// [m^3/kg]
// given expansion following law PV^n=constant

Pt = P1*(2/(n+1))^(n/(n-1));// critical pressure, [
    MN/m^2]

//velocity at throat is
Ct = sqrt(2*n/(n-1)*P1*10^6*v1*(1-(Pt/P1)^(((n-1)/n)
    )));// [m/s]
vt = v1*(P1/Pt)^(1/n);// [m^3/kg]
// using m_dot/At=Ct/vt
At = m_dot*vt/Ct*10^6;// throat area, [mm^2]
mprintf('\n (a) The throat area is =  %f  mm^2\n',At
    );
```

```

// at exit
C2 = sqrt(2*n/(n-1)*P1*10^6*v1*(1-(P2/P1)^(((n-1)/n)
    )));// [m/s]
v2 = v1*(P1/P2)^(1/n);// [m^3/kg]
A2 = m_dot*v2/C2*10^6;// exit area, [mm^2]

mprintf('\n        The exit area is  =  %f  mm^2\n',A2
    );

//  (b)
T2 = T1*(P2/P1)^((n-1)/n);//outlet temperature, [K]
t2 = T2-273;//[C]
//  at exit pressure saturation temperature is
ts = 139.9;// saturation temperature,[C]
Doc = ts-t2;// Degree of undercooling,[C]
mprintf('\n (b) The Degree of undercooling at exit
    is  =  %f C\n',Doc);

// There is some calculation mistake in the book so
    answer is not matching

//  End
```

Scilab code Exa 12.4 velocities and areas

```
clear;
clc;
disp('Example 12.4');

// aim : To determine the
//  (a) throat and exit velocities
//  (b) throat and exit areas

// Given values
```

```
P1 = 2.2;// inlet pressure, [MN/m^2]
T1 = 273+260;// inlet temperature, [K]
P2 = .4;// exit pressure,[MN/m^2]
eff = .85;// efficiency of the nozzle after throat
m_dot = 11;// steam flow rate in the nozzle, [kg/s]

// solution
// (a)
// assuming steam is following same law as previous question 12.3
Pt = .546*P1;// critical pressure,[MN/m^2]
// from Fig. 12.6
h1 = 2940;// [kJ/kg]
ht = 2790;// [kJ/kg]

Ct = sqrt(2*(h1-ht)*10^3);// [m/s]

//  again from Fig. 12.6
h2_prime = 2590;// [kJ/kg]
// using eff = (ht-h2)/(ht-h2_prime)

h2 = ht-eff*(ht-h2_prime); // [kJ/kg]

C2 = sqrt(2*(h1-h2)*10^3);// [m/s]

// (b)
// from chart
vt = .16;// [m^3/kg]
v2 = .44;// [m^3/kg]
//  using m_dot*v=A*C
At = m_dot*vt/Ct*10^6;// throat area, [mm^2]

A2 = m_dot*v2/C2*10^6;// throat area, [mm^2]

mprintf('\n (a) The throat velocity is = %f m/s\n',Ct);
mprintf('\n      The exit velocity is = %f m/s\n',C2);
```

```
mprintf('\n (b) The throat area is = %f mm^2\n',
    At);
mprintf('\n        The throat area is = %f mm^2\n',
    A2);

// End
```

Chapter 13

Steam turbines

Scilab code Exa 13.1 power developed and kinetic energy

```
clear;
clc;
disp('Example 13.1');

// aim : To determine
// 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

// Given values
alfa = 20;// blade angle, [degree]
Cai = 375;// steam exit velocity in the nozzle,[m/s]
U = 165;// blade speed, [m/s]
loss = .15;// loss of velocity due to friction

// solution
// using Fig13.12,
Cvw = 320;// change in velocity of whirl, [m/s]
cae = 132.5;// absolute velocity at exit, [m/s]
Pds = U*Cvw*10^-3;// Power developed for steam flow
   of 1 kg/s, [kW]
```

```
Kes = cae^2/2*10^-3;// Kinetic energy change of
    steam , [kW/kg]

mprintf('\n The power developed for a steam flow of
    1 kg/s is = %f kW\n',Pds)
mprintf('\n The energy of steam finally leaving the
    wheel is = %f kW/kg\n',Kes);

// End
```

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

```
clear;
clc;
disp('Example 13.2');

// aim : To determine
// (a) the entry angle of the blades
// (b) the work done per kilogram of steam per
    second
// (c) the diagram efficiency
// (d) the end-thrust per kilogram of steam per
    second

// given values
Cai = 600;// steam velocity , [m/s]
sia = 25;// steam inlet angle with blade , [degree]
U = 255;// mean blade speed , [m/s]
sea = 30;// steam exit angle with blade ,[degree]

// solution
// (a)
// using Fig.13.13(diagram for example 13.2)
eab = 41.5;// entry angle of blades , [degree]
```

```
mprintf('\n (a) The angle of blades is = %f degree\n',eab);

// (b)
Cwi_plus_Cwe = 590;// velocity of whirl, [m/s]
W = U*(Cwi_plus_Cwe);// work done on the blade,[W/kg]
mprintf('\n (b) The work done on the blade is = %f kW/kg\n',W*10^-3);

// (c)
De = 2*U*(Cwi_plus_Cwe)/Cai^2;// diagram efficiency
mprintf('\n (c) The diagram efficiency is = %f percent\n',De*100);

// (d)
// again from the diagram
Cfe_minus_Cfi = -90;// change invelocity of flow, [m/s]
Eth = Cfe_minus_Cfi;// end-thrust, [N/kg s]
mprintf('\n (d) The End-thrust is = %f N/kg',Eth);

// End
```

Scilab code Exa 13.3 power output and diagram efficiency

```
clear;
clc;
disp('Example 13.3');

// aim : To determine
// (a) the power output of the turbine
// (b) the diagram efficiency

```

```
// given values
U = 150;// mean blade speed, [m/s]
Cai1 = 675;// nozzle speed, [m/s]
na = 20;// nozzle angle, [degree]
m_dot = 4.5;// steam flow rate, [kg/s]

// solution
// from Fig. 13.15(diagram 13.3)
Cw1 = 915;// [m/s]
Cw2 = 280;// [m/s]

// (a)
P = m_dot*U*(Cw1+Cw2);// power of turbine,[W]
mprintf('\n (a) The power of turbine is  = %f kW\n'
    ,P*10^-3);

// (b)
De = 2*U*(Cw1+Cw2)/Cai1^2;// diagram efficiency
mprintf('\n (b) The diagram efficiency is  = %f
    percent\n',De*100);

//  End
```

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

```
clear;
clc;
disp('Example 13.4');

// aim : To determine
// (a) the power output of the stage
// (b) the specific enthalpy drop in the stage
// (c) the percentage increase in relative velocity
    in the moving blades due to expansion in the
```

```
bladse

// given values
N = 50;// speed, [m/s]
d = 1;// blade ring diameter, [m]
nai = 50;// nozzle inlet angle, [degree]
nae = 30;// nozzle exit angle, [degree]
m_dot = 600000;// steam flow rate, [kg/h]
se = .85;// stage efficiency

// solution
// (a)
U = %pi*d*N;// mean blade speed, [m/s]
// from Fig. 13.17(diagram 13.4)
Cwi_plus_Cwe = 444;// change in whirl speed, [m/s]
P = m_dot*U*Cwi_plus_Cwe/3600;// power output of the stage, [W]
mprintf('\n (a) The power output of the stage is = %f MW\n',P*10^-6);

// (b)
h = U*Cwi_plus_Cwe/se;// specific enthalpy,[J/kg]
mprintf('\n (b) The specific enthalpy drop in the stage is = %f kJ/kg\n ',h*10^-3);

// (c)
// again from diagram
Cri = 224;// [m/s]
Cre = 341;// [m/s]
Iir = (Cre-Cri)/Cri;// increase in relative velocity
mprintf('\n (c) The increase in relative velocity is = %f percent\n',Iir*100);

// End
```

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

```
clear;
clc;
disp('Example 13.5');

// aim : To determine
// (a) the blade height of the stage
// (b) the power developed in the stage
// (c) the specific enthalpy drop at the stage

// given values
U = 60;// mean blade speed, [m/s]
P = 350;// steam pressure, [kN/m^2]
T = 175;// steam temperature, [C]
nai = 30;// stage inlet angle, [degree]
nae = 20;// stage exit angle, [degree]

// solution
// (a)
m_dot = 13.5;// steam flow rate, [kg/s]
// at given T and P
v = .589;// specific volume, [m^3/kg]
// given H=d/10, so
H = sqrt(m_dot*v/(%pi*10*60));// blade height, [m]
mprintf('\n (a) The blade height at this stage is =
    %f mm\n',H*10^3);

// (b)
Cwi_plus_Cwe = 270;// change in whirl speed, [m/s]
P = m_dot*U*(Cwi_plus_Cwe);// power developed, [W]
mprintf('\n (b) The power developed is = %f kW\n'
    ,P*10^-3);

// (c)
s = .85;// stage efficiency
h = U*Cwi_plus_Cwe/s;// specific enthalpy,[J/kg]
```

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

// End
```

Chapter 14

Air and gas compressors

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

```
clear;
clc;
disp(' Example 14.1 ');

// aim : To determine
// (a) the free air delivered
// (b) the volumetric efficiency
// (c) the air delivery temperature
// (d) the cycle power
// (e) the isothermal efficiency

// given values
d = 200*10^-3;// bore, [m]
L = 300*10^-3;// stroke, [m]
N = 500;// speed, [rev/min]
n = 1.3;// polytropic index
P1 = 97;// intake pressure, [kN/m^2]
T1 = 273+20;// intake temperature, [K]
P3 = 550;// compression pressure, [kN/m^2]

```

```
// solution
// (a)
P4 = P1;
P2 = P3;
Pf = 101.325;// free air pressure, [kN/m^2]
Tf = 273+15;// free air temperature, [K]
SV = %pi/4*d^2*L;// swept volume, [m^3]
V3 = .05*SV;// [m^3]
V1 = SV+V3;// [m^3]
V4 = V3*(P3/P4)^(1/n);// [m^3]
ESV = (V1-V4)*N;// effective swept volume/min, [m^3]
// using PV/T=constant
Vf = P1*ESV*Tf/(Pf*T1);// free air delivered, [m^3/min]
mprintf('\n (a) The free air delivered is = %f m^3/min\n',Vf);

// (b)
VE = Vf/(N*(V1-V3));// volumetric efficiency
mprintf('\n (b) The volumetric efficiency is = %f percent\n',VE*100);

// (c)
T2 = T1*(P2/P1)^((n-1)/n);// free air temperature, [K]
mprintf('\n (c) The air delivery temperature is = %f C\n',T2-273);

// (d)
CP = n/(n-1)*P1*(V1-V4)*((P2/P1)^((n-1)/n)-1)*N/60;// cycle power, [kW]
 mprintf('\n (d) The cycle power is = %f kW\n',CP);

// (e)
// neglecting clearence
W = n/(n-1)*P1*V1*((P2/P1)^((n-1)/n)-1)
Wi = P1*V1*log(P2/P1);// isothermal efficiency
```

```
IE = Wi/W;// isothermal efficiency
mprintf('\n (e) The isothermal efficiency neglecting
    clearence is = %f percent\n',IE*100);

// End
```

