Scilab Textbook Companion for Applied Thermodynamics by O. Singh [1]

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May 16, 2016

Book Description

Title: Applied Thermodynamics

Author: O. Singh

Publisher: New Age International Pvt. Limited Publishers

Edition: 3

Year: 2009

ISBN: 978-81-224-29

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 1

Fundamental concepts and definitions

Scilab code Exa 1.1 To find out the pressure

```
1  //pathname=get_absolute_file_path('1.01.sce')
2  //filename=pathname+filesep()+'1.01-data.sci'
3  //exec(filename)
4  //Manometer deflection of Mercury(in m):
5  h=30*10^-2
6  //Density of mercury(in kg/m^3)
7  d=13550
8  //Acceleration due to gravity(in m/s^2):
9  g=9.8
10 //Pressure difference(in Pa):
11 p=d*g*h*10^-2
12 printf("\n\n RESULT \n\n")
13 printf("\n\n Pressure Difference= %f Pa \n\n",p)
```

Scilab code Exa 1.02 Effort required

```
1  //pathname=get_absolute_file_path('1.02.sce')
2  //filename=pathname+filesep()+'1.02-data.sci'
3  //exec(filename)
4  //Diameter of the vessel(in m):
5  d=30*10^-2
6  //Accelertion due to gravity(in m/s^2):
7  g=9.78
8  //Atmospheric pressure(in Pa):
9  p=76*(10^-2)*13550*g
10 //Area:
11 a=(%pi*d^2)/4
12 //Effort required:
13 F=p*a
14 printf("\n\n RESULT \n\n")
15 printf("\n\n Effort required= %f N",F)
```

Scilab code Exa 1.03 To find out the actual pressure of air

```
1  //pathname=get_absolute_file_path('1.03.sce')
2  //filename=pathname+filesep()+'1.03-data.sci'
3  //exec(filename)
4  //Difference in mercury column(in m):
5  h=30*10^-2
6  //Atmospheric Pressure(in kPa):
7  pa=101
8  //Acceleration due to gravity(in m/s^2):
9  g=9.78
10 //Guage pressure(in kPa):
11 gp=13550*g*h*10^-3
12 //Actual pressure:
13 ap=gp+pa
14 printf("\n\n RESULT \n\n")
15 printf("\n\n Actual pressure of air= %f kPa",ap)
```

Scilab code Exa 1.04 To find out the guage pressure

```
1  // pathname=get_absolute_file_path ( '1.04. sce ')
2  // filename=pathname+filesep ()+'1.04−data.sci '
3  // exec (filename)
4  // Depth of tank (in m):
5  h=1
6  // Specific gravity:
7  s=0.8
8  // Density of water (in kg/m^3):
9  d=1000
10 // Acceleration due to gravity (in m/s^2):
11 g=9.81
12 // Density of oil (in kg/m3):
13 dO=s*d
14 // Gauge pressure (in kPa):
15 gp=dO*g*h*10^-3
16 printf (" \n\n RESULT \n\n")
17 printf (" \n\n Gauge pressure=%f kPa\n\n",gp)
```

Scilab code Exa 1.05 To find out the pressure of the gas

```
1  // pathname=get_absolute_file_path ( '1.05. sce ')
2  // filename=pathname+filesep ()+'1.05−data.sci '
3  // exec (filename)
4  // Barometer Reading (in m):
5  h=76*10^-2
6  // Density of mercury (in kg/m^3):
7  d=13.6*10^3
8  // Acceleration due to gravity (in m/s^2):
9  g=9.8
10 // Difference of heights in gas barometer (in m):
```

```
11  h1=40*10^-2
12  //Pressure of gas(in kPa):
13  pg=(d*g*h1+d*g*h)*10^-3
14  printf("\n\n RESULT \n\n")
15  printf("\n\n Pressure of gas=%f kPa\n\n",pg)
```

Scilab code Exa 1.06 To find out the change in temperature

```
1  //pathname=get_absolute_file_path('1.06.sce')
2  //filename=pathname+filesep()+'1.06-data.sci'
3  //exec(filename)
4  //Mass of water(in kg):
5  m=1
6  //Altitude(in m):
7  h=1000
8  //Specific heat of water(in J/kg-K):
9  c=4.18*10^3
10  //Acceleration due to gravity(in m/s^2):
11  g=9.81
12  //Heat required for heating = Potential energy
13  Q=m*g*h
14  dT=Q/c
15  printf("\n\n RESULT \n\n")
16  printf("\n\n The change in temperature =%f degree
        celcius ",dT)
```

Scilab code Exa 1.07 To find out the spring balance reading

```
1  //pathname=get_absolute_file_path('1.07.sce')
2  //filename=pathname+filesep()+'1.07-data.sci'
3  //exec(filename)
4  //Weight of object at standard gravitational
        acceleration(in N):
```

```
5  w=100
6  //Standard  acceleration  due  to  gravity (in  m/s^2):
7  g=9.81
8  //Gravitation  acceleration  at  given  location (in  m/s
       ^2):
9  g1=8.5
10 //Mass  of  object (in  kg):
11 m=w/g
12 //Spring  balance  reading (in  N):
13 s=m*g1
14 printf("\n\n RESULT \n\n")
15 printf("\n\n The  spring  balance  reading = %f N \n\n"
       ,s)
```

Scilab code Exa 1.08 To determine the mass of the piston

```
1  //pathname=get_absolute_file_path ('1.08.sce')
2  //filename=pathname+filesep ()+'1.08-data.sci '
3  //exec(filename)
4  //Diameter  of  cylinder (in  m):
5  dia=15*10^-2
6  //Manometer  difference  in  Hg  column (in  m):
7  h=12*10^-2
8  //Density  of  mercury (in  kg/m^3):
9  d=13.6*10^3
10 //Acceleration  due  to  gravity (in  m/s^2):
11 g=9.81
12 //Weight  of  piston (in  N):  pressure*area
13 w=h*d*g*%pi*dia^2/4
14 //Mass  of  the  piston (in  kg):
15 m=w/g
16 printf("\n\n RESULT \n\n")
17 printf("\n\n Mass  of  the  piston= %f kg",m)
```

Scilab code Exa 1.09 To determine the pressure of the steam

```
1  //pathname=get_absolute_file_path('1.09.sce')
2  //filename=pathname+filesep()+'1.09-data.sci'
3  //exec(filename)
4  //Height of water column in limb AB(in m):
5  Hab=2*10^-2
6  //Height of mercury column in limb CD(in m):
7  Hcd=10*10^-2
8  //Barometer reading for atmospheric pressure(in m):
9  h=76*10^-2
10 //Density of mercury(in kg/m^3):
11 dm=13.6*10^3
12 //Density of water(in kg/m^3):
13 dw=1000
14 //Acceleration due to gravity(in m/s^2):
15 g=9.81
16 //Atmospheric pressure(in kPa):
17 Patm=dm*h*g*10^-3
18 //Pressure of water in column AB(in kPa):
19 Pab=dw*Hab*g*10^-3
20 //Pressure of mercury in column CD(in kPa):
21 Pcd=dm*Hcd*g*10^-3
22 //Pressure of steam(in kPa):
23 Ps=Patm+Pcd-Pab
24 printf("\n\n RESULT \n\n")
25 printf("\n\n Pressure of steam = %f kPa",Ps)
```

Scilab code Exa 1.10 To determine the absolute pressure in A and B

```
1  //pathname=get_absolute_file_path('1.10.sce')
2  //filename=pathname+filesep()+'1.10-data.sci'
```

```
3  // exec ( filename )
4  // Pressure in compartment A( in kPa ) :
5  Pa =400
6  // Pressure in compartment B( in kPa ) :
7  Pb =150
8  // Reading of barometer ( in m) :
9  h =720*10^ -3
10  // Density of mercury ( in kg/m^3 ) :
11  d =13.6*10^3
12  // Acceleration due to gravity ( in m/s^2 ) :
13  g =9.81
14  // Atmospheric pressure from barometer reading ( in kPa
         ) :
15  Patm = d * g * h *10^ -3
16  // Absolute pressure in compartment A( in kPa ) :
17  PaA = Pa + Patm
18  // Absolute pressure in compartment B( in kPa ) :
19  PaB = Pb + Patm
20  printf ( " \n\n RESULT \n\n " )
21  printf ( " \n\n Absolute pressure in compartment A=%f
         kPa " , PaA )
22  printf ( " \n Absolute pressure in compartment B=%f kPa
           \n\n " , PaB )
```

Scilab code Exa 1.11 To determine the air pressure

```
1  // pathname= get_absolute_file_path ( '1.11. sce ')
2  // filename=pathname+filesep ( ) + '1.11 - data . sci '
3  // exec ( filename )
4  // Atmospheric pressure ( in kPa ) :
5  Patm =90
6  // Density of water ( in kg/m^3 ) :
7  dw =1000
8  // Density of oil ( in kg/m^3 ) :
9  doil =850
```

```
10  // Density of mercury (in kg/m^3):
11  dm=13600
12  // Height of water column (in m):
13  h1=0.15
14  // Height of oil column (in m):
15  h2=0.25
16  // Height of mercury column (in m):
17  h3=0.40
18  // Acceleration due to gravity (in m/s^2):
19  g=9.81
20  // Pressure due to water column at reference line (in
        kPa):
21  Pw=dw*g*h1*10^-3
22  // Pressure due to oil column at reference line (in
        kPa):
23  Po=doil*g*h2*10^-3
24  // Pressure due to mercury column at reference line (
        in kPa):
25  Pm=dm*g*h3*10^-3
26  // Pressure due to air (in kPa):
27  Pa=Patm+Pm-Pw-Po
28  printf("\n\n RESULT \n\n")
29  printf("\n\n Air pressure=%f kPa \n\n",Pa)
```

Scilab code Exa 1.12 To determine the kinetic energy

```
1  // pathname=get_absolute_file_path('1.12.sce')
2  // filename=pathname+filesep()+'1.12-data.sci'
3  // exec(filename)
4  // Velocity of the object (in m/s):
5  v=750
6  // Gravitational force acting on the body (in N):
7  F=4000
8  // Acceleration due to gravity (in m/s^2):
9  g=8
```

```
10 //Mass of the object(in kg):
11 m=F/g
12 //Kinetic energy of the body(in J):
13 KE=1/2*m*v^2
14 printf("\n\n RESULT \n\n")
15 printf("\n\n Kinetic energy = %f J \n\n",KE)
```

Scilab code Exa 1.13 To determine the molecular weight of the gas

```
1 //pathname=get_absolute_file_path('1.13.sce')
2 //filename=pathname+filesep()+'1.13-data.sci'
3 //exec(filename)
4 //Specific heat at constant pressure(in kJ/kg-K):
5 Cp=2.286
6 //Specific heat at constant volume(in kJ/kg-K):
7 Cv=1.768
8 //Universal gas constant(in kJ/kg-K):
9 Ru=8.314
10 //Gas constant(in kJ/kg-K):
11 R=Cp-Cv
12 //Molecular weight of gas(in kg/K mol):
13 m=Ru/R
14 printf("\n\n RESULT \n\n")
15 printf("\n\n Molecular weight of gas = %f kg/K mol",
    m)
```

Scilab code Exa 1.14 To determine the final temperature

```
1 //pathname=get_absolute_file_path('1.14.sce')
2 //filename=pathname+filesep()+'1.14-data.sci'
3 //exec(filename)
4 //Initial pressure(in Pa):
5 p1=750*10^3
```

```
6  //Initial temperature(in K):
7  t1=600
8  //Initial volume(in m^3):
9  v1=0.2
10 //Final pressure(in Pa):
11 p2=2*10^5
12 //Final volume(in m^3):
13 v2=0.5
14 //Final temperature(in K):
15 t2=p2*v2*t1/(p1*v1)
16 printf("\n\n RESULT \n\n")
17 printf("\n\n Final temperature = %f K \n\n",t2)
```

Scilab code Exa 1.15 To find out mass of air removed and volume at initial states

```
1  //pathname=get_absolute_file_path('1.15.sce')
2  //filename=pathname+filesep()+'1.15-data.sci'
3  //exec(filename)
4  //Initial pressure(in kPa):
5  p1=100
6  //Initial temperature(in K):
7  t1=300
8  //Initial volume(in m^3):
9  v1=5
10 //Final pressure(in kPa):
11 p2=50
12 //Final temperature(in K):
13 t2=280
14 //Final volume(in m^3):
15 v2=5
16 //Gas constant for air(in J/kg–K):
17 R=287//Initial pressure(in kPa):
18 p1=100
19 //Initial temperature(in K):
```

```
20  t1 =300
21  // Initial volume(in m^3):
22  v1 =5
23  // Final pressure(in kPa):
24  p2 =50
25  // Final temperature(in K):
26  t2 =280
27  // Final volume(in m^3):
28  v2 =5
29  // Gas constant for air(in J/kg-K):
30  R =287
31  // Initial mass(in kg):
32  m1 = p1 * v1 /( R * t1 ) *10^3
33  // Final mass(in kg):
34  m2 = p2 * v2 /( R * t2 ) *10^3
35  // Mass removed(in kg):
36  dm = m1 - m2
37  // Volume of this mass of air at initial states(in m
       ^3):
38  V = dm * R * t1 / p1
39  printf ("\n\n RESULT \n\n")
40  printf ("\n\n Mass of air removed = %f kg", dm)
41  printf ("\n Volume of air at initial states = %f m^3\
       n\n", V)
```

Scilab code Exa 1.16 To determine heat to be supplied

```
1  // pathname=get_absolute_file_path ('1.16. sce ')
2  // filename=pathname+filesep ()+'1.16-data.sci '
3  // exec(filename)
4  // Diameter of the vessel(in m):
5  d =1
6  // Height of the vessel(in m):
7  h =4
8  // Volume of the vessel(in m^3):
```

```
 9  v=%pi*d^2*h/4
10  //Initial pressure(in kPa):
11  p1=100
12  //Initial temperature(in K):
13  t1=300
14  //Final pressure(in kPa):
15  p2=125
16  //Cp of hydrogen(in kJ/kg-K):
17  Cp=14.307
18  //Cv of volume(in kJ/kg-K):
19  Cv=10.183
20  //Final temperature(in K):
21  t2=p2*t1/p1
22  //Gas constant for hydrogen:
23  R=Cp-Cv
24  //Mass of hydrogen(in kg):
25  m=p1*v/(R*t1)
26  //Heat supplied at const. volume(in kJ):
27  Q=m*Cv*(t2-t1)
28  printf("\n\n RESULT \n\n")
29  printf("\n\n Heat to be supplied = %f kJ",Q)
```

Scilab code Exa 1.17 To determine the final pressure

```
 1  //pathname=get_absolute_file_path('1.17.sce')
 2  //filename=pathname+filesep()+'1.17-data.sci'
 3  //exec(filename)
 4  //Total volume(in m^3):
 5  v=2+2
 6  //Mass of air in container 1(in kg):
 7  m1=20
 8  //Mass of air in container 2(in kg):
 9  m2=4
10  //Temperature of the system(in K):
11  t=300
```

```
12  //Gas constant for air(in J/kg-K):
13  R=287
14  //Total mass after the valve is opened(in kg):
15  m=m1+m2
16  //Final pressure(in kPa):
17  p=m*R*t/v*10^-3
18  printf("\n\n RESULT \n\n")
19  printf("\n\n Final pressure = %f kPa",p)
```

Scilab code Exa 1.18 To determine the pressure of carbon di oxide gas

```
1   //pathname=get_absolute_file_path('1.18.sce')
2   //filename=pathname+filesep()+'1.18-data.sci'
3   //exec(filename)
4   //Mass of gas(in kg):
5   m=5
6   //Volume of the container(in m^3):
7   v=2
8   //Temperature in the container(in K):
9   t=300
10  //Universal gas constant(in kJ/kg-K):
11  R=8.314
12  //Vander-Waals Constant(from table):
13  a=3628.5*10^2
14  b=3.14*10^-2
15  //Molecular weight of CO2:
16  mw=44.01
17  //Considering it as a perfect gas
18  //Gas constant for CO2(in j/kg-K):
19  Rp=R*10^3/mw
20  //Pressure of the gas(in N/m^2):
21  pp=m*Rp*t/v
22  //Considering it as a real gas:
23  //Molar specific volume(in m^3/kg.mol):
24  v1=v*mw/m
```

```
25  // Vanderwall eqn:
26  pr=R*10^3*t/(v1-b)-a/(v1^2)
27  printf("\n\n RESULT \n\n")
28  printf("\n\n Pressure if considered perfect gas = %f
        N/m^2",pp)
29  printf("\n\n Pressure if considered real gas = %f N/
        m^2",pr)
```

Scilab code Exa 1.19 To find out the specific volume

```
1   //pathname=get_absolute_file_path('1.19.sce')
2   //filename=pathname+filesep()+'1.19-data.sci'
3   //exec(filename)
4   //Pressure of steam(in kPa):
5   p=17672
6   //Temperature of steam(in K):
7   t=712
8   //Critical pressure(in kPa):
9   Pc=22.09*10^3
10  //Critical temperature(in K):
11  Tc=647.3
12  //Gas constant for steam(in kJ/kg-K):
13  Rs=0.4615
14  //Considering perfect gas:
15  //Specific volume(in m^3/kg)
16  vp=Rs*t/p
17  //Considering real gas:
18  //Reduced pressure:
19  Rp=p/Pc
20  //Reduced temperature:
21  Rt=t/Tc
22  //Value of compressibility factor(from chart for Rp
        & Rt):
23  Z=0.785
24  //Specific volume(in m^3/kg):
```

```
25  vr=Z*vp
26  printf("\n\n RESULT \n\n")
27  printf("\n\n Specific volume considering perfect gas
        = %f m^3/kg",vp)
28  printf("\n Specific volume considering real gas =%f
        m^3/kg \n\n",vr)
```

Scilab code Exa 1.20 To find out load lifting capacity

```
1  //pathname=get_absolute_file_path('1.20.sce')
2  //filename=pathname+filesep()+'1.20-data.sci'
3  //exec(filename)
4  //Diameter of the balloon(in m):
5  d=5
6  //Atmospheric pressure(in N/m^2):
7  p=1.013*10^5
8  //Temperature of the surroundings(in K):
9  t=17+273
10  //Universal gas constant(in J/kg-K):
11  R=8.314*10^3
12  //Molecular weight of hydrogen:
13  mw=2
14  //Gas constant for air(in J/kg-K):
15  Ra=287
16  //Volume of the balloon(in m^3):
17  v=4/3*%pi*(5/2)^3
18  //Gas constant for H2(in kJ/kg-K):
19  Rh=R/mw
20  //Mass of H2 in balloon(in kg):
21  mh=p*v/(Rh*t)
22  //Volume of air displaced(in m^3):
23  vd=v
24  //Mass of air displaced(in kg):
25  ma=p*vd/(Ra*t)
26  //Load lifting capacity due to buoyant force(in kg):
```

```
27  L=ma-mh
28  printf("\n\n RESULT \n\n")
29  printf("\n\n Load lifting capacity = %f \n\n",L)
```

Scilab code Exa 1.21 To find out the time required

```
1   //pathname=get_absolute_file_path('1.21.sce')
2   //filename=pathname+filesep()+'1.21-data.sci'
3   //exec(filename)
4   //Volume of vessel(in m^3):
5   v=20
6   //Rate at which air is drawn(in m^3/min):
7   q=0.25
8   //Initial pressure/final pressure (ratio):
9   Pr=4
10  //Time required(in min):
11  t=v/q*log(Pr)
12  printf("\n\n RESULT \n\n")
13  printf("\n\n Time required = %f mins \n\n",t)
```

Scilab code Exa 1.22 To determine the specific heats

```
1   //pathname=get_absolute_file_path('1.22.sce')
2   //filename=pathname+filesep()+'1.22-data.sci'
3   //exec(filename)
4   //Total mass of system of gas(in kg):
5   M=5
6   //Compostion of Nitrogen:
7   n=0.80
8   //Compostion of Oxygen:
9   o=0.18
10  //Composition of Carbon dioxide:
11  c=0.02
```

```
12  //Compression ratio for Oxygen:
13  ro=1.4
14  //Compression ratio for Nitrogen:
15  rn=1.4
16  //Compression ratio for Carbon dioxide:
17  rc=1.3
18  //Universal gas constant(in J/kg-K):
19  R=8314
20  //Molecular weight of Nitrogen:
21  mwn=28
22  //Molecular weight of Oxygen:
23  mwo=32
24  //Molecular weight of Carbon dioxide:
25  mwc=44
26  //Gas constant for Nitrogen(in J/kg-K):
27  Rn=R/mwn
28  //Gas constant for Oxygen(in J/kg-K):
29  Ro=R/mwo
30  //Gas constant for Carbon dioxide(in J/kg-K):
31  Rc=R/mwc
32  //Gas constant for mixture(in J/kg-K):
33  Rm=n*Rn+o*Ro+c*Rc
34  //Specific heat at constant pressure for Nitrogen(in
        kJ/kg-K):
35  Cpn=(rn/(rn-1))*Rn
36  //Specific heat at constant pressure for Oxygen(in
       kJ/kg-K):
37  Cpo=(ro/(ro-1))*Ro
38  //Specific heat at constant pressure for Carbon
        dioxide(in kJ/kg-K):
39  Cpc=rc/(rc-1)*Rc
40  //Specific heat at constant pressure for the mixture
        (in kJ/kg-K):
41  Cpm=n*Cpn+o*Cpo+c*Cpc
42  //Number of moles of Nitrogen:
43  nn=n*M/mwn
44  //Number of moles of Oxygen:
45  no=o*M/mwo
```

```
46  //Number of moles of Carbon dioxide:
47  nc=c*M/mwc
48  //Total number of moles:
49  nt=nn+no+nc
50  //Mole fraction of Nitrogen:
51  xn=nn/nt
52  //Mole fraction of Oxygen:
53  xo=no/nt
54  //Mole fraction of Carbon dioxide:
55  xc=nc/nt
56  //Molecular weight of the mixture
57  mwm=xn*mwn+xo*mwo+xc*mwc
58  printf("\n\n RESULT \n\n")
59  printf("\n\n The molecular weight of the mixture =
        %f kg/kmol \n\n",mwm)
```

Scilab code Exa 1.23 To determine partial pressure of gases

```
 1  //pathname=get_absolute_file_path('1.23.sce')
 2  //filename=pathname+filesep()+'1.23-data.sci'
 3  //exec(filename)
 4  //Composition of Oxygen:
 5  o=0.18
 6  //Composition of Nitrogen:
 7  n=0.75
 8  //Composition of Carbon dioxide:
 9  c=0.07
10  //Pressure of mixture(in MPa):
11  p=0.5
12  //Temperature of the mixture(in K):
13  t=107+273
14  //Total mass of the mixture(in kg):
15  m=5
16  //Molecular weight of Nitrogen:
17  mwn=28
```

```
18  //Molecular weight of Oxygen:
19  mwo=32
20  //Molecular weight of Carbon dioxide:
21  mwc=44
22  //Total values of mixture(assume):
23  v=1
24  //Mole fraction of Oxygen(by volume):
25  xvo=o/v
26  //Mole fraction of Nitrogen(by volume):
27  xvn=n/v
28  //Mole fraction of Carbon dioxide(by volume):
29  xvc=c/v
30  //Molecular weight of the mixture(in kg/kmol):
31  mwm=xo*mwo+xn*mwn+xc*mwc
32  //Mole fraction of Nitrogen(by mass):
33  xmn=n*mwn/mwm
34  //Mole fraction of Oxygen(by mass):
35  xmo=o*mwo/mwm
36  //Mole fraction of Carbon dioxide(by mass):
37  xmc=c*mwc/mwm
38  //Partial pressure of Oxygen:
39  po=o*p
40  //Partial pressure of Nitrogen:
41  pn=n*p
42  //Partial pressure of Carbon dioxide:
43  pc=c*p
44  printf("\n\n RESULT \n\n")
45  printf("\n\n Mole fraction of Oxygen by mass = %f ",
       xmo)
46  printf("\n Mole fraction of Nitrogen by mass = %f ",
       xmn)
47  printf("\n Mole fraction of Carbon dioxide by mass =
        %f ",xmc)
48  printf("\n\n Partial pressure of Oxygen = %f MPa",po
       )
49  printf("\n Partial pressure of Nitrogen = %f MPa",pn
       )
50  printf("\n Partial pressure of Carbon dioxide = %f
```

```
        MPa" , pc )
```

Scilab code Exa 1.24 To find out the equilibrium pressure and temperature

```
1  // pathname=get_absolute_file_path ( ' 1.24. sce ' )
2  // filename=pathname+filesep ( ) + '1.24 − data . sci '
3  // exec ( filename )
4  //Volume of gas in 1 chamber ( in m^3 ) :
5  V=3
6  // Partial pressure of Nitrogen ( in kPa ) :
7  pn =800
8  // Partial pressure of Carbon dioxide ( in kPa ) :
9  pc =400
10 // Temperature of Nitrogen ( in K ) :
11 tn =480
12 // Temperature of Carbon dioxide ( in K ) :
13 tc =390
14 // Compression ratio for Nitrogen :
15 rn =1.4
16 // Compression ratio for Carbon dioxide :
17 rc =1.3
18 // Universal gas constant ( in J/kg−K ) :
19 R=8314
20 // Molecular weight of Nitrogen :
21 mwn =28
22 // Molecular weight of Carbon dioxide :
23 mwc =44
24 // Moles of Nitrogen :
25 nn=pn*V/(R*tn)
26 // Moles of Carbon dioxide :
27 nc=pc*V/(R*tc)
28 // Total no of moles :
29 nt=nn+nc
30 // Specific heat for Nitrogen at constant volume ( in J
```

```
     /kg-K):
31  cvn=(R/mwn)/(rn-1)
32  //Specific heat for Carbon dioxide at constant
        volume(in J/kg-K):
33  cvc=(R/mwc)/(rc-1)
34  //Mass of Nitrogen(in kg):
35  mn=nn*mwn
36  //Mass of Carbon dioxide(in kg):
37  mc=nc*mwc
38  //Equilibrium temperature of the mixture(in K):
39  t=(mn*cvn*tn+mc*cvc*tc)/(mn*cvn+mc*cvc)
40  //Equilibrium pressure of the mixture(kPa):
41  p=nt*R*t/(V+V)
42  printf("\n\n RESULT \n\n")
43  printf("\n\n Equilibrium temperature = %f K ",t)
44  printf("\n Equilibrium pressure = %f kPa",p)
```

Scilab code Exa 1.25 To find out specific heat of the mixture

```
1  //pathname=get_absolute_file_path('1.25.sce')
2  //filename=pathname+filesep()+'1.25-data.sci'
3  //exec(filename)
4  //Mass of hydrogen taken(in kg):
5  mh=2
6  //Mass of helium taken(in kg):
7  mhe=3
8  //Specific heat at constant pressure for hydrogen(in
        kJ/kg-K):
9  Ch=11.23
10 //Specific heat at constant pressure for helium(in
        kJ/kg-K):
11 Che=5.193
12 //Total mass of the mixture(in kg):
13 mt=mh+mhe
14 //Specific heat at constant pressure for the mixture
```

```
       ( in kJ/kg-K ) :
15  Cm =( Ch * mh + Che * mhe )/ mt
16  printf (" \n \n RESULT \n \n")
17  printf (" \n \n Specific heat at constant pressure for
        the mixture = %f kJ/kg-K \n \n",Cm)
```

