Scilab Textbook Companion for Thermodynamics Demystified by M. C. Potter[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

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Chapter 1

Basic Principles

Scilab code Exa 1.2 kinetic energy

```
1 clc
2 // solution
3
4 // initialization of variables
5 m=10 // mass in Kg
6 V=5 // velocity in m/s
7
8 KE=m*V**2/2 // kinetic energy in N-m
9 printf("The Kinetic Energy is "+string(KE)+" N.m")
```

Scilab code Exa 1.3 density and specific volume is asked

```
1 clc
2 // solution
3
4 // initialization of variables
5 V=3*5*20 // Volume of air in m^3 from dimensions
6 m=350 // mass in kg
```

```
7  g=9.81 // gavitational acceleration in m/s^2
8  rho=m/V // density
9  printf("The Density is %.3f kg/m^3 \n",rho)
10
11 v=1/rho // specific volume of air
12 printf(" The specific volume  is %.3f m^3/kg \n",v)
13
14 gama=rho*g // specific weight of air
15 printf(" The specific weight is %.2f N/m^3",gama)
```

Scilab code Exa 1.4 absolute pressure

```
1  clc
2  // solution
3
4  // initialization of variables
5  h=0.020 // height of mercury in m
6  gammawater=9810 // specific weight of water in N/m^3
7  Patm=0.7846*101.3 // atmospheric pressure in kPa
       from table B.1
8
9  Pgauge=13.6*gammawater*h/1000 // pressure in Pascal
       from condition gammaHg=13.6*gammawater
10
11 P=(Pgauge+Patm)// absolute pressure in KPa
12 printf("The Pressure is %.2f kPa",P)
```

Scilab code Exa 1.5 Compression in spring

```
1  clc
2  // solution
3
4  // initialization of variables
```

```
5  d=10/100 // diameter of cylinder in 'm'
6  P=600 // pressure in KPa
7  Patm=100 // atmospheric pressure in Kpa
8  K=4.8*1000 // spring constant in N/m
9
10 deltax=(P-Patm)*(%pi*1000*d**2)/(4*K) // by
       balancing forces on piston
11 printf("The Compression in spring is %.3f m",deltax)
```

Scilab code Exa 1.6 increase in kinetic energy

```
1  clc
2  // solution
3
4  // initialization of variables
5  ma=2200 // mass of Automobile 'a' in kg
6  va=25 //velocity of Automobile 'a' in m/s before
       collision
7  va1=13.89 // velocity of Automobile 'a' after
       collision in m/s
8  mb=1000 // mass of Automobile 'b' in kg
9  vb=24.44 //velocity of Automobile 'b' after
       collision in m/s
10
11 KE1=(ma*va**2)/2 // kinetic energy before collision
12 KE2=(ma*va1**2)/2+(mb*vb**2)/2 // kinetic energy
       after collision
13 U=(KE1-KE2)/1000 // internal energy from
       conservation of energy principle in kJ
14 printf("The increase in kinetic energy is of %.1f kJ
       ",U)
```

Chapter 2

Properties of Pure Substances

Scilab code Exa 2.1 saturated water is vaporized

```
1  clc
2  //solution
3  //    initialization of variables
4  m=10;   // mass of saturated water in kg
5   // All the necessary values are taken from table C
       .2
6   // part (a)
7
8  P=0.001; // Pressure in MPa
9  vf=0.001; // specific volume of saturated liquid at
      0.001 Mpa in Kg/m^3
10 vg=129.2;// specific volume of saturated vapour at
      0.001 Mpa in Kg/m^3
11 deltaV=m*(vg-vf)//properties of pure substance
12 printf("The Volume change at pressure "+string(P)+"
      MPa is %.0f m^3 \n",deltaV)
13
14 // part (b)
15 P=0.26;   // Pressure in MPa
16 vf=0.0011; //   specific volume of saturated liquid
      at 0.26 MPa( it is same from at 0.2 and 0.3 MPa
```

```
     upto 4 decimals )
17 vg=(P-0.2)*(0.6058-0.8857)/(0.3-0.2)+0.8857;  //
      specific volume of saturated vapour by
      interpolation of Values at 0.2 MPa and 0.3 MPa
18 deltaV=m*(vg-vf)
19 printf(" The Volume change at pressure "+string(P)+"
      MPa is %.2f m^3 \n",deltaV)
20
21 // part (c)
22 P=10;  // Pressure in MPa
23 vf=0.00145;  // specific volume of saturated liquid
      at 10 MPa
24 vg=0.01803; //specific volume of saturated vapour at
       10 MPa
25 deltaV=m*(vg-vf)
26 printf(" The Volume change at pressure "+string(P)+"
      MPa is %.4f m^3",deltaV)
```

Scilab code Exa 2.2 volume of vapour

```
 1 clc
 2 //solution
 3 //    initialization of variables
 4 m=4// mass of water in kg
 5 V=1 // volume in m^3
 6 T=150 // temperature of water in degree centigrade
 7
 8 // TABLE C.1 is used for values in wet region
 9 // Part (a)
10 P=475.8// pressure in KPa in wet region at
      temperature of 150 *C
11 printf("The pressure is %.1f kPa \n",P)
12
13 // Part (b)
14 // first we determine the dryness fraction
```

```
15  v=V/m// specific volume of water
16  vg=0.3928 // specific volume of saturated vapour
        @150 degree celsius
17  vf=0.00109 // specific volume of saturated liquid
        @150 degree celsius
18  x=(v-vf)/(vg-vf); //dryness fraction
19  mg=m*x; // mass of vapour
20  printf(" The mass of vapour present is %.3f kg \n",
        mg)
21
22  // Part(c)
23  Vg=mg*vg;// volume of vapour
24  printf(" The volume of vapour is %.3f m^3",Vg)
```

Scilab code Exa 2.3 the final volume of mixture

```
1  clc
2  //solution
3  //    initialization of variables
4  m=2 // mass of water in kg
5  P=220 // pressure in KPa
6  x=0.8 // quality of steam
7  // Table C.2 is used for values
8  vg=(P-200)*(0.6058-0.8857)/(300-200)+0.8857 //
        specific volume of saturated vapour @ given
        pressure by interpolating
9  vf=0.0011 // specific volume of saturated liquid @
        220 KPa
10  v=vf+x*(vg-vf)// property of pure substance
11  V=m*v // total volume
12  printf("The Total volume of the mixture is "+string(
        V)+" m^3")
```

Scilab code Exa 2.4 constant pressure cylinder

```
1  clc
2  //solution
3  //    initialization of variables
4  m=2 // mass of water in kg
5  P=2.2 // pressure in Mpa
6  T=800 // temperature in degree centigrade
7   // Table C.3 is used for values
8  v=0.2467+(P-2)*(0.1972-0.2467)/(2.5-2)// specific
       volue by interpolatin between 2 and 2.5 MPa
9  V=m*v // final volume
10 printf("The Final Volume is %.3f m^3",V)
```

Scilab code Exa 2.5 mass of air in the tire

```
1  clc
2  //solution
3  //    initialization of variables
4  V=0.6 // volume of tyre in m^3
5  Pgauge=200 // gauge pressure in KPa
6  T=20+273 // temperature converted to kelvin
7  Patm=100 // atmospheric pressure in KPa
8  R=287 // gas constant in Nm/kg.K
9  Pabs=(Pgauge+Patm)*1000 // calculating absolute
       pressue in Pa
10
11 m=Pabs*V/(R*T)// mass from ideal gas equation
12 printf("The Mass of air is %.2f Kg",m)
```

Scilab code Exa 2.6 the van der Waals equation

```
1  clc
```

```
2  //solution
3  //    initialization of variables
4  T=500+273 // temperature of steam in kelvin
5  rho=24 // density in Kg/m^3
6  R=0.462 // gas constant from Table B.2
7  v=1/rho // specific volume and density relation
8  // PART (a)
9  P=rho*R*T // from Ideal gas equation
10 printf("PART (a) The Pressure is "+string(P)+" KPa \
       n")
11 // answer is approximated in textbook
12
13 // PART (b)
14 a=1.703 //  van der Waal's constant a value from
       Table B.7
15 b=0.00169 // van der Waal's constant b value from
       Table B.7
16 P=(R*T/(v-b))-(a/v**2) // Pressure from van der Waal
       's equation
17 printf(" PART (b) The Pressure is "+string(P)+" KPa
       \n")
18 // answer is approximated in textbook
19
20 // PART (c)
21 a=43.9 //  van der Waal's constant a value from
       Table B.7
22 b=0.00117 // van der Waal's constant b value from
       Table B.7
23
24 P=(R*T/(v-b))-(a/(v*(v+b)*sqrt(T)))// Redlich-Kwong
       equation
25 printf(" PART (c) The Pressure is "+string(P)+" KPa
       \n")
26 // answer is approximated in textbook
27
28 // PART (d)
29 Tcr=947.4 // compressibilty temperature from table B
       .3
```

```
30  Pcr=22100 // compressibility pressure from table B.3
31
32  TR=T/Tcr // reduced temperature
33  PR=P/Pcr // reduced pressure
34  Z=0.93 // from compressiblility chart
35  P=Z*R*T/v // Pressure in KPa
36  printf(" PART (d) The Pressure is "+string(P)+" KPa
        \n")
37  // answer is approximated in textbook
38
39  // PART (e)
40  P=8000 // pressure from steam table @ 500*c and v=
        0.0417 m^3
41  printf(" PART (e) The Pressure is "+string(P)+" KPa
        \n")
42  // answer is approximated in textbook
```

Chapter 3

Heat and Work

Scilab code Exa 3.1 constant pressure work done

```
1  clc
2  //solution
3  //initialization of variables
4  m=1                    //  mass  in  kg
5  x=20/100          //quality  of  steam
6  P=200           //constant  pressure  in  kPa
7  T1=100            //temperature  intitial  in  degree
       centigrade
8  T2=400            //temperature  final  in  degree
       centigrade
9
10 //  first  we  find  initial  volume  v1  and  final  volume
       v2
11
12 //  using  table  C.2
13 vf=0.001061 //  specific  volume  of  saturated  liquid
       in  m^3  per  kg
14 vg=0.8857   //specific  volume  of  saturated  vapour  in
       m^3  per  kg
15
16 v1=vf+x*(vg-vf);
```

```
17
18  v2=1.549    //specific  volume  of  steam  in  m^3  per  kg
        at  T2=400*C  and  P2=0.2MPa
19  //  now  calculate  work
20  W=m*P*(v2-v1);    //work  done  in  constant  pressure
        process
21  printf("Work  done  is  %.1f  kJ",W)  //  work  is  in  kJ  as
        pressure  was  in  kPa
```

Scilab code Exa 3.2 110mm diameter cylinder work done

```
1  clc
2  //initialization  of  variables
3  D=110/1000  //  diameter  of  cylinder  in  m
4  V1=100e-6  //  initial  volume@  state  1  in  m^3
5  T1=60  //  initial  temp  @  state  1  in  *C
6  T2=200  //  final  temo  @  state  2  in  *C
7  M=50  //  weight  of  piston  in  kg
8  g=9.81  //  gravitational  accleration  in  m/sec^2
9  Patm=100000  //  atmospheric  pressure  in  Pa
10  A=%pi*(D^2)/4  //  area  of  piston  in  m^2
11
12  //  BALANCING  THE  FORCES  To  GET  PRESSURE  P
13  //  M.g=P.A-Patm
14  P=Patm+(M*g/A)  //  atm  pressure  is  added  to  get
        absolute  pressure
15
16  v1=0.001017  //  specific  volume  at  60*C  and  0.15Mpa
        pressure
17  m=V1/v1;  //  mass  of  water  in  kg
18
19  //  find  volume  at  state  2
20  v2=1.444  //  specific  volume  of  steam  at  200*C  and
        0.15  MPa
21  V2=m*v2//  final  volume  in  m^3
```

```
22
23  W=P*(V2-V1)/1000; // work done divided by 1000 to
        get in kJ
24  printf("The work done is %.1f kJ",W)
```

Scilab code Exa 3.3 isothermal work by the ideal gas

```
1   clc
2   //initialization of variables
3   P1=200        // initial pressure in kPa
4   V1=2          //initial volume in m^3
5   P2=100        //final pressure in kPa
6   C=P1*V1// isothermal process i.e P.V=constant
7   //  find final volume
8   V2=P1*V1/P2 // final volume by P1.V1=P2.V2
9
10  function[p]=pressure(v) // expressing pressure as
        function of volume
11      p=C/v;
12  endfunction
13
14  W=integrate('C/v','v',V1,V2) //itegrating over
        volume to get work
15  printf("The Work done by gas is %.0f kJ",W) //
        answer is approximated in textbook
```

Scilab code Exa 3.4 A 100 kg mass drops 3 m

```
1   clc//
2   //initialization of variables
3   M=100 // mass in kg
4   d=3 // depth by which mass drops in m
5   V=0.002 // increased volume in m^3
```

```
6 g=9.81 // gravitational accleration in m/sec^2
7 Pgauge=100*1000// gauge pressure in N/m
8 Patm =100*1000 // atmospheric pressure in N/m
9 P=Pgauge+Patm // to get absolute pressure
10
11 //calculate work done by paddle wheel
12 Wpaddlewheel=(-M*g*d) // work is negative as it is
      done on the system
13
14 //calculate work done on piston it
15 Wboundary=P*V // area mulitiplied by height is
      volume thus W=P.V
16 //net work
17 Wnet=Wpaddlewheel+Wboundary; // Work in joule as SI
      units are used
18 printf("The Net Work done is "+string(Wnet)+" J")
19 // in textbook answer is 2450 J which is when we
      assume g=9.80
```