Scilab code Exa 14.2 intermediate pressure volume and cycle power

```
clear;
clc;
disp(' Example 14.2 ');

// aim : To determine
// (a) the intermediate pressure
// (b) the total volume of each cylinder
// (c) the cycle power

// given values
v1 = .2;// air intake, [m^3/s]
P1 = .1;// intake pressure, [MN/m^2]
T1 = 273+16;// intake temperature, [K]
P3 = .7;// final pressure, [MN/m^2]
n = 1.25;// compression index
N = 10;// speed, [rev/s]

// solution
// (a)
P2 = sqrt(P1*P3);// intermediate pressure, [MN/m^2]
mprintf('\n (a) The intermediate pressure is = %f
    MN/m^2\n',P2);

// (b)
V1 = v1/N;// total volume,[m^3]
// since intercooling is perfect so 2 lie on the
   isothermal through1, P1*V1=P2*V2
```

```
V2 = P1*V1/P2;// volume, [m^3]
mprintf('\n (b) The total volume of the HP cylinder is = %f litres\n',V2*10^3);

 // (c)
 CP = 2*n/(n-1)*P1*v1*((P2/P1)^((n-1)/n)-1);// cycle power, [MW]
  mprintf('\n (c) The cycle power is = %f MW\n',CP*10^3);

 // there is calculation mistake in the book so answer is not matching

 // End
```

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

```
clear;
clc;
disp(' Example 14.3');

// aim : To determine
// (a) the intermediate pressures
// (b) the effective swept volume of the LP cylinder
// (c) the temperature and the volume of air delivered per stroke at 15 bar
// (d) the work done per kilogram of air

// given values
d = 450*10^-3;// bore , [m]
L = 300*10^-3;// stroke, [m]
cl = .05;// clearence
P1 = 1; // intake pressure, [bar]
T1 = 273+18;// intake temperature, [K]
```

```
P4 = 15;// final delivery pressure , [bar]
n = 1.3;// compression and expansion index
R = .29;// gas constant , [kJ/kg K]

// solution
// (a)
k=(P4/P1)^(1/3);
// hence
P2 = k*P1;// intermediare pressure , [bar]
P3 = k*P2;// intermediate pressure , [bar]

mprintf('\n (a) The intermediate pressure is P2 =
    %f bar\n',P2);
mprintf('\n     The intermediate pressure is  P3=
    %f bar\n',P3);

// (b)
SV = %pi*d^2/4*L;// swept volume of LP cylinder , [m
    ^3]
// hence
V7 = cl*SV;// volume , [m^3]
V1 = SV+V7;// volume , [m^3]
// also
P7 = P2;
P8 = P1;
V8 = V7*(P7/P8)^(1/n);// volume , [m^3]
ESV = V1-V8;// effective swept volume of LP cylinder
    , [m^3]

mprintf('\n (b) The effective swept volume of the LP
     cylinder is  =  %f litres\n',ESV*10^3);

// (c)
T9 = T1;
P9 = P3;
T4 = T9*(P4/P9)^((n-1)/n);// delivery temperature , [
    K]
// now using P4*(V4-V5)/T4=P1*(V1-V8)/T1
```

```
V4_minus_V5 = P1*T4*(V1-V8)/(P4*T1);// delivery volume, [m^3]

mprintf('\n (c) The delivery temperature is = %f C \n',T4-273);
mprintf('\n      The delivery volume is = %f litres\n',V4_minus_V5*10^3);

// (d)

W = 3*n*R*T1*((P2/P1)^((n-1)/n)-1)/(n-1);// work done/kg ,[kJ]
mprintf('\n (d) The work done per kilogram of air is = %f kJ\n',W);

// End
```

Scilab code Exa 14.4 pressure temperature and energy

```
clear;
clc;
disp('Example 14.4');

// aim : To determine
// (a) the final pressure and temperature
// (b) the energy required to drive the compressor

// given values
rv = 5;// pressure compression ratio
m_dot = 10;// air flow rate, [kg/s]
P1 = 100;// initial pressure, [kN/m^2]
T1 = 273+20;// initial temperature, [K]
n_com = .85;// isentropic efficiency of compressor
Gama = 1.4;// heat capacity ratio
cp = 1.005;// specific heat capacity, [kJ/kg K]
```

```
// solution
// (a)
T2_prim = T1*(rv)^((Gama-1)/Gama);// temperature
   after compression, [K]
// using isentropic efficiency=(T2_prim-T1)/(T2-T1)
T2 = T1+(T2_prim-T1)/n_com;// final temperature, [K
   ]
P2 = rv*P1;// final pressure, [kN/m^2]
mprintf('\n (a) The final temperature is = %f C\n
   ',T2-273);
mprintf('\n (b) The final pressure is = %f kN/m
   ^2\n',P2);

// (b)
E = m_dot*cp*(T1-T2);// energy required, [kW]
mprintf('\n (b) The energy required to drive the
   compressor is = %f kW',E);
if(E<0)
    disp('The negative sign indicates energy input')
      ;
else
    disp('The positive sign indicates energy output'
      );
end

 // End
```

Scilab code Exa 14.5 power developed

```
clear;
clc;
disp(' Example 14.5');

// aim : To determine
```

```
//  the power absorbed in driving the compressor

// given values
FC = .68;// fuel consumption rate, [kg/min]
P1 = 93;// initial pressure, [kN/m^2]
P2 = 200;// final pressure, [kN/m^2]
T1 = 273+15;// initial temperature, [K]
d = 1.3;// density of mixture, [kg/m^3]
n_com = .82;// isentropic efficiency of compressor
Gama = 1.38;// heat capacity ratio

// solution
R = P1/(d*T1);// gas constant, [kJ/kg K]
// for mixture
cp = Gama*R/(Gama-1);// heat capacity, [kJ/kg K]
T2_prim = T1*(P2/P1)^((Gama-1)/Gama);// temperature after compression, [K]
// using isentropic efficiency=(T2_prim-T1)/(T2-T1)
T2 = T1+(T2_prim-T1)/n_com;//  final temperature, [K]
m_dot = FC*15/60;// given condition, [kg/s]
P = m_dot*cp*(T2-T1);// power absorbed by compressor, [kW]
mprintf('\n The power absorbed by compressor is  = %f kW\n',P);

// End
```

Scilab code Exa 14.6 power

```
clear;
clc;
disp(' Example 14.6');

// aim : To determine
```

```
//  the power required to drive the blower

// given values
m_dot = 1;// air capacity, [kg/s]
rp = 2;// pressure ratio
P1 = 1*10^5;// intake pressure, [N/m^2]
T1 = 273+70;// intake temperature, [K]
R = .29;// gas constant, [kJ/kg k]

// solution
V1_dot = m_dot*R*T1/P1*10^3;// [m^3/s]
P2 = rp*P1;// final pressure, [n/m^2]
P = V1_dot*(P2-P1);// power required, [W]
mprintf('\n The power required to drive the blower is = %f kW\n',P*10^-3);

// End
```

Scilab code Exa 14.7 power

```
clear;
clc;
disp(' Example 14.7');

// aim : To determine
//  the power required to drive the vane pump

// given values
m_dot = 1;// air capacity, [kg/s]
rp = 2;// pressure ratio
P1 = 1*10^5;// intake pressure, [N/m^2]
T1 = 273+70;// intake temperature, [K]
Gama = 1.4;// heat capacity ratio
rv = .7;// volume ratio

```

```
// solution
V1 = .995;// intake pressure(as given previous
    question),[m^3/s]
// using P1*V1^Gama=P2*V2^Gama, so
P2 = P1*(1/rv)^Gama;// pressure, [N/m^2]
V2 = rv*V1;// volume,[m^3/s]
P3 = rp*P1;// final pressure, [N/m^2]
P = Gama/(Gama-1)*P1*V1*((P2/P1)^((Gama-1)/Gama)-1)+
    V2*(P3-P2);// power required,[W]
mprintf('\n The power required to drive the vane
    pump is = %f kW\n',P*10^-3);

// End
```

Scilab code Exa 14.8 power temperature and pressure

```
clear;
clc;
disp(' Example 14.8 ');

// aim : To determine
// the total temperature and pressure of the
    mixture

// given values
rp = 2.5;// static pressure ratio
FC = .04;// fuel consumption rate, [kg/min]
P1 = 60;// inilet pressure, [kN/m^2]
T1 = 273+5;// inilet temperature, [K]
n_com = .84;// isentropic efficiency of compressor
Gama = 1.39;// heat capacity ratio
C2 = 120;//exit velocity from compressor, [m/s]
rm = 13;// air-fuel ratio
cp = 1.005;// heat capacity ratio

```

```
// solution
P2 = rp*P1;// given condition, [kN/m^2]
T2_prim = T1*(P2/P1)^((Gama-1)/Gama);// temperature after compression, [K]
// using isentropic efficiency=(T2_prim-T1)/(T2-T1)
T2 = T1+(T2_prim-T1)/n_com;// final temperature, [K]
m_dot = FC*(rm+1);// mass of air-fuel mixture, [kg/s]
P = m_dot*cp*(T2-T1);// power to drive compressor, [kW]
mprintf('\n The power required to drive compressor is = %f kW\n',P);

Tt2 = T2+C2^2/(2*cp*10^3);// total temperature,[K]
Pt2 = P2*(Tt2/T2)^(Gama/(Gama-1));// total pressure, [kN/m^2]
mprintf('\n The temperature in the engine is = %f C\n',Tt2-273);
mprintf('\n The pressure in the engine cylinder is = %f kN/m^2\n',Pt2);

// There is calculation mistake in the book


// End
```

Chapter 15

Ideal gas power cycles

Scilab code Exa 15.1 thermal efficiency

```
clear;
clc;
disp('Example 15.1');

// aim : To determine
// the thermal efficiency of the cycle

// given values
T1 = 273+400;//  temperature limit, [K]
T3 = 273+70;// temperature limit, [K]

//  solution
//  using equation [15] of section 15.3
n_the = (T1-T3)/T1*100;// thermal efficiency
mprintf('\n The thermal efficiency of the cycle is
   = %f percent\n',n_the);

//  End
```

Scilab code Exa 15.2 volume ratios and thermal efficiency

```
clear;
clc;
disp('Example 15.2');

// aim : To determine
// (a) the volume ratios of the isothermal and adiabatic processes
// (b) the thermal efficiency of the cycle

// given values
T1 = 273+260;// temperature, [K]
T3 = 273+21;// temperature, [K]
er = 15;// expansion ratio
Gama = 1.4;// heat capacity ratio

// solution
// (a)
T2 = T1;
T4 = T3;
// for adiabatic process
rva = (T1/T4)^(1/(Gama-1));// volume ratio of adiabatic
rvi = er/rva;// volume ratio of isothermal
mprintf('\n (a) The volume ratio of the adiabatic process is = %f\n',rva);
mprintf('\n     The volume ratio of the isothermal process is = %f\n',rvi);

// (b)
n_the = (T1-T4)/T1*100;// thermal efficiency
mprintf('\n (b) The thermal efficiency of the cycle is = %f percent\n',n_the);

//  End
```