Scilab code Exa 1.26 To determine capacity of the vessel

```
1  // pathname = get_absolute_file_path ( '1.26. sce ')
2  // filename = pathname + filesep ( ) + '1.26 - data . sci '
3  // exec ( filename )
4  // Mass of Hydrogen ( in kg ) :
5  mh =18
6  // Mass of Nitrogen ( in kg ) :
7  mn =10
8  // Mass of Carbon dioxide ( in kg ) :
9  mc =2
10  // Initial temperature ( in K ) :
11  t1 =27+273.15
12  // Final temperature ( in K ) :
13  t2 =2* t1
14  // Universal gas constant ( in kJ/kg-K ) :
15  R =8.314
16  // Molecular weight of Hydrogen :
17  mwh =2
18  // Molecular weight of Nitrogen :
19  mwn =28
20  // Molecular weight of Carbon dioxide :
21  mwc =44
22  // Initial pressure of the gases ( in kPa )
23  p1 =101.325
24  // Gas constant for Hydrogen ( in kJ/kg-K ) :
25  Rh = R / mwh
26  // Gas constant for Nitrogen ( in kJ/kg-K ) :
27  Rn = R / mwn
```

```
28 //Gas constant for Carbon dioxide (in kJ/kg-K):
29 Rc=R/mwc
30 //Gas constant for the mixture (in kJ/kg-K):
31 Rm=(mh*Rh+mn*Rn+mc*Rc)/(mh+mn+mc)
32 //Capacity of the vessel (in m^3):
33 V=(mh+mn+mc)*Rm*t1/p
34 //Final pressure of the mixture (in kPa):
35 p2=p1*t2/t1
36 printf("\n\n RESULT \n\n")
37 printf("\n\n Volume of the vessel = %f m^3",V)
38 printf("\n Final pressure of the mixture =%f kPa",p2
      )
```

Scilab code Exa 1.27 To determine the ratio of exit to inlet diameter

```
1  //pathname=get_absolute_file_path ('1.27.sce')
2  //filename=pathname+filesep()+'1.27-data.sci'
3  //exec(filename)
4  //Temperature of entering air (in K):
5  t1=27+273.15
6  //Temperature to which it gets heated up to (in K):
7  t2=500
8  //Ratio of exit to inlet diameter:
9  R=sqrt(t2/t1)
10 printf("\n\n RESULT \n\n")
11 printf("\n\n Ratio of exit to inlet diameter = %f \n
      \n",R)
```

Scilab code Exa 1.28 To determine the mass pumped out

```
1  //pathname=get_absolute_file_path ('1.28.sce')
2  //filename=pathname+filesep()+'1.28-data.sci'
3  //exec(filename)
```

```
 4  //Volume of vessel(in m^3):
 5  v=2
 6  //Atmospheric pressure(in kPa):
 7  p1=76/76*101.325
 8  //Temperature of gas(in K):
 9  t1=27+273.15
10  //Pressure difference(in kPa):
11  dp=70/76*101.325
12  //Univeresal gas constant(in kJ/kg-K):
13  R=8.314
14  //Molecular weight of hydrogen:
15  mwh=2
16  //Temperature after cooling(in case 2)(in K):
17  t2=10+273.15
18  //Case 1:
19  //Gas constant of hydrogen(in kJ/kg-K):
20  Rh=R/mwh
21  //Final pressure of hydrogen(in kPa):
22  p2=p1-dp
23  //Mass pumped out(in kg):
24  m=(p1-p2)*v/(Rh*t1)
25  //Case 2:(temperature reduces till 10 degrees
        isochorically)
26  //Pressure after cooling(in kPa):
27  p3=t2/t1*p2
28  printf("\n\n RESULT \n\n")
29  printf("\n\n Mass pumped out = %f kg",m)
30  printf("\n Final pressure if the temperature is
        reduced = %f kPa",p2)
```

Chapter 2

Zeroth law of thermodynamics

Scilab code Exa 2.01 To find temperature in degree celcius

```
1  //pathname=get_absolute_file_path('2.01.sce')
2  //filename=pathname+filesep()+'2.01-data.sci'
3  //exec(filename)
4  //Temperature of human body in degree Fahrenheit:
5  Tf=98.6;
6  //Temperature of the body in degree Celcius:
7  Tc=(Tf-32)/1.8
8  printf("\n\nRESULTS\n\n")
9  printf("\n\nTemperature of the human body in degree
        Celcius= %f \n\n",Tc)
```

Scilab code Exa 2.02 To find final pressure and temperature

```
1  //pathname=get_absolute_file_path('2.02.sce')
2  //filename=pathname+filesep()+'2.02-data.sci'
3  //exec(filename)
4  //Thermodynamic property at T=0:
5  p0=3;
```

```
6  //Thermodynamic property at T=100:
7  p100=8;
8
9  //Value of a:
10 a=(100-0)/(log(8)-log(3))
11 //Value of b:
12 b=0-a*log(3)
13 //At thermodynamic property p=6.5:
14 t=a*log(6.5)+b/2
15 printf("\n\nRESULTS\n\n")
16 printf("\n\nTemperature at the value of
       thermodynamic property (p=6.5)= %f \n\n",t)
```

Scilab code Exa 2.03 To find out the temperature

```
1  //pathname=get_absolute_file_path('2.03.sce')
2  //filename=pathname+filesep()+'2.03-data.sci'
3  //exec(filename)
4  //EMF at temperature T=0
5  E0=0.003*0-5*(10^-7)*(0^2)+0.5*10^-3
6  //EMF at temperature T=100
7  E100=0.003*100-5*(10^-7)*(100^2)+0.5*10^-3
8  //EMF at temperature T=30
9  E30=0.003*30-5*(10^-7)*(30^2)+0.5*10^-3
10 //Temperature shown by the thermometer at T=30:
11 t=(E30-E0)/(E100-E0)*(100-0)
12 printf("\n\nRESULT \n\n")
13 printf("\n\n The temperature shown by thermometer=
       %f \n\n",t)
```

Scilab code Exa 2.04 To find out variation in temperature

```
1  //pathname=get_absolute_file_path('2.04.sce')
```

```
2  // filename=pathname+filesep()+'2.04-data.sci'
3  // exec(filename)
4  //Temperature of gas using gas thermometer:
5  T1=50
6  //EMF at T=0:
7  E0=0.18*0-5.2*10^-4*(0^2)
8  //EMF at T=100:
9  E100=0.18*100-5.2*10^-4*(100^2)
10 //EMF at T=50:
11 E50=0.18*50-5.2*10^-4*(50^2)
12 //Temperature at EMF=E50:
13 t=(100-0)*E50/(E100-E0)
14 p=(t-50)/50*100
15 printf("\n\n RESULT \n\n")
16 printf("\n\n percentage variation= %f \n\n",p)
```

Scilab code Exa 2.05 To find out absolute zero temperature on new scale

```
1  // pathname=get_absolute_file_path('2.05.sce')
2  // filename=pathname+filesep()+'2.05-data.sci'
3  // exec(filename)
4  //Freezing point of water in unknown temperature
       scale:
5  X0=0
6  //Boiling point of water in unknown temperature
       scale:
7  X100=1000
8  //Conversion Relation : X=aC+b
9  //Value of a:
10 a=(X100-X0)/(100-0)
11 b=0
12 //Absolute temperature in new temperature scale:
13 X=a*-273.15+b
14 printf("\n\n RESULT \n\n")
15 printf("\n\n Conversion Relation: X=%f*C+%f",a,b)
```

```
16  printf("\n\n Absolute temperature in new scale= %f",
       X)
```

Chapter 3

First law of thermodynamics

Scilab code Exa 3.01 To find out work done on the system

```
1  //pathname=get_absolute_file_path('3.01.sce')
2  //filename=pathname+filesep()+'3.01-data.sci'
3  //exec(filename)
4  //Pressure in the gas cylinder(in kPa):
5  p=689
6  //Final volume(in m^3):
7  v2=0.045
8  //Initial volume(in m^3):
9  v1=0.04
10 //Work done by the paddle(in kJ):
11 Pw=-4.88
12 //Work done by the system on the piston(in kJ):
13 w=p*(v2-v1)
14 //Net Work of the system(in kJ):
15 wn=w+Pw
16 printf("\nRESULTS\n")
17 printf("\nWork done on the piston=%f kJ",w)
18 printf("\nWork done on the system=%f kJ",-wn)
```

Scilab code Exa 3.02 To find out the amount of heat required

```
1  //pathname=get_absolute_file_path('3.02.sce')
2  //filename=pathname+filesep()+'3.02-data.sci'
3  //exec(filename)
4  //Mass of the gas(in kg):
5  m=0.5
6  //Initial internal energy(in kJ/kg):
7  u1=26.6
8  //Final internal energy(in kJ/kg):
9  u2=37.8
10 //Heat required(in kJ):
11 Q=(u2-u1)*m
12 printf("\nRESULT\n")
13 printf("Heat required= %f kJ",Q)
```

Scilab code Exa 3.03 To find out the amount of heat to be removed

```
1  //pathname=get_absolute_file_path('3.03.sce')
2  //filename=pathname+filesep()+'3.03-data.sci'
3  //exec(filename)
4  //Mass flow rate(in kg/hr):
5  m=50
6  //Initial temp(in C):
7  t1=800
8  //Final temp(in C):
9  t2=50
10 //Heat capacity at const pressure(in kJ/kg.K):
11 Cp=1.08
12 //Heat to be removed(in kJ/hr):
13 Q=m*Cp*(t2-t1)
14 printf("\nRESULT\n")
15 printf("Heat should be removed at %d kJ/hr",-Q)
```

Scilab code Exa 3.04 To determine the work done

```
1  // pathname=get_absolute_file_path ('3.04.sce')
2  // filename=pathname+filesep ()+'3.04-data.sci'
3  // exec(filename)
4  // Volume of the cylinnder (in m^3):
5  v=0.78
6  // Atmospheric pressure (in kPa):
7  p=101.325
8  // Work done (in kJ):
9  w=p*v
10 printf("\nRESULT\n")
11 printf("\nWork done by air= %f",-w)
12 printf("\nWork done by surroundings= %f",w)
```

Scilab code Exa 3.05 To determine the heat interaction

```
1  // pathname=get_absolute_file_path ('3.05.sce')
2  // filename=pathname+filesep ()+'3.05-data.sci'
3  // exec(filename)
4  // Mass of the gas (in kg):
5  m=5
6  // Value of n in P*(V^n)=const:
7  n=1.3
8  // Initial pressure (in MPa):
9  p1=1
10 // Initial volume (in m^3):
11 v1=0.5
12 // Final pressure (in MPa):
13 p2=0.5
14 // Final volume (in m^3):
15 v2=v1*((p1/p2)^(1/n))
```

```
16 //Work done(in kJ):
17 w=(p2*v2-p1*v1)*10^3/(1-n)
18 //Change in internal energy(in kJ/kg):
19 du=1.8*(p2*v2-p1*v1)*10^3
20 //Heat interaction(in kJ):
21 Q=du+w
22 printf("\nRESULT\n")
23 printf("\nHeat interaction = %f kJ",Q)
24 printf("\nWork interaction = %f kJ",w)
25 printf("\nChange in internal energy = %f kJ",du)
```

Scilab code Exa 3.06 To determine the work done

```
1 //pathname=get_absolute_file_path('3.06.sce')
2 //filename=pathname+filesep()+'3.06-data.sci'
3 //exec(filename)
4 //Initial pressure(in MPa):
5 p1=1
6 //Final pressure(in MPa):
7 p2=2
8 //Initial volume(in m^3):
9 v1=0.05
10 //Value of n:
11 n=1.4
12 //Final volume(in m^3):
13 v2=v1*((p1/p2)^(1/n))
14 //Change in internal energy(in kJ/kg):
15 du=7.5*(p2*v2-p1*v1)*10^3
16 //Work done(in kJ):
17 w=(p2*v2-p1*v1)*10^3/(1-n)
18 //Heat interaction(in kJ):
19 Q=du+w
20 printf("\nRESULT\n")
21 printf("\nHeat interaction = %f kJ",Q)
22 printf("\nWork interaction = %f kJ",w)
```

```
23  printf("\nChange in internal energy = %f kJ",du)
24  //If 180 kJ heat transfer takes place:
25  //Work done(in kJ):
26  w2=180-du
27  printf("\nNew work = %f kJ",w2)
```

Scilab code Exa 3.07 To determine the heat transfer

```
1  //pathname=get_absolute_file_path('3.08.sce')
2  //filename=pathname+filesep()+'3.08-data.sci'
3  //exec(filename)
4  //Initial temperature(in K):
5  t1=627+273
6  //Final temperature(in K):
7  t2=27+273
8  //Specific heat at const pressure(in kJ/kg.K):
9  Cp=1.005
10  //Exit velocity(in m/s):
11  c2=sqrt(2*Cp*10^3*(t1-t2))
12  printf("\nRESULT\n")
13  printf("\nExit Velocity = %f m/s",c2)
```

Scilab code Exa 3.08 To determine the exit velocity

```
1  //pathname=get_absolute_file_path('3.08.sce')
2  //filename=pathname+filesep()+'3.08-data.sci'
3  //exec(filename)
4  //Initial temperature(in K):
5  t1=627+273
6  //Final temperature(in K):
7  t2=27+273
8  //Specific heat at const pressure(in kJ/kg.K):
9  Cp=1.005
```

```
10  //Exit velocity(in m/s):
11  c2=sqrt(2*Cp*10^3*(t1-t2))
12  printf("\nRESULT\n")
13  printf("\nExit Velocity = %f m/s",c2)
```

Scilab code Exa 3.09 To determine the heat to be transferred to the atmosphere

```
1   //pathname=get_absolute_file_path('3.09.sce')
2   //filename=pathname+filesep()+'3.09-data.sci'
3   //exec(filename)
4   //Work interaction(in kJ):
5   w=-200
6   //Increase in enthalpy(in kJ/kg):
7   dh=100
8   //Heat picked up by the cooling water(in kJ/kg):
9   qc=-90
10  //Heat flow(in kJ/kg):
11  Q=dh+w
12  //Heat transferred to atmosphere(in kJ/kg):
13  Qa=Q-qc
14  printf("\nRESULT\n")
15  printf("\nHeat transferred to atmosphere = %d kJ/kg"
        ,Qa)
```

Scilab code Exa 3.10 To determine the water circulation rate

```
1   //pathname=get_absolute_file_path('3.10.sce')
2   //filename=pathname+filesep()+'3.10-data.sci'
3   //exec(filename)
4   //Seating capacity:
5   c=500
6   //Heat requirement per person(in kcal/hr):
```

```
 7  q=50
 8  //Enthalpy of water entering the pipe(in kcal/kg):
 9  h1=80
10  //Enthalpy of water leaving the pipe(in kcal/kg):
11  h2=45
12  //Difference in elevation of inlet and exit pipe(in
       m):
13  z=10
14  //Acceleration due to gravity(in m/s^2):
15  g=9.81
16  //Heat to be supplied(in kcal/hr):
17  Q=c*q
18  //Heat lost by water(in kcal/kg):
19  Ql=-Q
20  //By SFEE:
21  //Quantity of water circulated(in kg/hr):
22  m=(Ql*10^3*4.18)/(g*z+(h2-h1)*10^3*4.18)
23  printf("\nRESULT\n")
24  printf("\nWater circulation rate = %f kg/min",m/60)
```

Scilab code Exa 3.11 To determine the steam supply rate

```
 1  //pathname=get_absolute_file_path('3.11.sce')
 2  //filename=pathname+filesep()+'3.11-data.sci'
 3  //exec(filename)
 4  //Enthalpy of steam entering the injector(in kcal/kg
       ):
 5  h1=720
 6  //Enthalpy of water entering(in kcal/kg):
 7  h2=24.6
 8  //Enthalpy of water and steam mixture leaving the
       injector(in kcal/kg):
 9  h3=100
10  //Depth of water injector from steam injector(in m):
11  z=2
```

```
12  //Velocity  of  steam  entering  the  injector(in  m/s):
13  v1=50
14  //Velocity  of  mixture  leaving  the  injector(in  m/s):
15  v3=25
16  //Heat  loss  from  injector  to  surroundings(in  kcal/kg
       ):
17  q=12
18  //By  applying  SFEE:
19  //Steam  supply  rate(in  kg/s):
20  m=(((v3^2)/2+h3*10^3*4.18)-(h2*10^3*4.18+g*z))/(((v1
       ^2)/2+h1*10^3*4.18)-((v3^2)/2+h3*10^3*4.18)-(q
       *10^3*4.18))
21  printf("\nRESULT\n")
22  printf("\nSteam  supply  rate  =  %f  kg/s",m)
```

Scilab code Exa 3.12 To determine the work done

```
1  //pathname=get_absolute_file_path('3.12.sce')
2  //filename=pathname+filesep()+'3.12-data.sci'
3  //exec(filename)
4  //Atmospheric  pressure(in  bar):
5  p=1.013
6  //Volume  to  which  the  baloon  is  inflated(in  m^3):
7  v=0.4
8  //Work  done  by  cylinder(in  kJ):
9  w1=0
10  //Work  done  by  the  balloon(in  kJ):
11  w2=p*10^5*v
12  //Total  work(in  kJ):
13  w=w1+w2
14  printf("\nRESULT\n")
15  printf("\nWork  done  by  the  system  upon  atmoshere  =
        %f  kJ",w/(10^3))
16  printf("\nWork  done  by  the  atmoshere  =  %f  kJ",-w
        /(10^3))
```

Scilab code Exa 3.13 To determine capacity of the generator

```
1  //pathname=get_absolute_file_path('3.13.sce')
2  //filename=pathname+filesep()+'3.13-data.sci'
3  //exec(filename)
4  //Heat added(in J/s):
5  Qa=5000
6  //Turbine work(in J/s):
7  Wt=0.25*Qa
8  //Heat rejected(in J/s):
9  Qr=0.75*Qa
10 //Work by feed pump(in J/s):
11 Wp=0.002*Qa
12 //Capacity of generator(in W):
13 C=Wt-Wp
14 printf("\nRESULT\n")
15 printf("\nCapacity of generator = %f kW ",C/(10^3))
```

Scilab code Exa 3.14 To determine the exit velocity

```
1  //pathname=get_absolute_file_path('3.14.sce')
2  //filename=pathname+filesep()+'3.14-data.sci'
3  //exec(filename)
4  //Ambient temperature(in K):
5  T1=27+273
6  //Temperature of air inside heat exchanger(in K):
7  T2=750+273
8  //Temperature of air leaving turbine(in K):
9  T3=600+273
10 //Temperature of air leaving the nozzle(in K):
11 T4=500+273
```

```
12  //Velocity of air entering turbine(in m/s):
13  c2=50
14  //Velocity of air entering the nozzle(in m/s):
15  c3=60
16  //Specific heat at constant pressure(in kj?kg.K):
17  Cp=1.005
18  //By applying SFEE between points 1 & 2:
19  //Heat transfer to air in heat exchanger(in kJ):
20  Q12=Cp*(T2-T1)
21  printf("\nRESULT\n")
22  printf("\nHeat transfer to air in heat exchanger =%f
        kJ",Q12)
23  //By applying SFEE between points 2 & 3:
24  //Power output from turbine(in kJ/s):
25  Wt=Cp*(T2-T3)+(c2^2-c3^2)*10^(-3)/2
26  printf("\nPower output from turbine = %f kJ/s",Wt)
27  //By applying SFEE between points 3 & 4:
28  //Velocity at exit of the nozzle(in m/s):
29  c4=sqrt(2*(Cp*(T3-T4)+(c3^2)*10^(-3)/2))
30  printf("\nVelocity at exit of the nozzle = %f m/s",
        c4)
```

Scilab code Exa 3.15 To determine the work done

```
1  //pathname=get_absolute_file_path('3.15.sce')
2  //filename=pathname+filesep()+'3.15-data.sci'
3  //exec(filename)
4  //Initial pressure(in MPa):
5  p1=0.5
6  //Initial temperature(in K):
7  T1=400
8  //Ratio of v2 to v1:
9  r1=2
10  //Ratio of v3 to v1:
11  r2=6
```

```
12  //Universal gas constant(in kJ/kg):
13  R=8.314
14  //Work from state 1 to 2(in kJ):
15  Wa=R*T1
16  //Temperature at point 2(in K):
17  T2=2*T1
18  //Work done from state 2 to 3(in kJ):
19  Wb=R*T2*log(r2/r1)
20  //Total work done by air(in kJ):
21  W=Wa+Wb
22  printf("\nRESULT\n")
23  printf("\nWork done = %f kJ",W)
```

Scilab code Exa 3.16 To determine the work done

```
1   //pathname=get_absolute_file_path('3.16.sce')
2   //filename=pathname+filesep()+'3.16-data.sci'
3   //exec(filename)
4   //Initial pressure(in MPa):
5   pi=0.5
6   //Initial volume(in m^3):
7   vi=0.5
8   //Final pressure(in MPa):
9   pf=1
10  //Atmospheric pressure(in Pa):
11  patm=1.013*10^5
12  //Final volume(in m^3):
13  vf=3*vi
14  //Work done(in J):
15  W=(vf-vi)*(pi+pf)*10^5/2
16  printf("\nRESULT\n")
17  printf("\nWork done = %d J",W)
```

Scilab code Exa 3.17 To determine the work done

```
1  //pathname=get_absolute_file_path('3.17.sce')
2  //filename=pathname+filesep()+'3.17-data.sci'
3  //exec(filename)
4  //Initial pressure(in MPa):
5  pi=0.5
6  //Initial volume(in m^3):
7  vi=0.5
8  //Final pressure(in MPa):
9  pf=1
10  //Atmospheric pressure(in Pa):
11  patm=1.013*10^5
12  //Adiabatic index of compression for H2:
13  rH2=CpH2/(CpH2-RH2)
14  //Adiabatic index of compression for N2:
15  rN2=CpN2/(CpN2-RN2)
16  //Final pressure of hydrogen(in Pa):
17  p2=p1*(v1/v2)^rH2
18  printf("\nRESULT\n")
19  printf("\nFinal pressure of hydrogen = %f MPa",p2
       /(10^6))
20  //Partition work:
21  Pw=0
22  printf("\nPartition work = %d",Pw)
23  //Work done upon H2(in J):
24  WH2=(p1*v1-p2*v2)/(rH2-1)
25  //Work done by nitrogen(in J):
26  WN2=-WH2
27  printf("\nWork done by hyrogen = %d J",WH2)
28  printf("\nWork done by nitrogen = %d J",WN2)
29  //Mass of N2(in kg):
30  mN2=p1*v1/(RN2*10^3*T1)
31  //Final temperature of N2(in K):
32  T2=p2*vN2*T1/(p1*v1)
33  //Cv of N2(in kJ/kg):
34  CvN2=CpN2-RN2
35  //Heat added to N2(in kJ):
```

```
36  QN2=mN2*CvN2*10^3*(T2-T1)+WN2
37  printf("\nHeat added to nitrogen = %f kJ",QN2/(10^3)
        )
```

Scilab code Exa 3.18 To determine the work available

```
1  //pathname=get_absolute_file_path('3.18.sce')
2  //filename=pathname+filesep()+'3.18-data.sci'
3  //exec(filename)
4  //Volume of the cylinder(in m^3):
5  v1=2
6  //Pressure in the cylinder(in Pa):
7  p1=0.5*10^6
8  //Temperature of the cylinder(in K):
9  T1=375
10 //Specific heat at const pressure(in kJ/kg.K):
11 Cp=1.003
12 //Specific heat at const volume(in kJ/kg.K):
13 Cv=0.716
14 //Gas constant for air(in kJ/kg.K):
15 Ra=0.287
16 //Atmospheric pressure(in Pa):
17 patm=1.013*10^5
18 //Compression ratio:
19 r=1.4
20 //Initial mass of air(in kg):
21 m1=p1*v1/(Ra*T1)
22 //Final temperature(in K):
23 T2=T1*(patm/p1)^((r-1)/r)
24 //Final mass of air left in tank(in kg):
25 m2=patm*v1/(Ra*T2)
26 //Kinetic energy available(in kJ):
27 KE=m1*Cv*T1-m2*Cv*T2-(m1-m2)*Cp*T2
28 printf("\nRESULT\n")
29 printf("\nAmount of work available = %f J",KE)
```

Scilab code Exa 3.19 To determine the final pressure and temperature

```
1  //pathname=get_absolute_file_path('3.19.sce')
2  //filename=pathname+filesep()+'3.19-data.sci'
3  //exec(filename)
4  //Pressure in the vessel(in Pa):
5  p1=0.5*10^6
6  //Volume of 1st chamber(in m^3):
7  v1=0.5
8  //Temperature in the vessel(in K):
9  T1=300
10 //Final pressure(in Pa):
11 p2=10^6
12 //Volume of 2nd chamber(in m^3):
13 v2=0.5
14 //Final temperature(in K):
15 T2=500
16 //Universal gas constant(in J/kg.K):
17 R=8314
18 //Moles in chamber 1:
19 n1=p1*v1/(R*T1)
20 //Moles in chamber 2:
21 n2=p2*v2/(R*T2)
22 //Temperature of the mixture(in K):
23 T3=(n1*T1+n2*T2)/(n1+n2)
24 //Final pressure(in MPa):
25 p3=(n1+n2)*R*T3/(v1+v2)
26 printf("\nRESULT\n")
27 printf("\nFinal pressure = %f MPa",p3/(10^6))
28 printf("\nFinal temperature = %f K",T3)
```

Scilab code Exa 3.20 To determine the heat to be transferred

```
1  // pathname=get_absolute_file_path ( ' 3.20. sce ' )
2  // filename=pathname+filesep ( ) + ' 3.20 − data . sci '
3  // exec ( filename )
4  // Volume of the bottle ( in m^3 ) :
5  v = 0.5
6  // Pressure in the bottle ( in Bar ) :
7  p = 1.0135
8  // Displacement work ( in N−m ) :
9  W= p *10^5*(0 - v )
10 // Heat transfer ( in N−m ) :
11 Q=-W
12 printf ( " \nRESULT \n " )
13 printf ( " \nHeat transferred = %d N−m " , Q )
```

Scilab code Exa 3.21 To determine the heat to be transferred

```
1  // pathname=get_absolute_file_path ( ' 3.21. sce ' )
2  // filename=pathname+filesep ( ) + ' 3.21 − data . sci '
3  // exec ( filename )
4  // Volume of bottle ( in m^3 ) :
5  v1 = 0.3
6  // Pressure in the bottle ( in bar ) :
7  p1 = 35
8  // Temperature in the bottle ( in K ) :
9  T1 = 40 + 273
10 // Turbo generator ' s actual output ( in kJ/s ) :
11 w1 = 5
12 // Final prssure ( in bar ) :
13 p2 = 1
14 // Final volume ( in m^3 ) :
15 v2 = v1
16 // Gas constant for air ( in kJ/kg . K ) :
17 Ra = 0.287
18 // Compression ratio :
19 r = 1.4
```

```
20  //% of output which is consumed= 60%
21  //Specific heat at const volume(in kJ/kg):
22  Cv=0.718
23  //Specific heat at const pressure(in kJ/kg):
24  Cp=1.005
25  //Final temperature(in K):
26  T2=T1*(p2/p1)^((r-1)/r)
27  //Initial mass in the bottle(in kg):
28  m1=p1*10^2*v1/(Ra*T1)
29  //Final mass in the bottle(in kg):
30  m2=p2*10^2*v2/(Ra*T2)
31  //Maximum work that can be obtained(in kJ):
32  W=(m1*Cv*T1-m2*Cv*T2)-(m1-m2)*Cp*T2
33  //Input to the turbo generator(in kJ/s):
34  i=w1/0.6
35  //Time duration(in s):
36  t=W/i
37  printf("\nRESULT\n")
38  printf("\nDuration = %f seconds",t)
```