Scilab code Exa 3.5 drive shaft in an automobile delivers

```
1 clc
2 // initialization of variables
3 T=100 // torque of shaft in N.m
4 N=3000 // rotation speed in rpm
5 omega=(N*2*%pi/60) // angular velocity in rad/sec
6 // calculation of power
7 Wdot=(T*omega); // power is work done per unit time
8 printf("Power transmitted is %.1f hp",Wdot/746)  //
      divided by 746 to convert W into hp
9 //answer is approximated in textbook
```

Scilab code Exa 3.6 Heat supplied at constant pressure

19

```
1  clc
2  // initialization of variables
3  D=10/100   //diameter of cylinder in m
4  d=50/1000   //compression in spring in m
5  Patm=100000     // atmospheric pressure in Pa
6  K=10*1000    // spring constant converted in  N/m
7  w=50*9.81    // weight of piston in Newton =mass*
       gravitational acceleration
8
9  // find the initial pressure in cylinder by force
       balance
10 A=(%pi*D^2)/4; // area of piston
11 P1=((Patm*A)+w)/A;        // balancing forces on
       piston P1.A=Patm.A+W
12
13 // work done by air to raise the piston for 50mm if
       spring not present
14 Wgas=P1*A*d; // pressure*area= force and Work =
       Force* displacement
15
16 // work done on spring to compress
17 Wspring=(K*d^2)/2; // Work in j
18
19 // now total work done by air is sum of two works
20 Wnet=Wgas+Wspring; // Work in j
21
22 printf("The net work done by air is %.2f J",Wnet)
23 //The answer is approximated in textbook but here it
        is precise
```

Scilab code Exa 3.7 non quasiequilibrium process

```
1  clc
2  // variable initialization
3
```

```
4 d=2      // distance  travelled  by  weight  in m
5 m=50     //  mass  of  weight  in  kg
6 g=9.8    //  gravitaional  acceleration  in  m/ sec ^2
7
8 //  calculation  of  work  in  non−quasiequilibrium
      process
9 W=m*g*d;// work  in  joules
10
11 //  the  work  done  must  be  transferred  as  heat
12 Q=W;
13
14 printf("The  heat  that  must  transfer  is  "+string(Q)+"
       Joules")
```

Chapter 4

The First Law of Thermodynamics

Scilab code Exa 4.1 paddle wheel heat transfer

```
1  clc
2  //initialization of variables
3  K=100 // spring constant in kN/m
4  d=0.8 // dispacement of spring in m
5   // to get total work we integrate from 0 to 0.8
       displacement
6  x1=0; // lower limit of integration
7  x2=0.8;  // upper limit of integration
8  W12=integrate('K*x','x',x1,x2);
9  Q12=W12; // by first law of thermodynamics
10 printf("The Heat transfer is "+string(Q12)+" J")
```

Scilab code Exa 4.2 internal energy increase

```
1  clc
2  //initialization of variables
```

```
3  P= 5*746 // power of fan converted in watt
4  t=1*60*60 // time converted to seconds
5
6  // by first law of thermodynamics Q=delU + W
7  // Q=0 hence -W=delU
8  // first we find work input
9  W=-P*t // work in J
10 delU=-W // from 1st law
11 printf("The internal energy increase is "+string(
      delU)+" J")
12 // The answer is approximated in textbook
13 // our answer is precise
```

Scilab code Exa 4.3 frictionless piston

```
1  clc
2  //initialization of variables
3  P=400 // pressure in kPa
4  T1=200 // initial temperature in degree celsius
5  V1= 2 // initial volume in m^3
6  Q=3500 // heat added in kJ
7  v1=0.5342 // specific volume of steam at 200 degree
      celcius and 0.4 Mpa pressure from table C.3
8  u1=2647 // specific internal energy in kJ/kg @
      pressure = 0.4 MPa
9  m=V1/v1 // mass in kg
10 // we have a relation Between u2 and v2 from 1st law
       of thermodynamics
11 v2=1.06 // specific volume at state 2 by trial and
      error and interpolation
12 V2=m*v2
13 u2=((3500-400*(V2-V1))/m)+2647 // specific internal
      energy for v2=1.06 by trial and error
14
15 // on interpolation from steam table at 0.4 MPa we
```

```
               get  temperature
16  T2=644 // temperature  in  degree  celsius
17  printf (" The  temperature  for  u2= "+string ( u2 )+"  kJ
        and \n  v2  =" +string ( v2 )+"  kg/m^3  is  \n" +string ( T2 )
        +"  degree  celsius ")
18  // this  numerical  is  solved  by  trial  and  error  thus
        refer  to  Appendix  C
```

Scilab code Exa 4.4 concept of enthalpy

```
1  clc
2  // initialization  of  variables
3  P=400 //   pressure  in  kPa
4  T1=200 // initial  tmperature  in  degree  celsius
5  V=2 // initial  volume  in  m^3
6  Q=3500 // heat  added  in  kJ
7
8  // solution
9  h1=2860 // initial  enthalpy  @  200*C and  400  kPa  from
        steam  table
10  v=0.5342 // specific  volume  from  steam  table  C.3
11  m=V/v ;
12  h2 =( Q/m)+h1 ; // final  enthalpy  in  kJ/kg  from  energy
        equation
13
14  // NOW  USING  THIS  ENTHLAPY  AND  INTERPOlATING  FROM
        STEAM  TABLE
15  T2=600+(92.6/224) *100
16  printf (" The  Final  temperature  is   "+string ( T2 )+"
        degree  Celsius ")
17  // result  is  obtained  from  interpolation  on  steam
        table
```

Scilab code Exa 4.5 specific heat of superheated steam

```
1  clc
2  // initialization of variables
3  T1=300 // initial temperature in degree celsius
4  T2=700 // final temperature in degree celsius
5  P=150// pressure in kPa
6  m=3 // mass of steam in kg
7
8  // solution
9  // part (a)
10
11 delH=m*integrate('2.07+(T-400)/1480','T',T1,T2) //
       expressing as function of temperature and
       integrating
12 printf(" The change in Enthalpy is "+string(delH)+"
       kJ \n")
13
14 // part(b)
15 CPavg=delH/(m*(T2-T1)) // avg value of specific heat
        at constant pressure
16 printf(" The average value of Cp is "+string(CPavg)+
       " kJ/kg.*C")
```

Scilab code Exa 4.6 enthalpy change for 1 kg of nitrogen

```
1  clc
2  // initialization of variables
3  m=1 // mass of nitrogen in kg
4  T1=300 // initial temperature in Kelvin
5  T2=1200 // final temperature in Kelvin
6  M=28 // in kg/kmol
7  // part(a)
8  // the enthalpy change is found from gas table in
       App.E
```

```
 9  delh=36777-8723 // from gas table
10  delH=delh/M
11  printf("The entalpy change from gas table is "+
        string(delH)+" kJ/kg \n")
12
13  // part (b)
14  Cp=1.042 // from table B.2
15  delH=Cp*(T2-T1)
16  printf(" The entalpy change  by assuming constant
        specific heat is "+string(delH)+" kJ/kg")
```

Scilab code Exa 4.7 quasiequilibrium process

```
 1  clc
 2  // initialization of variables
 3  x=0.7 // quality of steam
 4  P1=200 // initial pressure in kPa
 5  P2=800 // final pressure in kPa
 6  V=2 // volume in m^3
 7  //The values are taken from TABLE C.2
 8  vf1=0.0010 //specific volume of saturated liquid at
        200 kPa
 9  vg1=0.8857 //specific volume of saturated gas at 200
         kPa
10  uf1=504.5 // specific internal energy of saturated
        liquid @ state 1
11  ug1=2529.5 // speciific internal energy of saturated
         gas @ state 1
12
13  v1=vf1+x*(vg1-vf1); //specific volume of vapour
14  m=V/v1
15
16  u1=uf1+x*(ug1-uf1) // specific internal energy of
        vapour @ state 1
17  v2=v1 // constant volume process
```

26

```
18  u2=((0.6761-0.6203)*(3661-3853)/(0.6761-0.6181))
        +3853// from  steam  table  @ 800kPa  by
        interpolating
19  Q=m*(u2-u1)// heat  transfer
20  printf("The  heat  transfer  is  "+string(Q)+"  kJ")
```

Scilab code Exa 4.8 piston cylinder arrangement

```
1  clc
2  // initialization  of  variables
3  V=0.02  // volume  in  m^3
4  P=400  // pressure  in  kPa
5  T1=50+273  // initial  temperature  in  kelvin
6  T2=700+273  // final  temperature  in  kelvin
7  Q=50  // heat  added  in  kJ
8  R=287  // constant  for  air
9  Cp=1  // constant  for  specific  heat  of  air
10
11 //using  the  ideal  gas  equation
12
13 m=P*1000*V/(R*T1)  // mass  of  air  in  kg
14 W=Q-(m*Cp*(T2-T1))  // work  done  from  first  law
15 printf("The  Paddle  work  is  "+string(W)+"  kJ")
```

Scilab code Exa 4.9 air in an insulated cylinder

```
1  clc
2  // initialization  of  variables
3  V1=2  // initial  volume  in  m^3
4  V2=0.2  // final  volume  in  m^3
5  T1=20+273// temperature  in  kelvin
6  P=200  // pressure  in  kPa
7  R=0.287  // constant  for  air
```

```
8  gama=1.4 // polytropic index for air
9  Cv=0.717// specific heat at constant volume for air
10 //solution
11
12 //using the ideal gas equation
13 m=(P*V1)/(R*T1) // mass in kg
14 // process is adiabatic thus
15 T2=T1*((V1/V2)**(gama-1))// final temperature
16
17 W=-m*Cv*(T2-T1)// work from first law
18 printf("The Work is "+string(W)+" kJ")
19 // solution is approximated in textbook
```

Scilab code Exa 4.10 Steam at 2000 kPa and 600 degree celsius

```
1  clc
2  // initialization of variables
3  P1=2000 // initial pressure in kPa
4  T1=600 // initial temperature in degree celsius
5  p2=600 // final pressure in kPa
6  T2=200 //   final temperature in degree celsius
7  d1=0.06 // diameter of inlet pipe in metre
8  d2=0.120 // diameter of outlet pipe in metre
9  V1=20 // velocity at inlet in m/s
10
11 //solution
12 // from superheat table C.3 values are noted
13 v1=0.1996 // specific volume of superheated steam @
      600*C and 2000 kPa
14 v2=0.3520 // specific volume of superheated steam @
      200*C and 2000 kPa
15 rho1=1/v1 //   initial density
16 rho2=1/v2 // final density
17 A1=(%pi*d1**2)/4 // inlet area
18 A2=(%pi*d2**2)/4 // exit area
```

```
19
20  V2=(rho1*A1*V1)/(rho2*A2) // from continuity
       equation
21  printf("The Exit velocity is "+string(V2)+" m/s \n")
22
23  mdot=rho1*A1*V1 // mass flow rate
24  printf(" The mass flow rate is "+string(mdot)+" kg/s
       ")
```

Scilab code Exa 4.11 throttling valve

```
1  clc
2  // initialization of variables
3  P1=8000 // initial pressure in kPa
4  T1=300 // temperature in degree celsius
5  P2=2000 // final pressure in kPa
6
7  //solution
8  h1=2785 // specific enthalpy of steam in kJ/kg @
       8000 kPa and 300 degree celsius from  steam table
9  h2=h1 // throttling process thus enthalpy is
       constant
10 T2=212.4 // from steam table as we know enthalpy and
        pressure
11 hf2=909 // specific enthalpy of saturated liquid @
       2000 kPa and 300 degree celsius
12 hg2=2799.5 // specific enthalpy of saturated gas @
       2000 kPa and 300 degree celsius
13 x2=(h2-hf2)/(hg2-hf2) // quality of steam
14
15 vg2=0.0992 //specific    volume of saturated gas @
       2000 kPa and 212.4*c
16 vf2=0.0012 //specific volume of saturated liquid @
       2000 kPa and 212.4*c
17 v2=vf2+x2*(vg2-vf2) // from properties of pure
```

```
        substance
18
19 printf("The Final Temperature and Specific volume is
        "+string(T2)+" *C and "+string(v2)+" m^3/kg")
```

Scilab code Exa 4.12 turbine power output

```
1  clc
2  // initialization of variables
3  P1=4000 // inlet pressure in kPa
4  T1=500 // inlet temperature in degree celsius
5  V1=200 // inlet steam velocity in m/s
6  d1=0.05 // inlet diameter in 'm'
7  P2=80 // exit pressure in kPa
8  d2=0.250 // exit diameter in 'm'
9
10 // solution
11 v1=0.08643 // specific volume from steam table @
        4000 kPa and 500*C
12 v2=2.087 // specific volume from steam table @ 80
        kPa and 500*C
13 rho1=1/v1 // density at inlet
14 rho2=1/v2 // density at outlet
15 A1=(%pi*d1**2)/4 // inlet area
16 A2=(%pi*d2**2)/4
17 mdot=rho1*A1*V1 // mass flow rate
18
19 //now using table C.3
20 h1=3445 // initial specific enthalpy @ 4000 kPa and
        500 *C
21 h2=2666 // final specific enthalpy @ 80 kPa and 500
        *C
22 WT=-mdot*(h2-h1) // maximum power from first law
23 printf("The power output is "+string(WT)+" kJ/s \n "
        )
```

```
24
25  V2 =( A1 * V1 * rho1 )/( A2 * rho2 )
26  delKE = mdot *(( V2 **2) -( V1 **2))/2
27  printf (" The change in K.E is "+ string ( delKE )+" J/s"
        )
28  // the amswer is different as the solution in scilab
        is highly precise while the solution in textbook
        is wrong due to approximation of exit velocity
```