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

```
clear;
clc;
disp('Example 15.3');

// aim : To determine
// (a) the pressure, volume and temperature at each
   corner of the cycle
// (b) the thermal efficiency of the cycle
// (c) the work done per cycle
// (d) the work ratio

// given values
m = 1;// mass of air, [kg]
P1 = 1730;// initial pressure of carnot engine, [kN/
   m^2]
T1 = 273+300;// initial temperature, [K]
R = .29;// [kJ/kg K]
Gama = 1.4;// heat capacity ratio

// solution
// taking reference  Fig. 15.15
// (a)
// for the isothermal process 1-2
// using ideal gas law
V1 = m*R*T1/P1;// initial volume, [m^3]
T2 = T1;
V2 = 3*V1;// given condition
// for isothermal process, P1*V1=P2*V2, so
P2 = P1*(V1/V2);// [MN/m^2]
// for the adiabatic process 2-3
V3 = 6*V1;// given condition
```

```
T3 = T2*(V2/V3)^(Gama-1);
// also for adiabatic process, P2*V2^Gama=P3*V3^Gama, so
P3 = P2*(V2/V3)^Gama;
// for the isothermal process 3-4
T4 = T3;
// for both adiabatic processes, the temperataure ratio is same,
// T1/T4 = T2/T3=(V4/V1)^(Gama-1)=(V3/V2)^(Gama-1), so
V4 = 2*V1;
// for isothermal process, 3-4, P3*V3=P4*V4, so
P4 = P3*(V3/V4);
disp('(a) At line 1');
mprintf('\n V1 = %f m^3, t1 = %f C, P1 = %f kN/m^2\n',V1,T1-273,P1);
disp('At line 2');
mprintf('\n V2 = %f m^3, t2 = %f C, P2 = %f kN/m^2\n',V2,T2-273,P2);
disp('At line 3');
mprintf('\n V3 = %f m^3, t3 = %f C, P3 = %f kN/m^2\n',V3,T3-273,P3);
disp('At line 4');
mprintf('\n V4 = %f m^3, t4 = %f C, P4 = %f kN/m^2\n',V4,T4-273,P4);
// (b)
n_the = (T1-T3)/T1;// thermal efficiency
mprintf('\n (b) The thermal efficiency of the cycle is = %f percent\n',n_the*100);
// (c)
W = m*R*T1*log(V2/V1)*n_the;// work done, [J]
```

```
mprintf('\n (c) The work done per cycle is = %f kJ\n',W);

//  (d)
wr = (T1-T3)*log(V2/V1)/(T1*log(V2/V1)+(T1-T3)/(Gama-1));// work ratio
mprintf('\n (d) The work ratio is = %f\n',wr);

// there is calculation mistake in the book so answer is not matching

//   End
```

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

```
clear;
clc;
disp('Example 15.4');

// aim : To determine
// (a) the pressure, volume and temperature at cycle state points
// (b) the heat received
// (c) the work done
// (d) the thermal efficiency
// (e) the carnot efficiency
// (f) the work ration
// (g) the mean effective pressure

// given values
ro = 8;// overall volume ratio;
rv = 6;// volume ratio of adiabatic compression
P1 = 100;// initial pressure , [kN/m^2]
V1 = .084;// initial volume, [m^3]
```

```
T1 = 273+28;// initial temperature, [K]
Gama = 1.4;// heat capacity ratio
cp = 1.006;// specific heat capacity, [kJ/kg K]

// solution
// taking reference  Fig. 15.18
// (a)
V2 = V1/rv;// volume at stage2, [m^3]
V4 = ro*V2;// volume at stage 4;[m^3]
// using PV^(Gama)=constant for process 1-2
P2 = P1*(V1/V2)^(Gama);// pressure at stage2,. [kN/m^2]
T2 = T1*(V1/V2)^(Gama-1);// [K]

P3 = P2;// pressure at stage 3, [kN/m^2]
V3 = V4/rv;// volume at stage 3, [m^3]
// since pressure is constant in process 2-3 , so using V/T=constant, so
T3 = T2*(V3/V2);// temperature at stage 3, [K]

// for process 1-4
T4 = T1*(V4/V1);// temperature at stage4, [K
P4 = P1;// pressure at stage4, [kN/m^2]

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);

// (b)
R = cp*(Gama-1)/Gama;// gas constant, [kJ/kg K]
m = P1*V1/(R*T1);// mass of gas, [kg]
Q = m*cp*(T3-T2);// heat received, [kJ]
mprintf('\n (b) The heat received is  =  %f kJ\n',Q);
```

```
// (c)
W = P2*(V3-V2)-P1*(V4-V1)+((P3*V3-P4*V4)-(P2*V2-P1*
    V1))/(Gama-1);// work done, [kJ]
mprintf('\n (c) The work done is  =  %f  kJ\n',W);

//  (d)
TE = 1-T1/T2;// thermal efficiency
mprintf('\n (d) The thermal efficiency is  =  %f
    percent\n',TE*100);

// (e)
CE = (T3-T1)/T3;// carnot efficiency
mprintf('\n (e) The carnot efficiency is  =  %f
    percent\n',CE*100);

// (f)
PW = P2*(V3-V2)+(P3*V3-P4*V4)/(Gama-1);// positive
    work done, [kj]
WR = W/PW;//  work ratio
mprintf('\n (f) The work ratio is  =  %f\n',WR);

// (g)
Pm = W/(V4-V2);// mean effective pressure, [kN/m^2]
mprintf('\n (g) The mean effective pressure is  =
    %f  kN/m^2\n',Pm);

//  there is minor variation in answer reported in
    the book

//  End
```

Scilab code Exa 15.5 thermal efficiency and specific fuel consumption

```
clear;
```

```
clc;
disp('Example 15.5');

// aim : To determine
// (a) the actual thermal efficiency of the turbine
// (b) the specific fuel consumption of the turbine
   in kg/kWh

// given values
P2_by_P1 = 8;
n_tur = .6;// ideal turbine thermal efficiency
c = 43*10^3;// calorific value of fuel, [kJ/kg]
Gama = 1.4;// heat capacity ratio

// solution
// (a)
rv = P2_by_P1;
n_tur_ide = 1-1/(P2_by_P1)^((Gama-1)/Gama);// ideal
   thermal efficiency
ate = n_tur_ide*n_tur;// actual thermal efficiency
mprintf('\n (a) The actual thermal efficiency of the
    turbine is = %f percent\n',ate*100);

// (b)
ewf = c*ate;// energy to work fuel, [kJ/kg]
kWh = 3600;// energy equivalent ,[kJ]
sfc = kWh/ewf;// specific fuel consumption, [kg/kWh]
mprintf('\n (b) The specific fuel consumption of the
    turbine is = %f kg/kWh',sfc);

// End
```

Scilab code Exa 15.6 relative efficiency

```
clear;
```

```
clc;
disp('Example 15.6');

// aim : To determine
// the relative efficiency of the engine

// given values
d = 80;// bore, [mm]
l = 85;// stroke, [mm]
V1 = .06*10^6;// clearence volume, [mm^3]
ate = .22;// actual thermal efficiency of the engine
Gama = 1.4;// heat capacity ratio

// solution
sv = %pi*d^2/4*l;// stroke volume, [mm^3]
V2 = sv+V1;// [mm^3]
rv = V2/V1;
ite = 1-(1/rv)^(Gama-1);// ideal thermal efficiency
re = ate/ite;// relative thermal efficiency
mprintf('\n The relative efficiency of the engine is
    = %f percent\n',re*100);

// End
```

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

```
clear;
clc;
disp('Example 15.7');

// aim : To determine
// (a) the pressure, volume and temperature at each
    cycle process change points
// (b) the heat transferred to air
```

```
// (c) the heat rejected by the air
// (d) the ideal thermal efficiency
// (e) the work done
// (f) the mean effective pressure

// given values
m = 1;// mass of air , [kg]
rv = 6;// volume ratio of adiabatic compression
P1 = 103;// initial pressure , [kN/m^2]
T1 = 273+100;// initial temperature, [K]
P3 = 3450;// maximum pressure, [kN/m^2]
Gama = 1.4;// heat capacity ratio
R = .287;// gas constant, [kJ/kg K]

// solution
// taking reference  Fig. 15.20
// (a)
// for point 1
V1 = m*R*T1/P1;// initial volume, [m^3]

// for point 2
V2 = V1/rv;// volume at point 2, [m^3]
// using PV^(Gama)=constant for process 1-2
P2 = P1*(V1/V2)^(Gama);// pressure at point 2,. [kN/m^2]
T2 = T1*(V1/V2)^(Gama-1);// temperature at point 2,[K]

// for point 3
V3 = V2;// volume at point 3, [m^3]
// since volume is constant in process 2-3 , so using P/T=constant, so
T3 = T2*(P3/P2);// temperature at stage 3, [K]

// for point 4
V4 = V1;//  volume at point 4, [m^3]
P4 = P3*(V3/V4)^Gama;// pressure at point 4, [kN/m^2]
```

```
// again  since volume is constant in process 4-1 , so using P/T=constant , so
T4 = T1*(P4/P1);// temperature at point 4, [K]

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);

//  (b)
cv = R/(Gama-1);//  specific heat capacity, [kJ/kg K]
Q23 = m*cv*(T3-T2);// heat transferred, [kJ]
mprintf('\n (b) The heat transferred to the air is  =  %f  kJ\n',Q23);

// (c)
Q34 = m*cv*(T4-T1);// heat rejected by air, [kJ]
mprintf('\n (c) The heat rejected by the air is  =  %f  kJ\n',Q34);

// (d)
TE = 1-Q34/Q23;// ideal thermal efficiency
mprintf('\n (d) The ideal thermal efficiency is  =  %f percent\n',TE*100);

// (e)
W = Q23-Q34;// work done  ,[kJ]
mprintf('\n (e) The work done  is  =  %f  kJ\n',W);

// (f)
Pm = W/(V1-V2);// mean effective pressure, [kN/m^2]
mprintf('\n (f)  The mean effefctive pressure is  =  %f kN/m^2\n',Pm);

```

```
// End
```

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

```
clear;
clc;
disp('Example 15.8');

// aim : To determine
// (a) the pressure, volume and temperature at cycle state points
// (b) the thermal efficiency
// (c) the theoretical output
// (d) the mean effective pressure
// (e) the carnot efficiency

// given values
rv = 9;// volume ratio
P1 = 101;// initial pressure , [kN/m^2]
V1 = .003;// initial volume, [m^3]
T1 = 273+18;// initial temperature, [K]
P3 = 4500;// maximum pressure, [kN/m^2]
N = 3000;
cp = 1.006;// specific heat capacity at constant pressure, [kJ/kg K]
cv = .716;// specific heat capacity at constant volume, [kJ/kg K]

// solution
// taking reference Fig. 15.20
// (a)
// for process 1-2
Gama = cp/cv;// heat capacity ratio
R = cp-cv;// gas constant, [kJ/kg K]
```

```
V2 = V1/rv;// volume at stage2 , [m^3]
// using PV^(Gama)=constant for process 1-2
P2 = P1*(V1/V2)^(Gama);// pressure at stage2 ,. [kN/m^2]
T2 = T1*(V1/V2)^(Gama-1);// [K]

// for process 2-3
V3 = V2;// volume at stage 3, [m^3]
// since volume is constant in process 2-3 , so using P/T=constant , so
T3 = T2*(P3/P2);// temperature at stage 3, [K]

// for process 3-4
V4 = V1;// volume at stage 4
// using PV^(Gama)=constant for process 3-4
P4 = P3*(V3/V4)^(Gama);// pressure at stage2 ,. [kN/m^2]
T4 = T3*(V3/V4)^(Gama-1);// temperature at stage 4,[K]

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);

// (b)
TE = 1-(T4-T1)/(T3-T2);// thermal efficiency
mprintf('\n (b) The thermal efficiency is = %f percent\n',TE*100);

// (c)
m = P1*V1/(R*T1);// mass os gas, [kg]
W = m*cv*((T3-T2)-(T4-T1));// work done, [kJ]
Wt = W*N/60;// workdone per minute, [kW]
mprintf('\n (c) The theoretical output is = %f
```

```
   kW\n',Wt);

// (d)
Pm = W/(V1-V2);// mean effective pressure, [kN/m^2]
mprintf('\n (g) The mean effefctive pressure is  =
   %f  kN/m^2\n',Pm);

// (e)
CE = (T3-T1)/T3;// carnot efficiency
mprintf('\n (e) The carnot efficiency is  =  %f
   percent\n',CE*100);


//  End
```