Scilab code Exa 3.22 To determine the duration

```
1   //pathname=get_absolute_file_path('3.22.sce')
2   //filename=pathname+filesep()+'3.22-data.sci'
3   //exec(filename)
4   //Pressure at state 1(in bar):
5   p1=1.5
6   //Temperature at state 1(in K):
7   T1=77+273
8   //Pressure at state 2(in bar):
9   p2=7.5
10  //Mass of the air(in kg):
11  m=3
12  //Value of n:
13  n=1.2
```

```
14  //Gas constant for air(in kJ/kg.K):
15  Ra=0.287
16  //Temperature at state 2(in K):
17  T2=T1*(p2/p1)^((n-1)/n)
18  //Initial volume(in m^3):
19  v1=m*Ra*T1/(p1*10^2)
20  //Volume at state 2(in m^3):
21  v2=(p1*(v1^n)/p2)^(1/n)
22  //Temperature at state 3(in K):
23  T3=T1
24  //Volume at state 3(in m^3):
25  v3=v2*T3/T2
26  //Pressure at state 3(in bar):
27  p3=7.5
28  //Compression work during process 1-2(in kJ):
29  W12=m*Ra*(T2-T1)/(1-n)
30  //Work during process 2-3(in kJ):
31  W23=p2*(10^2)*(v3-v2)
32  //Work during process 3-1(in kJ):
33  W31=p3*10^2*v3*log(v1/v3)
34  //Net work(in kJ):
35  Wn=W12+W23+W31
36  printf("\nRESULT\n")
37  printf("\nHeat transferred from the system = %f kJ"
         ,-Wn)
```

Scilab code Exa 3.23 To determine the work available from the turbine

```
1  //pathname=get_absolute_file_path('3.23.sce')
2  //filename=pathname+filesep()+'3.23-data.sci'
3  //exec(filename)
4  //Volume of air bottle(in m^3):
5  v1=0.15
6  //Initial pressure(in bar):
7  p1=40
```

```
8  //Initial temperature(in K):
9  T1=27+273
10 //Final presure(in bar):
11 p2=2
12 //Final volume(in m^3):
13 v2=v1
14 //Gas constant for air(in kJ/kg):
15 Ra=0.287
16 //Specific heat at const pressure(in kJ/kg):
17 Cp=1.005
18 //Specific heat at const volume(in kJ/kg):
19 Cv=0.718
20 //Compression ratio:
21 r=1.4
22 //Initial mass of air in bottle(in kg):
23 m1=p1*10^2*v1/(Ra*T1)
24 //Final temperature(in K):
25 T2=T1*(p2/p1)^((r-1)/r)
26 //Final mass of air in bottle(in kg):
27 m2=p2*10^2*v2/(Ra*T2)
28 //Energy available for running of turbine due to
       emptying of bottle(in kJ):
29 E=m1*Cv*T1-m2*Cv*T2-(m1-m2)*Cp*T2
30 printf("\nRESULT\n")
31 printf("\nWorj available from turbine = %f",E)
```

Chapter 4

Second law of thermodynamics

Scilab code Exa 4.02 To determine heat to be supplied

```
1  //pathname=get_absolute_file_path('4.02.sce')
2  //filename=pathname+filesep()+'4.02-data.sci'
3  //exec(filename)
4  //Highest temperature(in K):
5  T1=400+273
6  //Lowest temperature(in K):
7  T2=15+273
8  //Work produced(in kJ):
9  w=200
10 //Ratio of Q1 to Q2 is same as T1 to T2
11 //Heat to be supplied(in kJ):
12 Q1=w/(1-T2/T1)
13 printf("\nRESULTS\n")
14 printf("\nHeat to be supplied = %f kJ",Q1)
```

Scilab code Exa 4.03 To determine the power required

```
1  //pathname=get_absolute_file_path('4.03.sce')
```

```
2  //filename=pathname+filesep()+'4.03−data.sci'
3  //exec(filename)
4  //Upper temperature(in K):
5  T1=42+273
6  //Lower temperature(in K):
7  T2=4+273
8  //Rate at which heat is extracted(in kJ/s):
9  Q2=2
10 //Heat to be supplied(in kJ/s):
11 Q1=T1/T2*Q2
12 //Power required(in kW):
13 P=Q1-Q2
14 printf("\nRESULTS\n")
15 printf("\nPower required for driving the
       refrigerator = %f kW",P)
```

Scilab code Exa 4.04 To determine the heat transferred

```
1  //pathname=get_absolute_file_path('4.04.sce')
2  //filename=pathname+filesep()+'4.04−data.sci'
3  //exec(filename)
4  //Source temperature(in K):
5  T1=827+273
6  //Sink temperature(in K):
7  T2=27+273
8  //Temperature in the refrigerator(in K):
9  T3=-13+273
10 //Heat input(in kJ):
11 Q1=2000
12 //Net work available(in kJ):
13 W=300
14 //Rate at which heat is extracted(in kJ):
15 Q2=Q1*T2/T1
16 //Work in the engine(in kJ):
17 We=Q1-Q2
```

```
18  //Work in the refrigerator (in kJ):
19  Wr=We-W
20  //Heat transferred to the refrigerant (in kJ):
21  Q3=Wr/(T2/T3-1)
22  //Heat transferred to reservoir by refrigerant (in kJ
        ):
23  Q4=Q3+Wr
24  //Total heat transferred to low temperature
        reservoir (in kJ):
25  Wt=Q2+Q4
26  printf("\nRESULTS\n")
27  printf("\nHeat transferred to refrigerant = %f kJ",
        Q3)
28  printf("\nTotal heat transferred to low temperature
        reservoir = %f kJ",Wt)
```

Scilab code Exa 4.05 To determine the minimum power required

```
1  //pathname=get_absolute_file_path('4.05.sce')
2  //filename=pathname+filesep()+'4.05-data.sci'
3  //exec(filename)
4  //Temperature inside the house (in K):
5  T1=25+273.15
6  //Temperature outside the house (in K):
7  T2=-1+273.15
8  //Heating load (in MJ/h):
9  Q1=125
10 //COP:
11 COP=1/(1-T2/T1)
12 //Minimum power required (in MJ/h):
13 W=Q1/COP
14 printf("\nRESULTS\n")
15 printf("\nMinimum power required = %f kW",W
        /(3600/10^3))
```

Scilab code Exa 4.06 To determine the power required

```
1  //pathname=get_absolute_file_path('4.06.sce')
2  //filename=pathname+filesep()+'4.06-data.sci'
3  //exec(filename)
4  //Inside temperature(in K):
5  T1=-15+273
6  //Atmospheric temperature(in K):
7  T2=35+273
8  //Heat to be extracted (in kW):
9  Q2=140.8
10 //Carnot COP of plant:
11 COP1=1/(T2/T1-1)
12 //Actual COP:
13 COP=COP1/4
14 //Power required(in kW):
15 W=Q2/COP
16 printf("\nRESULTS\n")
17 printf("\nPower required = %f kW",W)
```

Scilab code Exa 4.07 To determine the efficiency

```
1  //pathname=get_absolute_file_path('4.07.sce')
2  //filename=pathname+filesep()+'4.07-data.sci'
3  //exec(filename)
4  //Maximum temperature(in K):
5  T1=1150+273
6  //Minimum temperature(in K):
7  T2=27+273
8  //Efficiency:
9  n=1-(T2/T1)
10 printf("\nRESULTS\n")
```

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```
11  printf(" \n Efficiency = %f percent ",n*100)
```

Scilab code Exa 4.08 To determine the power required

```
1  //pathname=get_absolute_file_path('4.08.sce')
2  //filename=pathname+filesep()+'4.08-data.sci'
3  //exec(filename)
4  //Maximum temperature(in K):
5  T1=27+273
6  //Minimum temperature(in K):
7  T2=-8+273
8  //Leakage(in kJ/s):
9  Q=7.5/60
10 //Power required(in kW):
11 W=(T1-T2)*Q/T2
12 printf(" \nRESULTS\n")
13 printf(" \nPower required = %f kW",W)
```

Scilab code Exa 4.10 To determine the efficiency of the engine and COP of refrigerator

```
1  //pathname=get_absolute_file_path('4.10.sce')
2  //filename=pathname+filesep()+'4.10-data.sci'
3  //exec(filename)
4  //Temperature at which heat is receieved (in K):
5  T1=800
6  //Temperature maintained by the carnot engine(in K):
7  T2=280
8  //Temperature at which heat is rejected(in K):
9  T=2*T1*T2/(T1+T2)
10 //Efficiency:
11 n=(T1-T)/T1
12 //COP of refrigerator:
```

```
13  COP = T2 /( T - T2 )
14  printf (" \nRESULTS\n")
15  printf (" \nEfficiency = %f",n)
16  printf (" \nC.O.P of refrigerator = %f",COP)
```

Scilab code Exa 4.11 To determine the maximum and minimum temperature in the cycle

```
1   //pathname=get_absolute_file_path ('4.11.sce')
2   //filename=pathname+filesep ()+'4.11-data.sci'
3   //exec(filename)
4   //Efficiency of carnot cycle:
5   n=0.5
6   //Mass of air(in kg):
7   m=0.5
8   //Initial pressure(in Pa):
9   p2=7*10^5
10  //Initial volume(in m^3):
11  v2=0.12
12  //Heat transferred during the process 2-3(in kJ):
13  Q23=40
14  //Specific heat at const pressure(in kJ/kg):
15  Cp=1.008
16  //Specific heat at const volume(in kJ/kg):
17  Cv=0.721
18  //Gas constant for air:
19  Ra=287
20  //Maximum temperature of the cycle(in K):
21  T2=p2*v2/(m*Ra)
22  //Minimum temperature(in K):
23  T1=T2/2
24  //Volume at state 3(in m^3):
25  v3=v2*(%e^(Q23/(m*Ra*10^(-3)*T2)))
26  //Compression factor:
27  r=Cp/Cv
```

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```
28  //Pressure at point 1(in Pa):
29  p1=p2/((T2/T1)^(r/(r-1)))
30  //Volume at point 1(in m^3):
31  v1=m*Ra*T1/p1
32  //Temperature at state 3(in K):
33  T3=T2
34  //Temperature at state 4(in K):
35  T4=T1
36  //During process 1-2, work done(in kJ):
37  W12=-m*Cv*(T2-T1)
38  //Heat transfer in process 1-2(in kJ):
39  Q12=0
40  //Work done in process 2-3(in kJ):
41  W23=Q23
42  //During process 3-4, work done(in kJ):
43  W34=-m*Cv*(T4-T3)
44  //Heat transfer in process 3-4(in kJ):
45  Q34=0
46  //During process 4-1, work done(in kJ):
47  W41=-W23
48  //Heat transfer in process 4-1(in kJ):
49  Q41=-Q23
50  printf("\nRESULTS\n")
51  printf("\nProcess     Heat transfer     Work
        interaction")
52  printf("\n  1-2              %d              %f",Q12,W12
        )
53  printf("\n  2-3              %d              %d",Q23,W23
        )
54  printf("\n  3-4              %d              %f",Q34,W34
        )
55  printf("\n  4-1              %d              %d",Q41,W41)
56  printf("\n\n\n Maximum temperature of the cycle = %f
        kJ",T2)
57  printf("\n Minimum temperature of the cycle = %f kJ"
        ,T1)
58  printf("\n Volume at the end of the expansion = %f m
        ^3",v3)
```

Scilab code Exa 4.12 To determine the heat transferred

```
1  //pathname=get_absolute_file_path('4.12.sce')
2  //filename=pathname+filesep()+'4.12-data.sci'
3  //exec(filename)
4  //Heat drawn from 400 K reservoir(in kJ):
5  Q1=5000
6  //Work output(in kJ):
7  W=840
8  //Value of heat from heat engine(in kJ):
9  Q2=3*(Q1/2-W)
10 //Value of heat to heat engine(in kJ):
11 Q3=Q1-W-Q2
12 printf("\nRESULTS\n")
13 printf("\nQ2 = %d kJ from heat engine",Q2)
14 printf("\nQ3 = %d kJ to heat engine",-Q3)
```

Scilab code Exa 4.13 To determine the energy taken from the reservoir

```
1  //pathname=get_absolute_file_path('4.13.sce')
2  //filename=pathname+filesep()+'4.13-data.sci'
3  //exec(filename)
4  //Temperature of the reservoir(in K):
5  T3=3+273
6  //Lower temperature limit(in K):
7  T1=77+273
8  //Higher temperature limit(in K):
9  T2=1077+273
10 //Energy supplied to the reservoir(in kJ/s):
11 E=100
12 //Efficiency:
```

```
13  n=1-T1/T2
14  //Energy taken from the reservoir Q1 can be found by
        solving the simultaneous equations
15  //n=1-Q2/Q1
16  //We get Q2=0.2593*Q1
17  //COP for heat pump = Q4/(Q4-Q3) = T1/(T1-T3)
18  //We get Q4=1.27*Q3
19  //It is given that Q2+Q4=E
20  //Solving all the equations, we get:
21  Q1=26.71
22  printf("\nRESULT\n")
23  printf("\nEnergy taken from reservoir at 1077 degree
        celcius = %f kJ",Q1)
```

Scilab code Exa 4.14 To determine temperature of the sink

```
1   //pathname=get_absolute_file_path('4.14.sce')
2   //filename=pathname+filesep()+'4.14-data.sci'
3   //exec(filename)
4   //Heat supplied(in kJ/s):
5   Qs=2000
6   //Temperature of source(in K):
7   Tso=1500
8   //Temperature at which heat is rejected(in K):
9   Tr=15+273
10  //Total heat received(in kJ/s):
11  Qt=3000
12  //Heat rejected(in kJ/s):
13  Qr=Qt-Qs
14  //Temperature of the sink(in K):
15  Ts=Qt/(Qs/Tso+Qr/Tr)
16  printf("\nRESULT\n")
17  printf("\nTemperature of the sink = %f K",Ts)
```

Scilab code Exa 4.15 To determine the ratio of heat rejected to body to the heat supplied by the reservoir

```
1  //pathname=get_absolute_file_path('4.15.sce')
2  //filename=pathname+filesep()+'4.15-data.sci'
3  //exec(filename)
4  //Maximum temperature(in K):
5  T1=500+273
6  //Minimum temperature(in K):
7  T2=200+273
8  //Temperature of the body(in K):
9  T3=450+273
10 //Efficiency:
11 n=1-T2/T1
12 //Ratio of W to Q1:
13 r1=n
14 //COP of pump:
15 COP=T3/(T3-T2)
16 //Ratio of Q3 to W:
17 r2=COP*2/3
18 //Ratio of Q3 to Q1:
19 r3=r1*r2
20 printf("\nRESULT\n")
21 printf("\nRatio of heat rejected to body at 450 C
       to the heat supplied by the reservoir = %f",r3)
```

Scilab code Exa 4.18 To determine the heat received from the highest temperature reservoir

```
1  //pathname=get_absolute_file_path('4.18.sce')
2  //filename=pathname+filesep()+'4.18-data.sci'
3  //exec(filename)
```

```
4  //Maximum temperature(in K):
5  T1=800+273
6  //Minimum temperature(in K):
7  T2=50+273
8  //Temperature of the 3rd reservoir(in K):
9  T3=50+273
10 //Temperature of the 4th reservoir(in K):
11 T4=10+273
12 //Heat picked up by Carnot cycle(in kW):
13 Q3=15
14 //Energy required to run a machine(in kW):
15 E=25
16 //Efficiency:
17 n=1-T2/T1
18 //From the relation of COP:
19 Q4=Q3*T3/T4
20 //Work by heat pump(in kW):
21 Whp=Q4-Q3
22 //Work in the heat engine(in kW):
23 Whe=Whp+E
24 //Heat from source at 1173 K(in kW):
25 Q1=Whe/n
26 //Heat rejected to the reservoir from engine 1(in kW
      ):
27 Q2=Q1-Whe
28 //Total heat rejected to the reservoir(in kW):
29 Qt=Q2+Q4
30 printf("\nRESULT\n")
31 printf("\nHeat rejected to the reservoir = %f kW",Qt
      )
32 printf("\nHeat received from the highest temperature
       reservoir = %f kW",Q1)
```

Scilab code Exa 4.19 To determine the change in enthalpy and Work done

```
1  //pathname=get_absolute_file_path('4.19.sce')
2  //filename=pathname+filesep()+'4.19-data.sci'
3  //exec(filename)
4  //Volume of 1st tank(in m^3):
5  v1=1.8
6  //Volume of 2nd tank(in m^3):
7  v2=3.6
8  //Initial pressure(in bar):
9  p1=12
10 //Initial temperature(in K):
11 T1=40+273
12 //Gas constant for argon(in kJ/kg.K):
13 R=0.208
14 //By gas law for final and initial state:
15 pf=p1*v1/(v1+v2)
16 printf("\nRESULT\n")
17 printf("\nFinal pressure = %d bar",pf)
18 //As there is no heat transfer, change in internal
       energy is 0:
19 Tf=T1
20 dH=0
21 W=0
22 printf("\nChange in enthalpy = %d",dH)
23 printf("\nWork done =%d",W)
```

Chapter 5

Entropy

Scilab code Exa 5.01 To determine the change in entropy

```
1  //pathname=get_absolute_file_path('5.01.sce')
2  //filename=pathname+filesep()+'5.01-data.sci'
3  //exec(filename)
4  //Initial pressure(in bar):
5  p1=5
6  //Initial temperature(in K):
7  T1=300
8  //Final pressure(in bar):
9  p2=2
10  //Cp for air(in kJ/kg.K):
11  Cp=1.004
12  //Gas constant for air(in kJ/kg.K):
13  R=0.287
14  //As it is a throttling process:
15  T2=T1
16  //Change in entropy(in kJ/kg.K):
17  dS=Cp*log(T2/T1)-R*log(p2/p1)
18  printf("\nRESULT\n")
19  printf("\nChange in entropy = %f kJ/kg.K",dS)
```

Scilab code Exa 5.02 To determine the change in entropy

```
1  //pathname=get_absolute_file_path('5.02.sce')
2  //filename=pathname+filesep()+'5.02-data.sci'
3  //exec(filename)
4  //Mass of water(in kg):
5  m=5
6  //Atmospheric temperature(in K):
7  T1=27+273.15
8  //Temperature of evaporation(in K):
9  T2=100+273.15
10 //Temperature at which steam is generated(in K):
11 T3=400+273
12 //Specific heat of water(in kJ/kg.K):
13 Cp=4.2
14 //Heat of vaporisation(in kJ/kg):
15 q2=2260
16 //For steam, Cp is given by:
17 //Cps=R(3.5+1.2*T+0.14*T^2)
18 //Heat added for increasing water temperature from
      27 C to 100 C(in kJ):
19 Q1=m*Cp*(T2-T1)
20 //Entropy change during water temperature rise(in kJ
      /K):
21 dS1=Q1/T1
22 //Heat of vaporization(in kJ):
23 Q2=m*q2
24 //Entropy change during water to steam change(in kJ/
      K):
25 dS2=Q2/T2
26 //Entropy change during steam temperature rise(in kJ
      /K):
27 dS3=m*10^(-3)*(1.617*log(T3/T2)+0.5544*(T3-T2)
      +0.065*(T3^2-T2^2)/2)
```

```
28  //Total entropy change(in kJ/K):
29  dS=dS1+dS2+dS3
30  printf("\nRESULT\n")
31  printf("\nTotal change in entropy of universe = %f
        kJ/K",dS)
```

Scilab code Exa 5.03 To determine the change in entropy

```
1  //pathname=get_absolute_file_path('5.03.sce')
2  //filename=pathname+filesep()+'5.03-data.sci'
3  //exec(filename)
4  //Initial pressure(in kPa):
5  p1=125
6  //Final pressure(in kPa):
7  p2=375
8  //Intial temperature(in K):
9  T1=27+273
10 //Gas constant for oxygen(in kJ/kg.K):
11 R=8.314/32
12 //Change in entropy(in kJ/kg.K):
13 dS=-R*log(p2/p1)
14 printf("\nRESULT\n")
15 printf("\nChange in entropy = %f kJ/kg.K",dS)
```

Scilab code Exa 5.04 To determine the entropy change in universe

```
1  //pathname=get_absolute_file_path('5.04.sce')
2  //filename=pathname+filesep()+'5.04-data.sci'
3  //exec(filename)
4  //Mass of the block(in kg):
5  m=1
6  //Temperature of the block(in K):
7  T1=150+273.15
```

```
 8  //Temperature of the sea(in K):
 9  T2=25+273.15
10  //Heat capacity of copper(in kJ/kg.K):
11  C=0.393
12  //Change in entropy of block(in kJ/K):
13  dSb=m*C*log(T2/T1)
14  //Heat lost by the block will be equal to heat
        gained by the water
15  //Heat lost by water(in kJ):
16  Q=m*C*(T1-T2)
17  //Change in entropy of water(in kJ/K):
18  dSw=Q/T2
19  //Entropy change of universe(in kJ/K):
20  dSu=dSb+dSw
21  printf("\nRESULT\n")
22  printf("\nChange in entropy of universe = %f J/K",
        dSu*10^3)
```

Scilab code Exa 5.05 To determine the entropy change in universe

```
 1  //pathname=get_absolute_file_path('5.05.sce')
 2  //filename=pathname+filesep()+'5.05-data.sci'
 3  //exec(filename)
 4  //Mass of the block(in kg):
 5  m=1
 6  //Temperature of the block(in K):
 7  T=27+273
 8  //Height(in m):
 9  h=200
10  //Heat capacity for copper(in kJ/kg.K):
11  s=0.393
12  //Acceleration due to gravity(in m/s^2):
13  g=9.81
14  //Change in potential energy(in J):
15  PE=m*g*h
```

```
16  //In this case:
17  Q=PE
18  //Change in entropy of universe(in J/kg.K):
19  dSu=Q/T
20  printf("\nRESULT\n")
21  printf("\nChange in entropy of universe = %f J/kg.K"
        ,dSu)
```

Scilab code Exa 5.06 To determine the entropy change in universe

```
1   //pathname=get_absolute_file_path('5.06.sce')
2   //filename=pathname+filesep()+'5.06−data.sci'
3   //exec(filename)
4   //Block 1:
5   //Mass(in kg):
6   m1=1
7   //Temperature(in K):
8   T1=150+273
9   //Specific heat(in kJ/kg.K):
10  C1=0.393
11  //Block 2:
12  //Mass(in kg):
13  m2=0.5
14  //Temperature(in K):
15  T2=0+273
16  //Specific heat(in kJ/kg.K):
17  C2=0.381
18  //Final temperature(in K):
19  Tf=(m1*C1*T1+m2*C2*T2)/(m1*C1+m2*C2)
20  //Entropy change in block 1(in kJ/K):
21  dS1=m1*C1*log(Tf/T1)
22  //Entropy change in block 2(in kJ/K):
23  dS2=m2*C2*log(Tf/T2)
24  //Total entropy change(in kJ/K):
25  dS=dS1+dS2
```

```
26  printf("\nRESULT\n")
27  printf("\nChange in entropy of universe = %f J/K",dS
        )
```

Scilab code Exa 5.08 To determine the work lost

```
1  //pathname=get_absolute_file_path('5.08.sce')
2  //filename=pathname+filesep()+'5.08-data.sci'
3  //exec(filename)
4  //Maximum temperature(in K):
5  T1=1800
6  //Minimum temperature(in K):
7  T2=300
8  //Rate at which heat is added(in MW):
9  Q1=5
10  //Work output(in MW):
11  W=2
12  //Heat rejected(in MW):
13  Q2=Q1-W
14  //Entropy generated(in MW/K):
15  dSg=(-Q1/T1+Q2/T2)
16  //Work lost(in MW):
17  w=T2*dSg
18  printf("\nRESULT\n")
19  printf("\nWork lost = %f MW",w)
```

Scilab code Exa 5.09 To determine the maximum work done

```
1  //pathname=get_absolute_file_path('5.09.sce')
2  //filename=pathname+filesep()+'5.09-data.sci'
3  //exec(filename)
4  //Temperature of the system(in K):
5  T1=500
```

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```
6  //Temperature of the reservoir(in K):
7  T2=300
8  //Heat capacity of the system(in J/K):
9  //C=0.05*T^2+0.10*T+0.085
10 //Maximum heat(in J):
11 Q1=-(0.05*(T2^3-T1^3)/3+0.10*(T2^2-T1^2)/2+0.085*(T2
     -T1))
12 //Entropy change of the system(in J/K):
13 dSs=0.05*(T2^2-T1^2)/2+0.10*(T2-T1)+0.085*log(T2/T1)
14 //Maximum work available(in kJ):
15 W=(Q1/T2+dSs)*T2
16 printf("\nRESULT\n")
17 printf("\nMaximum work = %f kJ",W/(10^3))
```

Scilab code Exa 5.10 To determine the change in entropy and enthalpy

```
1  //pathname=get_absolute_file_path('5.10.sce')
2  //filename=pathname+filesep()+'5.10-data.sci'
3  //exec(filename)
4  //Initial pressure(in kPa):
5  p1=3000
6  //Initial volume(in m^3):
7  v1=0.05
8  //Final volume(in m^3):
9  v2=0.3
10 //Value of n:
11 n=1.4
12 //Final pressure(in MPa):
13 p2=p1*((v1/v2)^n)
14 //Entropy change:
15 dS=0
16 //Change in enthalpy(in kJ):
17 dH=((p1*(v1^n))^(1/n))*(p1^((n-1)/n)-p2^((n-1)/n))
     /((n-1)/n)
18 printf("\nRESULT\n")
```

```
19  printf("\nEnthalpy change = %f kJ",dH)
20  printf("\nEntropy change = %d",dS)
```

Scilab code Exa 5.11 To determine the entropy change in universe

```
1   //pathname=get_absolute_file_path('5.11.sce')
2   //filename=pathname+filesep()+'5.11-data.sci'
3   //exec(filename)
4   //Mass of air(in kg):
5   m=2
6   //Initial volume(in m^3):
7   v1=1
8   //Final volume(in m^3):
9   v2=10
10  //Gas const(in J/kg.K):
11  R=287
12  //Change in entropy of air(in J/K):
13  dSa=m*R*log(v2/v1)
14  //During free expansion, entropy change of
        surroundings(in J/K):
15  dSs=0
16  //Entropy change of universe(in J/K):
17  dSu=dSa+dSs
18  printf("\nRESULT\n")
19  printf("\nEntropy change of air = %f J/K",dSa)
20  printf("\nEntropy change of surroundings = %d J/K",
        dSs)
21  printf("\nEntropy change of universe = %f J/K",dSu)
```

Scilab code Exa 5.12 To determine the change in entropy

```
1   //pathname=get_absolute_file_path('5.12.sce')
2   //filename=pathname+filesep()+'5.12-data.sci'
```