Scilab code Exa 4.13 maximum pressure increase by pump

```
1  clc
2  // initialization of variables
3  Wdot =10  // pump power in hp
4  g =9.81  // acceleration due to gravity
5  rho =1000  // density of water in kg/m^3
6  d1 =0.06  // inlet dimeter in 'm'
7  d2 =0.10  // oulet diamter in 'm'
8  V1 =10  // velocity of water at inlet in m/s
9
10  // solution
11  A1 =% pi *( d1 **2)/4  // area of inlet
12  A2 =% pi *( d2 **2)/4  // area of outlet
13  V2 = A1 * V1 / A2  // oulet velocity from continuity
        equation
14
15  mdot = rho * A1 * V1  // mass flow rate
16  delP =(((( Wdot *746)/ mdot ) -(( V2 **2) - V1 **2)/(2* g ))* rho )
        /1000  // change in pressure in kPa
17  printf (" The rise in pressure is "+ string ( delP )+" kPa
        ")
18  // The answer is approximated in textbook , our
        answer is precise
```

Scilab code Exa 4.14 the supersonic nozzle

```
1  clc
2  // initialization of variables
3  P1=7000 // inlet pressure in Pa
4  T1=420 // inlet temperature in degree celsius
5  V1=400// inlet velocity in m/s
6  d1=0.200 // inlet diameter in 'm'
7  V2=700 // exit velocity in m/s
8  k=1.4 // polytopic index for air
9  Cp=1000 // specific heat at constant pressure for
       air in j/kg.K
10 R=287 // specific gas constant for air
11 // solution
12
13 // part (a)
14 T2=(((V1**2)-V2**2)/(2*Cp))+T1 // outlet temperature
        in degree celsius
15 printf("The exit temperature is "+string(T2)+" *C \n
       ")
16
17 // part (b)
18
19 rho1=P1/(R*(T1+273)) // density at entrance
20 A1=(%pi*d1**2)/4
21 mdot=rho1*A1*V1 //
22 printf(" The mass flow rate is "+string(mdot)+" kg/s
        \n")
23
24 // part (c)
25
26 rho2=rho1*(((T2+273)/(T1+273))**(1/(k-1))) //
       density at exit
27 // now we find the exit diameter
```

```
28  d2=sqrt((rho1*V1*(d1)**2)/(rho2*V2))
29  printf(" The outlet diameter is "+string(d2)+" m")
```

Scilab code Exa 4.15 heat exchanger

```
1  clc
2  // initialization of variables
3  mdots=100 // mass flow rate of sodium in kg/s
4  Ts1=450 // inlet temperature of sodium in degree
        celsius
5  Ts2=350 // exit temperature of sodium in degree
        celsius
6  Cp=1.25 // specific heat of sodium in KJ/kg.*C
7  Tw1=20 // inlet temperature of water in degree
        celsius
8  Pw=5000 // inlet pressure of water in kPa
9
10 // solution
11 hw1=88.65 // enthalpy from table C.4
12 hw2=2794 // enthalpy from table C.3
13 mdotw=(mdots*Cp*(Ts1-Ts2))/(hw2-hw1) // mass flow
        rate of water
14 printf("The mass flow rate of water is "+string(
        mdotw)+" kg/s \n")
15 Qdot=mdotw*(hw2-hw1) // heat transfer in kW using
        energy equation
16 printf(" The rate of heat transfer is "+string(Qdot)
        +" kW")
```

Chapter 5

The Second Law of Thermodynamics

Scilab code Exa 5.4 Carnot engine

```
1 clc
2 // initialization of variables
3 Th=200+273 // higher temperture in kelvin
4 Tl=20+273 // lower temperture in kelvin
5 Wdot=15 // output of engine in kW
6
7 ef=1-(Tl/Th) // carnot efficiency
8
9 Qhdot=Wdot/ef // heat supplied by reservoir
10 printf(" The heat suppled by higher temperature
      reservoir is %.2f kW \n ",Qhdot)
11 // using forst law
12 Qldot=Qhdot-Wdot // heat rejected to reservoir
13 printf(" The heat suppled by lower temperature
      reservoir is %.2f kW",Qldot)
```

Scilab code Exa 5.5 percentage increase in work

```
1  clc
2  // initialization of variables
3  TL1=-5+273 // lower temperature in kelvin for first
       situation
4  TH=20+273 // higher temperature in kelvin
5  TL2=-25+273 //lower temperature in kelvin for second
        situation
6
7  //solution
8
9  COP1=TL1/(TH-TL1) // carnot refrigerator COP for
       first situation
10 // Let Heat be 100 kJ
11 QL=100 // assumption
12 W1=QL/COP1 // work done for situation 1
13
14 // for situation 2
15 COP2=TL2/(TH-TL2) // COP carnot for second situation
16 W2=QL/COP2 // work done
17
18 Per=(W2-W1)*100/W1 // percentage increase in work
       done
19 printf(" The perccentage increase in work is %.1f%%"
       ,Per)
```

Scilab code Exa 5.6 paddle wheel work

```
1  clc
2  // initialization of variables
3  T1=20+273 // initial temperature in kelvin
4  P=200 // pressure in kPa
5  V=2 //volume in m^3
6  R=0.287 // gas constant for air
```

```
7  W =720 // work done on air in kJ
8  Cv =0.717 // specific heat at constant volume for air
9
10 // solution
11 m =( P * V )/( R * T1 )// mass of air
12
13 T2 = T1 +( W /( m * Cv ))// final temperature in kelvin
14
15 delS = m * Cv * log ( T2 / T1 ) // ENROPY CHANGE FOR CONSTANT
       VOLUME PROCESS
16 printf (" The Entropy increase is %.3 f kJ /K " , delS )
```

Scilab code Exa 5.7 a combustion process in a cylinder

```
1  clc
2  // initialization of variables
3  T1 =350+273 // initial temperature in kelvin
4  P1 =1200 // initial pressure in kPa
5  P2 =140 // final pressure in kPa
6  k =1.4 // polytopic index for air
7  Cv =0.717 // specific heat at constant volume for
       air
8  // solution
9  T2 = T1 *(( P2 / P1 )**(( k -1)/ k ))  // reversible adiabatic
       process relation
10
11 w = - Cv *( T2 - T1 ) // work done by gases in reversible
       adiabatic process
12 printf (" The work done by gases is %.0 f kJ / kg " , w )
```

Scilab code Exa 5.8 with variable specific heats

```
1  clc
```

```
2  // initialization of variables
3  T1=20+273 // initial temperature in kelvin
4  P1=200 // pressure in kPa
5  V=2 //volume in m^3
6  R=0.287 // gas constant for air
7  W=-720 // negative as work is done on air in kJ
8
9  //solution
10
11 m=(P1*V)/(R*T1)// mass of air
12
13 u1=209.1 //specific internal energy of air at 293K
      and 200 kPa from table E.1
14 s1=1.678 // by interpolation from table E.1
15 // change  in internal energy= work done
16 u2=-(W/m)+u1 // final internal energy
17 T2=501.2// final temperature interpolated from table
      E.1 corresponding to value of u2
18 s2=2.222 // value of s from table E.3 by
      interpolating from corresponding to value of u2
19
20 P2=P1*(T2/T1) // final pressure in kPa
21
22 delS=m*(s2-s1-R*log(P2/P1))// entropy change
23 printf(" The Entropy increase is %.3f kJ/K ",delS)
```

Scilab code Exa 5.9 a reversible adiabatic process

```
1  clc
2  // initialization of variables
3  T1=350+273 // initial temperature in kelvin
4  P1=1200 // initial pressure in kPa
5  P2=140 // final pressure in kPa
6  k=1.4 // polytopic index for air
7
```

```
 8  //solution
 9  // The values are taken from table E.1
10  Pr660=23.13// relative pressure @ 660K
11  Pr620=18.36// relative pressure @ 620K
12  Pr1=((Pr660-Pr620)*3/40)+Pr620 // relative pressure
       by interpolation
13  Pr2=Pr1*(P2/P1) // relative pressure at state 2
14
15  Pr340=2.149 // relative pressure @ 340K
16  Pr380=3.176 // relative pressure @ 380K
17  T2=((Pr2-Pr340)/(Pr380-Pr340))*40+340 //
       interpolating final temperature from table E.1
18
19  // now interpolating u1 AND u2 from table E.1
20  u620=451.0// specific internal energy @ 620k
21  u660=481.0// specific internal energy @ 660k
22  u1=(u660-u620)*(3/40)+u620 // initial internal
       energy
23
24  u380=271.7 //specific internal energy @ 380k
25  u340=242.8 //specific internal energy @ 340k
26  u2=((Pr2-Pr340)/(Pr380-Pr340))*(u380-u340)+u340 //
       final internal energy
27
28  w=u2-u1 // work= change in internal energy
29  printf(" The work done by gas is %.0f kJ/kg",w)
30  // The answer is slightly different as values are
       approximated in textbook
```

Scilab code Exa 5.10 Steam in a rigid container

```
 1  clc
 2  // initialization of variables
 3  T1=300+273 // initial temperature in kelvin
 4  P1=600 // initial pressure in kPa
```

```
5  P2=40 // final pressure in kPa
6
7  //solution
8  //please refer to steam table for values
9  v1=0.4344 // specific volume from steam table @ 573k
       and 600 kPa
10 v2=v1 // rigid container
11 u1=2801 // specific internal energy from steam table
       @ 573k and 600 kPa
12 s1=7.372 // specific entropy @ 600 kPa and 573 K
13
14 vg2=0.4625 // specific volume of saturated vapour @
       40 kPa and 573 K
15 vf2=0.0011 // specific volume of saturated liquid @
       40 kPa and 573 K
16 sf2=1.777 // specific entropy of saturated liquid @
       40 kPa and 573 K
17 sg2=5.1197 // specific entropy of saturated vapour @
       40 kPa and 573 K
18 x=(v2-vf2)/(vg2-vf2)// quality of steam using pure
       substance relation
19
20 s2=sf2+x*sg2 // overall specific enthalpy at quality
       'x'
21 delS=s2-s1 // entropy change
22 printf(" The entropy change  is %0.3f kJ/kg.K \n ",
       delS)
23
24 //heat transfer
25 uf2=604.3 //specific internal energy of saturated
       liquid @ 40 kPa and 573 K
26 ug2=1949.3 //specific internal energy of saturated
       vapour @ 40 kPa and 573 K
27 u2=uf2+x*ug2 //specific internal energy @ quality x
28 q=u2-u1 // heat transfer in kJ/kg from first law as
       W=0
29 printf(" The heat transfer is %.0f kJ/kg",q)
30 // the answers are approximated in textbook but here
```

Scilab code Exa 5.11 Air in one half of an insulated tank

```
1  clc
2  // initialization of variables
3  v1=0.5 // assumed as air is filled in half of the
       tank
4  v2=1 // final volume when partition is removed
5  R=0.287 // gas contant for air
6  // solution
7  q=0 // heat transfer is zero
8  w=0 // work done is zero
9  // temperatue is constant as no change in internal
       energy by first law
10 dels=R*log(v2/v1)// change in entropy when
       temperature is constant
11 printf("The change in specific entropy is %.3f kJ/kg
       .K",dels)
```

Scilab code Exa 5.12 Two kilograms of steam

```
1  clc
2  // initialization of variables
3  T1=400+273 // initial temperature in kelvin
4  P=600 // pressure in kPa
5  Tsurr=25+273 // surrounding temperature in K
6  m=2 // mass of steam in kg
7
8  // solution
9  // please refer to steam table for values
10 s1=7.708 // specific entropy of steam @ 400 degree
       celsius and 0.6 MPa
```

40

```
11  s2=1.9316// specific enropy of condensed water @ 25
       degree celsius and 0.6 MPa
12  delSsys=m*(s2-s1) // entropy change in system i.e of
        steam
13
14  h1=3270 // specific enthalpy of steam @ 400 degree
       celsius and 0.6 MPa
15  h2=670.6//specific enropy of condensed water @ 25
       degree celsius and 0.6 MPa
16
17  Q=m*(h1-h2)// heat transfer at constant pressure
18  delSsurr=Q/Tsurr // entropy change in surroundings
19
20  sigma=delSsys+delSsurr // net entropy change
21
22  printf("The net entropy production is %.1f kJ/K",
       sigma)
```

Scilab code Exa 5.13 Superheated steam enters a turbine

```
1  clc
2  // initialization of variables
3  T1=600+273 // initial temperature in kelvin
4  P1=2 // initial pressure in MPa
5  P2=10 // final pressure in kPa
6  mdot=2 // mass flow rate in kg/s
7
8  //solution
9  //please refer to steam table for values
10 h1=3690 // specific enthalpy in kJ/kg @ 2MPa and 600
        degree celsius
11 s1=7.702 //specific entropy in kJ/kg.K @ 2MPa and
       600 degree celsius
12 s2=s1 // Reversible adiabatic process thus entropy
       is constant
```

```
13  sf2 =0.6491 // specific  entropy  of  saturated  liquid
        from  steam  table  @ 10  kPa
14  sg2 =8.151 // specific  entropy  of  saturated  vapour
        from  steam  table  @ 10  kPa
15
16  x2 =( s2 - sf2 ) /( sg2 - sf2 ) // quality  of  steam  at  turbine
        exit
17
18  h2f =191.8 // specific  enthalpy  of  saturated  liquid
        from  steam  table  @ 10  kPa
19  h2g =2584.8 // specific  enthalpy  of  saturated  vapour
        from  steam  table  @ 10  kPa
20  h2 = h2f + x2 *( h2g - h2f ) // specific  enthalpy  @ quality  '
        x'
21
22  WdotT = mdot *( h1 - h2 ) // from  work  done  in  adiabatic
        process
23  printf (" The  maximum  power  output  is  %.0 f  kJ/s" ,
        WdotT )
24  // the  answers  are  approximated  in  textbook  but  here
        they  are  precise  thus  minute  difference  is  there
```