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

```
clear;
clc;
disp('Example 15.9');

// aim : To determine
// (a) the pressure and temperature at cycle process
    change points
// (b) the work done
// (c)  the thermal efficiency
// (d)  the work ratio
// (e)  the mean effective pressure
// (f)  the carnot efficiency


// given values
rv = 16;// volume ratio of compression
P1 = 90;// initial pressure , [kN/m^2]
```

```
T1 = 273+40;// initial temperature, [K]
T3 = 273+1400;// maximum temperature, [K]
cp = 1.004;// specific heat capacity at constant pressure, [kJ/kg K]
Gama = 1.4;// heat capacoty ratio

// solution
cv = cp/Gama;// specific heat capacity at constant volume, [kJ/kg K]
R = cp-cv;// gas constant, [kJ/kg K]
// for one kg of gas
V1 = R*T1/P1;// initial volume, [m^3]
// taking reference  Fig. 15.22
// (a)
// for process 1-2
// using PV^(Gama)=constant for process 1-2
// also rv = V1/V2
P2 = P1*(rv)^(Gama);// pressure at stage2,. [kN/m^2]
T2 = T1*(rv)^(Gama-1);// temperature at stage 2, [K]

// for process 2-3
P3 = P2;// pressure at stage 3, [kN/m^2]
V2 = V1/rv;//[m^3]
// since pressure is constant in process 2-3 , so using V/T=constant, so
V3 = V2*(T3/T2);// volume at stage 3, [m^3]

// for process 1-4
V4 = V1;// [m^3]
P4 = P3*(V3/V4)^(Gama)
// since in stage 1-4 volume is constant, so P/T=constant,
T4 = T1*(P4/P1);// temperature at stage  4,[K]

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);

// (b)
W = cp*(T3-T2)-cv*(T4-T1);// work done, [kJ]
mprintf('\n (b) The work done is  =  %f kJ\n',W);

// (c)
TE = 1-(T4-T1)/((T3-T2)*Gama);// thermal efficiency
mprintf('\n (c) The thermal efficiency is  =  %f
    percent\n',TE*100);

// (d)
PW = cp*(T3-T2)+R*(T3-T4)/(Gama-1);// positive work
    done
WR = W/PW;//  work ratio
mprintf('\n (d) The work ratio is  =  %f\n',WR);

// (e)
Pm = W/(V1-V2);// mean effective pressure, [kN/m^2]
mprintf('\n (e) The mean effefctive pressure is  =
    %f kN/m^2\n',Pm);

// (f)
CE = (T3-T1)/T3;// carnot efficiency
mprintf('\n (f) The carnot efficiency is  =  %f
    percent\n',CE*100);

// value of t2 printed in the book is incorrect

// End
```

Scilab code Exa 15.10 maximum temperature and thermal efficiency

```
clear;
clc;
```

```
disp('Example 10');

// aim : To determine
// (a) the maximum temperature attained during the cycle
// (b) the thermal efficiency of the cycle

// given value
rva =7.5;// volume ratio of adiabatic expansion
rvc =15;// volume ratio of compression
P1 = 98;// initial pressure, [kn/m^2]
T1 = 273+44;// initial temperature, [K]
P4 = 258;// pressure at the end of the adiabatic expansion, [kN/m^2]
Gama = 1.4;// heat capacity ratio

// solution
// by seeing diagram
// for process 4-1, P4/T4=P1/T1
T4 = T1*(P4/P1);// [K]
// for process 3-4
T3 = T4*(rva)^(Gama-1);
mprintf('\n (a) The maximum temperature during the cycle is = %f C\n',T3-273);

// (b)

// for process 1-2,
T2 = T1*(rvc)^(Gama-1);// [K]
n_the = 1-(T4-T1)/((Gama)*(T3-T2));// thermal efficiency
mprintf('\n (b) The thermal efficiency of the cycle is = %f percent\n',n_the*100);

// End
```

Scilab code Exa 15.11 thermal efficiency and indicated power

```
clear;
clc;
disp('Example 15.11');

// aim : To determine
// (a) the thermal efficiency of the cycle
// (b) the indicated power of the cycle

// given values
// taking basis one second
rv = 11;// volume ratio
P1 = 96;// initial pressure , [kN/m^2]
T1 = 273+18;// initial temperature, [K]
Gama = 1.4;// heat capacity ratio

// solution
// taking reference  Fig. 15.24
// (a)
Beta = 2;// ratio of V3 and V2
TE = 1-(Beta^(Gama)-1)/((rv^(Gama-1))*Gama*(Beta-1));// thermal efficiency
mprintf('\n (a) the thermal efficiency of the cycle is = %f percent\n ',TE*100);

// (b)
// let V1-V2=.05, so
V2 = .05*.1;// [m^3]
// from this
V1 = rv*V2;// [m^3]
V3 = Beta*V2;// [m^3]
V4 = V1;// [m^3]
P2 = P1*(V1/V2)^(Gama);// [kN/m^2]
```

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

// End
```

Scilab code Exa 15.12 pressures and temperatures

```
clear;
clc;
disp('Example 15.12');

// aim : To determine
// (a) the pressure and temperature at the end of compression
// (b) the pressure and temperature at the end of the constant volume process
// (c) the temperature at the end of constant pressure process

// given values
P1 = 103;// initial pressure, [kN/m^2]
T1 = 273+22;// initial temperature, [K]
rv = 16;// volume ratio of the compression
Q = 244;//heat added, [kJ/kg]
Gama = 1.4;// heat capacity ratio
cv = .717;// heat capacity, [kJ/kg k]

// solution
// taking reference as Fig.15.26
// (a)
```

```
// for compression
// rv = V1/V2
P2 = P1*(rv)^Gama;// pressure at end of compression, [kN/m^2]
T2 = T1*(rv)^(Gama-1);// temperature at end of compression, [K]
mprintf('\n (a) The pressure at the end of compression is = %f MN/m^2\n',P2*10^-3);
mprintf('\n     The temperature at the end of compression is = %f C\n',T2-273);

// (b)
// for constant volume process,
// Q = cv*(T3-T2), so
T3 = T2+Q/cv;// temperature at the end of constant volume, [K]

// so for constant volume, P/T=constant, hence
P3 = P2*(T3/T2);// pressure at the end of constant volume process, [kN/m^2]
mprintf('\n (b) The pressure at the end of constant volume process is = %f MN/m^2\n ',P3*10^-3);
mprintf('\n     The temperature at the end of constant volume process is = %f C\n',T3-273);

// (c)
S = rv-1;// stroke
// assuming
V3 = 1;// [volume]
//so
V4 = V3+S*.03;// [volume]
// also for constant process V/T=constant, hence
T4 = T3*(V4/V3);// temperature at the end of constant presure process, [k]
mprintf('\n (c) The temperature at the end of constant pressure process is = %f C\n',T4-273);

//  End
```

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

```
clear;
clc;
disp('Example 15.13');

// aim : To determine
// (a) the pressure, volume and temperature at cycle process change points
// (b) the net work done
// (c) the thermal efficiency
// (d) the heat received
// (e) the work ratio
// (f) the mean effective pressure
// (g) the carnot efficiency


// given values
rv = 15;// volume ratio
P1 = 97*10^-3;// initial pressure , [MN/m^2]
V1 = .084;// initial volume, [m^3]
T1 = 273+28;// initial temperature, [K]
T4 = 273+1320;// maximum temperature, [K]
P3 = 6.2;// maximum pressure, [MN/m^2]
cp = 1.005;// specific heat capacity at constant pressure, [kJ/kg K]
cv = .717;// specific heat capacity at constant volume, [kJ/kg K]

// solution
// taking reference  Fig. 15.27
// (a)
R = cp-cv;// gas constant, [kJ/kg K]
```

```
Gama = cp/cv;// heat capacity ratio
// for process 1-2
V2 = V1/rv;// volume at stage2 , [m^3]
// using PV^(Gama)=constant for process 1-2
P2 = P1*(V1/V2)^(Gama);// pressure at stage2 ,. [MN/m
    ^2]
T2 = T1*(V1/V2)^(Gama-1);// temperature at stage 2,
    [K]

// for process 2-3
// since volumee is constant in process 2-3 , so
    using P/T=constant , so
T3 = T2*(P3/P2);// volume at stage 3, [K]
V3 = V2;// volume at stage 3, [MN/m^2]

// for process 3-4
P4 = P3;// pressure at stage 4, [m^3]
// since in stage 3-4 P is constant , so V/T=constant
    ,
V4 = V3*(T4/T3);// temperature at stage  4,[K]

// for process 4-5
V5 = V1;// volume at stage 5, [m^3]
P5 = P4*(V4/V5)^(Gama);// pressure at stage5 ,. [MN/m
    ^2]
T5 = T4*(V4/V5)^(Gama-1);// temperature at stage 5,
    [K]

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);

```

```
// (b)
W = (P3*(V4-V3)+((P4*V4-P5*V5)-(P2*V2-P1*V1))/(Gama-1))*10^3;// work done, [kJ]
mprintf('\n (b) The net work done is = %f kJ\n',W);

// (c)
TE = 1-(T5-T1)/((T3-T2)+Gama*(T4-T3));// thermal efficiency
mprintf('\n (c) The thermal efficiency is = %f percent\n',TE*100);

// (d)
Q = W/TE;// heat received, [kJ]
mprintf('\n (d) The heat received is = %f kJ\n',Q);

// (e)
PW = P3*(V4-V3)+(P4*V4-P5*V5)/(Gama-1)
WR = W*10^-3/PW;// work ratio
mprintf('\n (f) The work ratio is = %f\n',WR);

// (e)
Pm = W/(V1-V2);// mean effective pressure, [kN/m^2]
mprintf('\n (e) The mean effective pressure is = %f kN/m^2\n',Pm);

// (f)
CE = (T4-T1)/T4;// carnot efficiency
mprintf('\n (f) The carnot efficiency is = %f percent\n',CE*100);

// End
```

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

```
clear;
clc;
disp('Example 15.14');

// aim : To determine
// (a)  the thermal efficiency
// (b)  the heat received
// (c) the heat rejected
// (d) the net work
// (e)  the work ratio
// (f)  the mean effective pressure
// (g)  the carnot efficiency


// given values
P1 = 101;// initial pressure , [kN/m^2]
V1 = 14*10^-3;// initial volume, [m^3]
T1 = 273+15;// initial temperature, [K]
P3 = 1850;// maximum pressure, [kN/m^2]
V2 = 2.8*10^-3;// compressed volume, [m^3]
Gama = 1.4;// heat capacity
R = .29;// gas constant, [kJ/kg k]

// solution
// taking reference  Fig. 15.29
// (a)
// for process 1-2
// using PV^(Gama)=constant for process 1-2
P2 = P1*(V1/V2)^(Gama);// pressure at stage2 ,. [MN/m
    ^2]
T2 = T1*(V1/V2)^(Gama-1);// temperature at stage 2,
    [K]

// for process 2-3
// since volumee is constant in process 2-3 , so
```

```
    using P/T=constant , so
T3 = T2*(P3/P2);// volume at stage 3, [K]

// for process 3-4
P4 = P1;
T4 = T3*(P4/P3)^((Gama-1)/Gama);// temperature

TE = 1-Gama*(T4-T1)/(T3-T2);// thermal efficiency
mprintf('\n (a) The thermal efficiency is = %f
    percent\n',TE*100);

// (b)
cv = R/(Gama-1);// heat capacity at copnstant volume
    , [kJ/kg k]
m = P1*V1/(R*T1);// mass of gas, [kg]
Q1 = m*cv*(T3-T2);// heat received, [kJ/cycle]
mprintf('\n (b) The heat received is = %f kJ/cycle
    \n',Q1);

// (c)
cp = Gama*cv;// heat capacity at constant at
    constant pressure, [kJ/kg K]
Q2 = m*cp*(T4-T1);// heat rejected, [kJ/cycle]
mprintf('\n (c) The heat rejected is = %f kJ/cycle
    \n',Q2);