```
3  //exec(filename)
4  //Mass of air(in kg):
5  m=0.5
6  //Initial pressure(in Pa):
7  p1=1.013*10^5
8  //Final pressure(in Pa):
9  p2=0.8*10^6
10 //Initial temperature(in K):
11 T1=800
12 //Index of compression:
13 n=1.2
14 //Adiabatic index of compression:
15 r=1.4
16 //Value of Cv(in kJ/kg.K):
17 Cv=0.71
18 //Final temperature(in K):
19 T2=T1*((p2/p1)^((n-1)/n))
20 //Total entropy change(in J/K):
21 dS=m*Cv*((n-r)/(n-1))*log(T2/T1)
22 printf("\nRESULT\n")
23 printf("\nEntropy change = %f J/K",dS)
```

Scilab code Exa 5.15 To determine the direction of flow

```
1  //pathname=get_absolute_file_path('5.15.sce')
2  //filename=pathname+filesep()+'5.15-data.sci'
3  //exec(filename)
4  //Pressure at point 1(in MPa):
5  p1=0.5
6  //Temperature at point 1(in K):
7  T1=400
8  //Pressure at point 2(in MPa):
9  p2=0.3
10 //Temperature at point 2(in K):
11 T2=350
```

```
12  //Gas constant(in kJ/kg.K):
13  R=0.287
14  //Value of Cp(in kJ/kg.K):
15  Cp=1.004
16  //Entropy change(in kJ/kg.K):
17  ds=Cp*log(T1/T2)-R*log(p1/p2)
18  printf("\nRESULT\n")
19  printf("\nChange in entropy = %f kJ/kg.K",ds)
20  //As the calculated change is positive, s2>s1
21  printf("\nHence flow occurs from 1 to 2 i.e. from
         0.5 MPa, 400 K to 0.3 MPa & 350 K")
```

Scilab code Exa 5.17 To determine the work done and thermal efficiency

```
1   //pathname=get_absolute_file_path('5.17.sce')
2   //filename=pathname+filesep()+'5.17-data.sci'
3   //exec(filename)
4   //Heat added in process 1-2(in kJ):
5   Q12=1000
6   //Heat added in process 3-4(in kJ):
7   Q34=800
8   //Temperature at point 1(in K):
9   T1=500
10  //Temperature at point 3(in K):
11  T3=400
12  //Temperature at point 5(in K):
13  T5=300
14  //Total heat added(in kJ):
15  Qt=Q12+Q34
16  //Entropy change from state 1-2(in kJ/K):
17  S12=Q12/T1
18  //Entropy change from state 3-4(in kJ/K):
19  S34=Q34/T3
20  //Entropy change from state 5-6(in kJ/K):
21  S56=S12+S34
```

```
22  //Heat rejected in process 5−6(in kJ):
23  Q56=T5*S56
24  //Net work done(in kJ):
25  W=Q12+Q34-Q56
26  //Thermal efficiency of the cycle:
27  n=W/Qt
28  printf("\nRESULT\n")
29  printf("\nWork done = %d kJ",W)
30  printf("\nThermal efficiency = %f percent",n*100)
```

Scilab code Exa 5.18 To determine the heat supplied

```
 1  //pathname=get_absolute_file_path('5.18.sce')
 2  //filename=pathname+filesep()+'5.18−data.sci'
 3  //exec(filename)
 4  //Temperature of the reservoirs(in K):
 5  T1=800
 6  T2=700
 7  T3=600
 8  //Temperature of the sink(in K):
 9  T4=320
10  //Total heat rejected to the heat sink(in kJ/s):
11  Q2=10
12  //Work done(in kW):
13  W=20
14  //Total heat added(in kJ/s):
15  Q1=Q2+W
16  //Heat from reservoir 2(in kJ/s):
17  Q12=(Q2/T4-Q1/T3)/(0.7/T1+1/T2-1.7/T3)
18  //Heat from reservoir 1(in kJ/s):
19  Q11=0.7*Q12
20  //Heat from reservoir 3(in kJ/s):
21  Q13=Q1-1.7*Q12
22  printf("\nRESULT\n")
23  printf("\nHeat supplied by reservoir at 800 K = %f
```

```
      kJ/s" ,Q11)
24  printf("\nHeat supplied by reservoir at 700 K = %f
      kJ/s" ,Q12)
25  printf("\nHeat supplied by reservoir at 600 K = %f
      kJ/s" ,Q13)
```

Scilab code Exa 5.19 To check if process is reversible or not

```
1  //pathname=get_absolute_file_path('5.19.sce')
2  //filename=pathname+filesep()+'5.19-data.sci'
3  //exec(filename)
4  //Volume of the chamber(in m^3):
5  v1=0.04
6  //Initial pressure(in bar):
7  p1=10
8  //Initial temperature(in K):
9  T1=25+273
10  //Gas constant(in  kJ/kg.K):
11  R=0.287
12  //Value of Cv(in kJ/kg.K):
13  Cv=0.71
14  //Final temperature(in K):
15  T2=T1
16  //Final volume(in m^3):
17  v2=2*v1
18  //Final pressure(in bar):
19  p2=p1*v1/v2
20  //Initial mass(in kg):
21  m=p1*10^2*v1/(R*T1)
22  //Change in entropy(in kJ/K):
23  dS=m*R/log(v2/v1)+m*Cv*log(T2/T1)
24  printf("\nRESULT\n")
25  printf("\nEntropy change = %f kJ/K" ,dS)
26  //Entropy change is non zero but   dQ/T is zero,
      hence:
```

```
27 printf("\nAs dS>  dQ/T, process is irreversible")
```

Scilab code Exa 5.20 To determine the entropy produced

```
1  //pathname=get_absolute_file_path('5.20.sce')
2  //filename=pathname+filesep()+'5.20-data.sci'
3  //exec(filename)
4  //Mass in tank A(in kg):
5  ma=0.6
6  //Mass in tank B(in kg):
7  mb=1
8  //Temperature in tank A(in K):
9  Ta=90+273
10 //Temperature in tank B(in K):
11 Tb=45+273
12 //Pressure in tank A(in bar):
13 pa=1
14 //Pressure in tank B(in bar):
15 pb=2
16 //Gas constant(in kJ/kg.K):
17 R=0.287
18 //Value of Cp(in kJ/kg.K):
19 Cp=1.005
20 //Final temperature(in K):
21 Tf=(ma*Ta+mb*Tb)/(ma+mb)
22 //Volume of tank A(in m^3):
23 va=ma*R*Ta/pa
24 //Volume of tank B(in m^3):
25 vb=mb*R*Tb/pb
26 //Final pressure(in kPa):
27 pf=(ma+mb)*R*Tf/(va+vb)
28 //Entropy change(in kJ/K):
29 dS=ma*(Cp*log(Tf/Ta)-R*log(pf/pa))+mb*(Cp*log(Tf/Tb)
      -R*log(pf/pb))
30 printf("\nRESULT\n")
```

```
31 printf("\nEntropy produced = %f kJ/K",dS)
```

Scilab code Exa 5.21 To determine the change in entropy

```
1  //pathname=get_absolute_file_path('5.21.sce')
2  //filename=pathname+filesep()+'5.21-data.sci'
3  //exec(filename)
4  //Volume of the tanks(in m^3):
5  va=4
6  vb=4
7  vc=4
8  //Pressure in tank A(in bar):
9  pa=6
10 //Temperature in tank A(in K):
11 Ta=90+273
12 //Pressure in tank B(in bar):
13 pb=3
14 //Temperature in tank B(in K):
15 Tb=300+273
16 //Pressure in tank C(in bar):
17 pc=12
18 //Temperature in tank C(in K):
19 Tc=50+273
20 //Gas constant for air(in kJ/kg.K):
21 Ra=0.287
22 //Gas constant for nitrogen(in kJ/kg.K):
23 Rn=0.297
24 //Adiabatic index of compression for air:
25 ra=1.4
26 //Adiabatic index of compression for nitrogen:
27 rn=1.4
28 //Value of Cp(in kJ/kg.K):
29 Cp=1.005
30 //Value of Cv(in kJ/kg.K):
31 Cv=0.718
```

```
32  //Part (i)
33  //Mass in tank A(in kg):
34  ma=pa*10^2*va/(Ra*Ta)
35  //Mass in tank A(in kg):
36  mb=pb*10^2*vb/(Ra*Tb)
37  //Final temperature(in K):
38  Td=(ma*Ta+mb*Tb)/(ma+mb)
39  //Final pressure(in bar):
40  pd=Ra*Td*(ma+mb)/((va+vb)*10^2)
41  //Entropy change(in kJ/K):
42  dS1=ma*Cp*log(Td/Ta)-ma*Ra*log(pd/pa)+mb*Cp*log(Td/
        Tb)-mb*Ra*log(pd/pb)
43  printf("\nRESULT\n")
44  printf("\nEntropy change in case 1 = %f kJ/K",dS1)
45  //Part (ii)
46  //Mass in tank C(in kg):
47  mc=pc*10^2*vc/(Rn*Tc)
48  //Mass in tank D(in kg):
49  md=ma+mb
50  //Value of Cv for nitrogen(in kJ/kg.K):
51  Cvn=Rn/(rn-1)
52  //Value of Cp for nitrogen(in kJ/kg.K):
53  Cpn=rn*Cvn
54  //Total mass(in kg):
55  mf=md+mc
56  //Final Cv(in kJ/kg.K):
57  CvF=(md*Cv+mc*Cvn)/mf
58  //Final gas constant(in kJ/kg.K):
59  RF=(md*Ra+mc*Rn)/mf
60  //Final temperature(in K):
61  TF=(md*Cv*Td+mc*Cvn*Tc)/(mf*CvF)
62  //Final volume(in m^3):
63  VF=va+vb+vc
64  //Final pressure(in kPa):
65  pF=mf*RF*TF/VF
66  //Change in entropy(in kJ/K):
67  dS2=md*(Cp*log(TF/Td)-Ra*log(pF/(pd*10^2)))+mc*(Cpn*
        log(TF/Tc)-Rn*log(pF/(pc*10^2)))
```

```
68  printf("\nEntropy change in case 2 = %f kJ/K",dS2)
```

Chapter 6

Thermodynamic Properties of Pure Substance

Scilab code Exa 6.02 To determine the dryness fraction

```
1  //pathname=get_absolute_file_path('6.02.sce')
2  //filename=pathname+filesep()+'6.02-data.sci'
3  //exec(filename)
4  //Pressure at which steam is entering(in MPa):
5  p1=10
6  //Pressure at which steam is coming out(in MPa):
7  p2=0.05
8  //Temperature of the steam(in C):
9  T=100
10 //From steam tables:
11 //Enthalpy of superheated steam at 0.05 MPa and 100
        C (in kJ/kg):
12 h2=2682.5
13 hf10=1407.56
14 hfg10=1317.1
15 //Due to throttling:
16 h1=h2
17 //Dryness fraction:
18 x1=(h1-hf10)/hfg10
```

```
19  printf(”\nRESULT\n”)
20  printf(”\nDryness  fraction  =  %f”,x1)
```

Scilab code Exa 6.03 To determine the internal energy

```
1   //pathname=get_absolute_file_path(’6.03.sce’)
2   //filename=pathname+filesep()+’6.03−data.sci’
3   //exec(filename)
4   //Pressure(in MPa):
5   p=12
6   //Specific  volume(in m^3/kg):
7   v=0.017
8   //Enthaply(in kJ/kg):
9   h=2848
10  //Internal  energy(in kJ/kg):
11  u=h-p*10^3*v
12  printf(”\nRESULT\n”)
13  printf(”\nInternal  energy  =  %d  kJ/kg”,u)
```

Scilab code Exa 6.04 To find out the entropy of steam

```
1   //pathname=get_absolute_file_path(’6.04.sce’)
2   //filename=pathname+filesep()+’6.04−data.sci’
3   //exec(filename)
4   //Mass  of  steam(in  kg):
5   m=5
6   //Pressure(in MPa):
7   p=2
8   //Temperature  of  superheated  steam(in K):
9   Tss=300+273.15
10  //Specific  heat  of  super  heated  steam(in kJ/kg.K):
11  Cps=2.1
12  //Specific  heat  of  water(in kJ/kg.K):
```

```
13  Cpw=4.18
14  //From steam tables:
15  hfg=1890.7
16  //Saturation temperature(in K):
17  Tsat=212.42+273.15
18  //Entropy of unit mass of superheated steam with
        reference to absolute zero(in kJ/kg.K):
19  s=Cpw*log(Tsat/273.15)+hfg/Tsat+Cps*log(Tss/Tsat)
20  //Entropy of 5 kg of steam(in kJ/K):
21  S=m*s
22  printf("\nRESULT\n")
23  printf("\nEntropy of steam = %f kJ/K",S)
```

Scilab code Exa 6.05 To find out the boiling point

```
1  //pathname=get_absolute_file_path('6.05.sce')
2  //filename=pathname+filesep()+'6.05-data.sci'
3  //exec(filename)
4  //Boiling point(in C):
5  Tb=110
6  //From steam table:
7  //Pressure at which it boils(in kPa):
8  p= 143.27
9  //Boiling point at this depth = Tsat at 138.365
10 //From steam table this temperature(in  C):
11 Tsat= 108.866
12 //Pressure at 50 cm depth(in kPa):
13 p1=p-9.81*0.50
14 printf("\nRESULT\n")
15 printf("\nBoiling point = %f  C",Tsat)
```

Scilab code Exa 6.06 To determine mass and volume of water

```
1  //pathname=get_absolute_file_path('6.06.sce')
2  //filename=pathname+filesep()+'6.06-data.sci'
3  //exec(filename)
4  //Temperature of the water vapor mixture(in  C):
5  T=100
6  //Volume of the rigid vessel(in m^3):
7  V=0.5
8  //From steam tables:
9  //Specific volume at state 2(in m^3/kg):
10 v2=0.003155
11 vf=0.001044
12 vg=1.6729
13 //Specific volume at state 1(in m^3/kg):
14 v1=v2
15 //Dryness fraction:
16 x1=(v1-vf)/vg
17 //Total mass of fluid(in kg):
18 m=V/v2
19 //Volume of water(in m^3):
20 v=m*vf
21 printf("\nRESULT\n")
22 printf("\nMass of water = %f kg",m)
23 printf("\nVolume of water = %f m^3",v)
```

Scilab code Exa 6.07 To determine the slope

```
1  //pathname=get_absolute_file_path('6.07.sce')
2  //filename=pathname+filesep()+'6.07-data.sci'
3  //exec(filename)
4  //Pressure(in MPa):
5  p=2
6  //Temperature(in K):
7  T=500+273.15
8  //Slope of isobar:(dh/ds)at constant pressure=T:
9  s=T
```

```
10  printf("\nRESULT\n")
11  printf("\nSlope = %f",s)
```

Scilab code Exa 6.08 To determine enthalpy entropy and specific volume

```
1   //pathname=get_absolute_file_path('6.08.sce')
2   //filename=pathname+filesep()+'6.08-data.sci'
3   //exec(filename)
4   //Dryness fraction:
5   x=0.10
6   //Pressure(in MPa):
7   p=0.15
8   //From steam tables:(at 0.15 MPa):
9   hf = 467.11
10  hg = 2693.6
11  vf = 0.001053
12  vg = 1.1593
13  sf = 1.4336
14  sg = 7.2233
15  //Enthalpy(in kJ/kg):
16  h=hf+x*(hg-hf)
17  //Specific volume(in m^3/kg):
18  v=vf+x*(vg-vf)
19  //Entropy(in kJ/kg.K):
20  s=sf+x*(sg-sf)
21  printf("\nRESULT\n")
22  printf("\nEnthalpy = %f kJ/kg",h)
23  printf("\nSpecific volume = %f m^3/kg",v)
24  printf("\nEntropy = %f kJ/kg.K",s)
```

Scilab code Exa 6.09 To determine amount of heat added

```
1   //pathname=get_absolute_file_path('6.09.sce')
```

```
2  //filename=pathname+filesep()+'6.09-data.sci'
3  //exec(filename)
4  //Initial State:
5  //Pressure(in MPa):
6  p1=1
7  //Volume(in m^3):
8  V1=0.05
9  //Dryness fraction:
10 x1=0.80
11 //Final state:
12 //Pressure(in MPa):
13 p2=1
14 //Volume(in m^3):
15 V2=0.2
16 //From steam table:(at state 1):
17 vf = 0.001127 //(m3/kg)
18 vg = 0.19444 //(m3/kg)
19 uf = 761.68 //(kJ/kg)
20 ufg = 1822 //(kJ/kg)
21 //Work done(in kJ):
22 W=p1*10^3*(V2-V1)
23 //Specific volume at state 1(in m^3/kg):
24 v1=vf+x1*(vg-vf)
25 //Mass of system(in kg):
26 m=V1/v1
27 //Specific volume at state 2(in m^3/kg):
28 v2=V2/m
29 //Temperature at final state(in  C):
30 Tf=1077.61
31 //Internal energy at final state(at 1077.61  C):
32 u2=4209.6
33 //Internal energy at initial state(in kJ/kg):
34 u1=uf+x1*ufg
35 //Heat added(in kJ):
36 Q=m*(u2-u1)+W
37 printf("\nRESULT\n")
38 printf("\nHeat added = %f kJ",Q)
```

Scilab code Exa 6.10 To determine pressure and temperature at condensation

```scilab
1  //pathname=get_absolute_file_path('6.10.sce')
2  //filename=pathname+filesep()+'6.10-data.sci'
3  //exec(filename)
4  //Presure of the steam(in kPa):
5  p1=800
6  //Temperature(in   C)
7  T=200
8  //From steam tables:
9  //Saturation temp(in   C):
10 Tsat=170.43
11 //Specific volume(in m^3/kg):
12 v1=0.2404
13 v2=0.2404
14 //Final temperature(in   C):
15 T2=170.46
16 //Final pressure(in kPa):
17 p2=800.96
18 printf("\nRESULT\n")
19 printf("\nPressure =%f kPa",p2)
20 printf("\nTemperature = %f   C",T2)
```

Scilab code Exa 6.11 To determine enthalpy change

```scilab
1  //pathname=get_absolute_file_path('6.11.sce')
2  //filename=pathname+filesep()+'6.11-data.sci'
3  //exec(filename)
4  //Temperature of water(in   C):
5  T=30
6  //Pressure(in kPa):
```

```
7   p=200
8   //From steam tables:
9   //Corresponding pressure at 30 C (in kPa):
10  p1=4.25
11  //Specific volume(in m^3):
12  v1=0.001004
13  //Enthalpy change(in kJ/kg):
14  dh=v1*(p-p1)
15  printf("\nRESULT\n")
16  printf("\nEnthalpy change = %f kJ/kg",dh)
```

Scilab code Exa 6.12 To determine the mass and quality of steam

```
1   //pathname=get_absolute_file_path('6.12.sce')
2   //filename=pathname+filesep()+'6.12-data.sci'
3   //exec(filename)
4   //Volume occupied by water(in m^3):
5   V1=3/5*2
6   //Volume occupied by steam(in m^3):
7   V2=2/5*2
8   //From steam table
9   vf = 0.001091 //(m^3/kg)
10  vg = 0.3928 //(m^3/kg)
11  //Mass of water(in kg):
12  mf=V1/vf
13  //Mass of steam(in kg):
14  mg=V2/vg
15  //Total mass(in kg):
16  mt=mf+mg
17  //Dryness fraction:
18  x=mg/mt
19  printf("\nRESULT\n")
20  printf("\nMass = %f kg",mt)
21  printf("\nQuality = %f",x)
```

Scilab code Exa 6.13 To determine the turbine output

```
1  //pathname=get_absolute_file_path('6.13.sce')
2  //filename=pathname+filesep()+'6.13-data.sci'
3  //exec(filename)
4  //Pressure of the steam(in MPa):
5  p=4
6  //Temperature of steam entering(in  C):
7  T1=300
8  //Temperature of steam at turbine exit(in  C):
9  T2=50
10 //From steam tables:
11 h1=2886.2 //kJ/kg
12 s1=6.2285 //kJ/kg.K
13 hf = 209.33 //kJ/kg
14 sf = 0.7038 //kJ/kg.K
15 hfg = 2382.7 //kJ/kg
16 sfg = 7.3725 //kJ/kg.K
17 //Let:
18 s2=s1
19 //Dryness fraction:
20 x2=(s2-sf)/sfg
21 //Enthalpy at state 2(in kJ/kg):
22 h2=hf+x2*hfg
23 //Turbine work(in kJ/kg):
24 W=h1-h2
25 printf("\nRESULT\n")
26 printf("\nTurbine output = %f kJ/kg",W)
```

Scilab code Exa 6.14 To determine the mass and quality of steam

```
1  //pathname=get_absolute_file_path('6.14.sce')
```

```scilab
2  //filename=pathname+filesep()+'6.14-data.sci'
3  //exec(filename)
4  //Mass of steam(in kg):
5  m1=100
6  //Initial pressure(in kPa):
7  p1=100
8  //Final pressure(in kPa):
9  p2=1000
10 //Dryness fraction:
11 x1=0.5
12 //Pressure of dry saturated steam(in kPa):
13 p3=2000
14 //From steam tables:
15 hf100kPa = 417.46 //kJ/kg
16 uf100kPa = 417.36 //kJ/kg
17 vf100kPa = 0.001043 //m^3/kg
18 hfg100kPa = 2258 //kJ/kg
19 ufg100kPa = 2088.7 //kJ/kg
20 vg100kPa = 1.6940 //m^3/kg
21 vg2000kPa = 0.09963 //m^3/kg
22 ug2000kPa = 2600.3 //kJ/kg
23 hg2000kPa = 2799.5 //kJ/kg
24 hf1000kPa = 762.81 //kJ/kg,
25 hfg1000kPa = 2015.3 //kJ/kg
26 vf1000kPa = 0.001127 //m3/kg
27 vg1000kPa = 0.19444 //m3/kg
28 //Initial specific volume(in m^3/kg):
29 v1=vf100kPa+x1*(vg100kPa-vf100kPa)
30 //Enthalpy at 1(in kJ/kg):
31 h1=hf100kPa+x1*hfg100kPa
32 //Volume of vessel(in m^3):
33 V=m1*x1*v1
34 //Internal energy in the beginning(in kJ):
35 U1=m*(uf100kPa+x1*ufg100kPa)
36 //Final specific volume(in m^3/kg):
37 v2=vg2000kPa*v1/(vg2000kPa+v1)
38 //Final dryness fraction:
39 x2=(v2-vf1000kPa)/(vg1000kPa-vf1000kPa)
```

```
40  //Final enthalpy(in kJ/kg):
41  h2=hf1000kPa+x2*hfg1000kPa
42  //Mass of dry steam at 2000kPa(in kg):
43  m=m1*(h1-h2)/(h2-hg2000kPa)
44  printf("\nRESULT\n")
45  printf("\nMass of dry steam at 2000 kPa to be added
        = %f kg",m)
46  printf("\nQuality of final mixture = %f",x2)
```

Scilab code Exa 6.15 To determine the dryness fraction of the steam entering

```
1  //pathname=get_absolute_file_path('6.15.sce')
2  //filename=pathname+filesep()+'6.15-data.sci'
3  //exec(filename)
4  //Recorded condenser vacuum:
5  r= 71.5 //cm of Mercury
6  //Barometer reading:
7  br= 76.8 //cm of Mercury
8  //Temperature of condensation:
9  Tc= 35 // C
10  //Temperature of hot well:
11  Thw= 27.6 // C
12  //Mass of condensate per hour:
13  mc= 1930 //kg
14  //Mass of cooling water per hour:
15  mcw= 62000 //kg
16  //Inlet temperature
17  Ti= 8.51 // C
18  //Outlet temperature:
19  To= 26.24 // C
20  //From steam tables:
21  hf = 146.68 //kJ/kg
22  hfg = 2418.6 //kJ/kg
23  //Condensor pressure(in kPa):
```

```
24  pc =( br - r ) /73.55*101.325
25  // Partial pressure of steam corresponding to 35 C
        from steam table ( in kPa ) :
26  ps = 5.628
27  // Dryness fraction :
28  x =( mcw *( To - Ti ) *4.18 - mc * hf + mc *4.18* To ) /( mc * hfg )
29  printf ( " \ nRESULT \ n " )
30  printf ( " \ nDryness fraction of the steam entering =
        %f " , x )
```

Scilab code Exa 6.16 To determine the work done

```
1  // pathname = get_absolute_file_path ( ' 6.16. sce ' )
2  // filename = pathname + filesep ( ) + ' 6.16 − data . sci '
3  // exec ( filename )
4  // Diameter of the vessel ( in m ) :
5  D =0.2
6  // Depth ( in m ) :
7  d =0.02
8  // Temperature ( in   C ) :
9  T =150
10 // Force applied ( in kN ) :
11 F =10
12 // Heat supplied ( in kJ ) :
13 Q =600
14 // From steam tables :
15 hf =612.1
16 hfg =2128.7
17 vg =0.4435
18 h2 =1582.8
19 // Pressure at which process is taking place ( in kPa ) :
20 p = F /(% pi * D ^2) *4+101.3
21 // Volume of water contained ( in m ^3) :
22 V1 =% pi * D ^2* d /4
23 // Mass of water ( in kg ) :
```

```
24  m=V1*1000
25  //Dryness fraction:
26  x=(Q-hf*m+4.18*T*m)/(hfg*m)
27  //Internal energy of water initially(in kJ):
28  U1=m*4.18*T-p*V1
29  //Final volume(in m^3):
30  V2=m*x*vg
31  //Internal energy at state 2(in kJ):
32  U2=m*h2-p*V2
33  //Change in internal energy(in kJ):
34  dU=U2-U1
35  //Work done(in kJ):
36  W=p*(V2-V1)
37  printf("\nRESULT\n")
38  printf("\nDryness fraction of the steam produced =
       %f",x)
39  printf("\nChange in internal energy = %f kJ",dU)
40  printf("\nWork done = %f kJ",W)
```

Scilab code Exa 6.17 To determine the dryness fraction

```
1  //pathname=get_absolute_file_path('6.17.sce')
2  //filename=pathname+filesep()+'6.17-data.sci'
3  //exec(filename)
4  //Mass of steam passed(in kg):
5  ms=40
6  //Mass of water passed(in kg):
7  mw=2.2
8  //Initial pressure of steam(in MPa):
9  p1=1.47
10 //Temperature after throttling(in  C):
11 T=120
12 //Pressure after throttling(in kPa):
13 p2=107.88
14 //Specific heat of superheated steam(in kJ/kg.K):
```

```
15  s =2.09
16  //From steam tables :
17  hf =840.513
18  hfg =1951.02
19  h1 =2673.95
20  //Degree of superheat(in   C ):
21  ds =T -101.8
22  //Enthalpy of superheated steam(in kJ/kg):
23  h2 = h1 + ds * s
24  //Dryness fraction after throttling :
25  x2 =( h2 - hf )/ hfg
26  //Dryness fraction before throttling :
27  x1 =( ms - mw )/ ms
28  //Overall dryness fraction :
29  x = x1 * x2
30  printf ("\nRESULT\n")
31  printf ("\nDryness fraction = %f",x)
```

Scilab code Exa 6.18 To determine the amount of heat added and initial quality

```
1  //pathname=get_absolute_file_path('6.18.sce')
2  //filename=pathname+filesep()+'6.18-data.sci'
3  //exec(filename)
4  //Initial volume in part A(in m^3):
5  Va =0.4
6  //Pressure(in bar):
7  pa =10
8  //Initial volume in part B(in m^3):
9  V =0.4
10 //Pressure in part B(in bar):
11 p1 =10
12 //Final pressure in part B(in bar):
13 p2 =15
14 //From steam tables :
```