Scilab code Exa 5.14 turbine is assumed to be 80 percent efficient

```
1  clc
2  // initialization  of  variables
3
4  T1 =600+273 // initial  temperature  in  kelvin
5  P1 =2 // initial  pressure  in  MPa
6  P2 =10 // final  pressure  in  kPa
7  mdot =2 // mass  flow  rate  in  kg/s
8  EffT =0.8 // efficiency  of  turbine
9  WdotT =2496 // theoritical  power  of  turbine  in  kW
10
11  // solution
```

```
12  Wdota=EffT*WdotT // actual power output of turbine
13  h1=3690 // specific enthalpy @ 2MPa and 600 degree
        celsius
14  h2=h1-(Wdota/mdot) // final enthalpy from first law
        of thermodynamics
15
16  T2=((h2-2688)/(2783-2688))*(150-100)+100 // by
        interpolating from steam table @ P2= 10 kPa, h2
        =2770
17  s2=8.46 // final specific entropy by interpolation
        from steam table
18
19  printf("The temperature by interpolation is %.0f
        degree celsius \n",T2)
20  printf("The final entropy by interpolation is %.2f
        kJ/kg.K",s2)
21  // The temperature and entropy are found by
        interpolation from steam table and cannot be
        shown here.
```

Scilab code Exa 5.15 preheater is used in a power plant cycle

```
1  clc
2  // initialization of variables
3
4  T2=250 // temperature of steam in degree celsius
5  mdot2=0.5 // mass flow rate of steam in kg/s
6  T1=45 // temperature of water in degree celsius
7  mdot1=4 // mass flow rate of water in kg/s
8  P=600 // pressure in kPa
9
10
11 mdot3=mdot1+mdot2 // by mass balance
12
13 h2=2957 // specific enthalpy in kJ/kg of steam @ 600
```

```
        Kpa from steam table
14  h1=188.4 // specific enthalpy in kJ/kg  of water @
        600 Kpa from steam table
15
16  h3=(mdot1*h1+mdot2*h2)/mdot3 // specific enthalpy in
        kJ/kg at exit
17
18  // by interpolation from saturated steam table
19  T3=(h3-461.3)*10/(503.7-461.3)+110 // temperature of
        mixture
20
21  sf3=1.508 // entropy of saturated liquid in kJ/kg.K
        at 600Kpa and T3 temperature from steam table
22  s3=sf3
23  s2=7.182 // entropy of superheated steam in kJ/kg.K
        @ 600Kpa from steam table
24  s1=0.639 // entropy of entering water in kJ/kg.K at
        T= 45 degree celsius
25
26  sigmaprod=mdot3*s3-mdot2*s2-mdot1*s1
27  printf("The rate of entropy production is %0.3f kW/K
        ",sigmaprod)
```

Chapter 6

Power Vapor Cycles

Scilab code Exa 6.1 power plant operate at the pressures of 10 kPa

```scilab
1  clc
2  // solution
3  //initialization of variables
4  // Please refer to the given figure in question for
      quantities
5  P2=2*1000 //higher pressure converted in in kPa
6  P1=10 // lower pressure in kPa
7  rho=1000 // density of water in Kg/m^3
8  h1=192 // enthalpy at state 1 in kJ/kg
9  h3=3248 // enthalpy at state 3 in kJ/kg
10 s3=7.1279// entropy at state 3 in kJ/kg.K
11
12 //calculation of pump work
13 wp=(P2-P1)/rho // pump work given by equation 4.56
      in textbook
14 h2=h1+wp // by enrgy balance b/w state 1 and 2
15 q=h3-h2 // Heat input from 2 to 3
16
17 s4=s3 // isentropic process
18 sf=0.6491 // entropy of saturated liquid @10 kPa
      from steam table
```

```
19 sg=8.151 // entropy of saturated vapour @10 kPa from
       steam table
20 x=(s4-sf)/(sg-sf)// from property of pure substance
21 hf=191.8 //enthalpy of saturated liquid @10 kPa from
       steam table
22 hg=2584 // enthalpy of saturated vapour @10 kPa from
       steam table
23 h4=hf+x*(hg-hf)// enthalpy @ state 4
24
25 wt=h3-h4 // turbine work
26
27 efficiency=(wt-wp)/q // efficiency of power cycle
28 printf(" The Efficiency is %.3f or %.1f %% \n",
       efficiency,efficiency*100)
29 // the answer is correct within limits
```

Scilab code Exa 6.2 Increase the boiler pressure

```
 1 clc
 2 // solution
 3 //initialization of variables
 4 // Please refer to the given figure of question 6.1
       for quantities
 5 effi1=0.323 //old efficiency
 6 P2=4*1000 //higher pressure converted in in kPa
 7 P1=10 // lower pressure in kPa
 8 rho=1000 // density of water in Kg/m^3
 9 h1=192 // enthalpy at state 1 in kJ/kg
10 h3=3214 // enthalpy at state 3 i.e @400 degree
       celsius and 4MPa in kJ/kg
11 s3=6.769// entropy at state 3 i.e @400 degree
       celsius and 4MPa in kJ/kg.K
12
13 s4=s3 // insentropic process
14 sf=0.6491 // entropy of saturated liquid @10 kPa
```

```
     from steam table
15 sg=8.151 // entropy of saturated vapour @10 kPa from
       steam table
16
17 x=(s4-sf)/(sg-sf)// quality of steam
18
19 hf=192 //enthalpy of saturated liquid @10 kPa from
      steam table
20 hg=2584 // enthalpy of saturated vapour @10 kPa from
       steam table
21 h4=hf+x*(hg-hf)// enthalpy @ state 4
22 h2=h1 // isenthalpic process
23 qb=h3-h2 // heat addition
24
25 wt=h3-h4 // turbine work
26
27 effi2=(wt)/qb // efficiency of power cycle
28 printf(" The Efficiency is %.3f or %.1f %% \n",effi2
     ,effi2*100)
29 %increase=((effi2-effi1)/effi1)*100
30 printf(" The %% increase in Efficiency is %.2f \n",
     %increase)
```

Scilab code Exa 6.3 Increase the maximum temperature

```
1 clc
2 // solution
3 //initialization of variables
4 // Please refer to fig of question 6.1 for
     quantities
5 effi1=0.323 //old efficiency
6 P2=2*1000 //higher pressure converted in in kPa
7 P1=10 // lower pressure in kPa
8 rho=1000 // density of water in Kg/m^3
9 T2=600// max temperature of cycle in degree celsius
```

```
10  h1=192 // enthalpy at state 1 in kJ/kg
11  h3=3690 // enthalpy at state 3 in kJ/kg, 600*C and 2
        MPa pressure
12  s3=7.702// entropy at state 3 in kJ/kg.K, 600*C and
        2MPa pressure
13
14  s4=s3// isentropic process
15  sf=0.6491 // entropy of saturated liquid @10 kPa
        from steam table
16  sg=8.151 // entropy of saturated vapour @10 kPa from
         steam table
17
18  x=(s4-sf)/(sg-sf)// quality of steam
19
20  hf=192 //enthalpy of saturated liquid @10 kPa from
        steam table
21  hg=2584 // enthalpy of saturated vapour @10 kPa from
         steam table
22  h4=hf+x*(hg-hf)// enthalpy @ state 4
23
24  h2=h1 // isenthalpic process
25  qb=h3-h2 // heat addition
26
27  wt=h3-h4 // turbine work
28
29  effi2=(wt)/qb // efficiency of power cycle
30  printf(" The Efficiency is %.3f or %.1f %% \n",effi2
        ,effi2*100)
31  %increase=((effi2-effi1)/effi1)*100
32  printf(" The %% increase in Efficiency is %.2f \n",
        %increase)
```

Scilab code Exa 6.4 Decrease the condenser pressure

```
1  clc
```

```
2  // solution
3  //initialization of variables
4  // Please refer to fig of question 6.1 for
      quantities
5  effi1=0.323 //old efficiency
6  P2=2*1000 //higher pressure converted in in kPa
7  P1=4 // condenser pressure in kPa
8  rho=1000 // density of water in Kg/m^3
9  h1=192 // enthalpy at state 1 in kJ/kg
10 h3=3248 // enthalpy at state 3 in kJ/kg
11 s3=7.1279// entropy at state 3 in kJ/kg.K
12
13 s4=s3 // isentropic process
14
15 sf=0.4225 // entropy of saturated liquid @10 kPa
      from steam table
16 sg=8.4754 // entropy of saturated vapour @10 kPa
      from steam table
17
18 x=(s4-sf)/(sg-sf)// from property of pure substance
19
20 hf=121 //enthalpy of saturated liquid @4 kPa from
      steam table
21 hg=2554 // enthalpy of saturated vapour @4 kPa from
      steam table
22 h4=hf+x*(hg-hf)// enthalpy @ state 4h1=h2 //
      isenthalpic process
23 h2=h1 // isenthalpic process
24 qb=h3-h2 // heat addition
25
26 wt=h3-h4 // turbine work
27
28 effi2=(wt)/qb // efficiency of power cycle
29 printf(" The Efficiency is %.3f or %.1f %% \n",effi2
      ,effi2*100)
30 %increase=((effi2-effi1)/effi1)*100
31 printf(" The %% increase in Efficiency is %.2f \n",
      %increase)
```

```
32  // the answer in the textbook is different due to
        approximations
```

Scilab code Exa 6.5 High pressure steam enters a turbine at 2 MPa

```
1  clc
2  clear
3  // solution
4  //initialization of variables
5  P2=2*1000 //higher pressure converted in in kPa
6  P1=10 // lower pressure in kPa
7  h1=192 // enthalpy at 10 kPa in kJ/kg
8  h3=3248 // enthalpy @ state 3 in kJ/kg from table C
        .3
9  s3=7.128 // entropy @ state 3 in kJ/kg.K from table
        C.3
10 s4=s3 // isentropic process
11
12 h2=h1 //isenthalpic process
13 h4=((s4-7.038)/(7.233-7.038))*(3056-2950)+2950 //
        using adjacent values for
14 //interpolation from table C.3
15 h5=3267 // enthalpy at 800 kPa and $00 degree
        celsius
16 s5=7.572 // entropy at 800 kPa and $00 degree
        celsius
17
18 s6=s5 // isentropic process
19 sf=0.6491// entropy of saturated liquid @10 kPa
        from steam table
20 sg=8.151 // entropy of saturated vapour @10 kPa from
         steam table
21
22 x=(s6-sf)/(sg-sf)// quality of steam
23
```

```
24  hf=192 //enthalpy of saturated liquid @10 kPa from
        steam table
25  hg=2585 // enthalpy of saturated vapour @10 kPa from
        steam table
26
27  h6=hf+x*(hg-hf)// enthalpy @ state 6
28
29  // we now calculate energy input
30  qb=(h5-h4)+(h3-h2)// heat interaction
31
32  // we now calculate work output
33  wt=(h5-h6)+(h3-h4)// turbine work
34
35  eff=(wt)/qb // efficiency of power cycle
36  printf(" The Efficiency is %.4f9 or %.2f %% \n",eff,
        eff*100)
```

Scilab code Exa 6.6 inserted an open feedwater heater

```
1  clc
2  clear
3  // solution
4  // initialization of variables
5  // Please refer to fig of question 6.1 for
        quantities
6  effi1=0.357//efficiency from example 6.3
7  P2=2*1000 //higher pressure converted in in kPa
8  P1=10 // lower pressure in kPa
9  rho=1000 // density of water in Kg/m^3
10 T2=600// max temperature of cycle in degree celsius
11 h1=192 // enthalpy at state 1 in kJ/kg
12 h3=3690 // enthalpy at state 3 in kJ/kg, 600*C and 2
        MPa pressure
13 h4=2442 // enthalpy from example 6.3
14 h6=505 // specific enthalpy @ 200 kPa from steam
```

```
          table
15  h7=h6 // isenthalpic process
16  s3=7.702// entropy at state 3 in kJ/kg.K, 600*C and
        2MPa pressure
17
18  h2=h1 // isenthalpic process
19  s5=s3 // isentropic process
20  h5=(s3-7.509)*(2971-2870)/(7.709-7.509)+2870 //
        interpolationg from steam table 2 200 kPa using
        s5=s3= 7.702 kJ/kg.
21
22  m6=1 // let mass of steam =1 Kg
23  m5=(h6-h2)*(m6)/(h5-h2)
24  m2=m6-m5 // conservation of mass
25
26  wt=h3-h5+(h5-h4)*m2 // work done by turbine
27  qb=h3-h7 // heat given to bolier
28  effi2=(wt)/qb // efficiency of power cycle
29  printf(" The Efficiency is %.3f or %.1f %% \n",effi2
        ,effi2*100)
30  %increase=((effi2-effi1)/effi1)*100
31  printf(" The %% increase in Efficiency is %.2f \n",
        %increase)
32  // The anwer is different in textbook as there the
        intermediate values are approximated while in
        scilab the calculations are precise
```

Scilab code Exa 6.7 efficiency of this reheat regeneration cycle

```
1  clc
2  // solution
3  //initialization of variables
4  P2=2*1000 //higher pressure converted in  kPa
5  P1=10 // lower pressure in kPa
6  h1=192 // enthalpy at 10 kPa  in kJ/kg
```

```
 7  h3=3248 // enthalpy @ state 3 in kJ/kg from table C
        .3
 8  s3=7.128 // entropy @ state 3 in kJ/kg.K from table
        C.3
 9
10  s4=s3 // isentropic process
11
12  h4=((s4-7.038)/(7.233-7.038))*(3056-2950)+2950 //
        using adjacent values for
13  //interpolation from table C.3
14  h5=3267 // enthalpy at 800 kPa and $00 degree
        celsius
15  s5=7.572 // entropy at 800 kPa and $00 degree
        celsius
16
17  s6=s5 // isentropic process
18  sf=0.6491// entropy of saturated liquid @10 kPa
        from steam table
19  sg=8.151 // entropy of saturated vapour @10 kPa from
         steam table
20
21  x=(s6-sf)/(sg-sf)// quality of steam
22
23  hf=192 //enthalpy of saturated liquid @10 kPa from
        steam table
24  hg=2585 // enthalpy of saturated vapour @10 kPa from
         steam table
25
26  h6=hf+x*(hg-hf)// enthalpy @ state 6
27  h7=721 // enthalpy of saturated liquid @800 kPa from
         steam table
28  h8=h7 // isenthalpic process
29  h2=h1 // isenthalpic process
30
31  m8=1 // let mass of steam =1 Kg
32  m4=(h8-h2)*(m8)/(h4-h2)
33  m2=m8-m4 // conservation of mass
34
```

```
35  wt=h3-h4+(h5-h6)*m2 // work done by turbine
36  qb=h3-h8+(h5-h4)*m2 // heat given to bolier
37
38  effi=(wt)/qb // efficiency of power cycle
39  printf(" The Efficiency is %.3f or %.1f %% \n",effi,
        effi*100)
```