// (d)
W = Q1-Q2;// net work , [kJ/cycle]
mprintf('\n (d) The net work is = %f kJ/cycle\n',
    W);

// (e)
// pressure is constant for process 1-4, so V/T=
    constant
V4 = V1*(T4/T1);// volume, [m^3]
V3 = V2;// for process 2-3
P4 = P1;// for process 1-4
PW = (P3*V3-P1*V1)/(Gama-1);// positive work done, [
```

```
kJ/cycle]
WR = W/PW;//  work ratio
mprintf('\n (e) The work ratio is  =  %f\n',WR);

// (f)
Pm = W/(V4-V2);// mean effective pressure, [kN/m^2]
mprintf('\n (f) The mean effefctive pressure is  =  %f  kN/m^2\n',Pm);

// (g)
CE = (T3-T1)/T3;// carnot efficiency
mprintf('\n (g) The carnot efficiency is  =  %f percent\n',CE*100);

// there is minor variation in answer reported in the book

//  End
```

Scilab code Exa 15.15 work done and thermal efficiency

```
clear;
clc;
disp('Example 15.15');

// aim : To determine
// (a) the net work done
// (b) the ideal thermal efficiency
// (c) the thermal efficiency if the process of generation is not included

// given values
P1 = 110;// initial pressure, [kN/m^2)
T1 = 273+30;// initial temperature, [K]
V1 = .05;// initial volume, [m^3]
```

```
V2 = .005;// volume, [m^3]
T3 = 273+700;// temperature, [m^3]
R = .289;// gas constant, [kJ/kg K]
cv = .718;// heat capacity, [kJ/kg K]

// solution
// (a)
m = P1*V1/(R*T1);// mass , [kg]
W = m*R*(T3-T1)*log(V1/V2);// work done, [kJ]
mprintf('\n (a) The net work done is = %f kJ\n',W);

// (b)
n_the = (T3-T1)/T3;// ideal thermal efficiency
mprintf('\n (b) The ideal thermal efficiency is = %f percent\n',n_the*100);

// (c)
V4 = V1;
V3 = V2;
T4 = T3;
T2 = T1;

Q_rej = m*cv*(T4-T1)+m*R*T1*log(V1/V2);// heat rejected
Q_rec = m*cv*(T3-T2)+m*R*T3*log(V4/V3);// heat received

n_th = (1-Q_rej/Q_rec);// thermal efficiency
mprintf('\n (c) the thermal efficiency if the process of regeneration is not included is = %f percent\n',n_th*100);

// End
```

Scilab code Exa 15.16 maximum temperature work done and thermal efficiency

```
clear;
clc;
disp('Example 15.16');

// aim : To determine
// (a) the maximum temperature
// (b) the net work done
// (c) the ideal thermal efficiency
// (d) the thermal efficiency if the process of regeneration is not included

// given values
P1 = 100;// initial pressure, [kN/m^2)
T1 = 273+20;// initial temperature, [K]
V1 = .08;// initial volume, [m^3]
rv = 5;// volume ratio
R = .287;// gas constant, [kJ/kg K]
cp = 1.006;// heat capacity, [kJ/kg K]
V3_by_V2 = 2;

// solution
// (a)
// using Fig.15.33
// process 1-2 is isothermal
T2 = T1;
// since process 2-3 isisobaric, so V/T=constant
T3 = T2*(V3_by_V2);// maximumtemperature, [K]
mprintf('\n (a) The maximum temperature is = %f C\n',T3-273);

// (b)
m = P1*V1/(R*T1);// mass , [kg]
W = m*R*(T3-T1)*log(rv);// work done, [kJ]
mprintf('\n (b) The net work done is = %f kJ\n',W);
```

```
// (c)
TE = (T3-T1)/T3;// ideal thermal efficiency
mprintf('\n (c) The ideal thermal efficiency is  =
    %f  percent\n',TE*100);

// (d)
T4 = T3;
T2 = T1;

Q_rej = m*cp*(T4-T1)+m*R*T1*log(rv);// heat rejected
Q_rec = m*cp*(T3-T2)+m*R*T3*log(rv);// heat received

n_th = (1-Q_rej/Q_rec);// thermal efficiency
mprintf('\n (d) the thermal efficiency if the
    process of regeneration is not included is  = %f
      percent\n',n_th*100);

//  End
```

Scilab code Exa 15.17 work done and thermal efficiency

```
clear;
clc;
disp('Example 15.17');

// aim : To determine
// (a) the net work done
// (b) thethermal efficiency

// given values
m = 1;// mass of air, [kg]
T1 = 273+230;// initial temperature, [K]
P1 = 3450;// initial pressure, [kN/m^2]
P2 = 2000;// pressure, [kN/m^2]
```

```
P3 = 140;// pressure, [kN/m^2]
P4 = P3;
Gama = 1.4; // heat capacity ratio
cp = 1.006;// heat capacity, [kJ/kg k]

// solution
T2 =T1;// isothermal process 1-2
// process 2-3 and 1-4 are adiabatic so
T3 = T2*(P3/P2)^((Gama-1)/Gama);// temperature, [K]
T4 = T1*(P4/P1)^((Gama-1)/Gama);// [K]
R = cp*(Gama-1)/Gama;// gas constant, [kJ/kg K]
Q1 = m*R*T1*log(P1/P2);// heat received, [kJ]
Q2 = m*cp*(T3-T4);// heat rejected

//hence
W = Q1-Q2;// work done
mprintf('\n (a) The net work done is = %f kJ\n',W);

// (b)
TE = 1-Q2/Q1;// thermal efficiency
mprintf('\n (b) The thermal efficiency is = %f percent\n',TE*100);

// End
```

Scilab code Exa 15.18 thermal efficiency and Carnot efficiency

```
clear;
clc;
disp('Example 15.18');

// aim : To determine
// thermal eficiency
// carnot efficiency
```

```
// given values
rv = 5;// volume ratio
Gama = 1.4;// heat capacity ratio

// solution
// under given condition

TE = 1-(1/Gama*(2-1/rv^(Gama-1)))/(1+2*((Gama-1)/Gama)*log(rv/2));// thermal efficiency
mprintf('\n The thermal efficiency is  =  %f percent \n',TE*100);

CE = 1-1/(2*rv^(Gama-1));// carnot efficiency
mprintf('\n The carnot efficiency is  =  %f \n',CE*100);

//  End
```

Chapter 16

Internal combustion engines

Scilab code Exa 16.1 power output thermal efficiency and work ratio

```
clear;
clc;
disp('Example 16.1');

// aim : To determine
// (a) the net power output of the turbine plant if
    the turbine is coupled to the compresser
// (b) the thermal efficiency of the plant
// (c) the work ratio

// Given values
P1 = 100;// inlet pressure of compressor, [kN/m^2]
T1 = 273+18;// inlet temperature, [K]
P2 = 8*P1;// outlet pressure of compressor, [kN/m^2]
n_com = .85;// isentropic efficiency of compressor
T3 = 273+1000;//inlet temperature of turbine, [K]
P3 = P2;// inlet pressure of turbine, [kN/m^2]
P4 = 100;// outlet pressure of turbine, [kN/m^2]
n_tur = .88;// isentropic efficiency of turbine
m_dot = 4.5;// air mass flow rate, [kg/s]
cp = 1.006;// [kJ/kg K]
```

```
Gamma = 1.4;// heat capacity ratio

// (a)
// For the compressor
T2_prime = T1*(P2/P1)^((Gamma-1)/Gamma);// [K]
T2 = T1+(T2_prime-T1)/n_com;//  exit pressure of
    compressor, [K]

// for turbine
T4_prime = T3*(P4/P3)^((Gamma-1)/Gamma);// [K]
T4 = T3-(T3-T4_prime)*n_tur;// exit temperature of
    turbine, [K]

P_output = m_dot*cp*((T3-T4)-(T2-T1));// [kW]
mprintf('\n (a) The net power output is  =  %f  kW\n
    ',P_output);

// (b)
n_the = ((T3-T4)-(T2-T1))/(T3-T2)*100;// thermal
    efficiency
mprintf('\n (b) The thermal efficiency of the plant
    is  =  %f percent\n',n_the);

// (c)
P_pos = m_dot*cp*(T3-T4);// Positive cycle work, [kW
    ]

W_ratio = P_output/P_pos;// work ratio
mprintf('\n (c) The work ratio is  =  %f\n',W_ratio)

//  End
```

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

```
clear;
clc;
disp('Example 16.2');

// aim : To determine
// (a) the pressure ratiowhich will give the maximum net work output
// (b) the maximum net specific work output
// (c) the thermal efficiency at maximum work output
// (d) the work ratio at maximum work output
// (e) the carnot efficiency within the cycle temperature limits

// Given values
// taking the refrence as Fig.16.35
T3 = 273+1080;// [K]
T1 = 273+10;// [K]
cp = 1.007;// [kJ/kg K]
Gamma = 1.41;// heat capacity ratio

// (a)
r_pmax = (T3/T1)^((Gamma)/(Gamma-1));// maximum pressure ratio
// for maximum net work output
r_p = sqrt(r_pmax);
mprintf('\n (a) The pressure ratio which give the maximum network output is = %f\n',r_p);

// (b)
T2 = T1*(r_p)^((Gamma-1)/Gamma);// [K]
// From equation [23]
T4 = T2;
W_max = cp*((T3-T4)-(T2-T1));// Maximum net specific work output, [kJ/kg]

mprintf('\n (b) The maximum net specific work output is = %f kJ/kg\n',W_max);

```

```
// (c)
W = cp*(T3-T2);
n_the = W_max/W;// thermal efficiency
mprintf('\n (c) The thermal efficiency at maximum
    work output is = %f percent\n ',n_the*100);

// (d)
// From the equation [26]
W_ratio = n_the;// Work ratio
mprintf('\n (d) The work ratio at maximum work
    output is = %f\n',W_ratio);

// (e)
n_carnot = (T3-T1)/T3*100;// carnot efficiency
mprintf('\n (e) The carnot efficiency within the
    cycle temperature limits is = %f percent\n',
    n_carnot);

// End
```

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

```
clc;
disp('Example 16.3');

// aim : To determine
// (a) the net power output of the plant
// (b) the exhaust temperature from the heat
    exchanger
// (c) the thermal efficiency of the plant
// (d) the thermal efficiency of the plant if there
    were no heat exchanger
// (e) the work ratio

```

```
// Given values
T1 = 273+15;// temperature, [K]
P1 = 101;// pressure, [kN/m^2]
P2 = 6*P1; // [kN/m^2]
eff = .65;// effectiveness of the heat exchanger,
T3 = 273+870;// temperature, [K]
P4 = 101;// [kN/m^2]
n_com = .85;// efficiency of compressor,
n_tur = .80;// efficiency of turbine
m_dot = 4;// mass flow rate, [kg/s]
Gama = 1.4;// heat capacity ratio
cp = 1.005;// [kJ/kg K]

// solution
// (a)
// For compressor
T2_prim = T1*(P2/P1)^((Gama-1)/Gama);// [K]

// using n_com = (T2_prim-T1)/(T2-T1)')

T2 = T1+(T2_prim-T1)/n_com
// For turbine
P3 = P2;
T4_prim = T3*(P4/P3)^((Gama-1)/Gama);// [K]

T4=T3-n_tur*(T3-T4_prim); // [K]
P_out = m_dot*cp*((T3-T4)-(T2-T1));// net power output, [kW]
mprintf('\n (a) The net power output of the plant is = %f kW\n',P_out);

// (b)
mtd = T4-T2;// maximum temperature drop for heat transfer, [K]
atd = eff*mtd;// actual temperature, [K]
et = T4-atd;// Exhaust temperature from heat exchanger, [K]
t6 = et-273;// [C]
```