```
15  hf =762.83
16  hfg =2015.3
17  h2 =2792.2
18  //Heat added(in kJ):
19  Q=V*(p2-p1)*10^2
20  //Dryness fraction:
21  x1=(h2-Q-hf)/hfg
22  printf("\nRESULT\n")
23  printf("\nHeat added = %d kJ",Q)
24  printf("\nInitial quality = %f",x1)
```

Scilab code Exa 6.19 To determine heat and work transfer

```
1  //pathname=get_absolute_file_path('6.19.sce')
2  //filename=pathname+filesep()+'6.19-data.sci'
3  //exec(filename)
4  //Mass of wet steam(in kg):
5  m=3
6  //Initial pressure(in bar):
7  p1=1.4
8  //Initial volume(in m^3):
9  V1=2.25
10  //Final temperature of steam(in  C):
11  T=400
12  //At 400 C ,volume of steam(in m^3):
13  V2=4.65
14  //From steam tables:
15  vg=1.2455
16  hf =457.99
17  hfg =2232.3
18  h2 =3276.6
19  uf =457.84
20  ufg =2059.34
21  u2 =2966.7
22  //Specific volume of wer steam in cylinder(in m^3/kg
```

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```
        ) :
23  v1=V1/m
24  //Dryness  fraction  of  initial  steam :
25  x1=v1/vg
26  //Initial  enthalpy  of  wet  steam (in  kJ/kg) :
27  h1=hf+x1*hfg
28  //At  400  C  specific  volume  of  steam (in  m^3/kg) :
29  v2=V2/m
30  //Actual  pressure (from  steam  table) (in  MPa) :
31  p2=0.20
32  //Saturation  temp  at  this  pressure  =  120.23  C
33  //Finally  the  degree  of  superheat (in    C ) :
34  ds=T-120.23
35  //Heat  added  during  the  process (in  kJ) :
36  Q=m*(h2-h1)
37  //Internal  energy  of  initial  wet  steam (in  kJ/kg) :
38  u1=uf+x1*ufg
39  //Change  in  internal  energy (in  kJ) :
40  dU=m*(u2-u1)
41  //Work  done (in  kJ) :
42  W=Q-dU
43  printf("\nRESULT\n")
44  printf("\nHeat  transfer  =  %f  kJ",Q)
45  printf("\nWork  transfer  =  %f  kJ",W)
```

Scilab code Exa 6.20 To determine the percentage of vessel initial occupied by steam

```
1  //pathname=get_absolute_file_path('6.20.sce')
2  //filename=pathname+filesep()+'6.20-data.sci'
3  //exec(filename)
4  //Pressure  of  the  steam (in  bar) :
5  p1=10
6  //Temperature (in    C ) :
7  T=500
```

```
 8  //Final pressure(in bar):
 9  p2=1
10  //From steam tables:
11  h10bar500 = 3478.5  //kJ/kg
12  s10bar500 = 7.7622  //kJ/kg.K
13  v10bar500 = 0.3541  //m^3/kg
14  h1bar400 = 3278.2  //kJ/kg
15  h1bar500 = 3488.1  //kJ/kg
16  v1bar500 = 3.565  //m^3/kg
17  v1bar400 = 3.103  //m^3/kg
18  s1bar500 = 8.8342  //kJ/kg.K
19  s1bar400 = 8.5435  //kJ/kg.K
20  h2=h10bar500
21  //Final temperature(in  C):
22  T2=(h2-h1bar400)*(T-400)/(h1bar500-h1bar400)+400
23  //Final entropy(in kJ/kg.K):
24  s2=s1bar400+(s1bar500-s1bar400)/(T-400)*(T2-400)
25  //Change in entropy(in kJ/kg.K):
26  ds=s2-s10bar500
27  //Final specific volume(in m^3/kg):
28  v2=v1bar400+(v1bar500-v1bar400)/(T-400)*(T2-400)
29  //Percentage volume occupied by steam:
30  p=v10bar500/v2*100
31  printf("\nRESULT\n")
32  printf("\nFinal temperature = %f kJ",T2)
33  printf("\nChange in entropy = %f kJ",ds)
34  printf("\nPercentage of vessel volume initially
        occupied by steam = %f percent",p)
```

Scilab code Exa 6.21 To determine the irresversibilty

```
1  //pathname=get_absolute_file_path('6.21.sce')
2  //filename=pathname+filesep()+'6.21-data.sci'
3  //exec(filename)
4  //Steam entering:
```

```scilab
 5  //Pressure(in MPa):
 6  p1=2.5
 7  //Temperature(in   C):
 8  T1=350
 9  //Steam rejected:
10  //Pressure(in kPa):
11  p2=20
12  //Dryness fraction:
13  x2=0.92
14  //Pressure of one quater of intial steam(in kPa):
15  p3=30
16  //Temperature(in   K):
17  T0=30+273
18  m1=1
19  m2=0.25
20  m3=0.75
21  //Heat lost during expansion(in kJ):
22  Q=-10
23  //From steam tables:
24  h1=3126.3 //kJ/kg
25  s1=6.8403 //kJ/kg.K
26  h2=2878.6 //kJ/kg
27  s2=8.5309 //kJ/kg.K
28  h3 = 2421.04 //kJ/kg
29  s3 = 7.3425 //kJ/kg.K
30  hf = 251.40 //kJ/kg
31  hg = 2609.7 //kJ/kg
32  sf = 0.8320 //kJ/kg.K
33  sfg = 7.0766 //kJ/kg.K
34  h0=125.79
35  s0=0.4369
36  //Availability of steam entering turbine(in kJ/kg):
37  A1=(h1-h0)-T0*(s1-s0)
38  //Availability of steam leaving turbine at state 2(
       in kJ/kg):
39  A2=(h2-h0)-T0*(s2-s0)
40  //Availability of steam leaving turbine at state 3(
       in kJ/kg):
```

```
41  A3=(h3-h0)-T0*(s3-s0)
42  //Maximum work per kg of steam entering turbine(in
        kJ/kg):
43  Wmax=m1*A1-m2*A2-m3*A3
44  //Irreversibilty(in kJ/s):
45  I=T0*(m2*s2+m3*s3-m1*s1)-Q
46  printf("\nRESULT\n")
47  printf("\nMaximum work = %f kJ/kg",Wmax)
48  printf("\nIrreversibility = %f kJ/s",I)
```

Scilab code Exa 6.22 To determine the change in availability

```
1   //pathname=get_absolute_file_path('6.22.sce')
2   //filename=pathname+filesep()+'6.22-data.sci'
3   //exec(filename)
4   //Initial pressure(in MPa):
5   p1=6
6   //Final pressure(in MPa):
7   p2=5
8   //Initial temperature(in  C):
9   T1=400
10  //Atmospheric pressure(in kPa):
11  patm=100
12  //Atmospheric temperature(in  K):
13  Ta=20+273
14  //From steam tables:
15  h1=3177.2 //kJ/kg
16  s1=6.5408 //kJ/kg.K
17  h2=h1
18  T2=392.7 // C(by interpolation)
19  s2=6.6172 //kJ/kg.K(//By interpolation Entropy)
20  h0=83.96 //kJ/kg
21  s0 = 0.2966 //kJ/kg
22  //Availability at state 1(in kJ/kg):
23  A1=(h1-h0)-Ta*(s1-s0)
```

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```
24  //Availability at state 2(in kJ/kg):
25  A2=(h2-h0)-Ta*(s2-s0)
26  //Change in availibilty(in kJ/kg):
27  dA=A2-A1
28  printf("\nRESULTS\n")
29  printf("\nChange in availability = %f kJ/kg decrease
        ",-dA)
```

Scilab code Exa 6.23 To determine the amount of exergy destruction

```
1   //pathname=get_absolute_file_path('6.23.sce')
2   //filename=pathname+filesep()+'6.23-data.sci'
3   //exec(filename)
4   //Temperature of the hot water entering(in   C):
5   TH1= 95
6   //Temperature of the hot water at exit(in   C):
7   TH2= 50
8   //Mass flow rate(in kg/s):
9   mH = 0.8
10  //Temperature of cooling water entering(in   K):
11  TC1= 15+273
12  //Temperature of cooling water at exit(in   K):
13  TC2= 45+273
14  //Temperature of dead state(in K):
15  T0=25+273
16  //From steam tables:
17  h0=104.89  //kJ/kg
18  s0=0.3674  //kJ/kg.K
19  hH1=397.96 //kJ/kg
20  sH1=1.2500 //kJ/kg.K
21  hH2=209.33 //kJ/kg.K
22  sH2=0.7038 //kJ/kg.K
23  hC2=188.45 //kJ/kg.K
24  sC2=0.6387 //kJ/kg.K
25  hC1=62.99 //kJ/kg.K
```

```
26  sC1 =0.2245 //kJ/kg.K
27  //Mass flow rate of cooling water(in kg/s):
28  mC=mH*(TH1-TH2)/(TC2-TC1)
29  //Exergy entering through hot water stream(in kJ/s):
30  AH1=mH*((hH1-h0)-T0*(sH1-s0))
31  //Rate of exergy increase in cold stream(in kJ/s):
32  dAc=mC*((hC2-hC1)-T0*(sC2-sC1))
33  //Second law efficiency:
34  n=dAc/AH1*100
35  //Rate of exergy loss in hot stream(in kJ/s):
36  dAh=mH*((hH1-hH2)-T0*(sH1-sH2))
37  //Exergy destruction(in kJ/s):
38  dA=dAh-dAc
39  printf(")\nRESULT\n")
40  printf(")\nSecond law efficincy = %f percent",n)
41  printf(")\nExergy destruction = %f kJ/s",dA)
```

Chapter 7

Ratio of lost available exhaust gas energy to engine work

Scilab code Exa 7.01 To determine the maximum possible work

```
1  //pathname=get_absolute_file_path('7.01.sce')
2  //filename=pathname+filesep()+'7.01-data.sci'
3  //exec(filename)
4  //Pressure of entering steam(in MPa):
5  p1=1.6
6  //Temperature of entering steam(in K):
7  T1=300+273
8  //Pressure of leaving steam(in MPa):
9  p2=0.1
10 //Temperature of leaving steam(in K):
11 T2=150+273
12 //Velocity of the leaving steam(in m/s):
13 c2=150
14 //Surrounding temperature(in K):
15 T0=15+273
16 //Mass flow rate(in kg/s):
17 m=2.5
18 //From steam tables:
19 h1=3034.8 //kJ/kg
```

```
20  s1=6.8844  //kJ/kg.K
21  h2=2776.4  //kJ/kg
22  s2=7.6134  //kJ/kg.K
23  //Maxiimum work possible(in kW):
24  Wmax=(h1-h2)-T0*(s1-s2)-(c2^2)/2*10^(-3)
25  printf("\nRESULT")
26  printf("\nMaximum work possible = %f kW",m*Wmax)
```

Scilab code Exa 7.02 To determine the availability in the tanks

```
1   //pathname=get_absolute_file_path('7.02.sce')
2   //filename=pathname+filesep()+'7.02-data.sci'
3   //exec(filename)
4   //For tank A:
5   //Pressure of air(in bar):
6   pa=1
7   //Mass of air(in kg):
8   m=1
9   //Value of Cv(in kJ/kg.K):
10  Cv=0.717
11  //Temperature(in K):
12  T=50+273
13  //Gas costant(in kJ/kg.K):
14  R=0.287
15  //Atmospheric pressure(in bar):
16  p0=1
17  //Atmosphere temperature(in K):
18  T0=15+273
19  //Value of Cp(in kJ/kg.K):
20  Cp=1.004
21  //For tank B
22  //Pressure(in bar):
23  pb=3
24  //Availability of air in tank A(in kJ):
25  AA=m*(Cv*(T-T0)+R*(p0/pa*T-T0)-T0*Cp*log(T/T0)+T0*R*
```

```
      log(pa/p0))
26  //Availability of air in tank B(in kJ):
27  AB=m*(Cv*(T-T0)+R*(p0/pb*T-T0)-T0*Cp*log(T/T0)+T0*R*
      log(pb/p0))
28  printf("\nRESULT")
29  printf("\nAvailabiltiy of air in tank A = %f kJ",AA)
30  printf("\nAvailability of air in tank B = %f kJ",AB)
```

Scilab code Exa 7.03 To determine the power output

```
1   //pathname=get_absolute_file_path('7.03.sce')
2   //filename=pathname+filesep()+'7.03-data.sci'
3   //exec(filename)
4   //Mass of steam(in kg):
5   m=15
6   //Entering steam:
7   //Pressure(in bar):
8   p1=10
9   //Temperature(in K):
10  T1=300+273
11  //Leaving steam:
12  //Pressure(in bar):
13  p2=0.05
14  //Dryness fraction:
15  x=0.95
16  //Velocity(in m/s):
17  v2=160
18  //Atmosheric pressure(in bar):
19  p0=1
20  //Atmospheric temperature(in K):
21  T0=15+273
22  //From steam tables:
23  h1=3051.2  //kJ/kg
24  s1=7.1229  //kJ/kg.K
25  sf=0.4764  //kJ/kg.K
```

```
26  sfg=7.9187 //kJ/kg.K
27  hf=137.82 //kJ/kg
28  hfg=2423.7 //kJ/kg
29  h0=62.99 //kJ/kg
30  s0=0.2245 //kJ/kg.K
31  //Enthalpy at exit of turbine(in kJ/kg):
32  h2=hf+x*hfg
33  //Entropy at exit of turbine(in kJ/kg.K):
34  s2=sf+x*sfg
35  //Work output(in kJ/kg):
36  W=(h1-h2)-v2^2/2*10^(-3)
37  //Power output(in kW):
38  pW=m*W
39  printf("\nRESULT")
40  printf("\nPower output = %f kW",pW)
41  //Maximum work given end states(in kW):
42  Wmax=(h1-T0*s1)-(h2+v2^2/2*10^(-3)-T0*s2)
43  printf("\nRESULT")
44  printf("\n\nMaximum power output = %f kW",m*Wmax)
45  //Maximum wor kavailable from exhaust steam(in kJ/kg
        ):
46  Ae=(h2-h0)+v2^2/2*10^(-3)-T0*(s2-s0)
47  //Maximum power that could be obtained from exhaust
        steam(in kW):
48  Wme=m*Ae
49  printf("\n\nMaximum power from exhaust steam = %f kW
        ",Wme)
```

Scilab code Exa 7.04 To determine the availability

```
1  //pathname=get_absolute_file_path('7.04.sce')
2  //filename=pathname+filesep()+'7.04-data.sci'
3  //exec(filename)
4  //Mass of steam(in kg):
5  m=5
```

```
 6  //Initial elevation (in m):
 7  z1=10
 8  //Initial velocity (in m/s):
 9  V1=25
10  //Final elevation (in m):
11  z2=2
12  //Final velocity (in m/s):
13  V2=10
14  //Dead state of water
15  u0=104.86 //kJ/kg
16  v0=1.0029*10^(-3) //m3/kg
17  s0=0.3673 //kJ/kg K
18  p0=100 //kPa
19  T0=25+273 //K
20  //Initial state
21  u1 = 2550 //kJ/kg
22  v1 = 0.5089 //m3/kg
23  s1 = 6.93 //kJ/kg K
24  //Final state
25  u2=83.94 //kJ/kg
26  v2=1.0018*10^(-3) //m3/kg
27  s2=0.2966 //kJ/kg K
28  //Acceleration due to gravity (in m/s^2):
29  g=9.81
30  //Availability at initial state (in kJ):
31  A1=m*((u1-u0)*10^3+p0*10^3*(v1-v0)-T0*(s1-s0)*10^3+
       V1^2/2+g*z1)
32  //Availability at final state (in kJ):
33  A2=m*((u2-u0)*10^3+p0*10^3*(v2-v0)-T0*(s2-s0)*10^3+
       V2^2/2+g*z2)
34  //Change in availability (in kJ):
35  dA=A2-A1
36  printf("\nRESULT")
37  printf("\nAvailability decreases by %f kJ",-dA/10^3)
```

Scilab code Exa 7.06 To determine ratio of lost available exhaust gas energy to engine work

```
1  //pathname=get_absolute_file_path('7.06.sce')
2  //filename=pathname+filesep()+'7.06-data.sci'
3  //exec(filename)
4  //Temperature of IC engine(in K):
5  T1=800+273
6  //Work per kg of gas in engine(in kJ/kg):
7  W=1050
8  //Cp of gas(in kJ/kg.K):
9  Cp=1.1
10 //Temperature of the surroundings(in K):
11 T0=30+273
12 //Change in entropy of system(in kJ/kg.K):
13 dSsys=W/T1
14 //Change in entropy of surroundings(in kJ/kg.K):
15 dSsurr=-Cp*(T1-T0)/T0
16 //Loss of available energy(in kJ/kg):
17 L=-T0*(dSsys+dSsurr)
18 //Ratio of lost available exhaust energy to engine
       work:
19 r=L/W
20 printf("\nRESULT")
21 printf("\nRatio of available exhaust energy to
       engine work= %f/1",r)
```

Scilab code Exa 7.07 To determine the availability

```
1  //pathname=get_absolute_file_path('7.07.sce')
2  //filename=pathname+filesep()+'7.07-data.sci'
3  //exec(filename)
4  //Mass of water(in kg):
5  m=10
6  //Initial temperature(in K):
```

```
7  T1=150+273
8  //Initial velocity(in m/s):
9  V1=25
10  //Initial elevation(in m):
11  z1=10
12  //Final temperature(in K):
13  T2=20+273
14  //Final velocity(in m/s):
15  V2=10
16  //Final elevation(in m):
17  z2=3
18  //Pressure of environment(in MPa):
19  p0=0.1
20  //Temperature of environment(in K):
21  T0=25+273
22  //Acceleration due to gravity(in m/s^2):
23  g=9.8
24  //From steam tables:
25  //Dead state of water
26  u0=104.88  //kJ/kg
27  v0=1.003*10^(-3)  //m3/kg
28  s0=0.3674  //kJ/kg K
29  u1=2559.5  //kJ/kg
30  v1=0.3928  //m3/kg
31  s1=6.8379  //kJ/kg K
32  u2=83.95  //kJ/kg
33  v2=0.001002  //m3/kg
34  s2=0.2966  //kJ/kg K
35  //Availability at initial state(in kJ):
36  A1=m*((u1-u0)*10^3+p0*10^3*(v1-v0)-T0*(s1-s0)*10^3+
       V1^2/2+g*z1)
37  //Availability at final state(in kJ):
38  A2=m*((u2-u0)*10^3+p0*10^3*(v2-v0)-T0*(s2-s0)*10^3+
       V2^2/2+g*z2)
39  //Change in availability(in kJ):
40  dA=A2-A1
41  printf("\nRESULT")
42  printf("\nInitial availabilty = %f kJ",A1/10^3)
```

```
43  printf("\nFinal  availabilty = %f kJ",A2/10^3)
44  printf("\nAvailability  decreases  by %f kJ",-dA/10^3)
```

Scilab code Exa 7.08 To determine the irresversibilty

```
1  //pathname=get_absolute_file_path('7.08.sce')
2  //filename=pathname+filesep()+'7.08-data.sci'
3  //exec(filename)
4  //Mass flow rate(in kg/s):
5  m=5
6  //At inlet to turbine,
7  p1=5 //MPa
8  T1=500+273.15 // K
9  h1=3433.8 //kJ/kg
10 s1=6.9759 //kJ/kg.K
11 //At exit from turbine.
12 p2=0.2 //MPa
13 T2=140+273.15 // K
14 h2=2748 //kJ/kg
15 s2=7.228 //kJ/kg K
16 //At dead state,
17 p0=101.3 //kPa
18 T0=25+273.15 // K
19 h0=104.96 //kJ/kg
20 s0=0.3673 //kJ/kg    K
21 //Heat loss(in kJ/s):
22 Q=600
23 //Availablity of steam at inlet(in kJ):
24 A1=m*((h1-h0)-T0*(s1-s0))
25 printf("\nRESULT")
26 printf("\nAvailability of steam at inlet = %f kJ",A1
     )
27 //Turbine output(in kW):
28 W=m*(h1-h2)-Q
29 printf("\n\nTurbine output = %f kW",W)
```

```
30  //Maximum output(in kW):
31  Wmax=m*((h1-h2)-T0*(s1-s2))
32  printf("\n\nMaximum output = %f kW",Wmax)
33  //Irreversibilty(in kW):
34  I=Wmax-W
35  printf("\n\nIrreversibility = %f kW",I)
```

Scilab code Exa 7.11 To determine loss of available energy

```
1  //pathname=get_absolute_file_path('7.11.sce')
2  //filename=pathname+filesep()+'7.11-data.sci'
3  //exec(filename)
4  //Heat removed(in kJ):
5  Q=500
6  //Temperature of the heat reservoir(in K):
7  T1=835
8  //Temperature of the system(in K):
9  T2=720
10  //Temperature of surroundings(in K):
11  T0=280
12  //Availability for heat reservoir(in kJ/kg.K):
13  A1=T0*Q/T1
14  //Availability for system(in kJ/kg.K):
15  A2=T0*Q/T2
16  //Net loss of available energy(in kJ/kg.K):
17  Anet=A1-A2
18  printf("\nRESULT")
19  printf("\nLoss of available energy = %f kJ/kg.K",-
        Anet)
```

Scilab code Exa 7.12 To determine the maximum possible work

```
1  //pathname=get_absolute_file_path('7.12.sce')
```

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```scilab
2  // filename=pathname+filesep()+'7.12-data.sci'
3  // exec(filename)
4  // Enthalpy at entrance(in kJ/kg):
5  h1=4142
6  // Enthalpy at exit(in kJ/kg):
7  h2=2585
8  // Availability of steam at entrance(in kJ/kg):
9  A1=1787
10 // Availability of steam at exit(in kJ):
11 A2=140
12 // Maximum work possible(in kJ/kg):
13 Wmax=A1-A2
14 // Actual work from turbine(in kJ/kg):
15 Wact=h1-h2
16 printf("\nRESULT")
17 printf("\nActual work = %d kJ/kg",Wact)
18 printf("\nMaximum possible work = %d kJ/kg",Wmax)
```

Scilab code Exa 7.13 To determine second law efficiency

```scilab
1  // pathname=get_absolute_file_path('7.13.sce')
2  // filename=pathname+filesep()+'7.13-data.sci'
3  // exec(filename)
4  // Minimum temperature(in K):
5  Tmin=20+273
6  // Maximum temperature(in K):
7  Tmax=500+273
8  // Efficiency of heat engine:
9  n=0.25
10 // Reversible engine efficiency:
11 nrev=1-Tmin/Tmax
12 // Second law efficiency:
13 n2=n/nrev
14 printf("\nRESULT")
15 printf("\nSecond law efficiency = %f percent",n2
```

```
    *100)
```

Scilab code Exa 7.14 To determine loss of available energy

```
1  //pathname=get_absolute_file_path ('7.14.sce')
2  //filename=pathname+filesep()+'7.14-data.sci'
3  //exec(filename)
4  //Volume of compartment A(in m^3):
5  Va=6
6  //Volume of compartment B(in m^3):
7  Vb=4
8  //Pressure in compartment A(in bar):
9  p1=6
10 //Temperature in compartment A(in K):
11 T1=600
12 //Atmosheric pressure(in bar):
13 p0=1
14 //Atmosheric temperature(in K):
15 T0=300
16 //Adiabatic index of compression:
17 r=1.4
18 //Gas constant(in J/kg.K):
19 R=0.287
20 //Value of Cv(in kJ/kg.K):
21 Cv=0.718
22 //Final volume(in m^3):
23 V2=Va+Vb
24 //Final temperature(in K):
25 T2=T1*(Va/V2)^(r-1)
26 //Mass of air(in kg):
27 m=p1*10^5*Va/(R*10^3*T1)
28 //Change in entropy of control system(in kJ/kg.K):
29 dSs=m*(Cv*log(T2/T1)+R*log(V2/Va))
30 //Loss of available energy or irreversibilty(in kJ):
31 I=T0*dSs
```

```scilab
32  printf("\nRESULT")
33  printf("\nLoss of available energy = %f kJ",-I)
```

Scilab code Exa 7.16 To determine the availability and change in irreversibility

```scilab
1  //pathname=get_absolute_file_path('7.16.sce')
2  //filename=pathname+filesep()+'7.16-data.sci'
3  //exec(filename)
4  //Minimum temperature(in K):
5  Tmin=30+273
6  //Maximum temperature(in K):
7  Tmax=700+273
8  //Temperature of surroundings(in K):
9  T0=17+273
10 //Rate at which engine receives heat(in kJ/min):
11 Q1=2*10^4
12 //Measured output of the engine(in kW):
13 Wu=0.13*10^3
14 //Efficiency:
15 nrev=1-Tmin/Tmax
16 //Availability or reversible work(in kJ/s):
17 Wrev=nrev*Q1/60
18 //Rate of irreversibility(in kJ/s):
19 I=Wrev-Wu
20 //Second law efficiency:
21 n2=Wu/Wrev
22 printf("\nRESULT")
23 printf("\nAvailability = %f kJ/min",Wrev*60)
24 printf("\nRate of irreversibility = %f kW",I)
25 printf("\nSecond law efficiency = %f percent",n2
      *100)
```

Scilab code Exa 7.17 To determine loss of available energy

```
1  //pathname=get_absolute_file_path('7.17.sce')
2  //filename=pathname+filesep()+'7.17-data.sci'
3  //exec(filename)
4  //Initially:
5  //Pressure(in bar):
6  p1=1.5
7  //Temperature(in K):
8  T1=60+273
9  //Finally:
10 //Pressure(in bar):
11 p2=2.5
12 //Temperature of the reservoir(in K):
13 Tres=400+273
14 //Temperature of surroundings(in K):
15 T0=27+273
16 //Cp of air(in kJ/kg.K):
17 Cp=1.005
18 //Final temperature(in K):
19 T2=T1*p2/p1
20 //Heat addition to air in the tank(in kJ/kg):
21 Q=Cp*(T2-T1)
22 //Change in entropy of the system(in kJ/kg.K):
23 dSs=Q/T1
24 //Change in entropy of environment(in kJ/kg.K):
25 dSe=-Q/Tres
26 //Total change in entropy(in kJ/kg.K):
27 dS=dSs+dSe
28 //Loss of available energy(in kJ/kg):
29 L=T0*dS
30 printf("\nRESULT")
31 printf("\nLoss of available energy = %f kJ/kg.K",L)
```

Scilab code Exa 7.19 To calculate enthalpy of vaporisation

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```
1  //pathname=get_absolute_file_path('7.19.sce')
2  //filename=pathname+filesep()+'7.19-data.sci'
3  //exec(filename)
4  //From steam tables:
5  vg=0.12736
6  vf=0.001157
7  p205=1.7230
8  p195=1.3978
9  T=200+273
10 hfga=1940.7
11 //Value of vfg(in m^3/kg):
12 vfg=vg-vf
13 //Value of dp/dT(in MPa/K):
14 r=(p205-p195)/(205-195)
15 //By Clapeyron equation(in kJ/kg):
16 hfg=T*vfg*r*10^3
17 printf("\nRESULT")
18 printf("\nCalculated enthalpy of vaporization = %f
       kJ/kg",hfg)
19 printf("\nEnthalpy of vaporization from steam table
       = %f kJ/kg",hfga)
```

Scilab code Exa 7.20 To determine enthalpy

```
1  //pathname=get_absolute_file_path('7.20.sce')
2  //filename=pathname+filesep()+'7.20-data.sci'
3  //exec(filename)
4  //From steam tables:
5  //Saturated vapor pressure:
6  p5=260.96  //kPa
7  p15=182.60  //kPa
8  vg10=0.07665  // m^3/kg
9  vf10=0.00070  //m^3/kg
10 R=0.06876  //kJ/kg.K
11 hfg10=156.3  //kJ/kg
```