Scilab code Exa 6.8 A Rankine cycle operates between 2 MPa and 10 kPa

```
1  clc
2  clear
3  // solution
4  //initialization of variables
5
6  // for rankine cycle refer to fig 6.9
7
8  effiT=0.8 // turbine efficiency
9  P2=2*1000 // higher pressure converted in  kPa
10 P1=10 // lower pressure in kPa
11 h1=192 // enthalpy at 10 kPa  in kJ/kg
12 h3=3690 // enthalpy of superheated steam @ 2 MPa
       from steam table in kJ/kg
13 s3=7.702 //entropy of superheated steam @ 2 MPa from
        steam table in kJ/kg.K
14 // state 4' is repsresented by '41'
15 h2=h1 //isenthalpic process
16 s41=s3 // entropy is constant
17 sf=0.6491 // entropy of saturated liquid @10 kPa
       from steam table
18 sg=8.151 // entropy of saturated vapour @10 kPa from
        steam table
19 x=(s41-sf)/(sg-sf)// from property of pure substance
20
21 hf=191.8 //enthalpy of saturated liquid @10 kPa from
        steam table
```

```
22  hg=2584 // enthalpy of saturated vapour @10 kPa from
         steam table
23  h41=hf+x*(hg-hf)// enthalpy @ state 41
24
25  wa=effiT*(h3-h41)// turbine efficiency =(actual work
      )/(isentropic work)
26
27  qb=h3-h2 // heat supplied
28
29  effi=(wa)/qb // efficiency of power cycle
30  printf(" The Efficiency is %.3f or %.1f %% \n",effi,
      effi*100)
31
32  h4=h3-wa // adiabatic process
33
34  // now using interpolation for superheated steam @
      10 kPa
35  T4=(h4-2688)*(150-100)/(2783-2688)+100
36
37  printf("\n The Temperature from interpolation comes
       out to be %i degree celsius",T4)
```

Scilab code Exa 6.9 ideal vapor refrigeration cycle

```
1  clc
2  // solution
3  //initialization of variables
4  // refer to fig 6.10c
5
6  mdot=0.6 // mass flow rate of refrigerant in kg/sec
7  T1=-24 // evaporator temperature in degree celsius
8  T2=39.39 // condenser temperature in degree celsius
9  h1=232.8 // enthalpy of saturated R134a vapour @ −24
         degree celsius from table D.1
10  s1=0.9370 // entropy of saturated R134a vapour @ −24
```

```
        degree celsius from table D.1
11 h3 =105.3 // enthalpy of saturated R134a liquid @ −24
        degree celsius from table D.2
12 h4 =h3 // isenthalpic process
13
14 // interpolating enthalpy from table D.3 @ 39.39
     degree celsius
15 h2 =( s1 -0.9066) *(280.19 -268.68) /(0.9428 -0.9066)
     +268.68
16 QdotE =mdot *(h1 -h4) // heat transfer rate
17 WdotC =mdot *(h2 -h1)// power given to compressor
18
19 COP =QdotE/WdotC // coefficient of performance
20
21 Hp =( WdotC/0.746) /( QdotE/3.52) //calculating
     Horsepower required per Ton
22
23 printf (" The rate of refrigeration is %0.1 f kJ/s \n "
     ,QdotE )
24 printf (" The coefficient of performance is %0.2 f \n "
     ,COP )
25 printf (" The rating in horsepower per ton is %0.3 f \n
     " ,Hp )
```

Scilab code Exa 6.10 compressor is 80 percent efficient

```
1 clc
2
3 // solution
4 //initialization of variables
5 // refer to fig 6.10c
6 effi =0.8 // compressor efficiency
7 mdot =0.6 // mass flow rate of refrigerant in Kg/sec
8 T4 = -24 // temperature of evaporator
9 T2 =39.39 // temperature of condensor
```

```scilab
10  T1=-20 // supeheating temperature
11  T3=40 // subcooling temperature
12  h3=106.2 // enthalpy of liquid R-134a @ 40 degree
       celsius from table D.1
13  h4=h3 // isenthalpic process
14  h1=236.5 // enthalpy of superheated R-134a @ 0.10
       MPa and -20 degree celsius from table D.3
15  s1=0.960 //entropy of superheated R-134a @ 0.10 MPa
       and -20 degree celsius from table D.3
16
17  s2dash=s1 // isentropic process
18
19  // using interpolation from table D.3 @ 1.0 MPa for
       s2dash=0.960
20  h2dash=(s2dash-0.9428)*(291.36-280.19)
       /(0.9768-0.9428)+280.19
21
22  h2=(h2dash-h1)/(effi)+h1 // by definition of
       compressor efficiency
23
24  QdotE=mdot*(h1-h4)//heat transfer rate power given
       to compressor
25
26  wdotc=mdot*(h2-h1)// power given to compressor
27
28  COP=QdotE/wdotc // coefficient of performance
29
30  printf("The rate of refrigeration is %0.1f kJ/s \n "
       ,QdotE)
31
32  printf("The coefficient of performance is %0.2f \n "
       ,COP)
33  // The value of Wdotc is shown wrong in the textbook
       . It should be multiplied by mass flow rate
```

Scilab code Exa 6.11 A heat pump using R134a

```
1  clc
2  // solution
3  //initialization of variables
4  // refer to fig 6.10c
5
6  QdotC=300 //heating Load in KWh or heat rejected by
       condensor
7  T1=-12 // evaporator temperature in degree celsius
8  P2=800 // condensor pressure in kPa
9  h1=240 // specific enthalpy of saturated R-134a
       vapour @ -12 degree celsius from table D.1
10 s1=0.927 // specific entropy of saturated R-134a
       vapour @ -12 degree celsius from table D.1
11 s2=s1 // isentropic process
12 h3=93.4 //specific enthalpy of saturated R-134a
       liquid @ 800 kPa from tableD.2
13
14 // extrapolating enthalpy from table D.2 @ 0.8 MPa
       for s=0.927
15 h2=273.7-(0.9374-s2)*(284.4-273.7)/(0.9711-0.9374)
16
17 // QdotE=mdot*(h1-h4) is heat transfer rate
18 mdot=QdotC/(h2-h3)// mass flow rate
19
20 WdotC=mdot*(h2-h1)// power given to compressor
21
22 //part(a)
23 COP=QdotC/WdotC // coefficient of performance
24 printf("The coefficient of performance is %0.2f \n "
       ,COP)
25
26 //part(b)
27 cost=WdotC*0.07 // cost of electricity
28 printf("The cost of electricity is $ %0.3f /hr \n",
       cost)
29
```

```
30  // part (c)
31  costgas=(300*3600*0.50)/100000 // cost of gas
32  printf("The cost of gas is $ %0.2 f /hr \n Thus heat
        pump is better ",costgas)
```

Chapter 7

Power Gas Cycles

Scilab code Exa 7.1 the percent clearance and the MEP

```
1  clc
2  // solution
3  // initialization of variables
4
5  r=12 // compression ratio
6  k=1.4 // polytropic index for air
7  p1=200 // pressure at state 1 in kPa
8  p3=10000 // pressure at state 3 in kPa
9
10 c=100/(r-1) // clearance in percentage
11 printf("The percent clearance is %0.2f %% \n",c)
12 v3=100 // let us assume v3=100 m^3 for calculations
13 p2=p1*(r**k) // polytopic process pressure relation
14 p4=p3*(1/(r**k))// polytropic process pressure
      relation
15 w34=v3*(r*p4-p3)/(1-k) // polytropic work done in
      process 3 to 4
16 v2=v3 // constant volume process
17 w12=v2*(p2-r*p1)/(1-k)
18 wcycle=w12+w34 // total work in cycle
19  // now equating the polytropic work calculated to
```

```
             work by MEP
20  MEP=wcycle/(r*v2-v2) // as work = pressure*change in
        volume
21  printf("The MEP is %i kPa",MEP)
22  // The solution is wrong in textbook as calculation
        for P2 is wrong
```

Scilab code Exa 7.2 Otto cycle with compression ratio of 10

```
 1  clc
 2  //solution
 3  // initialization of variables
 4
 5  r=10 // compression ratio
 6  k=1.4 // polytropic index for air
 7  R=0.287 // specific gas constant for air
 8  Cv=0.717 // specific heat at constant volume
 9  Wnet=1000 // net work output in kJ/kg
10  T1=227+273 // low air temperaure in kelvin
11  p1=200 // low pressure in kPa
12
13  effi=1-(1/r^(k-1)) // thermal efficeiency
14  printf("The maximum possible thermal efficiency is
        %0.1f %% \n",effi*100)
15
16  T2=T1*(r)^(k-1) // isentropic process temperature
        relation
17
18  T4=((Wnet/Cv)+T2-T1)/((r^(k-1))-1) // using
        expression for work
19
20  T3=T4*(r)^(k-1)
21
22  efficarnot=1-T1/T3
23  printf("The carnot efficiency is %0.1f %%",
```

```
      efficarnot *100)
24
25  v1=R*T1/p1 // initial volume
26  v2=v1/r // from compression ratio
27
28  MEP=Wnet/(v1-v2) // mean effective pressure equation
29
30  printf("The MEP is %0.0f kPa",MEP)
```

Scilab code Exa 7.3 A diesel cycle with a compression ratio 18

```
1  clc
2  //solution
3  // initialization of variables
4
5
6  r=18 // compression ratio
7  k=1.4 // polytropic index for air
8  R=0.287 // specific gas constant for air
9  Cv=0.717 // specific heat at constant volume
10  Cp=1.0 // specific heat at constant pressure
11  T1=200+273 // lower temperaure in kelvin
12  P1=200 // low pressure in kPa
13  T3=2000 // higher temperature of cycle in kelvin
14
15  v1=R*T1/P1 // specific volume at state 1 in m^3
16  v2=v1/r // specific volume after compression in m^3
17
18  T2=T1*(v1/v2)^(k-1) // temperature after compression
19  P2=P1*(v1/v2)^k // pressure after compression
20  P3=P2 // diesel cycle
21  v3=R*T3/P3 // volume at state 3
22
23  rc=v3/v2 // cutoff ratio
24
```

```
25  effi=1-((rc^k)-1)/(r^(k-1)*k*(rc-1))
26
27
28  printf("The thermal efficiency is %0.2f %% \n",effi
        *100)
29
30  v4=v1 // diesel cycle
31  T4=T3*(v3/v4)^(k-1) // adiabatic process
32
33  qin=Cp*(T3-T2) // using first law
34  qout=Cv*(T4-T1) // heat rejected
35
36  Wnet=qin-qout // net work
37  MEP=Wnet/(v1-v2) // expression of mean effective
        pressure in terms of work
38
39  printf(" The MEP is %i kPa",MEP)
```

Scilab code Exa 7.4 without constant specific heats

```
1  clc
2  //solution
3  // initialization of variables
4
5  r=18 // compression ratio
6  k=1.4 // polytropic index for air
7  R=0.287 // specific gas constant for air
8  T1=200+273 // lower temperaure in kelvin
9  P1=200 // low pressure in kPa
10  T3=2000 // higher temperature of cycle in kelvin
11
12  v1=R*T1/P1 // specific volume at state 1 in m^3
13  //using table E.1
14  u1=340 // specific internal energy in kJ/kg
15  vr1=198.1 // in m^3/kg
```

```
16
17  vr2=vr1*(1/r) // as r=v1/v2
18
19  // now finding corresponding values from table E.1
20  T2=1310 // temperature in kelvin
21  Pr2=34 // pressure in kPa
22  h2=1408 // specific entropy in kJ/kg
23  v2=v1/18 // volume at state 2
24  P2=R*T2/v2 // pressure at state 2
25
26  h3=2252.1 // specific enthalpy in kJ/kg from table E
        .1
27  vr3=2.776
28  P3=P2 // diesel cycle
29  v3=R*T3/P3 // after compression volume
30  v4=v1 // isochoric process
31  vr4=vr3*v4/v3 // isentropic process
32  // now using Vr4 we read corresponding value from
        table E.1
33  T4=915 // final temperature in kelvin
34  u4=687.5 // specific internal energy at state 4
35
36  qin=h3-h2 // using first law
37  qout=u4-u1 // heat rejected
38
39  Wnet=qin-qout // net work
40  effi=100*Wnet/qin // thermal efficiency
41  printf("The thermal efficiency is %0.2f %% \n",effi)
42
43  MEP=Wnet/(v1-v2) // expression of mean effective
        pressure in terms of work
44
45  printf(" The MEP is %0.2f kPa \n",MEP)
46
47  erroreffi=(66.6-effi)*100/effi // error in
        efficiency
48  errorMEP=(515-MEP)*100/MEP // error in MEP
49
```

```
50  printf(" The %% error in efficiency is %0.1f %% \n",
        erroreffi)
51  printf(" The %% error in MEP is %0.1f %% \n",
        errorMEP)
52
53  // the answers are slight different due to
        approximation in textbook ... here answers are
        precise
```