```
mprintf('\n (b) The exhaust temperature from the
    heat exchanger is  =  %f C\n',t6);

// (c)
T5 = T2+atd;// [K]
n_the = ((T3-T4)-(T2-T1))/(T3-T5)*100;// thermal
    effficiency
mprintf('\n (c) The thermal efficiency of the plant
    is  =  %f percent\n',n_the);

// (d)
// with no heat exchanger
n_the = ((T3-T4)-(T2-T1))/(T3-T2)*100;// thermal
    efficiency without heat exchanger
mprintf('\n (d) The thermal efficiency of the plant
    if there wereno heat exchanger is  =  %f  percent
    \n',n_the);

// (e)
P_pos = m_dot*cp*(T3-T4);// positive cycle work;// [
    kW]
w_rat = P_out/P_pos;// work ratio
mprintf('\n (e) The work ratio is  =  %f\n',w_rat)

//  End
```

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

```
clear;
clc;
disp('Example 16.4');

// aim : To determine
// (a) the pressure and temperature as the air
```

```
leaves the compressor turbine
// (b) the power output from the free power turbine
// (c) the thermal efficiency of the plant
// (d) the work ratio
// (e) the carnot efficiency within the cycle temperature limits

// Given values
T1 = 273+19;// temperature , [K]
P1 = 100;// pressure , [kN/m^2]
P2 = 8*P1; // [kN/m^2]
P3 = P2;// [kN/m^2]
T3 = 273+980;// temperature , [K]
n_com = .85;// efficiency of rotary compressor
P5 = 100;// [kN/m^2]
n_cum = .88;// isentropic efficiency of combustion chamber compressor ,
n_tur = .86;// isentropic efficiency of turbine
m_dot = 7;// mass flow rate of air , [kg/s]
Gama = 1.4;// heat capacity ratio
cp = 1.006;// [kJ/kg K]

// solution
// (a)
// For compressor
T2_prim = T1*(P2/P1)^((Gama-1)/Gama);// [K]

T2 = T1+(T2_prim-T1)/n_com;// temperature , [K]

// for compressor turbine
// T3-T4 = T2-T1, because compressor turbine power= compressor power so
T4 = T3-(T2-T1);//turbine exit temperature , [K]
T4_prim = T3-(T3-T4)/n_cum;// [K]

// For turbine
// T4_prim = T3*(P4/P3)^((Gama-1)/Gama)
P4 = P3*(T4_prim/T3)^(Gama/(Gama-1));// exit air
```

```
pressure of air, [kN/m^2]

mprintf('\n (a) The temperature as the air leaves the compressor turbine is = %f C\n',T4-273);
mprintf('\n      The pressure as the air leaves the compressor turbine is = %f kN/m^2\n',P4);

// (b)
T5_prim = T4*(P5/P4)^((Gama-1)/Gama);// [K]


T5 = T4-n_tur*(T4-T5_prim);// temperature, [K]

PO = m_dot*cp*(T4-T5);// power output
mprintf('\n (b) The power output from the free power turbine is = %f kW\n',PO);

// (c)

n_the = (T4-T5)/(T3-T2)*100;// thermal effficiency
mprintf('\n (c) The thermal efficiency of the plant is = %f percent\n',n_the);

// (d)

WR = (T4-T5)/(T3-T5);// work ratio
mprintf('\n (d) The work ratio is = %f\n',WR);

// (e)
CE = (T3-T1)/T3;// carnot efficiency
mprintf('\n (e) The carnot efficiency is = %f percent\n',CE*100);

// End
```

Scilab code Exa 16.5 pressure temperature and power developed

```
clear;
clc;
disp('Example 16.5');

// aim : To determine
// (a) the pressure and temperature of the air compression
// (b) the power developed by the gas turbine
// (c) the temperature and pressure of the airentering the exhaust jet as it leaves the gas turbine

// Given values
T1 = 273-22.4;// temperature, [K]
P1 = 470;// pressure, [bar]
P2 = 30*P1; // [kN/m^2]
P3 = P2;// [kN/m^2]
T3 = 273+960;// temperature, [K]
r = 1.25;// ratio of turbine power to compressor power
n_tur = .86;// isentropic efficiency of turbine
m_dot = 80;// mass flow rate of air, [kg/s]
Gama = 1.41;// heat capacity ratio
cp = 1.05;// [kJ/kg K]

// solution
// (a)
// For compressor
T2_prim = T1*(P2/P1)^((Gama-1)/Gama);// [K]
// using n_tur=(T2_prim-T1)/(T2-T1)
T2 = T1+(T2_prim-T1)/n_tur;// temperature, [K]

mprintf('\n (a) The pressure of the air after compression is = %f bar\n',P2);

mprintf('\n       The temperature of the air after
```

```
    compression is  =  %f  C\n',T2-273);

// (b)
Td  = r*(T2-T1);// temperature drop in turbine, [K]
PO = m_dot*cp*Td;// power output, [kW]
mprintf('\n (b) The power developed by the gas
    turbine is  =  %f  MW\n',PO*10^-3);

// (c)
t3 = T3-273;// [C]
t4 = t3-Td;// temeprerature of air leaving turbine,[
    K]
Tdi = Td/n_tur;// isentropic temperature drop, [K]
T4_prim = t3-Tdi+273;// temperature, [K]
// using T4_prim=T3*(P4/P3)^((Gama-1)/Gama)
P4 = P3*(T4_prim/T3)^(Gama/(Gama-1));// exit air
    pressure of air, [kN/m^2]

mprintf('\n (c) The air pressure as it leaves the
    gas turbine is  =  %f  bar\n',P4);

// Result in the book is not matching because they
    have taken pressure in mbar  but in in question
    it is given in bar

//   End
```

Scilab code Exa 16.6 mass theoretical output and thermal efficiency

```
clc;
disp('Example 16.6');

// aim : To determine
// (a) the mass of fuel oil used by the gas turbine
// (b) the mass flow of steam from the boiler
```

```
// (c) the theoretical output from the steam turbine
// (d) the overall theoretical thermal efficiency of the plant

// given values
Po = 150;// generating plant output, [MW]
n_the1 = .35;// thermal efficiency
CV = 43;// calorific value of fuel, [MJ]
me = 400;// flow rate of exhaust gas, [kg/s]
T = 90;// boiler exit temperature, [C]
T1 = 550;// exhaust gas temperature, [C]
P2 = 10;// steam generation pressure, [MN/m^2]
T2 = 450;// boiler exit temperature, [C]
Tf = 140;// feed water temperature, [C]
n_tur = .86;// turbine efficiency
P3 = .5;// exhaust temperature, [MN/m^2]
n_boi = .92;// boiler thermal efficiency
cp = 1.1;// heat capacity, [kJ/kg]


// solution
// (a)
ER = Po*3600/n_the1;// energy requirement from the fuel, [MJ/h]
mf = ER/CV*10^-3;// fuel required, [tonne/h]
mprintf('\n (a) The mass of fuel oil used by the gas is = %f tonne/h\n',mf);

// (b)

ET = me*cp*(T1-T)*3600*n_boi;// energy transferred to steam,[kJ/h]
// from steam table
h1 = 3244;// specific enthalpy, [kJ/kg]
hf = 588.5;// specific enthalpy, [kJ/kg]
ERR = h1-hf;// energy required to raise steam, [kJ/kg]
ms = ET/ERR*10^-3;// mass flow of steam, [tonne/h]
```

```
mprintf('\n (b) The mass flow  rate of steam from the boiler is  =  %f  tonne/h\n',ms);

// again from steam table
s1 = 6.424;// specific entropy, [kJ/kg K]
sf2 = 1.86;// specific entropy, [kJ/kg K
sg2 = 6.819;// specific entropy, [kJ/kg K]

hf2 = 640.1;// specific enthalpy,[kJ/kg]
hg2 = 2747.5;// specific enthalpy, [kJ/kg]
// for ths process s1=s2=sf2+x2*(sg2-sf2)
s2 = s1;
// hence
x2 = (s2-sf2)/(sg2-sf2);// dryness fraction

h2_prim = hf2+x2*(hg2-hf2);// specific enthalpy of steam, [kJ/kg]

TO = n_tur*(h1-h2_prim);//theoretical steam turbine output, [kJ/kg]
TOt = TO*ms/3600;// total theoretical steam turbine output, [MW]

mprintf('\n (c) The theoretical output from the steam turbine is  =  %f  MW\n',TOt);

// (d)
n_tho = (Po+TOt)*n_the1/Po;// overall theoretical thermal efficiency
mprintf('\n (d) The overall thermal efficiency is  =  %f  percent\n',n_tho*100);

//  End
```

Chapter 17

Engine and plant trials

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

```
clear;
clc;
disp('Example 17.1');

// aim : To determine
// the indicated and brake output and the mechanicl
   efficiency
// draw up an overall energy balance and as % age

// given values
h = 21;// height of indicator diagram, [mm]
ic = 27;// indicator calibration, [kN/m^2 per mm]
sv = 14*10^-3;// swept volume of the cylinder;,[m^3]
N = 6.6;// speed of engine, [rev/s]
ebl = 77;// effective brake load, [kg]
ebr = .7;// effective brake radious, [m]
fc = .002;// fuel consumption, [kg/s]
CV = 44000;// calorific value of fuel, [kJ/kg]
cwc = .15;// cooling water circulation, [kg/s]
Ti = 38;// cooling water inlet temperature, [C]
```

```
To = 71;// cooling water outlet temperature, [C]
c = 4.18;// specific heat capacity of water, [kJ/kg]
eeg = 33.6;// energy to exhaust gases, [kJ/s]
g = 9.81;// gravitational acceleration, [m/s^2]

// solution
PM = ic*h;// mean effective pressure, [kN/m^2]
LA = sv;// swept volume of the cylinder, [m^3]
ip = PM*LA*N/2;// indicated power,[kW]
T = ebl*g*ebr;// torque, [N*m]
bp = 2*%pi*N*T;// brake power, [W]
n_mech = bp/ip*10^-3;// mechanical efficiency
mprintf('\n The Indicated power is = %f kW\n',ip);
mprintf('\n The Brake power is = %f kW\n',bp
   *10^-3);
mprintf('\n The mechanical efficiency is = %f
   percent\n',n_mech);

ef = CV*fc;// energy from fuel, [kJ/s]
eb = bp*10^-3;// energy to brake power,[kJ/s]
ec = cwc*c*(To-Ti);// energy to coolant,[kJ/s]
es = ef-(eb+ec+eeg);// energy to surrounding,[kJ/s]

disp('Energy can be tabulated as :-');
disp('
   ------------------------------------------------------------------------------------------
   ');
disp('

   kJ/s                                  Percentage    ')
disp('
   ------------------------------------------------------------------------------------------
   ');
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 suroundings,etc
    .          %f                    %f\n',ef,ef/ef
    *100,eb,eb/ef*100,ec,ec/ef*100,eeg,eeg/ef*100,es,
    es/ef*100);

//  End
```

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

```
clear;
clc;
disp('Example 17.2');

// aim : To determine
// (a) bp
// (b) ip
// (c) mechanical efficiency
// (d) indicated thermal efficiency
// (e) brake specific steam consumption
// (f) draw up complete energy account for the test
    one-minute basis taking 0 C as datum

// given values
d = 200*10^-3;// cylinder diameter, [mm]
L = 250*10^-3;// stroke, [mm]
N = 5;// speed, [rev/s]
r = .75/2;// effective radious of brake wheel, [m]
Ps = 800;// stop valve pressure, [kN/m^2]
x = .97;// dryness fraction of steam
BL = 136;// brake load, [kg]
SL = 90;// spring balance load, [N]
PM = 232;// mean effective pressure, [kN/m^2]
Pc = 10;// condenser pressure, [kN/m^2]
```