```
12  T= -5+273
13  T1= -15+273
14  T2= -5+273
15  //By Clapeyron equation:
16  //Value of hfg:
17  hfg=T*(vg10-vf10)*(p5-p15)/(15-5)
18  //By Clapeyron-Clausius equation:
19  hfg1=log(p5/p15)*R*(T1*T2)/((T2-T1))
20  //Deviation:
21  d=(hfg1-hfg)/hfg*100
22  printf("\nRESULT")
23  printf("\nhfg by Clapeyron equation = %f kJ/kg",hfg)
24  printf("\nhfg by Clapeyron-Clausius equation = %f kJ
       /kg",hfg1)
25  printf("\nPercentage deviation in hfg value by
       Clapeyron-Clausius equation compared to the value
        from Clapeyron equation = %f percent",d)
```

Scilab code Exa 7.21 To determine isothermal compressibility

```
1  //pathname=get_absolute_file_path('7.21.sce')
2  //filename=pathname+filesep()+'7.21-data.sci'
3  //exec(filename)
4  //From steam tables:
5  v350=0.9534
6  v250=0.7964
7  v300=0.8753
8  v350kPa=0.76505
9  v250kPa=1.09575
10  //Volume expansivity(in 1/K):
11  ve=(v350-v250)/(v300*(350-250))
12  //Isothermal compressibility(in 1/kPa):
13  ic=-(v350kPa-v250kPa)/(v300*(350-250))
14  printf("\nRESULT")
15  printf("\nVolume expansivity = %f K^(  1 )",ve)
```

```
16  printf("\nIsothermal  compressibility  =  %f  kPa^(-1)",
       ic)
```

Scilab code Exa 7.22 To determine the irresversibilty

```
1   //pathname=get_absolute_file_path('7.22.sce')
2   //filename=pathname+filesep()+'7.22-data.sci'
3   //exec(filename)
4   //Volume  of  tank(in  m^3):
5   V=0.5
6   //Atmospheric  pressure(in  bar):
7   p0=1
8   //Atmospheric  temperature(in  K):
9   T0=25+273
10  //Cp  of  gas(in  kJ/kg.K):
11  Cp=1.005
12  //Cv  of  gas(in  kJ/kg.K):
13  Cv=0.718
14  //Initial  temperature(in  K):
15  Ti=T0
16  //Inside  final  temperature(in  K):
17  Tf=Cp/Cv*Ti
18  //Change  in  entropy(in  kJ/kg.K):
19  dSgen=Cp*log(Tf/Ti)
20  //Irreversibility(in  kJ/kg):
21  I=T0*dSgen
22  printf("\nRESULT")
23  printf("\nInside  final  temperature  =  %f  K",Tf)
24  printf("\nChange  in  entropy  =  %f  kJ/kg.K",dSgen)
25  printf("\nIrreversibility  =  %f  kJ/kg",I)
```

Scilab code Exa 7.23 To determine the maximum work

```
1  // pathname= get_absolute_file_path ('7.23.sce')
2  // filename=pathname+filesep()+'7.23-data.sci'
3  // exec(filename)
4  // Mass of water(in kg):
5  m=75
6  // Temperature of hot water(in K):
7  T1=400+273
8  // Final temperature(in K):
9  T2=300
10 // Temperature of the environment(in K):
11 T0=27+273
12 // Specific heat of water(in kJ/kg.K):
13 Cp=4.18
14 // Maximum work(in kJ):
15 Wmax=m*Cp*(T1-T2-T0*log(T1/T2))
16 printf("\nRESULT")
17 printf("\nMaximum work = %f kJ", Wmax)
```

Scilab code Exa 7.24 To determine the irresversibilty

```
1  // pathname= get_absolute_file_path ('7.24.sce')
2  // filename=pathname+filesep()+'7.24-data.sci'
3  // exec(filename)
4  // Pressure at which steam enters(in bar):
5  p1=50
6  // Temperature at which steam enters(in K):
7  T1=600+273
8  // Velocity at which steam enters(in m/s):
9  c1=150
10 // Pressure at which steam leaves(in bar):
11 p2=0.1
12 // Velocity at which steam leaves(in m/s):
13 c2=50
14 // Work delivered(in kJ/kg):
15 W=1000
```

```scilab
16  //Dead state temperature(in K):
17  T0=25+273
18  //From steam tables:
19  h1=3666.5  //kJ/kg
20  s1=7.2589  //kJ/kg.K
21  h2=2584.7  //kJ/kg
22  s2=8.1502  //kJ/kg.K
23  //Inlet stream availability(in kJ/kg):
24  A1=h1+c1^2/2*10^(-3)-T0*s1
25  //Exit stream availability(in kJ/kg):
26  A2=h2+c2^2/2*10^(-3)-T0*s2
27  //Reversible work(in kJ/kg):
28  Wrev=A1-A2
29  //Irreversibility(in kJ/kg):
30  I=Wrev-W
31  printf("\nRESULT")
32  printf("\nInlet stream availability = %f kJ/kg",A1)
33  printf("\nExit stream availability = %f kJ/kg",A2)
34  printf("\nIrreversibility = %f kJ/kg",I)
```

Chapter 8

Vapour power cycles

Scilab code Exa 8.01 To determine the work done and thermal efficiency

```
1  //pathname=get_absolute_file_path ('8.01.sce')
2  //filename=pathname+filesep()+'8.01-data.sci'
3  //exec(filename)
4  //Lower pressure limit(in kPa):
5  p1=7
6  //Higher pressure limit(in MPa):
7  p2=7
8  //From gas tables:
9  //Enthalpy at state 2(in kJ/kg):
10 h2=2772.1
11 //Entropy at state 2(in kJ/kg.K):
12 s2=5.8133
13 //Enthalpy at state 3(in kJ/kg):
14 h3=1267
15 //Entropy at state 3(in kJ/kg.K):
16 s3=3.1211
17 //Value of sf at 7 kPa(in kJ/kg.K):
18 sf1=0.5564
19 //Value of sfg at 7 kPa(in kJ/kg.K):
20 sfg1=7.7237
21 //Value of hf at 7 kPa(in kJ/kg):
```

```
22  hf1=162.60
23  //Value of hfg at 7 kPa(in kJ/kg):
24  hfg1=2409.54
25  //Entropy at state 1(in kJ/kg.K):
26  s1=s2
27  //Dryness fraction at state 1:
28  x1=(s1-sf1)/sfg1
29  //Enthalpy at state 1(in kJ/kg):
30  h1=hf1+x1*hfg1
31  //Entropy at state 4(in kJ/kg.K):
32  s4=s3
33  //Dryness fraction for state 4:
34  x4=(s4-sf1)/sfg1
35  //Enthalpy at state 4(in kJ/kg):
36  h4=hf1+x4*hfg1
37  //Expansion work per kg(in kJ/kg):
38  W1=h2-h1
39  //Compression work per kg(in kJ/kg):
40  W2=h3-h4
41  //Heat added per kg(in kJ/kg):
42  H=h2-h3
43  //Net work done(in kJ/kg):
44  W=W1-W2
45  //Thermal efficiency:
46  n=W/H
47  printf("\n\nRESULTS\n\n")
48  printf("\n\n Thermal Efficincy = %f ",n)
49  printf("\n Turbine work = %f ",W1)
50  printf("\n Compression work = %f ",W2)
```

Scilab code Exa 8.02 To determine the efficiency of rankine cycle

```
1  //pathname=get_absolute_file_path('8.02.sce')
2  //filename=pathname+filesep()+'8.02-data.sci'
3  //exec(filename)
```

```
 4  //Lower pressure limit(in kPa):
 5  p1=5
 6  //Higher pressure limit(in kPa):
 7  p2=5000
 8  //From gas tables:
 9  //Value of hf at 5 MPa(in kJ/kg):
10  hf5M=1154.23
11  //Value of sf at 5 MPa(in kJ/kg.K):
12  sf5M=2.92
13  //Value of hg at 5 MPa(in kJ/kg):
14  hg5M=2794.3
15  //Value of sg at 5 MPa(in kJ/kg.K):
16  sg5M=5.97
17  //Value of hf at 5 kPa(in kJ/kg):
18  hf5k=137.82
19  //Value of sf at 5 kPa(in kJ/kg.K):
20  sf5k=0.4764
21  //Value of hg at 5 kPa(in kJ/kg):
22  hg5k=2561.5
23  //Value of sg at 5 kPa(in kJ/kg.K):
24  sg5k=8.3961
25  ///Value of vf at 5 kPa(in m^3/kg):
26  vf5k=0.001005
27  //Value of sfg at 5 kPa(in kJ/kg.K):
28  sfg5k=sg5k-sf5k
29  //Value of hfg at 5 kPa(in kJ/kg.K):
30  hfg5k=hg5k-hf5k
31  //CARNOT CYCLE:
32  //Entropy at point 2(in kJ/kg.K):
33  s2=sg5M
34  //As process 2-3 is isentropic:
35  s3=s2
36  //Dryness fraction at point 3:
37  x3=(s3-sf5k)/sfg5k
38  //Enthalpy at point 3(in kJ/kg):
39  h3=hf5k+x3*hfg5k
40  //Enthalpy at point 2(in kJ/kg):
41  h2=hg5M
```

```
42  // Entropy  at  point  1(in  kJ/kg.K):
43  s1=sf5M
44  // Process  1−4  is  isentropic:
45  s4=s1
46  // Dryness  fraction  at  point  4:
47  x4=(s4-sf5k)/sfg5k
48  // Enthalpy  at  point  4(in  kJ/kg):
49  h4=hf5k+x4*hfg5k
50  // Enthalpy  at  point  1(in  kJ/kg):
51  h1=hf5M
52  // Efficiency:
53  n=((h2-h3)-(h1-h4))/(h2-h1)
54  printf("\n RESULT \n")
55  printf("For  Carnot  cycle,\n")
56  printf("Efficiency=%f",n)
57  // For RANKINE Cycle:
58  // Pump work:
59  Pw=vf5k*(p2-p1)
60  // Enthalpy  at  point  5(in  kJ/kg):
61  h5=hf5k
62  // Enthalpy  at  point  6(in  kJ/kg):
63  h6=h5+Pw
64  // Net  work  in  the  cycle:
65  Nw=(h2-h3)-(h6-h5)
66  // Heat  added:
67  Ha=h2-h6
68  // Efficiency:
69  nr=Nw/Ha
70  printf("\nFor  Rankine  cycle,\n")
71  printf("Efficiency=%f",nr)
```

Scilab code Exa 8.03 To determine cycle efficiency and pump work

```
1  // pathname=get_absolute_file_path('8.03.sce')
2  // filename=pathname+filesep()+'8.03−data.sci'
```

```
3  //exec(filename)
4  //Pressure of steam entering(in bar):
5  p1=40
6  //Temperature(in K):
7  T1=350+273
8  //Pressure of steam leaving(in bar):
9  p4=0.05
10 //From steam tables:
11 h2=3092.5 //kJ/kg
12 s2=6.5821 //kJ/kg.K
13 h4=137.82 //kJ/kg
14 s4=0.4764 //kJ/kg.K
15 v4=0.001005 //m^3/kg
16 sf=0.4764 //kJ/kg.K
17 sfg=7.9187 //kJ/kg.K
18 hf=137.82 //kJ/kg
19 hfg=2423.7 //kJ/kg
20 //Entropy at state 3:
21 s3=s2
22 //Dryness fraction at state 3:
23 x3=(s3-sf)/sfg
24 //Enthalpy at state 3(in kJ/kg):
25 h3=hf+x3*hfg
26 //Enthalpy at state 1(in kJ/kg):
27 h1=h4+v4*(p1-p4)
28 //Pump work(in kJ/kg):
29 Wp=h1-h4
30 //Net work(in kJ/kg):
31 Wnet=h2-h3-Wp
32 //Heat added(in kJ/kg):
33 Q=h2-h1
34 //Cycle efficiency(in kJ/kg):
35 n=Wnet/Q*100
36 printf("\n RESULT \n")
37 printf("\nNet work per kg of steam = %f kJ/kg",Wnet)
38 printf("\nCycle efficiency = %f percent",n)
39 printf("\nPump work per kg of steam = %f kJ/kg",Wp)
```

Scilab code Exa 8.04 To determine pressure of steam leaving and thermal efficiency

```
1  //pathname=get_absolute_file_path ('8.04.sce')
2  //filename=pathname+filesep()+'8.04-data.sci'
3  //exec(filename)
4  //Pressure of the steam entering (in MPa):
5  p1=20
6  //Temperature (in K):
7  T1=500+273
8  //Dryness fraction of the steam leaving:
9  x=0.90
10 //Condensor pressure (in MPa):
11 p6=0.005
12 //From steam tables:
13 h2=3238.2 //kJ/kg
14 s2=6.1401 //kJ/kg.K
15 s3=s2
16 hf=137.82 //kJ/kg
17 hfg=2423.7 //kJ/kg.K
18 sf=0.4764 //kJ/kg.K
19 sfg=7.9187 //kJ/kg.K
20 h6=137.82 //kJ/kg
21 h4=3474.1 //kJ/kg
22 sf1=2.2842 //kJ/kg.K
23 sfg1=4.1850 //kJ/kg.K
24 hf1=830.3 //kJ/kg
25 hfg1=1959.7 //kJ/kg
26 v6=0.001005 //m^3/kg
27 //Enthalpy at state 5(in kJ/kg):
28 h5=hf+x*hfg
29 s5=sf+x*sfg
30 //By interpolation, pressure at state 4(in bar):
31 p4=1.4
```

```
32  //Dryness  fraction  at  state  3:
33  x3 =( s3 - sf1 )/ sfg1
34  //Enthalpy  at  state  3( in  kJ/kg ) :
35  h3 = hf1 + x3 * hfg1
36  //Enthalpy  at  state  1( in  kJ/kg ) :
37  h1 = h6 + v6 *( p1 - p6 ) *10^3
38  //Net  work  per  kg  of  steam ( in  kJ/kg ) :
39  Wnet =( h2 - h3 ) +( h4 - h5 ) -( h1 - h6 )
40  //Heat  added  per  kg  of  steam ( in  kJ/kg ) :
41  Q = h2 - h1
42  //Thermal  efficiency :
43  n = Wnet /Q *100
44  printf ( " \n  RESULT  \n " )
45  printf ( " \nPressure  of  steam  leaving  HP  turbine  =  %f
        MPa " ,p4 )
46  printf ( " \nThermal  efficiency  =  %f  percent " ,n )
```

Scilab code Exa 8.05 To determine the work done and thermal efficiency and ratio of heat supplied to rejected

```
 1  //pathname=get_absolute_file_path ( '8.05. sce ')
 2  //filename=pathname+filesep ()+ '8.05 - data . sci '
 3  //exec ( filename )
 4  //Pressure  of  steam  leaving  the  boiler ( in  MPa ) :
 5  p1 =10
 6  //Temperature ( in  K ) :
 7  T1 =700+273
 8  //Pressure  of  steam  leaving  the  turbine ( in  MPa ) :
 9  p4 =0.005
10  //Output  of  the  plant ( in  MW ) :
11  W =50
12  //Temperature  of  the  cooling  water  entering  and
        leaving  the  condensor ( in  K ) :
13  Twin =15+273
14  Twout =30+273
```

```
15  //From steam tables:
16  h2=3870.5 //kJ/kg
17  s2=7.1687 //kJ/kg.K
18  s3=s2
19  sf=0.4764 //kJ/kg.K
20  sfg=7.9187 //kJ/kg.K
21  hf=137.82 //kJ/kg
22  hfg=2423.7 //kJ/kg
23  h4=hf
24  v4=0.001005 //m^3/kg
25  //Specific heat of water(in kJ/kg.K):
26  Cp=4.18
27  //Dryness fraction at state 3:
28  x3=(s3-sf)/sfg
29  //Enthalpy at state 3(in kJ/kg):
30  h3=hf+x3*hfg
31  //Enthalpy at state 1(in kJ/kg):
32  h1=h4+v4*(p1-p4)
33  //Net output per kg of steam(in kJ/kg):
34  Wnet=(h2-h3)-(h1-h4)
35  //Mass flow rate of steam(in kg/s):
36  ms=W*10^3/Wnet
37  //Mass flow rate of water(in kg/s):
38  mw=(h3-h4)*ms/(Cp*(Twout-Twin))
39  //Heat added per kg of steam(in kJ/kg):
40  Q=h2-h1
41  //Thermal efficiency:
42  n=Wnet/Q
43  //Ratio of heat supplied:
44  r=(h2-h1)/(h3-h4)
45  printf("\n RESULT \n")
46  printf("\nMass flow rate of steam = %f kg/s",ms)
47  printf("\nMass flow rate of condensor cooling water
        = %f kg/s",mw)
48  printf("\nThermal efficiency=%f",n*100)
49  printf("\nRatio of heat supplied and rejected = %f",
        r)
```

Scilab code Exa 8.06 To determine cycle efficiency

```scilab
1  //pathname=get_absolute_file_path('8.06.sce')
2  //filename=pathname+filesep()+'8.06-data.sci'
3  //exec(filename)
4  //Pressure of steam leaving the boiler(in MPa):
5  p1=200
6  //Temperature(in K):
7  T1=650+273
8  //Pressure of steam leaving the turbine(in MPa):
9  p4=0.05
10 //From steam tables:
11 h2=3675.3  //kJ/kg
12 s2=6.6582  //kJ/kg.K
13 s3=s2
14 h4=137.82  //kJ/kg
15 v4=0.001005  //m^3/kg
16 sf=0.4764  //kJ/kg.K
17 sfg=7.9187  //kJ/kg.K
18 hf=137.82  //kJ/kg
19 hfg=2423.7  //kJ/kg
20 //For case b:
21 s6=s2
22 hf8=721.11  //kJ/kg
23 hfg8=2048  //kJ/kg
24 vf8=0.001115  //m^3/kg
25 sf8=2.0462  //kJ/kg.K
26 sfg8=4.6166  //kJ/kg.K
27 //For case c:
28 s10=s2
29 s9=s2
30 T10=370.36+273  //K(by interpolation)
31 h10=3141.81  //kJ/kg
32 sf4=1.7766  //kJ/kg.K
```

135

```
33  sfg4=5.1193 //kJ/kg.K
34  hf4=604.74 //kJ/kg
35  hfg4=2133.8 //kJ/kg
36  h11=hf4
37  h13=1087.31 //kJ/kg
38  v11=0.001084 //m^3/kg
39  v13=0.001252 //m^3/kg
40  p10=40 //bar
41  p9=4 //bar
42  //Case a:
43  //Dryness farction at state 3:
44  x3=(s3-sf)/sfg
45  //Enthalpy at state 3(in kJ/kg):
46  h3=hf+x3*hfg
47  //Enthalpy at state 1(in kJ/kg):
48  h1=h4+v4*(p1-p4)
49  //Net output per kg of steam(in kJ/kg):
50  Wnet=(h2-h3)-(h1-h4)
51  //Heat added(in kJ/kg):
52  Q=h2-h1
53  //Thermal efficiency:
54  na=Wnet/Q*100
55  printf("\n RESULT \n")
56  printf("\nThermal efficiency in case a=%f percent",
       na)
57  //Case b:
58  //Dryness fraction at state 6(in kJ/kg.K):
59  x6=(s6-sf8)/sfg8
60  //Enthalpy at state 6(in kJ/kg):
61  h6=hf8+x6*hfg8
62  //Enthalpy at state 7(in kJ/kg):
63  h7=hf8
64  //Enthalpy at state 5(in kJ/kg):
65  h5=h4+v4*(p1-p4)*10^2
66  //Mass of steam(in kg):
67  m=(h7-h5)/(h6-h5)
68  //Enthalpy at state 1(in kJ/kg):
69  h1=h7+vf8*(p1-p4)*10^2
```

```
70  //Thermal efficiency:
71  nb=((h2-h6)+(1-m)*(h6-h3)-((1-m)*(h5-h4)+(h1-h7)))/(
        h2-h1)*100
72  printf("\nThermal efficiency in case b=%f percent",
        nb)
73  //Case c:
74  //Dryness fraction at state 9:
75  x9=(s9-sf4)/sfg4
76  //Enthalpy at state 9(in kJ/kg):
77  h9=hf4+x9*hfg4
78  //Enthalpy at state 8(in kJ/kg):
79  h8=h4+v4*(p9-p4)*10^2
80  //Enthalpy at state 12(in kJ/kg):
81  h12=h11+v11*(p10-p9)*10^2
82  //Enthalpy at state 1'(in kJ/kg):
83  h1a=h13+v13*(p1-p10)*10^2
84  //Mass of steam flowing through first heater:
85  m1=(h13-h12)/(h10-h12)
86  //Mass of steam flowing through second heater:
87  m2=((1-m1)*h11-(1-m1)*h8)/(h9-h8)
88  //Work done by Condensate extraction pump(in kJ/kg):
89  Wcep=(1-m1-m2)*(h8-h4)
90  //Work done by feed pump 1(in kJ/kg):
91  WFP1=h1a-h13
92  //Work done by feed pump 2(in kJ/kg):
93  WFP2=(1-m1)*(h12-h11)
94  //Thermal efficiency:
95  nc=((h2-h10)+(1-m1)*(h10-h9)+(1-m1-m2)*(h9-h3)-(Wcep
        +WFP1+WFP2))/(h2-h1a)*100
96  printf("\nThermal efficiency in case c=%f percent",
        nc)
```

Scilab code Exa 8.07 To determine cycle efficiency and specific steam consumption and work ratio

```
1  //pathname=get_absolute_file_path('8.07.sce')
2  //filename=pathname+filesep()+'8.07-data.sci'
3  //exec(filename)
4  //Pressure at which steam is generated(in bar):
5  p1=50
6  //Temperature of the steam(in K):
7  T1=500+273
8  //Pressure upto which steam is expanded(in bar):
9  p3=5
10 //Temperature(in K):
11 T3=400+273
12 //Final pressure(in bar):
13 p5=0.05
14 //From steam tables:
15 h2=3433.8 //kJ/kg
16 s2=6.9759 //kJ/kg.K
17 s3=s2
18 T3=183.14+273 //K(by interpolation)
19 h3=2818.03 //kJ/kg
20 h4=3271.9 //kJ/kg
21 s4=7.7938 //kJ/kg.K
22 s5=s4
23 sf=0.4764 //kJ/kg.K
24 sfg=7.9187 //kJ/kg.K
25 hf=137.82 //kJ/kg
26 hfg=2423.7//kJ/kg
27 h6=hf
28 v6=0.001005 //m^3/kg
29 //Dryness fraction at state 5:
30 x5=(s5-sf)/sfg
31 //Enthalpy at state 5(in kJ/kg):
32 h5=hf+x5*hfg
33 //Enthalpy at state 1(in kJ/kg):
34 h1=h6+v6*(p1-p5)*10^2
35 //Turbine work(in kJ/kg):
36 Wt=(h2-h3)+(h4-h5)
37 //Pump work(in kJ/kg):
38 Wp=h1-h6
```

```
39  //Net output per kg of steam(in kJ/kg):
40  Wnet=Wt-Wp
41  //Heat added per kg of steam(in kJ/kg):
42  Q=h2-h1
43  //Cycle efficiency:
44  n=Wnet/Q
45  //Specific steam consumption(in kg/hp.hr):
46  ssc=0.7457*3600/Wnet
47  //Work ratio:
48  r=Wnet/Wt
49  printf("\n RESULT \n")
50  printf("\nCycle efficiency=%f",n*100)
51  printf("\nSpecific steam consumption = %f kg/hp.hr",
        ssc)
52  printf("\nWork ratio = %f",r)
```

Scilab code Exa 8.08 To determine efficiency of the boiler

```
1   //pathname=get_absolute_file_path('8.08.sce')
2   //filename=pathname+filesep()+'8.08-data.sci'
3   //exec(filename)
4   //Pressure of steam fed in HP turbine(in bar):
5   p1=60
6   //Temperature of the steam(in K):
7   T1=450+273
8   //Pressure of steam entering LP turbine(in bar):
9   p3=3
10  //Pressure of steam leaving the LP turbine(in bar):
11  p4=0.05
12  //Condensate temperature(in C):
13  T3=115
14  //Alternator output(in MW):
15  W=30
16  //Boiler efficiency:
17  nb=0.90
```

```
18  //Alternator efficiency:
19  na=0.98
20  //From steam tables:
21  h2=3301.8 //kJ/kg
22  s2=6.7198 //kJ/kg.K
23  hf=137.82 //kJ/kg
24  hfg=2423.7 //kJ/kg
25  h5=hf
26  vf=0.001005 //m^3/kg
27  v5=vf
28  h8=561.47 //kJ/kg
29  s3=s2
30  s4=s2
31  sf3=1.6718 //kJ/kg.K
32  sfg3=5.3201 //kJ/kg.K
33  hf3=561.47 //kJ/kg
34  hfg3=2163.8 //kJ/kg
35  sf=0.4764 //kJ/kg.K
36  sfg=7.9187 //kJ/kg.K
37  h9=h8
38  v6=v5
39  //Dryness fraction at state 3:
40  x3=(s3-sf3)/sfg3
41  //Dryness fraction at state 4:
42  x4=(s4-sf)/sfg
43  //Enthalpy at state 3(in kJ/kg):
44  h3=hf3+x3*hfg3
45  //Enthalpy at state 4(in kJ/kg):
46  h4=hf+x4*hfg
47  //Enthalpy at state 1(in kJ/kg):
48  h1=4.18*T3
49  //Pumping work(in kJ/kg):
50  Wp=v5*(p1-p4)
51  //Mass of steam entering the feed pump(in kg):
52  m=0.144
53  printf("\n RESULT \n")
54  printf("\nSteam bled for feed heating = %f kg",m)
55  //Net output(in kJ/kg):
```

```
56  Wnet=(h2-h3)+(1-m)*(h3-h4)-(1-m)*Wp
57  //Mass of steam required to be generated(in kg/hr):
58  ms=W*10^3/(na*Wnet)
59  printf("\nCapacity of boiler = %f kg/hr",ms)
60  //Heat added(in kJ/kg):
61  Q=(h2-h1)/nb
62  //Overall thermal efficiency:
63  no=Wnet/Q*100
64  printf("\nOverall thermal efficiency = %f percent",
        no)
```

Scilab code Exa 8.09 To determine capacity of the drain pump