Scilab code Exa 7.5 thermal efficiency for this Brayton cycle

```
1   clc
2   // solution
3   // initialization of variables
4   Cp=1.0 // specific heat at constant pressure
5   k=1.4 // polytropic index for air
6   T1=25+273 // temperature at compressor inlet
7   T3=850+273 // maximum temperature in kelvin
8
9   r=5 // pressure ratio=P2/P1 & P4/P3
10
11  T2=T1*(r)^((k-1)/k) // temperature after compression
12
13  T4=T3*(1/r)^((k-1)/k) // final temperature
14
15  Wcomp=Cp*(T2-T1) // compressor work
16  Wturb=Cp*(T3-T4) // turbine work
17
18  BWR=Wcomp/Wturb // back work ratio
19
20  printf("The BWR is %0.1f %%\n",BWR*100)
21
22  Effi=1-r^((1-k)/k) // thermal efficiency
23
24  printf(" The thermal efficiency is %0.1f %% \n",Effi
```

65

```
      *100)
```

Scilab code Exa 7.6 compressor and gas turbine have efficiency of 75 percent

```
1  clc
2  //solution
3  // initialization of variables
4
5  Cp=1.0 // specific heat at constant pressure
6  k=1.4 // polytropic index for air
7  T1=25+273 // temperature at compressor inlet
8  T3=850+273 // maximum temperature in kelvin
9
10 r=5 // pressure ratio=P2/P1 & P4/P3
11 efficomp=0.75 // efficiency of compressor
12 effiturb=0.75 // efficiency of turbine
13
14 T2dash=T1*(r)^((k-1)/k) // temperature after
       compression
15 Wcomp=Cp*(T2dash-T1)/efficomp // compressor work
16
17 T4dash=T3*(1/r)^((k-1)/k) // final temperature
18 Wturb=Cp*(T3-T4dash)*effiturb // turbine work
19
20 BWR=100*Wcomp/Wturb // back work ratio
21
22 printf("The BWR is %0.1f %%\n",BWR)
23
24 T2=(Wcomp/Cp)+T1 // actual temperature of state 2
25
26 qin=Cp*(T3-T2) // using first law
27
28 Wnet=(Wturb-Wcomp) // net work
29
```

```
30  effi =100* Wnet / qin // thermal efficiency
31  printf ("The thermal efficiency is %0.2 f %% \n", effi)
```

Scilab code Exa 7.7 ideal regenerator to the gas turbine cycle

```
1   clc
2   // solution
3   // initialization of variables
4
5   Cp =1.0 // specific heat at constant pressure
6   k =1.4 // polytropic index for air
7   T1 =25+273 // temperature at compressor inlet
8   T3 =850+273 // maximum temperature in kelvin
9
10  r =5 // pressure ratio=P2/P1 & P4/P3
11
12  T2= T1 *( r )^(( k -1)/ k ) // temperature after compression
13
14  T4= T3 *(1/ r )^(( k -1)/ k ) // final temperature
15
16  Wcomp = Cp *( T2 - T1 ) // compressor work
17  Wturb = Cp *( T3 - T4 ) // turbine work
18
19  BWR = Wcomp / Wturb // back work ratio
20
21  printf ("The BWR is %0.1 f %%\n", BWR *100)
22
23  effi =(1 -(( T1 / T4 )*( r ^(( k -1)/ k ))))// efficiency
24  printf (" The thermal efficiency is %0.1 f %% \n", effi
        *100)
25  // The solution in textbook is incorrect dur to
        wrong value of T4 (temperature at state 4)
```

Scilab code Exa 7.8 gas turbine provides the energy to the boiler

```
1  clc
2  clear
3  //solution
4  // initialization of variables
5
6  //REFER TO FIG.:7.8
7
8  Cp=1 // specific constant at constant pressure
9  k=1.4 // polytropic constant for air
10 T5=25+273 // temperature at state 5 in kelvin
11 T7=850+273 // temperature at state 4 in kelvin
12 T9=350 // exit temperature of water from bolier in
       kelvin
13 WdotST=100000 // power from steam turbine in Watt
14 r=5 // pressure ratio=P2/P1 & P4/P3
15
16 h1=192 // specific enthalpy at 10 Kpa from steam
       table
17 h2=h1 // isenthalpic process
18 h3=3214 // specific enthalpy at 4 Mpa and 400 degree
        celsius from steam table
19 s3=6.769 // specific entropy at 4 Mpa and 400 degree
        celsius from steam table
20
21 s4=s3 // isentropic process
22 sf=0.6491 // specific entropy of saturated liquid at
        10 kPa and 45 degree celsiusfrom table C.2
23 sg=8.1510 // specific entropy of saturated liquid at
        10 kPa and 45 degree celsiusfrom table C.2
24 x4=(s4-sf)/(sg-sf) // quality of steam
25
26 hf=h1 // specific enthalpy of saturated liquid @ 10
     Kpa
27 hg=2584.6
28 h4=hf+x4*(hg-hf) // specific entropy at state 4
29
```

```
30  mdots=WdotST/(h3-h4) // steam mass flow rate from
        turbine output

31
32  T6=T5*(r^((k-1)/k)) // adiabatic process relation
33  T8=T7*(1/r^((k-1)/k)) // adiabatic process relation

34
35  // Now using energy balance in boiler
36  mdota=mdots*(h3-h2)/(Cp*(T8-T9)) // mass flow rate
        of water
37  Wdotturb=mdota*Cp*(T7-T8) //  power produced by
        turbine

38
39  Wdotcomp=mdota*Cp*(T6-T5) // energy needed by
        compressor

40
41  WdotGT=Wdotturb-Wdotcomp // net turbine work

42
43  Qdotin=mdota*Cp*(T7-T6) // energy input by combustor

44
45  effi=100*(WdotST+WdotGT)/Qdotin // combined
        efficiency

46
47  printf("The thermal efficiency of the combined cycle
         is %0.1f %% ",effi)
```

Scilab code Exa 7.9 compressor with compression ratio of 10

```
1  clc
2  clear
3  //solution
4  // initialization of variables
5
6  Cp=1 // specific constant at constant pressure
7  k=1.4 // polytropic constant for air
8  r=10
```

```
 9  T2=-10+273 // temperature at entry  of compressor
10  T4=30+273 // temperature at entry of turbine
11
12  T3=T2*(r^((k-1)/k)) // temperature at state 3 in
        kelvin
13  T1=T4*(1/r^((k-1)/k)) // temperature at state 1 in
        degree celsius
14  printf("The minimum temperature is %0.1f degree
        celsius \n",T1-273)
15
16  qin=Cp*(T2-T1) // heat input
17  Wcomp=Cp*(T3-T2)// compressor work
18  Wturb=Cp*(T4-T1) // turbine work
19
20  COP=qin/(Wcomp-Wturb) // COP of refrigeration
21  printf(" The COP is %0.2f ",COP)
```

Scilab code Exa 7.10 adding ideal internal heat exchanger and regenerator

```
 1  clc
 2  clear
 3  //solution
 4  // initialization of variables
 5
 6  Cp=1 // specific constant at constant pressure
 7  k=1.4 // polytropic constant for air
 8  r=10
 9  T3=-10+273 // temperature at entry  of compressor
10  T6=-40+273 // temperature at entry of turbine
11
12  T5=T3 // heat exchanger
13  T2=T6 // heat exchanger
14
15  T4=T3*(r^((k-1)/k)) // temperature after compression
```

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```
16  T1=T6*(1/r^((k-1)/k))  // temperature after exit from
        turbine

17

18  printf("The minimum temperature is %0.i degree
        celsius \n",T1-273)

19

20  qin=Cp*(T2-T1)  // heat input
21  Wcomp=Cp*(T4-T3)// compressor work
22  Wturb=Cp*(T6-T1)  // turbine work

23

24  COP=qin/(Wcomp-Wturb)  // COP of refrigeration
25  printf(" The COP is %0.3f ",COP)

26

27  // the answer is correct within given limits
```

Chapter 8

Psychrometrics

Scilab code Exa 8.1 air at 25 degree Celsius and 100 kPa in 150 metre cube

```
 1 clc
 2 // solution
 3 //initialization of variables
 4 Ra=0.287 // specific gas constant for air
 5 P=100 // pressure of room in kPa
 6 V=150 // volume of room in m^3
 7 T=25+273 // temperature of air in kelvin
 8 phi=0.6 // relative humidity
 9 Pg=3.29 // saturation vapour pressure in kPa at 25 *
     C from table C.1
10 Mv= 18 // molecular mass of water vapor
11 Ma=28.97 // molecular mass of air
12
13 Pv=Pg*phi // partial pressure of water vapour
14
15 Pa=P-Pv // partial pressure of air
16
17 w=0.622*(Pv/Pa) // humidity ratio in Kg of water/ Kg
      of dry air
18 Tdp=17.4 // dew point temperature from interpolation
```

```
       in table C.2 corresponding to partial pressure
       Pv=1.98 kPa
19
20  ma=Pa*V/(Ra*T) // mass of air
21  mv=w*ma // mass of water vapour in  kg
22
23  // now we find volume percentage
24  Nv=mv/Mv // moles of vapour
25  Na=ma/Ma // moles of air
26
27  Vw= Nv/(Na+Nv) // fraction of volume occupied by
        water vapour
28
29  printf(" The humidity ratio is %0.3f Kg water/ kg of
         dry air \n",w)
30  printf("The dew point is %0.1f degree celsius \n ",
      Tdp)
31  printf("The mass of water vapour in the air is %0.2f
        kg \n",mv)
32  printf("The volume percentage of the room that is
      water vapor is %0.2f %%",Vw*100)
33  // The answers are correct within given limits
34  // The variation in answers is due to approximations
        made by
35  // textbook while scilab is precise
```

Scilab code Exa 8.2 air is cooled below the dew point to 10 degree Celsius

```
1  clc
2  clear
3  // solution
4  //initialization of variables
5  Ra=0.287 // specific gas constant for air
6  P=100 // pressure of room in kPa
7  w1=0.0126 // old humidity ratio of example 8.1−
```

```
 8  Pg=3.29 // saturation vapour pressure in kPa at 25 *
        C from table C.1
 9  mv=2.17 // initial mass of water vapour in example
        8.1
10  T=25+273 // temperature after reheat
11  V=150 // volume of room in m^3
12  Pv=1.228 // saturation vapour pressure in kPa @ 10
        degree celsius from table C.1
13  Pa=P-Pv // partial pressure of air
14  w2=0.622*(Pv/Pa) // new humidity ratio in Kg of
        water/ Kg of dry air
15  deltaw=w1-w2 // difference in humidity ratio
16  ma=Pa*V/(Ra*T) // mass of air
17  deltamv=deltaw*ma // mass of water vapour condensed
18  X=deltamv*100/mv // percentage of water vapour
        condensed
19  printf("The percentage that condenses is %0.1f %% \n
        ",X)
20  // AFTER REHEATING
21  phi=1.608*w2*Pa/Pg
22  printf("The relative humidity is %0.1f %%",phi*100)
```

Scilab code Exa 8.3 100 kPa air stream

```
 1  clc
 2  // solution
 3  //initialization of variables
 4  T1=40 // dry bulb temperature in degree celsius
 5  T2=20 // wet bulb temperature in degree celsius
 6  Cp=1.0 // specific heat
 7  P=100 // pressure of air stream in kPa
 8  pg1=7.383 //saturation pressure @ 40 degree celsius
 9  hfg2=2454 // latent heat for 20 degree celsius
10  Pg2=2.338 // saturation pressure @ 20 degree celsius
11  w2=0.622*Pg2/(P-Pg2) // specific humidity for wet
```

```
12 hg1=2574 // specific enthalpy of saturated vapour @
      40 degree celsius
13 hf2=83.9 //spedific enthalpy of saturated liquid @
      20 degree celsius
14 w1=((w2*hfg2)+Cp*(T2-T1))/(hg1-hf2)// specific
      humidity for 40 degree celsius
15 printf("The humidity ratio is %0.5f kg water/ Kg dry
       air \n",w1)
16 pv1=100*w1/(0.622+w1) // partial pressure of vapour
17 phi=pv1/pg1 // relative humidity
18 printf("The relative humidity is %0.1f %% \n",phi
      *100)
19
20 hv=hg1 // temperature is at DBT=40 degree celsius
21 h=Cp*T1+w1*hv // specific enthalpy  of air
22 printf("The specific enthalpy is %0.1f kJ/kg dry air
      ",h)
```

Scilab code Exa 8.5 Hot dry air passes through an evaporative cooler

```
1 clc
2 //solution
3 // initialization of variables
4
5 T1=40 // inlet temperature in degree celsius
6 T2=27 // outlet temperature in degree celsius
7 phi1= 10 // relative humidity at inlet
8 // as no heat transfer takes place thus isenthalpic
      process
9 //Thus following the enthalpy line at DBT=40 and
      Relative humidity=10
10 phi2=45 // by interpolation of constant enthalpy
      line
11 w1=0.0046// specific humidity @ T=40 and phi1=10
```

```
12  w2=0.010 // specific humidity at outlet
13  W=w2-w1 // amount of water added
14  Tmin=18.5 // minimum temperature at 100% relative
        humidity
15  printf("The relative humidity is %i %% \n ",phi2)
16  printf("The added water is %0.04f kg water/kg dry
        air \n",W)
17  printf("The lowest possible temperature is %0.1f *C
        ",Tmin)
```

Scilab code Exa 8.6 incoming volume flow rate is 50 metre cube per min

```
1   clc
2   //solution
3   // initialization of variables
4   T1=5+273 // outside air temperature in kelvin
5   P=100 // pressure in kPa
6   Ra=0.287 // specific gas constant for air
7   phi=0.7 // relative humidity outside
8   Qf=50/60 // volume flow rate in m^3/sec
9   Pg1=0.872 // saturation pressure at 278 K
10  Pv1=phi*Pg1 // partial pressure of water vapour
11  Pa1=P-Pv1 // partial pressure of air
12
13  rhoa=Pa1/(Ra*T1) // density of dry air
14
15  mdota= Qf*rhoa // mass flow rate of dry air
16
17  // using psychrometric chart at T1=5*C and phi1=70%
18  h1=14 // inlet enthalpy in kJ/kg
19  h2=35 // enthalpy after heating in kJ/kg
20
21  Qdot=mdota*(h2-h1) // heat transfer rate
22  // from psychrometric chart for T=25 *C and 35 kJ/kg
        enthalpy
```