```
m_dot = 3.36;// steam consumption, [kg/min]
CC = 113;// condenser cooling water, [kg/min]
Tr = 11;// temperature rise of condenser cooling water, [K]
Tc = 38;// condensate temperature, [C]
C = 4.18;// heat capacity of water, [kJ/kg K]
g = 9.81;// gravitational acceleration, [m/s^2]

// solution
// from steam table
// at 800 kN/m^2
tf1 = 170.4;// saturation temperature, [C]
hf1 = 720.9;// [kJ/kg]
hfg1 = 2046.5;// [kJ/kg]
hg1 = 2767.5;// [kJ/kg]
vg1 = .2403;// [m^3/kg]

// at 10 kN/m^2
tf2 = 45.8;// saturation temperature, [C]
hf2 = 191.8;// [kJ/kg]
hfg2 = 2392.9;// [kJ/kg]
hg2 = 2584.8;// [kJ/kg]
vg2 = 14.67;// [m^3/kg]

// (a)
T = (BL*g-SL)*r;// torque, [Nm]
bp = 2*%pi*N*T*10^-3;// brake power,[W]
mprintf('\n (a) The brake power is =  %f kW\n',bp);

// (b)
A = %pi*d^2/4;// area, [m^2]
ip = PM*L*A*N*2;// double-acting so*2, [kW]
mprintf('\n (b) The indicated power is = %f kW\n',ip);

// (c)
n_mec = bp/ip;// mechanical efficiency
```

```
mprintf('\n (c) The mechanical efficiency is = %f percent\n',n_mec*100);

// (d)
h = hf1+x*hfg1;// [kJ/kg]
hf = hf2;
ITE = ip/((m_dot/60)*(h-hf));// indicated thermal efficiency
mprintf('\n (d) The indicated thermal efficiency is = %f percent\n',ITE*100);
// (e)
Bsc=m_dot*60/bp;// brake specific steam consumption, [kg/kWh]
mprintf('\n (e) The brake steam consumption is = %f kg/kWh\n',Bsc);

// (f)
// energy balanvce reckoned from 0 C
Es = m_dot*h;// energy supplied, [kJ]
Eb = bp*60;// energy to bp, [kJ]
Ecc = CC*C*Tr;// energy to condensate cooling water, [kJ]
Ec = m_dot*C*Tc;// energy to condensate, [kJ]
Ese = Es-Eb-Ecc-Ec;// energy to surrounding,etc, [kJ]

mprintf('\n (f) Energy supplied/min is = %f kJ\n',Es);

mprintf('\n     Energy to bp/min is = %f kJ\n',Eb);
mprintf('\n     Energy to condenser cooling water/min is = %f kJ\n',Ecc);
mprintf('\n     Energy to condensate/min is = %f kJ\n',Ec);
mprintf('\n     Energy to surrounding, etc/min is = %f kJ\n',Ese);

```

```
// answer in the book is misprinted

//  End
```

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

```
clear;
clc;
disp('Example 17.3');

// aim : To determine
// (a) the brake power
// (b) the brake specific fuel consumption
// (c) the indicated thermal efficiency
// (d) the energy balance, expressing the various
   items

// given values
t = 30;// duration of trial, [min]
N = 1750;// speed of engine, [rev/min]
T = 330;// brake torque, [Nm]
mf = 9.35;// fuel consumption, [kg]
CV = 42300;// calorific value of fuel, [kJ/kg]
cwc = 483;// jacket cooling water circulation, [kg]
Ti = 17;// inlet temperature, [C]
To = 77;// outlet  temperature, [C]
ma = 182;// air consumption, [kg]
Te = 486;// exhaust temperature, [C]
Ta = 17;// atmospheric temperature, [C]
n_mec = .83;// mechanical efficiency
c = 1.25;// mean specific heat capacity of exhaust
   gas, [kJ/kg K]
C = 4.18;// specific heat capacity, [kJ/kg K]

```

```
// solution
// (a)
bp = 2*%pi*N*T/60*10^-3;// brake power, [kW]
mprintf('\n (a) The Brake power is = %f kW\n',bp);

// (b)
bsf = mf*2/bp;//brake specific fuel consumption, [kg/kWh]
mprintf('\n (b) The brake specific fuel consumption is = %f kg/kWh\n',bsf);

// (c)
ip = bp/n_mec;// indicated power, [kW]
ITE = ip/(2*mf*CV/3600);// indicated thermal efficiency
mprintf('\n (c) The indicated thermal efficiency is = %f percent\n',ITE*100);

// (d)
// taking basis one minute
ef = CV*mf/30;// energy from fuel, [kJ]
eb = bp*60;// energy to brake power,[kJ]
ec = cwc/30*C*(To-Ti);// energy to cooling water,[kJ]
ee = (ma+mf)/30*c*(Te-Ta);// energy to exhaust, [kJ]
es = ef-(eb+ec+ee);// energy to surrounding,etc,[kJ]

mprintf('\n (d) Energy from fuel is = %f kJ\n',ef);
mprintf('\n     Energy to brake power is = %f kJ\n',eb);
mprintf('\n     Energy to cooling water is = %f kJ\n',ec);
mprintf('\n     Energy to exhaust is = %f kJ\n',ee);
mprintf('\n     Energy to surrounding, etc is = %f kJ\n',es);
```

```
//  End
```

Scilab code Exa 17.4 indicated power and mechanical efficiency

```
clear;
clc;
disp('Example 17.4');

// aim : To determine
// (a) the indicated power of the engine
// (b) the mechanical efficiency of the engine

// given values
bp = 52;// brake power output, [kW]
bp1 = 40.5;// brake power of cylinder cut1, [kW]
bp2 = 40.2;// brake power of cylinder cut2, [kW]
bp3 = 40.1;// brake power of cylinder cut3, [kW]
bp4 = 40.6;// brake power of cylinder cut4, [kW]
bp5 = 40.7;// brake power of cylinder cut5, [kW]
bp6 = 40.0;// brake power of cylinder cut6, [kW]

// sollution
ip1 = bp-bp1;// indicated power of cylinder cut1, [
   kW]
ip2 = bp-bp2;// indicated power of cylinder cut2, [
   kW]
ip3 = bp-bp3;// indicated power of cylinder cut3, [
   kW]
ip4 = bp-bp4;// indicated power of cylinder cut4, [
   kW]
ip5 = bp-bp5;// indicated power of cylinder cut5, [
   kW]
ip6 = bp-bp6;// indicated power of cylinder cut6, [
   kW]
```

```
ip = ip1+ip2+ip3+ip4+ip5+ip6;// indicated power of
    engine ,[kW]
mprintf('\n (a) The indicated power of the engine is
      =  %f  kW\n',ip);

// (b)
n_mec = bp/ip;// mechanical efficiency
mprintf('\n (b) The mechanical  efficiency of the
    engine is  =  %f percent\n',n_mec*100);

// End
```

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

```
clear;
clc;
disp('Example 17.5');

// aim : To determine
// the brake power,indicated power and mechanicl
    efficiency
// draw up an energy balance and as % age of the
    energy supplied

// given values
N = 50;// speed,  [rev/s]
BL = 267;// break load.,[N]
BL1 = 178;// break load of cylinder cut1,  [N]
BL2 = 187;// break load of cylinder cut2,  [N]
BL3 = 182;// break load of cylinder cut3,  [N]
BL4 = 182;// break load of cylinder cut4,  [N]

FC = .568/130;// fuel consumption,  [L/s]
```

```
s = .72;// specific gravity of fuel
CV = 43000;// calorific value of fuel, [kJ/kg]

Te = 760;// exhaust temperature, [C]
c = 1.015;// specific heat capacity of exhaust gas, [kJ/kg K]
Ti = 18;// cooling water inlet temperature, [C]
To = 56;// cooling water outlet temperature, [C]
mw = .28;// cooling water flow rate, [kg/s]
Ta = 21;// ambient tempearture, [C]
C = 4.18;// specific heat capacity of cooling water, [kJ/kg K]

// solution
bp = BL*N/455;// brake power of engine, [kW]
bp1 = BL1*N/455;// brake power of cylinder cut1, [kW]
i1 = bp-bp1;// indicated power of cylinder cut1, [kW]
bp2 = BL2*N/455;// brake power of cylinder cut2, [kW]
i2 = bp-bp2;// indicated power of cylinder cut2, [kW]
bp3 = BL3*N/455;// brake power of cylinder cut3, [kW]
i3 = bp-bp3;// indicated power of cylinder cut3, [kW]
bp4 = BL4*N/455;// brake power of cylinder cut4, [kW]
i4 = bp-bp4;// indicated power of cylinder cut4, [kW]

ip = i1+i2+i3+i4;// indicated power of engine, [kW]
n_mec = bp/ip;// mechanical efficiency

mprintf('\n The Brake power is  =  %f kW\n',bp);
mprintf('\n The Indicated power is  =  %f kW\n',ip);
mprintf('\n The mechanical efficiency is  =  %f
```

```
percent\n',n_mec*100);

mf = FC*s;// mass of fuel/s, [kg]
ef = CV*mf;// energy from fuel/s, [kJ]
me = 15*mf;// mass of exhaust/s,[kg],(given in condition)
ee = me*c*(Te-Ta);// energy to exhaust/s,[kJ]
ec = mw*C*(To-Ti);// energy to cooling water/s,[kJ]
es = ef-(ee+ec+bp);// energy to surrounding,etc/s,[kJ]

disp('Energy can be tabulated as :-');
disp('---------------------------------------------------------------------------------');
disp('                                        kJ/s                    Percentage    ')
disp('---------------------------------------------------------------------------------');
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 suroundings,etc.              %f                  %f\n',ef,ef/ef*100,bp,bp/ef*100,ee,ee/ef*100,ec,ec/ef*100,es,es/ef*100);

// there is minor variation in the result reported in the book
//  End
```

Scilab code Exa 17.6 brake power fuel consumption and thermal efficiency

```
clear;
clc;
disp('Example 17.6');

// aim : To determine
// (a) the break power of engine
// (b) the fuel consumption of the engine
// (c) the brake thermal efficiency of the engine

// given values
d = 850*10^-3;// bore , [m]
L = 2200*10^-3;// stroke, [m]
PMb = 15;// BMEP of cylinder, [bar]
N = 95/60;// speed of engine, [rev/s]
sfc = .2;// specific fuel oil consumption, [kg/kWh]
CV = 43000;// calorific value of the fuel oil, [kJ/
    kg]

// solution
// (a)
A = %pi*d^2/4;// area, [m^2]
bp = PMb*L*A*N*8/10;// brake power,[MW]
mprintf('\n (a) The brake power is = %f MW\n',bp)
    ;

 // (b)
 FC = bp*sfc;// fuel consumption, [kg/h]
 mprintf('\n (b) The fuel consumption is = %f
    tonne/h\n',FC);

 // (c)
 mf = FC/3600;// fuel used, [kg/s]
```

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

// End
```