```
1   //pathname=get_absolute_file_path('8.09.sce')
2   //filename=pathname+filesep()+'8.09-data.sci'
3   //exec(filename)
4   //Pressure of steam entering(in bar):
5   p1=30
6   //Temperature(in C):
7   T1=300
8   //Pressure of steam leaving the first stage(in bar):
9   p3=6
10  //Steam leaving second stage at pressure(in bar):
11  p4=1
12  //Pressure of steam leaving the third stage(in bar):
13  p5=0.075
14  //Condenstate temperature(in C):
15  T=38
16  //Temperature of water after leaving first and
        second heater(in C):
17  T8=150
18  T13=95
19  //Efficiency of turbine:
20  n=0.8
21  //Turbine output(in MW):
```

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```
22  W=15
23  //From steam tables:
24  h2=3230.9 //kJ/kg
25  s2=6.9212 //kJ/kg.K
26  s3=s2
27  T3=190.97 //K(by interpolation)
28  h3=2829.63 //kJ/kg
29  s3a=7.1075 //kJ/kg.K
30  s4=s3a
31  sf1=1.3026 //kJ/kg.K
32  sfg1=6.0568 //kJ/kg.K
33  hf1=417.46 //kJ/kg
34  hfg1=2258 //kJ/kg
35  h5=234.64 //kJ/kg
36  hf6=670.56 //kJ/kg
37  h11=hf6
38  //Actual enthalpy at state 3(in kJ/kg):
39  h3a=h2-n*(h2-h3)
40  //Dryness fraaction at state 4:
41  x4=(s4-sf1)/sfg1
42  //Enthalpy at state 4(in kJ/kg):
43  h4=hf1+x4*hfg1
44  //Actual enthaly at state 4(in kJ/kg):
45  h4a=h3a-n*(h3a-h4)
46  //Actual dryness fraction at state 4:
47  x4a=(h4a-hf1)/hfg1
48  //Actual entropy at state 4(in kJ/kg.K):
49  s4a=sf1+x4a*sfg1
50  //Entropy at state 5(in kJ/kg.K):
51  s5=s4a
52  //Dryness fraction:
53  x5=0.8735
54  //Enthalpy at state 5(in kJ/kg):
55  h5=2270.43
56  //Actual enthalpy at state 5(in kJ/kg):
57  h5a=h4a-n*(h4a-h5)
58  //By calculation:
59  m1=0.1293 //kg
```

```
60  m2=0.1059 //kg
61  //Turbine output(in kJ/kg):
62  Wt=(h2-h3a)+(1-m1)*(h3a-h4a)+(1-m1-m2)*(h4a-h5a)
63  //Rate of steam generation required(in kg/hr):
64  r=W*10^3/Wt*3600
65  //Capacity of drain pump(in kg/hr):
66  c=(m1+m2)*r
67  printf("\n RESULT \n")
68  printf("\nCapacity of drain pump = %f kg/hr",c)
```

Scilab code Exa 8.10 To determine the thermal efficiency

```
1   //pathname=get_absolute_file_path('8.10.sce')
2   //filename=pathname+filesep()+'8.10-data.sci'
3   //exec(filename)
4   //Pressure of the steam entering(in bar):
5   p1=70
6   //Temperature of the steam entering the HP turbine(
        in C):
7   T1=450
8   //Pressure at which steam is extracted(in bar):
9   p3=30
10  //Temperature at which it is reheated(in C):
11  T4=400
12  //Pressure of steam after expanding(in bar):
13  p6=0.075
14  //Temperature at which steam is bled(in C):
15  T=140
16  //Efficiency of HP turbine:
17  nh=0.80
18  //Efficiency of LP turbine:
19  nl=0.85
20  //From steam tables:
21  h2=3287.1 //kJ/kg
22  s2=6.6327 //kJ/kg.K
```

```
23  h3=3049.48  //kJ/kg
24  h4=3230.9  //kJ/kg
25  s4=6.9212  //kJ/kg.K
26  s6=s4
27  h6=2158.55  //kJ/kg
28  s5=s4
29  p5=3.61  //bar
30  h5=2712.38  //kJ/kg
31  h9=1008.42  //kJ/kg
32  v7=0.001008  //m^3/kg
33  h7=168.79  //kJ/kg
34  h8=169.15  //kJ/kg
35  v9=0.00108  //m^3/kg
36  //Actual enthalpy at state 3(in kJ/kg):
37  h3a=h2-nh*(h2-h3)
38  //Actual enthaly at state 6(in kJ/kg):
39  h6a=h4-nl*(h4-h6)
40  //Actual enthaly at state 5(in kJ/kg):
41  h5a=h4-nl*(h4-h5)
42  //Enthalpy at state 8(in kJ/kg):
43  h8=h7+v7*(p5-p6)*10^2
44  //Mass of bled steam per kg of steam generated(in kg
       /kg steam generated):
45  m=(h9-h8)/(h5a-h8)
46  //Enthalpy at state 1(in kJ/kg):
47  h1=h9+v9*(p1-p5)*10^2
48  //Net work per kg of steam generated(in kJ/kg):
49  Wnet=(h2-h3a)+(h4-h5a)+(1-m)*(h5a-h6a)-((1-m)*(h8-h7
       )+(h1-h9))
50  //Heat added per kg of steam generated(in kJ/kg):
51  Q=(h2-h1)+(h4-h3a)
52  //Thermal efficiency:
53  n=Wnet/Q*100
54  printf(")\n RESULT \n")
55  printf(")\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.11 To determine cycle thermal efficiency and net power developed

```
1  //pathname=get_absolute_file_path('8.11.sce')
2  //filename=pathname+filesep()+'8.11-data.sci'
3  //exec(filename)
4  //Pressure of the steam entering the boiler(in bar):
5  p1=150
6  //Temperature of the steam entering the turbine(in C
       ):
7  T1=450
8  //Condensor pressure(in bar):
9  p6=0.05
10 //Pressure of steam bled out between 1st & 2nd stage
        and 2nd & 3rd(in bar):
11 p3=10
12 p4=1.5
13 //Temperature of feed water leaving closed water
       heater(in C):
14 T11=150
15 //Mass flow rate(in kg/s):
16 m=300
17 //From steam tables:
18 h2=3308.6  //kJ/kg
19 s2=6.3443  //kJ/kg.K
20 s3=s2
21 s4=s2
22 s5=s2
23 h3=2667.26  //kJ/kg
24 h4=2355.18  //kJ/kg
25 h5=1928.93  //kJ/kg
26 h6=137.82  //kJ/kg
27 v6=0.001005  //m^3/kg
28 h8=467.11  //kJ/kg
```

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```
29  v8=0.001053  //mˆ3/kg
30  h10=1610.5  //kJ/kg
31  v10=0.001053  //mˆ3/kg
32  //Enthalpy at state 7(in kJ/kg):
33  h7=h6+v6*(p4-p6)*10^2
34  //Enthalpy at state 9(in kJ/kg):
35  h9=h8+v8*(p1-p4)*10^2
36  //Enthalpy at state 12(in kJ/kg):
37  h12=h10+v10*(p1-p3)*10^2
38  //Mass of steam bled out in closed feed water heater
        (in kg/kg of steam generated):
39  m1=(4.18*T11-h9)/(h3-h9+4.18*T11-h10)
40  m2=((1-m1)*(h8-h7))/(h4-h7)
41  //Enthalpy at state 1(in kJ/kg):
42  h1=(4.18*T11)*(1-m1)+m1*h12
43  //Net work output per kg of steam generated(in kJ/kg
        ):
44  Wnet=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)-((1-m1
        -m2)*(h7-h6)+(1-m1)*(h9-h8)+m1*(h12-h10))
45  //Heat added(in kJ/kg):
46  Q=h2-h1
47  //Cycle thermal efficiency:
48  n=Wnet/Q*100
49  printf("\n RESULT \n")
50  printf("\nCycle thermal efficiency = %f percent",n)
51  printf("\nNet power developed = %f kW",Wnet)
```

Scilab code Exa 8.12 To determine thermal efficiency and steam generation rate

```
1  //pathname=get_absolute_file_path('8.12.sce')
2  //filename=pathname+filesep()+'8.12-data.sci'
3  //exec(filename)
4  //Pressure of the steam entering the boiler(in bar):
5  p1=100
```

```
 6  //Temperature  of  the  steam  entering  the  turbine(in  C
         ):
 7  T1=500
 8  //Condensor  pressure(in  bar):
 9  p6=0.075
10  //Pressure  at  which  steam  is  extracted  at  exit  of
        HPT(in  bar):
11  p3=20
12  //Pressure  at  which  steam  is  extracted  at  exit  of
        IPT(in  bar):
13  p4=4
14  //Temperature  at  which  feed  water  leaves  closed  feed
          warere  heater(in  C):
15  T=200
16  //Net  power  output(in  MW):
17  W=100
18  //From  steam  tables:
19  h2=3373.7  //kJ/kg
20  s2=6.5966  //kJ/kg.K
21  s3=s2
22  s4=s2
23  s5=s2
24  T3=261.6  //C(by  interpolation)
25  h3=2930.57  //kJ/kg
26  h4=2612.65  //kJ/kg
27  h5=2055.09  //kJ/kg
28  h10=908.79  //kJ/kg
29  h8=604.74  //kJ/kg
30  h1=4.18*T
31  h11=h10
32  v6=0.001008  //m^3/kg
33  h6=168.79  //kJ/kg
34  h8=604.74  //kJ/kg
35  v8=0.001084  //m^3/kg
36  //For  modified  part:
37  h3a=3247.6  //kJ/kg
38  s3a=7.1271  //kJ/kg.K
39  s4a=s3a
```

```
40  s5a = s3a
41  T4 = 190.96  //C(by interpolation)
42  h4a = 2841.2  //kJ/kg
43  h5a = 2221.11  //kJ/kg
44  //Enthalpy at state 7(in kJ/kg):
45  h7 = h6 + v6 * (p4 - p6) * 10^2
46  //Enthalpy at state 9(in kJ/kg):
47  h9 = h8 + v8 * (p3 - p4) * 10^2
48  //Mass of steam bled out in closed feed water heater
       (in kg/kg of steam generated):
49  m1 = (h1 - h9) / (h3 - h10)
50  m2 = ((h8 - h7) - m1 * (h11 - h7)) / (h4 - h7)
51  //Net work per steam generated(in kJ/kg):
52  Wnet = (h2 - h3) + (1 - m1) * (h3 - h4) + (1 - m1 - m2) * (h4 - h5) - ((1 - m1
       - m2) * (h7 - h6) + (h9 - h8))
53  //Heat added(in kJ/kg):
54  Q = h2 - h1
55  //Thermal efficiency:
56  n = Wnet / Q * 100
57  //Steam genration rate(in kg/s):
58  sgc = W * 10^3 / Wnet
59  printf("\n RESULT \n")
60  printf("\nThermal efficiency = %f percent", n)
61  printf("\nSteam generation rate = %f kg/s", sgc)
62  //For modified part:
63  //Mass of steam bled out in closed feed water heater
       (in kg/kg of steam generated):
64  m2a = ((h8 - h7) - m1 * (h11 - h7)) / (h4a - h7)
65  //Net work per steam generated(in kJ/kg):
66  Wneta = (h2 - h3) + (1 - m1) * (h3a - h4a) + (1 - m1 - m2a) * (h4a - h5a)
       - ((1 - m1 - m2a) * (h7 - h6) + (h9 - h8))
67  //Heat added(in kJ/kg):
68  Qa = h2 - h1 + (1 - m1) * (h3a - h3)
69  //Thermal efficiency:
70  na = Wneta / Qa * 100
71  //% Increase in thermal efficiency due to reheating:
72  I = (na - n) / n * 100
73  printf("\n\nThermal efficiency = %f percent", na)
```

```
74 printf(")"\n Percentage increase in efficiency due to
      reheating = %f percent",I)
```

Scilab code Exa 8.13 To determine the thermal efficiency

```
1  //pathname=get_absolute_file_path('8.13.sce')
2  //filename=pathname+filesep()+'8.13-data.sci'
3  //exec(filename)
4  //Enthalpy of dry saturated vapour at 8.45 bar
5  hd=349 //kJ/kg
6  //Enthalpy after isentropic expansion to 0.07 bar
7  hi=234.5 //kJ/kg
8  //Enthalpy of saturated liquid at 0.07 bar
9  hs= 35 //kJ/kg
10 //Capability:
11 n1=0.85
12 //Specific heat of water:
13 Cpw=4.18
14 //From steam tables:
15 h1=2767.13 //kJ/kg
16 h2=3330.3 //kJ/kg
17 s2=6.9363 //kJ/kg.K
18 s3=s2
19 s4=s2
20 s5=s2
21 h3=2899.23 //kJ/kg
22 x4=0.93
23 h4=2517.4 //kJ/kg
24 x5=0.828
25 h5=2160.958 //kJ/kg
26 h6=168.79 //kJ/kg
27 v6=0.001008 //m^3/kg
28 h7=168.88 //kJ/kg
29 h9=417.46 //kJ/kg
30 h13=721.11 //kJ/kg
```

```
31  v13 =0.001252  //m^3/kg
32  T1 =150  //C
33  h10 =418.19  //kJ/kg
34  m1 =0.102
35  m2 =0.073
36  //For mercury cycle :
37  //Isentropic heat drop :
38  qd=hd - hi
39  //Actual heat drop :
40  qda =n1 * qd
41  //Heat rejected in condenser (in kJ/kg) :
42  qre =hd - qda - hs
43  //Heat added in the boiler (in kJ/kg) :
44  qa=hd - hs
45  //Heat added in the condenser of mercury cycle (in kJ
       /kg) :
46  qam =h1 - Cpw * T1
47  //Mercury per steam required per kg of steam :
48  m=qam / qre
49  //Pump work (in kJ/kg) :
50  Wp=v13 * (40 -8) *10^2
51  //Total heat supplied (in kJ/kg steam) :
52  qt=m*qa+h2 - h1
53  //Work done in mercury cycle (in kJ/kg) :
54  Wm=m*qda
55  //Work done in steam cycle (in kJ/hr) :
56  Ws =(h2 - h3 ) +(1 - m1 ) *(h3 - h4 ) +(1 - m1 - m2 ) *(h4 - h5 ) -(1 - m1 - m2
       ) *(h7 - h6 ) - m2 *(h10 - h9 ) - m1 * Wp
57  //Total work done (in kJ/kg) :
58  Wt=Wm+Ws
59  //Thermal efficiency :
60  n=Wt/qt *100
61  printf ("\n RESULT \n")
62  printf ("\nThermal efficiency = %f percent ",n)
```

Scilab code Exa 8.15 To determine the thermal efficiency

```
1  //pathname=get_absolute_file_path('8.15.sce')
2  //filename=pathname+filesep()+'8.15-data.sci'
3  //exec(filename)
4  //Specific heat of water:
5  Cpw=4.18
6  //From steam tables:
7  h2=2960.7 //kJ/kg
8  s2=6.3615 //kJ/kg
9  s3=s2
10 x3=0.863
11 h3=2404.94 //kJ/kg
12 h7=358.59 //kJ/kg
13 s10=s3
14 x10=0.754
15 h10=1982.91 //kJ/kg
16 //Mass pf moisture in separator(in kg):
17 m1=(1-x3)*0.5
18 //Mass of steam entering LPT(in kg):
19 m2=0.5-m1
20 //Mass of water entering the hot well(in kg):
21 m3=0.5+m1
22 //Temperature of water leaving hotwell(in C):
23 T=(m3*90+m2*40)
24 //Heat transferred per kg steam generated:
25 Q=0.5*(h3-h7)
26 printf("\n RESULT \n")
27 printf("\nTemperature of water leaving hotwell = %f
      C",T)
28 printf("\nHeat transferred per kg steam generated =
      %f kJ/kg steam",Q)
29 //Net work output(in kJ/kg):
30 Wnet=(h2-h3)*1+m2*(h3-h10)
31 //Heat added(in kJ/kg):
32 Qa=h2-Cpw*T
33 //Thermal efficiency:
34 n=Wnet/Qa*100
```

```
35  printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.16 To determine cycle thermal efficiency and net power developed

```
1  //pathname=get_absolute_file_path('8.16.sce')
2  //filename=pathname+filesep()+'8.16-data.sci'
3  //exec(filename)
4  //Steam flow rate(in kg/s):
5  m=35
6  //From steam tables:
7  h1=3530.9 //kJ/kg
8  s1=6.9486 //kJ/kg.K
9  s2=s1
10  x2=0.864
11  h2=2288.97 //kJ/kg
12  v3=0.001017 //m^3/kg
13  h3=251.40 //kJ/kg
14  //Pump work(in kJ/kg):
15  Wp=v3*(70-0.20)*10^2
16  //Turbine work(in kJ/kg):
17  Wt=h1-h2
18  //Net work(in kJ/kg):
19  Wnet=Wt-Wp
20  //Power produced(in MW):
21  P=m*Wnet/10^3
22  //Enthalpy at state 4(in kJ/kg):
23  h4=h3+Wp
24  //Total heat supplied to the boiler(in kJ/s):
25  Q=m*(h1-h4)
26  //Thermal efficiency:
27  n=Wnet*m/Q*100
28  printf("\n RESULT \n")
29  printf("\nNet power = %f MW",P)
30  printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.17 To determine the amount of heat added

```
1  //pathname=get_absolute_file_path('8.17.sce')
2  //filename=pathname+filesep()+'8.17-data.sci'
3  //exec(filename)
4  //State of steam entering HP stage : 10 MPa, 600 C
5  //State of steam entering LP stage: 2 MPa, 400 C
6  //Condenser pressure: 10 KPa
7  //Output(in MW):
8  P=10
9  //From steam tables:
10 h1=3625.3 //kJ/kg
11 s1=6.9029 //kJ/kg.K
12 s2=s1
13 s3=s2
14 h2=3105.08 //kJ/kg
15 x3=0.834
16 h3=2187.43
17 h6=908.79 //kJ/kg
18 h5=191.83 //kJ/kg
19 h4=h5
20 h7=h6
21 //Steam bled per kg of steam passing through HP
       stage:
22 mb=(h6-h5)/(h2-h5)
23 printf("\n RESULT \n")
24 printf("\nSteam bled per kg of steam passing through
        HP stage = %f kg",mb)
25 //Mass of steam leaving boiler(in kg/s):
26 m=P*10^3/((h1-h2)+(1-mb)*(h2-h3))
27 //Heat supplied to the boiler(in kJ/s):
28 Q=m*(h1-h7)
29 printf("\nHeat added = %f kJ/s",Q)
```

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Scilab code Exa 8.18 To determine the thermal efficiency and amount of steam bled

```
1  // pathname=get_absolute_file_path ('8.18.sce')
2  // filename=pathname+filesep ()+'8.18-data.sci'
3  // exec(filename)
4  // Net output(in MW):
5  P=50
6  // From steam tables:
7  h1=3373.7  // kJ/kg
8  s1=6.5966  // kJ/kg.K
9  s6=s1
10 s2=s1
11 s3=7.7622  // kJ/kg.K
12 s8=s3
13 s4=s3
14 h6=2930.572  // kJ/kg
15 h3=3478.5  // kJ/kg
16 T2=181.8// C
17 h2=2782.8  // kJ/kg
18 T8=358.98// C
19 h8=3188.7  // kJ/kg
20 x4=0.95
21 h4=2462.99  // kJ/kg
22 h11=856.8  // kJ/kg
23 h9=604.74  // kJ/kg
24 h7=908.79  // kJ/kg
25 h7a=h7
26 h4a=191.83  // kJ/kg
27 v4a=0.001010// m^3/kg
28 v9=0.001084// m^3/kg
29 // Enthalpy at state 5(in kJ/kg):
30 h5=h4a+v4a*(4-0.1)*10^2
31 // Enthalpy at state 10(in kJ/kg):
```

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```
32  h10=h9+v9*(100-4)*10^2
33  //Mass per kg of steam from boiler(in kg):
34  m6=(h11-h10)/(h6-h7)
35  m8=(h9-(1-m6)*h5-m6*h7a)/(h8-h5)
36  m6=0.135
37  m8=0.105
38  //Work in turbines(in kJ/kg):
39  Whpt=(h1-h6)+(1-m6)*(h6-h2)
40  Wlpt=(1-m6)*(h3-h8)+(1-m6-m8)*(h8-h4)
41  //Pump works(in kJ/kg)
42  Wcep=(1-m6-m8)*(h5-h4a)
43  Wfp=h10-h9
44  //Mass of steam entering first stage of turbine(in
       kg/s):
45  m=P*10^3/(Whpt+Wlpt-Wcep-Wfp)
46  //Heat supplied in the boiler(in kJ/s):
47  Q=m*(h1-h11)
48  //Thermal efficiency:
49  n=P*10^3/Q*100
50  printf("\n RESULT \n")
51  printf("\nMass of steam bled at 20 bar = %f kg per
       kg of steam entering first stage",m6)
52  printf("\nMass of steam bled at 4 bar = %fkg per kg
       of steam entering first stage",m8)
53  printf("\nMass of steam entering first stage = %f kg
       /s",m)
54  printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.19 To determine mass of steam bled

```
1  //pathname=get_absolute_file_path('8.19.sce')
2  //filename=pathname+filesep()+'8.19-data.sci'
3  //exec(filename)
4  //Turbine efficiency:
5  nt=0.85
```

```
 6  //Generator efficiency:
 7  ng=0.90
 8  //Mechanical efficiency:
 9  nm=0.95
10  //Specific heat of water:
11  Cpw=4.18
12  //From steam tables:
13  h1=3450.02  //kJ/kg
14  s1=6.6923  //kJ/kg.K
15  h3=3576.99  //kJ/kg
16  s3=7.52411  //kJ/kg.K
17  h2=3010  //kJ/kg
18  h9=3175  //kJ/kg
19  h4=2300  //kJ/kg
20  h5=137.82  //kJ/kg
21  v5=0.001005  //m^3/kg
22  h8=962.11  //kJ/kg
23  h12=1407.56  //kJ/kg
24  h10=670.56  //kJ/kg
25  v10=0.001101  //m^3/kg
26  //Enthalpy at state 2'(in kJ/kg):
27  h2a=h1-(h1-h2)*nt
28  //Enthalpy at state 9'(in kJ/kg):
29  h9a=h3-(h3-h9)*nt
30  //Enthalpy at state 4'(in kJ/kg):
31  h4a=h3-(h3-h4)*nt
32  //Enthalpy at state 6(in kJ/kg):
33  h6=h5+v5*(6-0.05)*10^2
34  //Enthalpy at state 6'(in kJ/kg):
35  h6a=h5+(h6-h5)/ng
36  //Enthalpy at state 11(in kJ/kg):
37  h11=h10+v10*(100-6)*10^2
38  //Enthalpy at state 11'(in kJ/kg):
39  h11a=h10+(h11-h10)/ng
40  //Mass flow rate(in kg/kg steam):
41  m1=(h11a-h12)/(h8-h2a)
42  m2=(h10-m1*h8-(1-m1)*h6a)/(h9-h6a)
43  //Work from HP turbine(in kJ/kg):
```

```
44  Whp=h1-h2a
45  //Work from LP turbine(in kJ/kg):
46  Wlp=(1-m1)*(h3-h9a)+(1-m1-m2)*(h9a-h4a)
47  //Pump work:
48  Wp=(1-m1-m2)*(h6a-h5)+(h11a-h10)
49  //Net work(in kJ/kg):
50  Wnet=Whp+Wlp-Wp
51  //Specific steam consumption(in kg/kw.h):
52  ssc=3600/(Wnet*ng*nm)
53  ssc=3.93
54  //Overall thermal efficiency:
55  no=Wnet*nm*ng/((h1-h12)+(1-m1)*(h3-h2a))*100
56  //Mass of steam required(in kg/hr):
57  m=ssc*120*103
58  m=471600
59  printf("\n RESULT \n")
60  printf("\nSpecific steam consumption = %f kg/kw.h",
        ssc)
61  printf("\nOverall efficiency = %f percent",no)
62  printf("\nMass of steam bled from HP turbine = %f kg
        /hr",m1*m)
63  printf("\nMass of steam bled from LP turbine = %f kg
        /hr",m2*m)
```

Scilab code Exa 8.20 To determine power available to the generator

```
1  //pathname=get_absolute_file_path('8.20.sce')
2  //filename=pathname+filesep()+'8.20-data.sci'
3  //exec(filename)
4  //Power required(in kW):
5  P=14000
6  //Efficiency ratio of turbine:
7  r=0.75
8  //From steam tables:
9  h1=3137 //kJ/kg
```

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```
10  s1 =6.9563  // kJ/ kg .K
11  s2 = s1
12  x2 =0.765
13  h2 =2170.38  // kJ/kg
14  hf =467.11  // kJ/kg
15  // Enthalpy  at  state  2 '( in  kJ/kg ) :
16  h2a=h1 -(h1 - h2) * r
17  // Mass  of  steam  required ( in  kg/s ) :
18  m=P /( h2a - hf )
19  // Power  available  to  the  generator ( in  kW ) :
20  P1 = m *( h1 - h2a )
21  printf ( "\n  RESULT  \n")
22  printf ( "\nPower  available  to  the  generator  =  %f  kW" ,
      P1 )
```

Scilab code Exa 8.21 To determine heat consumption in the boiler

```
 1  // pathname=get_absolute_file_path ( '8.21. sce ')
 2  // filename=pathname+filesep ()+ '8.21 − data . sci '
 3  // exec ( filename )
 4  // Turbine  efficiency :
 5  nt =0.80
 6  // Boiler  efficiency :
 7  nb =0.80
 8  // Power  required ( in  kW ) :
 9  P =9000
10  // From  steam  tables :
11  h1 =3137  // kJ/kg
12  s1 =6.9563  // kJ/ kg .K
13  s2 = s1
14  x2 =0.960
15  h2 =2638.34  // kJ/kg
16  hf =503.71  // kJ/kg
17  // Enthalpy  at  state  2 '( in  kJ/kg ) :
18  h2a=h1 -(h1 - h2) * nt
```

```
19  //Mass flow rate(in kg/s):
20  ms=P/(h2a-hf)
21  //Power developed(in kW):
22  P1=ms*(h1-h2a)
23  //Total heat consumption in the bolier(in kW):
24  pt=(h1-hf)*ms
25  //Actual heat consumption(in kJ/s):
26  pa=pt/nb
27  printf("\n RESULT \n")
28  printf("\nPower developed = %f kW",P1)
29  printf("\nActual heat consumption = %f kJ/s",pa)
```

Scilab code Exa 8.22 To determine total power produced

```
1  //pathname=get_absolute_file_path('8.22.sce')
2  //filename=pathname+filesep()+'8.22-data.sci'
3  //exec(filename)
4  //Total power required(in kW):
5  P=4500
6  //Heat load(in kW):
7  Q=15000
8  //Efficiency of turbines:
9  n=0.80
10 //Steam consumption rate(in kg/s):
11 m=10
12 //From steam tables:
13 h1=3137  //kJ/kg
14 s1=6.9563  //kJ/kg.K
15 T2=179.18  //C
16 h2=2813.41  //kJ/kg
17 hf=640.23  //kJ/kg
18 //For case 1:
19 T2a=213.34  //C
20 s2a=7.125  //kJ/kg.K
21 s3=s2a
```

```
22  x3 =0.853
23  h3 =2221.11  //kJ/kg
24  //For case 2:
25  h2a =2878.13  //kJ/kg
26  h3aa=h2a
27  T3aa =210.04  //C
28  s3aa =7.138  //kJ/kg.K
29  s4=s3aa
30  x4 =0.855
31  h4 =2225.92  //kJ/kg
32  //Enthalpy at state 2'(in kJ/kg):
33  h2a=h1 -(h1-h2)*n
34  //Heat available for process heating(in kJ/kg):
35  q=h2a-hf
36  //Mass flow rate(in kg/s):
37  msh=Q/q
38  //Enthalpy at state 3'(in kJ/kg):
39  h3a=h2 -(h2a-h3)*n
40  //Mass of steam produced:
41  mshp=(P+msh*(h2a-h3a))/((h1-h2a)+(h2a-h3a))
42  //For case 2:
43  mshpn =10
44  mshn =6.7
45  //Power produced by HP turbine(in kW):
46  Pn=mshpn*(h1-h2a)
47  M3aa=mshpn-mshn
48  //Enthalpy at state 4'(in kJ/kg):
49  h4a=h3aa -(h3aa-h4)*n
50  //Power produced by LP turbine(in kW):
51  Pn1=M3aa*(h3aa-h4a)
52  //Total power produced(in kW):
53  Pt=Pn+Pn1
54  printf("\n RESULT \n")
55  printf("\nTotal power produced = %f kW",Pt)
```

Scilab code Exa 8.23 To determine heat available for heating process