```
23  phi2 =19 // realtive humidity
24  printf (" The heat transfer rate is %0.1 f kJ/s \n",
       Qdot )
25  printf (" The final relative humidity is %i %% ", phi2)
```

Scilab code Exa 8.7 heat transfer if the incoming volume flow rate of air is 60 metre cube per min

```
1   clc
2   // solution
3   // initialization of variables
4   //DATA TAKEN FROM PSYCHROMETRIC CHART
5   T1 =5+273 // outside temperature in kelvin
6   h1 =10// enthalpy in kJ/kg @ T=5 *C and 40 % relative
        humidity
7   Pg1 =0.872 // saturaion pressure in kPa for 5 degree
       celsius DBT
8   phi1 =0.4
9   h2 =33 // specific enthalpy at 25 *C and 40 %
       relatuve humidity
10  h3 =45 // specific enthalpy at state 3
11  P =100 // atmospheric pressure in kPa
12  Ra =0.287 // specific gas constant for air
13  Qf =60/60 // volume flow rate in m^3/s
14  Pv1 = phi1 * Pg1 // partial presure of water vapour
15  Pa1 =P - Pv1 // partial pressure of air
16  w2 =0.0021 // specific humidity @ 40 % relative
       humidity and 25*C temperature
17  w3 =0.008 // final specific humidity
18  rhoa1 = Pa1 /(Ra * T1) // air density
19  mdota = Qf * rhoa1 // mass flow rate of dry air
20
21  Qdot = mdota *( h2 - h1) // heat transfer rate
22
23  // as the process is isothermal thus
```

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```
24 mdots=mdota*(w3-w2)// mass flow rate of steam by
      conservation of mass
25 printf("the rate of steam supplied is %0.4f kg/s \n"
      ,mdots)
26 // also using energy balance
27 hs=(mdota*(h3-h2))/mdots // enthalpy of steam
28 hf=604.7 // enthalpy of saturated liquid @ 400 kPa
29 hg=2738.5 // enthalpy of saturated vapour @ 400 kPa
30 xs=(hs-hf)/(hg-hf)
31 printf("The quality of steam is %0.2f ",xs)
```

Scilab code Exa 8.8 Outside air at 30 degree C and 90 percent relative humidity

```
1 clc
2 //solution
3 // initialization of variables
4 // REFER TO FIG. 8.4
5 T1=30 // outside temperature in degree celsius
6 phi1=0.9 // outside relative humidity
7 T2=23 // room temperature in degree celsius
8 phi2=0.4 // relative humidity in room
9
10 // using psychrometric chart
11 w1=0.0245 // specific humidity @ 30 *C and relative
      humidity 0.9
12 h1=93 // specific enthalpy @ 30 *C and relative
      humidity 0.9
13 w2=w1 // during cooling humidity remains constant
14 w3=0.007 // specific humidity @ 23 *C and relative
      humidity 0.4
15 h4=41 // final specific enthalpy
16 h3=26 // specific enthalpy @ 23 *C and relative
      humidity 0.4
17 deltaw=w3-w2 // moisture removed
```

```
18  printf("the amount of moisture removed is %0.4f kg \
       n",deltaw)
19
20
21  qout=h3-h1 // heat removed F–G–H process
22
23  printf(" the heat removed is %i kJ/kg \n ",qout)
24
25  qin=h4-h3 // heat added to bring to desired state
26
27  printf(" the heat added is %i kJ/kg ",qin)
```

Scilab code Exa 8.9 Outside cool air is mixed with inside air

```
 1  clc
 2  //solution
 3  // initialization of variables
 4  P=100 // atospheric pressure in kPa
 5  R=0.287 // specific gas constant for air
 6  T1=15+273 // outside temperature in kelvin
 7  phi1=0.4// outside air relative humidity
 8  Qf1=40 // outside air flow rate in m^3/min
 9  T2=32+273 // inside temperature in kelvin
10  phi2=0.7 // inside air relative humidity
11  Qf2=20 // outside air flow rate in m^3/min
12  Ps1=1.7 // saturation pressure @ 15 degree celsius
        and 40% humidity
13  Ps2=4.9 // saturation pressure @ 32 degree celsius
        and 70% humidity
14
15  Pv1=Ps1*phi1 // partial pressure of water vapour
        outside
16
17  Pv2=Ps2*phi2 // partial pressure of water vapour
        inside
```

```
18
19  Pa1=P-Pv1 //partial pressure of dry air outside
20  Pa2=P-Pv2 //partial pressure of dry air inside
21
22  rhoa1=Pa1/(R*T1) // density of outside air
23  mdota1=Qf1*rhoa1 // mass flow rate of air outside
24
25  rhoa2=Pa2/(R*T2) // density of inside air
26  mdota2=Qf2*rhoa2 // mass flow rate of inside air
27   // using psychrometric chart locating state 1 and 2
28  h1=37 // specific enthalpy @ DBT 15*C and 40 %
        humidity
29  w1=0.0073 // specific humidity @ DBT 15*C and 40 %
        humidity
30  h2=110 // specific enthalpy @ DBT 32*C and 70 %
        humidity
31  w2=0.0302 // specific humidity @ DBT 32*C and 70 %
        humidity
32  ratio=mdota1/mdota2 // ratio of distance between
        states
33  // using this ratio state 3 is located on
        psychrometric chart
34  T3=(mdota1*T1+mdota2*T2)/(mdota1+mdota2)-273 //
        final temparature in celsius
35
36  phi3=65// final relative humidity at T3 from
        psychrometric chart
37
38  printf("The relative humidity is %i %% \n",phi3)
39  printf(" The resultant temperature is %i degree
        celsius",T3)
```

Scilab code Exa 8.10 cooling tower of power plant

```
1  clc
```

```scilab
2  //solution
3  // initialization of variables
4  mdotw3=10000 // mass flow rate of water entering in
       cooling tower in kg/min
5  Tw1=40+273 // temperature of water entering cooling
       tower in kelvin
6  Ta1=20+273 // temperature of air entering cooling
       tower in kelvin
7  phi1=0.5// relative humidity of entering air
8  Tw2=25+273 // temperature of water leaving cooling
       tower in kelvin
9  Ta2=32+273 // temperature of air leaving cooling
       tower in kelvin
10 phi2=0.98 // relative humidity of leaving air
11 // from psychrometric chart
12 h1=37// specific enthalpy of air @ 20*C DBT and 50%
       humidity
13 w1=0.0073 // specific humidity of air @ 20*C DBT and
        50% humidity
14 h2=110// specific enthalpy of air @ 32*C DBT and 98%
        humidity
15 w2=0.030 // specific humidity of air @ 32*C DBT and
       98% humidity
16
17 h3=167.5 // specific enthalpy of water from steam
       table at 40 degree celsius
18 h4=104.9 // specific enthalpy of water from steam
       table at 25 degree celsius
19
20 mdota=(mdotw3*(h4-h3))/(h1-h2+(w2-w1)*h4) // by
       energy balance
21
22
23 v1=0.84 // specific volume of air entering tower
       from psychrometric chart
24
25 Qf=mdota*v1 // volume flow rate in m^3/min
26 printf("The volume flow rate of air into the cooling
```

```
        tower  is  %i  m^3/min  \n",Qf)
27
28  mdot4=mdotw3-(w2-w1)*mdota  // by  mass  balance
29  printf("The  mass  flow  rate  of  water  that  leaves  the
        cooling  tower  is  %i  kg/min",mdot4)
30  // The  answers  is  slightly  different  in  textbook  due
        to  approximations  in  calculations  while  in
        scilab  solution  is  precise
```

Chapter 9

Combustion

Scilab code Exa 9.1 air fuel ratio of 20

```
1  clc
2  clear
3  // initialization of variables
4
5  AFactual=20 // air fuel ratio actual
6  // The energy balance is done from equation
7
8  // C4H10 + 6.5(O2+3.76N2)--------> 4CO2 + 5H2O + 24.44
       N2
9
10 P=100 // atmospheic preesure in kPa
11 mair=6.5*(1+3.76)*29 // mass of air
12 mfuel=1*58 // mass of fuel
13 AFth=mair/mfuel // theoritical air-fuel ratio
14 %excessair=(AFactual-AFth)*100/AFth
15
16 printf("The %% excess air is %0.2f %% \n",%excessair
       )
17
18 // NOW THE REACTION IS
19 // C4H10+ (1+%excessair/100)*6.5*(O2+3.76N2) -------->
```

```
          4CO2 + 5H2O + 1.903 O2 + 31.6 N2
20
21  %CO2=4/42.5*100  // VOLUME % OF CO2
22
23  printf("The volume %% of CO2 is %0.2f %% \n",%CO2)
24
25  // NOW WE FIND DEW POINT
26  Nv=5 // moles of water
27  N=42.5 // moles of air
28  Pv=P*(Nv/N) // partial pressure of vapour
29  Tdp=49// dew point temperature in degree celsius
       from table C.2
30
31  printf("The Dew point temperature is %i degree
       celsius",Tdp)
```

Scilab code Exa 9.2 Butane with 90 percent theoretical air

```
1  clc
2  // initialization of variables
3
4  %air=0.9 // 90% air is used for combustion
5
6  // THE REACTION IS
7  // C4H10 + 0.9*6.5*(O2+3.76N2)-----> aCO2 + 5H20 +
       bCO
8  // a and b are calculated by atomic balance
9  a=2.7
10 b=1.3
11 %CO=b*100/31 // volume % of CO
12
13 printf("The volume %% of CO is %0.2f %% \n",%CO)
14
15 mair=6.5*%air*4.76*29 // mass of air in kg
16 mfuel=1*58 // mass of fuel butane in kg
```

```
17  AF = mair / mfuel  // air−fuel ratio
18
19  printf (" The air to fuel ratio is %0.2 f kg air/ kg
        fuel " , AF )
20  // THE SOLUTION IS CORRECT BUT  THERE ARE SOME
        PRINTING MISTAKES IN TEXTBOOK
```

Scilab code Exa 9.3 Butane is burned with dry air

```
 1  clc
 2  // initialization of variables
 3
 4  // THE REACTION IS
 5  // aC4H10 + b(O2+3.76N2)−−−−> CO2 + 1CO + 3.5 H20 +
        84.6 N2 + cH2O
 6  // a , b and c are calculated by atomic balance
 7  // C:  4a=11+1
 8  // H:10 a=2c
 9  // O:2 b=22+1+7+c
10  // solving these equations using matrix
11  A =[4 0 0;10 0 -2;0 2 -1]
12  B =[12;0;30]
13  x = A \ B
14  a = x (1)
15  b = x (2)
16  c = x (3)
17
18  // Now equation becomes
19  //C4H10 + 7.5( O2+3.76N2)−−−−> 3.67CO2 + 0.33CO +
        1.17 H20 + 28.17N2 + 5H2O
20  //MOLES OF AIR in this equation is 7.5 moles
21  mairactual =7.5 // in moles
22  //MOLES OF AIR in standard equation of Ex.9 is 6.5
23  mairtheoritical =6.5
24  %theoriticalair =100*( mairactual / mairtheoritical )
```

```
25  printf("The %% theoritical air is %0.1f %% ",
        %theoriticalair)
```

Scilab code Exa 9.4 Volumetric analysis of the products of combustion

```
1  clc
2  // initialization of variables
3  // The reaction equation is
4  //CaHb + c(O2+3.76N2)----> 10.4CO2 + 1.2CO + 2.8O2 +
       85.6N2 + dH2O
5
6  // using atomic balancing
7  // C:a=10.4+12
8  //N:3.76c=85.6
9  //O:2c=20.8+1.2+5.6+d
10  //H:b=2d
11
12  // Solving these equations using matrix
13  A=[1 0 0 0;0 0 3.76 0;0 0 2 -1;0 1 0 -2]
14  B=[11.6;85.6;27.6;0]
15  x=A\B
16  a=x(1)
17  b=x(2)
18  c=x(3)
19  d=x(4)
20
21  // substituing these values in reaction equation
22  //C11.6H37.9 + 21.08(O2+3.76N2)----> 11.6CO2 + 18.95
       H2O + 79.26N2
23  %theoriticalair=22.8*100/21.08 // theoritical air
24  excessair=%theoriticalair -100
25
26  printf("The excess air is %i %%",excessair)
```

Scilab code Exa 9.5 enthalpy of combustion of gaseous and liquid propane

```
1  clc
2  // initialization of variables
3  // The reaction equation is
4  //C3H8 + 5(O2+3.76N2)---> 3CO2 + 18.8N2 + 4H2O
5
6  // All the enthalpy of formation values are taken
       from Table B.5 with units in kJ/mol
7  hfCO2 =-393520 // enthalpy associated with CO2
8  hfH2O =-285830 // enthalpy associated with H2O(l)
9  hfC3H8 =-103850// ehthalpy associated with C3H8
10
11  // by first law Q= Hproducts - Hreactants
12
13  Qg=3*(hfCO2)+4*(hfH2O)-(hfC3H8) // enthalpy of
       combustion for gaseous propane
14
15  printf("The enthalpy of combustion for gaseous
       propane is %i kJ\n",Qg)
16
17  hv=15060 // enthalpy of vaporization for propane
18
19  Ql=3*(hfCO2)+4*(hfH2O)-(hfC3H8-hv) // enthalpy of
       combustion for liquid propane
20
21  printf(" The enthalpy of combustion for liquid
       propane is %i kJ\n",Ql)
22
23  //The answers are slightly different in textbook as
       they have approximated the result while in SCILAB
        results are precise
```