Chapter 18

Refrigeration

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

```
clear;
clc;
disp('Example 18.1');

// aim : To determine
// (a) the coefficient of performance
// (b) the mass flow of the refrigerant
// (c) the cooling water required by the condenser

// given values
P1 = 462.47;// pressure limit, [kN/m^2]
P3 = 1785.90;// pressure limit, [kN/m^2]
T2 = 273+59;// entering saturation temperature, [K]
T5 = 273+32;// exit temperature of condenser, [K]
d = 75*10^-3;// bore, [m]
L = d;// stroke, [m]
N = 8;// engine speed, [rev/s]
VE = .8;// olumetric efficiency
cpL = 1.32;// heat capacity of liquid, [kJ/kg K]
c = 4.187;// heat capacity of water, [kj/kg K]
```

```
// solution
// from given table
// at P1
h1 = 231.4;// specific enthalpy, [kJ/kg]
s1 = .8614;// specific entropy,[ kJ/kg K
v1 = .04573;// specific volume, [m^3/kg]

// at P3
h3 = 246.4;// specific enthalpy, [kJ/kg]
s3 = .8093;// specific entropy,[ kJ/kg K
v3 = .04573;// specific volume, [m^3/kg]
T3= 273+40;// saturation temperature, [K]
h4 = 99.27;// specific enthalpy, [kJ/kg]
// (a)
s2 = s1;// specific entropy, [kJ/kg k]
// using s2=s3+cpv*log(T2/T3)
cpv = (s2-s3)/log(T2/T3);// heat capacity, [kj/kg k]

// from Fig.18.8
T4 = T3;
h2 = h3+cpv*(T2-T3);// specific enthalpy, [kJ/kg]
h5 = h4-cpL*(T4-T5);// specific enthalpy, [kJ/kg]
h6 = h5;
COP = (h1-h6)/(h2-h1);// coefficient of performance
mprintf('\n (a) The coefficient of performance of the refrigerator is = %f\n',COP);

// (b)
SV = %pi/4*d^2*L;// swept volume of compressor/rev, [m^3]
ESV = SV*VE*N*3600;// effective swept volume/h, [m^3]
m = ESV/v1;// mass flow of refrigerant/h,[kg]
mprintf('\n (b) The mass flow of refrigerant/h is = %f kg\n',m);

// (c)
```

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

//  End
```

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

```
clear;
clc;
disp('Example 18.2');

// aim : To determine
// (a) the mass flow of R401
// (b) the dryness fraction of  R401 at the entry to
     the evaporator
// (c) the power of driving motor
// (d) the ratio of heat transferred from condenser
    to the power required to the motor

// given values
P1 = 411.2;// pressure limit , [kN/m^2]
P3 = 1118.9;// pressure limit , [kN/m^2]
Q = 100*10^3;// heat transfer from the condenser ,[kJ
    /h]
T2 = 273+60;// entering saturation temperature , [K]

// given
// from given table
// at P1
```

```
h1 = 409.3;// specific enthalpy, [kJ/kg]
s1 = 1.7431;// specific entropy,[ kJ/kg K

// at P3
h3 = 426.4;// specific enthalpy, [kJ/kg]
s3 = 1.7192;// specific entropy,[ kJ/kg K
T3 = 273+50;// saturation temperature, [K]
h4 = 265.5;// specific enthalpy, [kJ/kg]
// (a)
s2 = s1;// specific entropy, [kJ/kg k]
// using s2=s3+cpv*log(T2/T3)
cpv = (s2-s3)/log(T2/T3);// heat capacity, [kj/kg k]

// from Fig.18.8
h2 = h3+cpv*(T2-T3);// specific enthalpy, [kJ/kg]
Qc = h2-h4;// heat transfer from condenser, [kJ/kg]
mR401 = Q/Qc;// mass flow of R401, [kg]
 mprintf('\n (a) The mass flow of R401 is = %f kg/h\n',mR401);

// (b)
hf1 = 219;// specific enthalpy, [kJ/kg]
h5 = h4;
// using h5=hf1+s5*(h1-hf1),so
x5 = (h5-hf1)/(h1-hf1);// dryness fraction
mprintf('\n (b) The dryness fraction of R401 at the entry to the evaporator is = %f\n',x5);

// (c)
P = mR401*(h2-h1)/3600/.7;// power to driving motor, [kW]
 mprintf('\n (c) The power to driving motor is = %f kW\n',P);

// (d)
r = Q/3600/P;// ratio
mprintf('\n (d) The ratio of heat transferred from condenser to the power required to the motor is
```

```
    = %f : 1\n',r);

// End
```

Chapter 19

Psychrometry

Scilab code Exa 19.1 moisture content

```
clear;
clc;
disp('Example 19.1');

// aim : To compare the moisture content and the
    true specific volumes of  atmosphere air
// (a) temperature is 12 C and the air is saturaded
// (b) temperature is 31 C and air is .75 saturated

// Given values
P_atm = 101.4;// atmospheric pressure, [kN/m^2]
R = .287;// [kJ/kg K]

// solution
// (a)
T = 273+12;// air temperature, [K]
// From steam table at 12 C
p = 1.4;// [kN/m^2]
vg = 93.9;// [m^3/kg]
pa = P_atm-p;// partial pressure of the dry air, [kN
    /m^2]
```

```
va = R*T/pa;// [m^3/kg]

mw = va/vg;// mass of water vapor in the air,[kg]
v = va/(1+mw);// specific volume of humid air, [m^3/kg]

mprintf('\n (a) The mass of water vapor in the humid air is = %f kg\n',mw);
mprintf('\n     The specific volume of humid air is = %f m^3/kg\n',v);

// (b)
x = .75;// dryness fraction
T = 273+31;// air temperature, [K]
// From steam table
p = 4.5;// [kN/m^2]
vg = 31.1;// [m^3/kg]
pa = P_atm-p;// [kN/m^2]
va = R*T/pa;// [m^3/kg]
mw1= va/vg;// mass of water vapor in the air, [kg]
mw_actual = mw1*x;// actual mass of vapor, [kg]
v = va/(1+mw_actual);// true specific volume of humid air,[m^3/kg]

mprintf('\n (b) The mass of water vapor in the humid air is = %f kg\n',mw1);
mprintf('\n    The specific volume of humid air is = %f m^3/kg\n',v);

ewv = mw_actual/mw ;
mprintf('\n On the warm day the air conteains %f times the mass of water vapor as on the cool day\n',ewv);

// End
```

Scilab code Exa 19.2 partial pressures specific humidity and composition

```
clear;
clc;
disp('Example 19.2');

// aim : To determine
// (a) the partial pressures of the vapor and the dry air
// (b) the specific humidity of the mixture
// (c) the composition of the mixture

//  Given values
phi = .65;// Relative humidity
T = 2733+20;// temperature, [K]
p = 100;// barometric pressure, [kN/m^2]

// solution
// (a)
//  From the steam table at 20 C
pg = 2.34;// [kN/m^2]
ps = phi*pg;// partial pressure of vapor, [kN/m^2]
pa = p-ps;// partial pressure of dry air, [kN/m^2]
mprintf('\n (a) The partial pressure of vapor is  = %f  kN/m^2\n',ps);
mprintf('\n     The partial pressure of dry air is = %f kN/m^2\n',pa);

// (b)
// from equation [15]
omega = .622*ps/(p-ps);// specific humidity of the mixture
mprintf('\n (b) The specific humidity of the mixture is  = %f kg/kg dry air\n',omega);
```

```
// (c)
// using eqn [1] from section 19.2
y = 1/(1+omega);// composition of the mixture
mprintf('\n (c) The composition of the mixture is = %f\n',y);

// End
```

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

```
clear;
clc;
disp('Example 19.3');

// aim : To determine
// (a) the specific humidity
// (b) the dew point
// (c) the degree of superheat of the superheated vapor
// (d) the mass of condensate formed per kg of dry air if the moist air is cooled to 12 C

// Given values
t = 25;// C
T = 273+25;// moist air temperature, [K]
phi = .6;// relative humidity
p = 101.3;// barometric pressure, [kN/m^2]
R = .287;// [kJ/kg K]

// solution
// (a)
// From steam table at 25 C
pg = 3.17;// [kN/m^2]
```

```
ps = phi*pg;// partial pressure of the vapor, [kN/m^2]
omega = .622*ps/(p-ps);// the specific humidity of air

mprintf('\n (a) The specific humidity is = %f kg/kg air\n',omega);

// (b)
// Dew point is saturated temperature at ps is,
t_dew = 16+2*(1.092-1.817)/(2.062-1.817);// [C]
mprintf('\n (b) The dew point is = %f C\n',t_dew);

// (c)
Dos = t-t_dew;// degree of superheat, [C]
mprintf('\n (c) The degree of superheat is = %f C\n',Dos);

// (d)
// at 25 C
pa = p-ps;// [kN/m^2]
va = R*T/pa;// [m^3/kg]
// at 16.69 C
vg = 73.4-(73.4-65.1)*.69/2;// [m^3/kg]
ms1= va/vg;
// at 12 C
vg = 93.8;// [m^3/kg]
ms2 = va/vg;

m = ms1-ms2;// mas of condensate
mprintf('\n (d) The mass of condensate is = %f kg/kg dry air\n',m);

// there is calculation mistake in the book so answer is no matching

// End
```

Scilab code Exa 19.4 volume mass and heat transfer

```
clear;
clc;
disp('Example 19.4');

// aim : To determine
// (a) the volume of external saturated air
// (b) the mass of air
// (c) the heat transfer
// (d) the heat transfer required by the combind water vapour

// given values
Vb = 56000;// volume of building, [m^3]
T2 = 273+20;// temperature of air in thebuilding, [K]
phi = .6;// relative humidity
T1 = 8+273;// external air saturated temperature, [K]
p0 = 101.3;// atmospheric pressure, [kN/m^2]
cp = 2.093;// heat capacity of saturated steam, [kJ/kg K]
R = .287;// gas constant, [kJ/kg K]

// solution
// from steam table at 20 C saturation pressure of steam is,
pg = 2.34;// [kN/m^2]

// (a)
pvap = phi*pg;// partial pressure of vapor, [kN/m^2]
P = p0-pvap;// partial pressure of air, [kN/m^2]
V = 2*Vb;// air required, [m^3]
```

```
// at 8 C saturation pressure ia
pvap = 1.072;// [kN/m^2]
P2 = p0-pvap;// partial pressure of entry at 8 C, [kN/m^2]

// using P1*V1/T1=P2*V2/T2;
V2 = P*V*T1/(T2*P2);// air required at 8 C, [m^3/h]
mprintf('\n (a) The volume of air required is = %f m^3/h\n',V2);

// (b)
// assuming
pg = 1.401;// pressure , [kN/m^2]
Tg = 273+12;// [K]
vg = 93.8;// [m^3/kg]
// at constant pressure
v = vg*T2/Tg;// volume[m^3/kg]
mv = V/v;// mass of vapor in building at 20 C, [kg/h]
// from steam table at 8 C
vg2 = 121;// [m^3/kg]
mve = V2/vg2;// mass of vapor supplied with saturated entry air , [kg/h]
mw = mv-mve;// mass of water added , [kg/h]
mprintf('\n (b) The mass of water added is = %f kg/h\n ',mw);

// (c)
// for perfect gas
m = P2*V2/(R*T1);// [kg/h]
Cp = .287;// heat capacity , [kJ/kg K]
Q = m*Cp*(T2-T1);// heat transfer by dry air ,[kJ/h]
mprintf('\n (c) The heat transfer required by dry air is = %f MJ/h\n',Q*10^-3);

// (d)
// from steam table
h1 = 2516.2;// specific enthalpy of saturated vapor
```

```
at 8 C,[kJ/kg]
hs = 2523.6;// specific enthalpy of saturated vapor at 20 C, [kJ/kg]
h2 = hs+cp*(T2-T1);// specific enthalpy of vapor at 20 c, [kJ/kg]
Q1 = mve*(h2-h1);// heat transfer required for vapor , [kJ]

// again from steam table
hf1 = 33.6;// [kJ/kg]
hg3 = 2538.2;// [kJ/kg]
Q2 = mw*(hg3-hf1);// heat transfer required for water, [kJ/h]
Qt = Q1+Q2;// total heat transfer, [kJ/h]
mprintf('\n (d) The heat transferred required for vapor+supply water is = %f MJ/h\n',Qt*10^-3);

// there is minor variation in the answer reported in the book

// End
```