Scilab code Exa 9.6 propane and air enter a steady flow combustion chamber

```
1  clc
2  // initialization of variables
3  // The reaction equation is
4  //C3H8 + 5(O2+3.76N2)---> 3CO2 + 18.8N2 + 4H2O
5
6  // All the enthalpy of formation values are taken
       from Table B.5 with units in kJ/mol
7  hfCO2=-393520 // enthalpy of formation associated
       with CO2
8  hbarCO2=22280 //enthalpy associated with CO2 at 600K
         from table E.4
9  hdotbarCO2=9364//enthalpy associated with CO2 at 298
       K from table E.4
10
11 hfH2O=-241820 // enthalpy of formation associated
       with gaseous H2O
12 hbarH2O=20402 //enthalpy associated with H20 at 600K
        from table E.6
13 hdotbarH2O=9904//enthalpy associated with H20 at 298
       K from table E.6
14
15 hfC3H8=-103850// ehthalpy of formation associated
       with C3H8
16
17 hbarN2=17563 //enthalpy associated with N2 at 600K
       from table E.2
18 hdotbarN2=8669//enthalpy associated with N2 at 298K
       from table E.2
19 // by first law Q= Hproducts - Hreactants
20
21 Qg=3*(hfCO2+hbarCO2-hdotbarCO2)+4*(hfH2O+hbarH2O-
```

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```
     hdotbarH2O)+18.8*(hbarN2-hdotbarN2)-(hfC3H8) //
         enthalpy of combustion
22
23 printf("The heat transfer required is %i kJ\n",Qg)
24
25 //The answer is WRONG textbook as they have made an
         error in calculating Qg
```

Scilab code Exa 9.7 Liquid octane fuels a jet engine

```
1 clc
2 // initialization of variables
3 // The reaction equation is
4
5 //C8H18 + 12.5(O2+3.76N2)----> 8CO2 + 47N2 + 9H2O
6
7 // All the enthalpy of formation values are taken
         from Table B.5 with units in kJ/mol
8 hfCO2=-393520 // enthalpy of formation associated
         with CO2
9 hbarCO2=42769 //enthalpy associated with CO2 at 1000
         K from table E.4
10 hdotbarCO2=9364//enthalpy associated with CO2 at 298
         K from table E.4
11
12 hfH2O=-241820 // enthalpy of formation associated
         with gaseous H2O
13 hbarH2O=35882 //enthalpy associated with H20 at 1000
         K from table E.6
14 hdotbarH2O=9904//enthalpy associated with H20 at 298
         K from table E.6
15 hfC3H8=-103850// ehthalpy of formation associated
         with C3H8
16
17 hbarN2p=(30784+29476)/2 //enthalpy associated with
```

```
        N2 at 1000K from table E.2 by averaging enthalpy
        at 1020K and 980K for product
18  hbarN2r=17563 //enthalpy associated with N2 at 600K
        from table E.2 for reactant
19  hdotbarN2=8669//enthalpy associated with N2 at 298K
        from table E.2
20
21  hfC8H18=-249910 // enthalpy of formation associated
        with octane taken from internet as not provided
        in textbook
22
23  hbarO2=17929 // enthalpy associated with O2 at 600K
        table E.3
24  hdotbarO2=8682//enthalpy associated with O2 at 298K
        table E.3
25
26  // using first law and including kinetic energy
        change
27  // 0=Hp-Hr+Mp*(V^2)/2
28
29  Hp=8*(hfCO2+hbarCO2-hdotbarCO2)+9*(hfH2O+hbarH2O-
        hdotbarH2O)+47*(hbarN2p-hdotbarN2)
30  // enthalpy of products
31
32  Hr=(hfC8H18)+12.5*(hbarO2-hdotbarO2)+47*(hbarN2r-
        hdotbarN2)
33  // enthalpy of reactants
34
35  Mp=8*44+9*18+47*28 //(mass of products by
        multiplying molecular mass to number of moles)
36
37  V=sqrt(2*1000*(Hr-Hp)/Mp)// exit velocity using
        energy balance
38
39  printf("The exit velocity is %i m/s",V)
40
41  //The answers are slightly different in textbook as
        they have approximated the values while in SCILAB
```

Scilab code Exa 9.8 octane with 300 percent excess air

```
1  clc
2  // initialization of variables
3
4  // The reaction equation with theoritical air is
5  // C8H18 + 12.5(O2+3.76N2)----> 8CO2 + 47N2 + 9H2O
6
7  // for 400% theoritical air reaction is
8
9  // C8H18 + 50(O2+3.76N2)----> 8CO2 + 188N2 + 9H2O +
       37.5O2
10
11 // All the enthalpy of formation values are taken
       from Table B.5 with units in kJ/mol
12 hfCO2=-393520 // enthalpy of formation associated
       with CO2
13 hbarCO2=42769 //enthalpy associated with CO2 at 1000
       K from table E.4
14 hdotbarCO2=9364//enthalpy associated with CO2 at 298
       K from table E.4
15 hfH2O=-241820 // enthalpy of formation associated
       with gaseous H2O
16 hbarH2O=35882 //enthalpy associated with H20 at 1000
       K from table E.6
17 hdotbarH2O=9904//enthalpy associated with H20 at 298
       K from table E.6
18 hbarN2p=(30784+29476)/2 //enthalpy associated with
       N2 at 1000K from table E.2 by averaging enthalpy
       at 1020K and 980K
19 hdotbarN2=8669//enthalpy associated with N2 at 298K
       from table E.2
20
```

```
21  hfC8H18 = -249910 // enthalpy associated with octane
        taken from internet as not provided in textbook
22  hbarO2 =31389 // enthalpy associated with O2 at 1000K
        table E.3
23  hdotbarO2 =8682 //enthalpy associated with O2 at 298K
        table E.3
24
25  Hp =8*( hfCO2 + hbarCO2 - hdotbarCO2 ) +9*( hfH2O + hbarH2O -
        hdotbarH2O ) +37.5*( hbarO2 - hdotbarO2 ) +188*( hbarN2p -
        hdotbarN2 )// enthalpy of products
26
27  Hr =( hfC8H18 )
28  // enthalpy of reactants
29
30  Q=Hp -Hr // using first law2
31
32  printf (" The heat transfer is %i kJ",Q)
33
34  //The answers are slightly different in textbook as
        they have approximated the values while in SCILAB
         results are precise
```

Scilab code Exa 9.9 constant volume bomb calorimeter

```
1  clc
2  // initialization of variables
3
4  // The reaction equation is
5  //C3H8 + 5O2——> 8CO2 + 4H2O
6
7  // All the enthalpy of formation values are taken
        from Table B.5 with units in kJ/mol
8  hfCO2 = -393520 // enthalpy associated with CO2
9  hfH2O = -241820 // enthalpy associated with gaseous
        H2O
```

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```
10  hfC3H8=103850// enthalpy of formation associated
       with C3H8
11  hfgC3H8=15060// enthalpy of vapourization associated
       with C3H8
12  T=20+273 // temperature in kelvin
13  Rbar=8.314 // universal gas constant
14  Nr=6 // number of moles of reactants
15  Np=7 // number of moles of products
16  Hp=3*(hfCO2)+4*(hfH2O) // enthalpy of products
17
18  Hr=hfC3H8+hfgC3H8 // enthalpy of reactants
19
20  Q=(Hp-Hr-(Nr-Np)*Rbar*T)*10^(-3) // heat transfer
       from first law
21
22  printf(" The heat transfer is %i MJ",Q)
23
24  //The answers are slightly different in textbook as
       they have approximated the values while in SCILAB
        results are precise
```

Scilab code Exa 9.10 propane with 250 percent theoretical air

```
1  clc
2  // initialization of variables
3
4  // The reaction equation for theoritical air is
5  //C3H8 + 5(O2 + 3.76N2) ———> 3CO2 + 4H2O + 18.8N2
6
7  // for 250% theoritical air reaction becomes
8  //C3H8 + 12.5(O2 + 3.76N2) ———> 3CO2 + 4H2O + 47N2 +
       7.5O2
9
10 // All the enthalpy of formation values are taken
       from Table B.5 with units in kJ/mol
```

```
11
12  Np=47+7.5+4+3 // number of moles of product
13  hfCO2=-393520 // enthalpy of formation associated
        with CO2
14  hbarCO2=(62963+65271)/2 //enthalpy associated with
        CO2 at 1380 K from table E.4
15  hbarCO2dash=(58381+60666)/2 //enthalpy associated
        with CO2 at 1300 K by average from table E.4
16  hdotbarCO2=9364//enthalpy associated with CO2 at 298
        K from table E.4
17
18  hfC3H8=-103850// ehthalpy of formation associated
        with C3H8
19
20  hfH2O=-241820 // enthalpy of formation associated
        with gaseous H2O
21  hbarH2O=(51521+53351)/2 //enthalpy associated with
        H20 at 1380 K by taking average from table E.6
22  hbarH2Odash=48807 //enthalpy associated with H20 at
        1300 K  from table E.6
23  hdotbarH2O=9904//enthalpy associated with H20 at 298
        K from table E.6
24
25  hbarN2=42920 //enthalpy associated with N2 at 1380K
        from table E.2 by interpolating enthalpy between
        1020K and 980K
26  hbarN2dash=40170 //enthalpy associated with N2 at
        1300 K from table E.2
27  hdotbarN2=8669//enthalpy associated with N2 at 298K
        from table E.2
28
29  hfO2=(44198+45648)/2 // enthalpy associated with O2
        at 1380 Kby taking average from table E.3
30  hfO2dash=48807 // enthalpy associated with O2 at
        1380 Kby taking average from table E.3
31  hdotbarO2=8682//enthalpy associated with O2 at 298K
        table E.3
32
```

```
33  // for adiabatic flame temperature first assume
        products composed only of nitrogen and Q=0 as
        adiabatic
34  hp=(hfC3H8-3*(hfCO2)-4*(hfH2O))/Np +hdotbarN2
35  // using hp we assume temp=1380 K
36  // then energy for 1380 k is
37  H1=3*(hfCO2+hbarCO2-hdotbarCO2)+4*(hfH2O+hbarH2O-
        hdotbarH2O)+7.5*(hfO2-hdotbarO2)+47*(hbarN2-
        hdotbarN2) // energy assuming temperature to be
        1380 K
38
39  //this is very large
40
41  // now at 1300 K adiabatic temperature
42  H2=3*(hfCO2+hbarCO2dash-hdotbarCO2)+4*(hfH2O+
        hbarH2Odash-hdotbarH2O)+7.5*(hfO2dash-hdotbarO2)
        +47*(hbarN2dash-hdotbarN2) // energy assuming
        temperature to be 1300 K
43
44   // now interpolation between these two temperatures
45  Tp=1300-((hp+H2)/(H1-H2))*(1380-1300) // adiabatic
        temperature by interpolation
46  printf("The adiabatic flame temperature is %i K",Tp)
47
48  //The answers is different in textbook as they hav
        printed the value of hfCO2 with positive sign
        while calculating H2
```

Scilab code Exa 9.11 the adiabatic flame temperature

```
1  clc
2  // initialization of variables
3
4  // The reaction equation for theoritical air is
5  //C3H8 + 5(O2 + 3.76N2) ---> 3CO2 + 4H2O + 18.8N2
```

```
 6
 7  // All the enthalpy of formation values are taken
        from Table B.5 with units in kJ/mol
 8
 9  Np=18.8+4+3 // number of moles of product
10  hfCO2=-393520 // enthalpy associated with CO2
11  hbarCO2=137400 //enthalpy associated with CO2 at
        2600 K from table E.4 by interpolation
12  hbarCO2dash=125152 //enthalpy associated with CO2 at
          2400 K from table E.4
13  hdotbarCO2=9364//enthalpy associated with CO2 at 298
        K from table E.4
14
15  hfC3H8=-103850// ehthalpy associated with C3H8
16
17  hfH2O=-241820 // enthalpy associated with gaseous
        H2O
18  hbarH2O=114273 //enthalpy associated with H20 at
        2600 K from table E.6
19  hbarH2Odash=103508 //enthalpy associated with H20 at
          2400 K  from table E.6
20  hdotbarH2O=9904//enthalpy associated with H20 at 298
        K from table E.6
21
22  hbarN2=86600 //enthalpy associated with N2 at 2600 K
         from table E.2 by interpolation
23  hbarN2dash=79320 //enthalpy associated with N2 at
        2400 K from table E.2
24  hdotbarN2=8669//enthalpy associated with N2 at 298K
        from table E.2
25
26  // for adiabatic flame temperature first assume
        products composed only of nitrogen and Q=0 as
        adiabatic
27  hp=(hfC3H8-3*(hfCO2)-4*(hfH2O))/Np +hdotbarN2
28
29  // using hp we assume temp=2600 K
30  // then energy for 2600 k is
```

```
31  H1 =3*( hfCO2 + hbarCO2 - hdotbarCO2 ) +4*( hfH2O + hbarH2O -
       hdotbarH2O ) +18.8*( hbarN2 - hdotbarN2 ) // energy
       assuming temperature to be 2600 K
32
33  // now at 2400 K adiabatic temperature
34  H2 =3*( hfCO2 + hbarCO2dash - hdotbarCO2 ) +4*( hfH2O +
       hbarH2Odash - hdotbarH2O ) +18.8*( hbarN2dash -
       hdotbarN2 ) // energy assuming temperature to be
       2400 K
35
36   // now interpolation between these two temperatures
37  Tp =2400 -(( hp+H2 ) /( H1 -H2 ) ) *(2600 -2400) // adiabatic
       temperature by interpolation
38  printf (" The adiabatic flame temperature is %i K", Tp )
39
40  // The answers are slightly different in textbook as
       they have approximated the values while in SCILAB
        results are precise
```