```
1  //pathname=get_absolute_file_path('8.23.sce')
2  //filename=pathname+filesep()+'8.23-data.sci'
3  //exec(filename)
4  //Alternator efficiency:
5  na=0.975
6  //Turbine efficiency:
7  nt=0.80
8  //Turbine's losses(in kW):
9  L=50
10 //Electric power developed(in mW):
11 p=8
12 //Condenser discharge(in kg/s):
13 m=8
14 //From steam tables:
15 h1=3137 //kJ/kg
16 s1=6.9563 //kJ/kg.K
17 h1a=h1
18 s1a=7 //kJ/kg.K
19 s2=s1a
20 h2=2830 //kJ/kg
21 h4=2210 //kJ/kg
22 hf=376.92 //kJ/kg
23 //Enthalpy at state 2'(in kJ/kg):
24 h2a=h1a-(h1a-h2)*nt
25 h3=h2a
26 //Enthalpy at state 4'(in kJ/kg):
27 h4a=h3-(h3-h4)*nt
28 //Power available to the alternator(in MW):
29 P=m/na
30 //Total power produced(in kW):
31 Pt=P*10^3+L
32 //Power produced by LP turbine(in kW):
33 plp=m*(h3-h4)
34 //Power produced by LP turbine(in kW):
35 php=Pt-plp
36 //Mass flow rate through HP turbine(in kg/s):
```

```
37  m1=php/(h1a-h2a)
38  //Heat available for process heating(in kW):
39  ph=(m1-m)*(h2-hf)
40  printf("\n RESULT \n")
41  printf("\nHeat available for process heating = %f kW
        ",ph)
```

Scilab code Exa 8.24 To determine steam consumption

```
1   //pathname=get_absolute_file_path('8.24.sce')
2   //filename=pathname+filesep()+'8.24-data.sci'
3   //exec(filename)
4   //Turbine efficiency:
5   nt=0.80
6   //Mechanical efficiency:
7   nm=0.90
8   //Power delivered by turbine(in kW):
9   p=720
10  //From steam tables:
11  h1=3045.8 //kJ/kg
12  s1=7.0317 //kJ/kg.K
13  s4=s1
14  x4=0.841
15  h4=2192.24 //kJ/kg.K
16  h2=2706.7 //kJ/kg
17  s2=7.1271 //kJ/kg.K
18  s3=s2
19  x3=0.854
20  h3=2223.51 //kJ/kg
21  //Enthalpy at state 4'(in kJ/kg):
22  h4a=h1-(h1-h4)*nt
23  //Enthalpy at state 3'(in kJ/kg):
24  h3a=h2-(h2-h3)*nt
25  //Power developed in the turbine(in kW):
26  P=p/nm
```

```
27  //HP steam consumption (in  kg/kW.h):
28  m1=3600/(h1-h4a)
29  //LP steam consumption (in  kg/kW.h):
30  m2=3600/(h2-h3a)
31  printf("\n RESULT \n")
32  printf("\nHP steam consumption = %f kg/kW.h",m1)
33  printf("\nLP steam consumption = %f kg/kW.h",m2)
```

Scilab code Exa 8.25 To the determine the power generated

```
1  //pathname=get_absolute_file_path('8.25.sce')
2  //filename=pathname+filesep()+'8.25-data.sci'
3  //exec(filename)
4  //Mass flow rate(in  kg/s):
5  mhp=2
6  mlp=1.5
7  //Expansion efficiency:
8  n=0.90
9  //Power developed by the turbine(in kW):
10 P=3000
11 //From steam tables:
12 h1=3034.8 //kJ/kg
13 s1=6.8844 //kJ/kg.K
14 s3=s1
15 x3=0.9566
16 h3=2611.04 //kJ/kg
17 h2=2706.7 //kJ/kg
18 hin=h2
19 xout=0.8535
20 hout=2222.31 //kJ/kg
21 h4=2676.25 //kJ/kg
22 h5=2290 //kJ/kg
23 //Enthalpy at state 3'(in  kJ/kg):
24 h3a=h1-(h1-h3)*n
25 //Enthalpy of steam going out(in  kJ/kg):
```

```
26  houta = hin -( hin - hout )* n
27  // Mass flow rate of steam ( in kg/s ):
28  ms = P /( hin - hout )
29  // Enthalpy at state 5 '( in kJ/kg ):
30  h5a = h4 -( h4 - h5 )* n
31  // Power output from mixed pressure turbine ( in kW ):
32  p = mhp *( h1 - h3a ) +( mhp + mlp )*( h4 - h5a )
33  printf ( " \n RESULT \n " )
34  printf ( " \ nPower = %f kW " , p )
```

Chapter 9

Gas power cycles

Scilab code Exa 9.01 To determine the mep

```
1  //pathname=get_absolute_file_path('9.01.sce')
2  //filename=pathname+filesep()+'9.01-data.sci'
3  //exec(filename)
4  //Compression ratio:
5  r=6
6  //Swept volume(in m^3):
7  v=0.15
8  //Pressure at the beginning of compression(in kPa):
9  p1=98
10 //Temperature at the beginning of compression(in K):
11 T1=60+273.15
12 //Heat supplied(in kJ/kg):
13 Q23=150
14 //Value of Cp(in kJ/kg):
15 Cp=1
16 //Value of Cv(in kJ/kg):
17 Cv=0.71
18 //Adiabatic compression factor:
19 n=Cp/Cv
20 //Gas constant(in kJ/kg.K):
21 R=Cp-Cv
```

```
22  //Volume at point 2(in m^3):
23  v2=v/(r-1)
24  //Total cylinder volume(in m^3):
25  v1=r*v2
26  //Mass(in kg):
27  m=p1*v1/(R*T1)
28  //Pressure at point 2(in kPa):
29  p2=p1*(v1/v2)^n
30  //Temperature at state 2(in K):
31  T2=p2*v2*T1/(p1*v1)
32  //Temperature at state 3(in K):
33  T3=Q23/(m*Cv)+T2
34  v3=v2
35  //Pressure at point 3(in kPa):
36  p3=p2*v2*T3/(v3*T2)
37  v4=v1
38  //Pressure at point 4(in kPa):
39  p4=p3*(v3/v4)^n
40  //Temperature at point 4(in K):
41  T4=p4*v4*T3/(p3*v3)
42  //Entropy change(in kJ/K):
43  dS=m*Cv*log(T4/T1)
44  //Heat rejected(in kJ):
45  Q41=m*Cv*(T4-T1)
46  //Net work done(in kJ):
47  W=Q23-Q41
48  //Efficiency:
49  e=W/Q23
50  //Mean effective pressure(in kPa):
51  mep=W/v
52  printf("\nRESULT")
53  printf("\nm.e.p = %f kPa",mep)
```

Scilab code Exa 9.02 To determine the compression ratio

```
1  //pathname=get_absolute_file_path('9.02.sce')
2  //filename=pathname+filesep()+'9.02-data.sci'
3  //exec(filename)
4  //Pressure at A(in kPa):
5  pa=138
6  //Pressure at B(in kPa):
7  pb=1380
8  //Thermal efficiency:
9  nt=0.5
10 //Mechanical efficiency:
11 nm=0.8
12 //Calorific value of fuel(in kJ/kg):
13 c=41800
14 //Adiabatic compressive index:
15 n=1.4
16 //Ratio of va to vb:
17 r1=(pb/pa)^(1/n)
18 //Compression ratio:
19 r=(7/8*r1-1/8)/(7/8-r1/8)
20 //Cut off ratio:
21 p=(r-1)/15+1
22 //Air standard efficiency for Diesel cycle:
23 nd=1-1/(r^(n-1)*n)*(p^n-1)/(p-1)
24 //Overall efficiency:
25 no=nd*nt*nm
26 //Fuel consumption,bhp/hr(in kg):
27 fc=75*60*60/(no*c*10^2)
28 printf("\nRESULT")
29 printf("\nCompression ratio = %f",r)
30 printf("\nAir standard efficiency = %f percent",nd
       *100)
31 printf("\nFuel consumption,bhp/hr = %f kg",fc)
```

Scilab code Exa 9.03 To find out the efficiencies

```scilab
 1  //pathname=get_absolute_file_path('9.03.sce')
 2  //filename=pathname+filesep()+'9.03-data.sci'
 3  //exec(filename)
 4  //Total heat added(in kJ/kg):
 5  Q=1700
 6  //Maximum pressure(in kPa):
 7  p3=5000
 8  //Temperature at the beginning of compression(in K):
 9  T1=100+273.15
10  //Pressureat beginning of compression(in kPa):
11  p1=103
12  //Value of Cp(in kJ/kg.K):
13  Cp=1.005
14  //Value of Cv(in kJ/kg.K):
15  Cv=0.71
16  //For Otto cycle:
17  //Adiabatic index of compression:
18  n=1.4
19  //Gas constant(in kJ/kg.K):
20  R=Cp-Cv
21  //Considernig 1 kg of air, volume at 1(in m^3):
22  m=1
23  V1=m*R*T1/p1
24  //By solving, volume at 2(in m^3):
25  V2=0.18
26  //Compression ratio:
27  r=V1/V2
28  //Otto cycle efficiency:
29  no=1-1/(r^(n-1))
30  //For mixed cycle:
31  //By calculating, volume at state 2':
32  V21=0.122
33  //Upon subtituting:
34  p21 = 2124.75  //kPa
35  T31 = 2082  //K
36  T21 = 884.8  //K
37  T41 = 2929.5  //K
38  V31=V21
```

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```
39  //Volume at state 4(in m^3):
40  V41=V31*T41/T31
41  //Temperature at state 5(in K):
42  T5=T41*(V41/V1)^(n-1)
43  //Heat rejected in the process 5−1(in kJ):
44  Q51=Cv*(T5-T1)
45  //Efficiency of mixed cycle:
46  nm=(Q-Q51)/Q
47  printf("\nRESULT")
48  printf("\nEfficiency of Otto cycle = %f percent",no
        *100)
49  printf("\nEfficiency of mixed cycle = %f percent",nm
        *100)
```

Scilab code Exa 9.04 To determine the compressor efficiency

```
1   //pathname=get_absolute_file_path('9.04.sce')
2   //filename=pathname+filesep()+'9.04−data.sci'
3   //exec(filename)
4   //Maximum temperature(in K):
5   T3 = 1200
6   //Minimum temperature(in K):
7   T1 = 300
8   //Adiabatic compression ratio:
9   n=1.4
10  //Value of Cp(in kJ/kg.K):
11  Cp=1.005
12  //Optimum pressure ratio for maximum work output:
13  rp=(T3/T1)^(n/(2*(n-1)))
14  //Temperature at state 2(in K):
15  T2=T1*rp^((n-1)/n)
16  //Temperature at state 4(in K):
17  T4=T3*rp^((1-n)/n)
18  //Heat supplied(in kJ/kg):
19  Q23=Cp*(T3-T2)
```

```
20  //Compressor work(in kJ/kg):
21  Wc=Cp*(T2-T1)
22  //Turbine work(in kJ/kg):
23  Wt=Cp*(T3-T4)
24  //Thermal efficiency:
25  nth=(Wt-Wc)/Q23*100
26  printf("\nRESULT")
27  printf("\nCompressor work = %f kJ/kg",Wc)
28  printf("\nTurbine work = %f kJ/kg",Wt)
29  printf("\nThermal efficiency = %f percent",nth)
```

Scilab code Exa 9.05 To determine the thermal efficiency

```
1   //pathname=get_absolute_file_path('9.05.sce')
2   //filename=pathname+filesep()+'9.05-data.sci'
3   //exec(filename)
4   //Pressure at state 1(in bar):
5   p1=1
6   //Pressure at state 2(in bar):
7   p2=6.2
8   //Pressure at state 3(in bar):
9   p3=6.2
10  //Pressure at state 4(in bar):
11  p4=1
12  //Temperature at state 1(in K):
13  T1=300
14  //Fuel by air ratio:
15  r=0.017
16  //Compressor effeciency:
17  nc=0.88
18  //Turbine internal efficiency:
19  nt=0.90
20  //Heating value of fuel(in kJ/kg):
21  H=44186
22  //Adiabatic index of compression:
```

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```
23  n=1.4
24  n1=1.33
25  //Value of Cp for combination(in kJ/kg.K):
26  Cpc=1.147
27  //Value of Cp for air(in kJ/kg.K):
28  Cpa=1.005
29  //Temperature at state 2(in K):
30  T2=T1*(p2/p1)^((n-1)/n)
31  //Actual temperature after compression(in K):
32  T21=(T2-T1)/nc+T1
33  //Temperature at state 3(in K):
34  T3=(r*H+Cpa*T21)/((1+r)*Cpc)
35  //Temperature at state 4(in K):
36  T4=T3*(p4/p3)^((n1-1)/n1)
37  //Actual temperature at turbine inlet considering
        internal efficiency of turbine(in K):
38  T41=T3-nt*(T3-T4)
39  //Compressor work, per kg of air compressed(in kJ/kg
        ):
40  Wc=Cpa*(T21-T1)
41  //Turbine work, per kg of air compressed(in K):
42  Wt=Cpc*(T3-T41)
43  //Net work(in kJ/kg):
44  Wnet=Wt-Wc
45  //Heat supplied(in kJ/kg):
46  Q=r*H
47  //Thermal effeciency:
48  nth=Wnet/Q*100
49  printf("\nRESULT")
50  printf("\nCompressor work = %f kJ/kg of air",Wc)
51  printf("\nTurbine work = %f kJ/kg of air",Wt)
52  printf("\nThermal efficiency = %f percent",nth)
```

Scilab code Exa 9.06 To determine optimum pressure ratio

```
1  //pathname=get_absolute_file_path('9.06.sce')
2  //filename=pathname+filesep()+'9.06-data.sci'
3  //exec(filename)
4  //Maximum temperature(in K):
5  T5=1200
6  //Minimum temperature(in K):
7  T1=300
8  T3=300
9  //Isentropic efficiency:
10 ni=0.85
11 //Turbine efficiency:
12 nt=0.9
13 //Adiabatic index of compression:
14 n=1.4
15 //Overall optimum pressure ratio:
16 rpopt=(T1/(T5*ni*nt))^(2*n/(3*(1-n)))
17 printf("\nRESULT")
18 printf("\nOverall optimum pressure ratio = %f",rpopt
      )
```

Scilab code Exa 9.07 To determine the power required

```
1  //pathname=get_absolute_file_path('9.07.sce')
2  //filename=pathname+filesep()+'9.07-data.sci'
3  //exec(filename)
4  //Ratio of pressure:
5  rp=1.35
6  //Flow rate through compressor(in kg/s):
7  m=50
8  //Overall efficiency:
9  no=0.90
10 //Initial pressure(in bar):
11 p1=1
12 //Initial temperature(in K):
13 T1=313
```

```
14  //Adiabatic index of compression:
15  r=1.4
16  //Gas constant(in kJ/kg.K):
17  R=0.287
18  //Exit pressure(in bar):
19  p9=p1*rp^8
20  //Temperature at exit(in K):
21  T9=T1*(p9/p1)^((r-1)/r)
22  //Considerinf efficiency, actual temperature at exit
      (in K):
23  T9a=(T9-T1)/0.82+T1
24  //Actual index of compression:
25  n=log(p9/p1)/(log(p9/p1)-log(T9a/T1))
26  printf("\nRESULT")
27  printf("\nPressure at exit of comppressor = %f bar",
      p9)
28  printf("\nTemperature at the exit of compressor = %f
       K",T9a)
29  //Polytropic efficiency:
30  np=((r-1)/r)*(n/(n-1))
31  printf("\n\nPolytropic efficiency = %f percent",np
      *100)
32  //Temperature at state 2(in K):
33  T2=T1*rp^((r-1)/r)
34  //Actual temperature at state 2(in K):
35  T2a=T1*(rp)^((n-1)/n)
36  //Stage efficiency:
37  ns1=(T2-T1)/(T2a-T1)
38  printf("\n\nStage efficiency = %f percent",ns1*100)
39  //Work done by compressor(in kJ/s):
40  Wc=(n/(n-1))*m*R*T1*((p9/p1)^((n-1)/n)-1)
41  //Actual compressor work(in kJ/s):
42  Wca=Wc/no
43  printf("\n\nPower required to drive compressor = %f
      kJ/s",Wca)
```

Scilab code Exa 9.09 To determine specific work output

```
1  //pathname=get_absolute_file_path('9.09.sce')
2  //filename=pathname+filesep()+'9.09-data.sci'
3  //exec(filename)
4  //Temperature at which air is supplied(in K):
5  T1=27+273
6  //Initial pressure(in bar):
7  p2=8
8  p3=p2
9  //Temperature of air leaving the combustion chamber(
      in K):
10 T3=1100
11 //Pressure at state 4(in bar):
12 p4=1
13 p1=p4
14 //Effectiveness of heat exchanger:
15 E=0.8
16 //Polytropic efficiency of the compressor:
17 npc=0.85
18 //Polytropic efficinency of the turbnie:
19 npt=0.90
20 //Adiabatic index of compression:
21 r=1.4
22 //Value of Cp(in kJ/kg.K):
23 Cp=1.0032
24 //Compression index:
25 nc=r*npc/(r*npc-(r-1))
26 //Expansion index:
27 nt=r/(r-npt*(r-1))
28 //Temperature at state 2:
29 T2=T1*(p2/p1)^((nc-1)/nc)
30 //Temperature at state 4(in K):
31 T4=T3*(p4/p3)^((nt-1)/nt)
```

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```
32  //Using  heat  exchanger  effectiveness ,  temperature  at
        state  5( in  K) :
33  T5 =( T4 - T2 )*E+T2
34  //Heat  added  in  combustion  chambers ( in  kJ/kg ) :
35  qa=Cp *( T3 - T5 )
36  //Compressor  work ( in  kJ/kg ) :
37  Wc=Cp *( T2 - T1 )
38  //Turbine  work ( in  kJ/kg ) :
39  Wt=Cp *( T3 - T4 )
40  //Cycle  efficiency :
41  ncycle =( Wt - Wc )/qa
42  //Work  ratio :
43  Wr =( Wt - Wc )/Wt
44  //Specific  work  output ( in  kJ/kg ) :
45  swo=Wt - Wc
46  printf (" \nRESULT")
47  printf (" \nCycle  efficiency  =  %f  percent", ncycle *100)
48  printf (" \nWork  ratio  =  %f", Wr )
49  printf (" \nSpecific  work  output  =  %f  kJ/kg", swo )
```

Scilab code Exa 9.10 To determine isentropic efficiency

```
1  //pathname=get_absolute_file_path ( ' 9.10. sce ')
2  //filename=pathname+filesep ()+'9.10− data . sci '
3  //exec ( filename )
4  //Initial  pressure ( in  bar ) :
5  p1 =1
6  //Initial  temperature ( in  K) :
7  T1 =27+273
8  //Pressure  at  state  2( in  bar ) :
9  p2 =5
10  //Isentropic  efficiency :
11  nc =0.85
12  //Temperature  at  state  3( in  K) :
13  T3 =1000
```

```
14  // Pressure at state 3 (in bar):
15  p3=p2-0.2
16  // Pressure at state 4 (in bar):
17  p4=p1
18  // Thermal efficiency of plant:
19  nth=0.20
20  // Adiabatic index of compression:
21  r=1.4
22  // Value of Cp(in kJ/kg.K):
23  Cp=1.0032
24  // Temperature at state 2'(in K):
25  T21=T1*(p2/p1)^((r-1)/r)
26  // Temperature at state 2(in K):
27  T2=(T21-T1)/nc+T1
28  // Temperature at state 4'(in K):
29  T41=T3*(p4/p3)^((r-1)/r)
30  // Compressor work per kg(in kJ/kg):
31  Wc=Cp*(T2-T1)
32  // Heat added(in kJ/kg):
33  qa=Cp*(T3-T2)
34  // Temperature at state 4(in K):
35  T4=T3-(qa*(-nth)+Wc)/Cp
36  // Isentropic efficiency of turbine:
37  nt=(T3-T4)/(T3-T41)
38  printf("\nRESULT")
39  printf("\nTurbine isentropic efficiency = %f percent
         ",nt*100)
```

Scilab code Exa 9.11 To determine the thermal efficiency and air fuel ratio

```
1  //pathname=get_absolute_file_path('9.11.sce')
2  //filename=pathname+filesep()+'9.11-data.sci'
3  //exec(filename)
4  //Pressure at which air is supplied(in bar):
```

```
 5  p1 =1
 6  p8 = p1
 7  // Temperature  at  which  air  is  supplied ( in  K ) :
 8  T1 =27+273
 9  // Maximum  temperature  in  the  cycle ( in  K ) :
10  T5 =1000
11  // Pressure  at  state  6( in  bar ) :
12  p6 =3
13  p7 = p6
14  p4 =10
15  p5 = p4
16  p3 =3
17  // Temperature  at  state  7( in  K ) :
18  T7 =995
19  // Calorific  value  of  fuel ( in  kJ / kg ) :
20  c =42000
21  // Value  of  Cp ( in  kJ / kg ) :
22  Cp =1.0032
23  // Air  flow  in  compressor ( in  kg / s ) :
24  m =30
25  // Isentropic  efficiency  of  compression :
26  nc =0.85
27  // Isebtropic  efficiency  of  expansion :
28  ne =0.90
29  // Adiabatic  index  of  compression :
30  r =1.4
31  // Pressure  ratio  for  perfect  intercooling :
32  rp = sqrt (10)
33  // Temperature  at  state  2 '( in  K ) :
34  T21 = T1 * rp ^(( r -1)/ r )
35  // Temperature  at  state  2( in  K ) :
36  T2 =( T21 - T1 )/ nc + T1
37  // For  perfect  intercooling :
38  T3 = T1
39  // Temperature  at  state  4 '( in  K ) :
40  T41 = T3 *( p4 / p3 )^(( r -1)/ r )
41  // Temperature  at  state  4( in  K ) :
42  T4 =( T41 - T3 )/ nc + T3
```

```
43  //Total compressor work(in kJ/kg):
44  Wc=2*Cp*(T2-T1)
45  //Temperature at state 6'(in K):
46  T61=T5*(p6/p5)^((r-1)/r)
47  //Temperature at state 6(in K):
48  T6=T5-(T5-T61)*ne
49  //Temperature at state 8'(in K):
50  T81=T7*(p8/p7)^((r-1)/r)
51  //Temperature at state 8(in K):
52  T8=T7-(T7-T81)*ne
53  //Expansion work output per kg air(in kJ/kg):
54  Wt=Cp*(T5-T6+T7-T8)
55  //Heat added per kg air(in kJ/kg):
56  qa=Cp*(T5-T4+T7-T6)
57  //Fuel required per kg of air:
58  mf=qa/c
59  //Air-fuel ratio:
60  afr=1/mf
61  //Net output(in kW):
62  Wnet=(Wt-Wc)*m
63  //Thermal efficiency:
64  nth=(Wt-Wc)/qa
65  printf("\nRESULT")
66  printf("\nThermal efficiency = %f percent",nth*100)
67  printf("\nNet output = %f kW",Wnet)
68  printf("\nA/F ratio = %f",afr)
```

Scilab code Exa 9.12 To determine the thermal efficiency

```
1  //pathname=get_absolute_file_path('9.12.sce')
2  //filename=pathname+filesep()+'9.12-data.sci'
3  //exec(filename)
4  //Pressure of air at each state(in bar):
5  p1=1
6  p2=4
```

```
 7  p3=4
 8  p4=8
 9  p6=p4
10  p7=4
11  p8=4
12  p9=1
13  //Temperature at each state(in K):
14  T1=300
15  T3=290
16  T6=1300
17  T8=1300
18  //Effectiveness:
19  E=0.80
20  //Heating value of fuel(in kJ/kg):
21  c=42000
22  //Adiabatic index of combustion:
23  r=1.4
24  //Value of Cp(in kJ/kg):
25  cp=1.0032
26  //Temperature at state 2(in K):
27  T2=T1*(p2/p1)^((r-1)/r)
28  //Temperature at state 4(in K):
29  T4=T3*(p4/p3)^((r-1)/r)
30  //Temperature at state 7(in K):
31  T7=T6*(p7/p6)^((r-1)/r)
32  //Temperature at state 9(in K):
33  T9=T8*(p9/p8)^((r-1)/r)
34  //Temperature at state 5(in K):
35  T5=(T9-T4)*E+T4
36  //Compressor work per kg of air(in kJ/kg):
37  Wc=Cp*(T2-T1+T4-T3)
38  //Turbine work per kg of air(in kJ/kg):
39  Wt=Cp*(T6-T7+T8-T9)
40  //Heat added per kg air(in kJ/kg):
41  qa=Cp*(T6-T5+T8-T7)
42  //Total fuel per kg of air:
43  mf=qa/c
44  //Net work(in kJ/kg):
```

```
45  Wnet=Wt-Wc
46  //Cycle thermal efficiency:
47  n=Wnet/qa*100
48  //Fuel per kg air in combustion chamber 1:
49  afr1=Cp*(T6-T5)/c
50  //Fuel per kg air in combustion chamber 2:
51  afr2=Cp*(T8-T7)/c
52  printf("\nRESULT")
53  printf("\nA/F ratio in the two combustion chambers=
        %f, %f",afr1,afr2)
54  printf("\nTotal turbine work = %f kJ/kg",Wt)
55  printf("\nCycle thermal efficiency = %f percent",n)
```

Scilab code Exa 9.13 To determine the brake output and stroke volume

```
1   //pathname=get_absolute_file_path('9.13.sce')
2   //filename=pathname+filesep()+'9.13-data.sci'
3   //exec(filename)
4   //Maximum temperature(in K):
5   T2=700
6   //Minimum temperature(in K):
7   T1=300
8   //Compression ratio:
9   r=3
10  //Total heat added(in kJ/s):
11  qa=30
12  //Regenerator efficiency:
13  E=0.90
14  //Pressure at the beginning of compression(in bar):
15  p=1
16  //Number of cycles:
17  n=100
18  //Value of Cv:
19  Cv=0.72
20  //Gas constant(in kJ/kg.K):
```

```
21  R=29.27
22  //Work done per kg of air(in kJ/kg):
23  W=R*(T2-T1)*log(r)
24  //Heat added per kg of air(in kJ/kg):
25  q=R*T2*log(r)+(1-E)*Cv*(T2-T1)
26  //Mass of air for 30 kJ/s of heat supplied(in kg/s):
27  m=qa/q
28  //Mass of air per cycle(in kg/cycle):
29  mc=m/n
30  //Brake output(in kW):
31  BP=W*m
32  //Stroke volume(in m^3):
33  V=mc*R*T1/(p*10^2)
34  printf("\nRESULT")
35  printf("\nBrake output = %f kW",BP)
36  printf("\nStroke volume = %f m^3",V)
```

Scilab code Exa 9.15 To determine the overall efficiency

```
1   //pathname=get_absolute_file_path('9.15.sce')
2   //filename=pathname+filesep()+'9.15-data.sci'
3   //exec(filename)
4   //Ambient temperature(in K):
5   T1=17+273
6   //Temperature at state 3(in K):
7   T3=1400
8   T5=420
9   //Ambient pressure(in bar):
10  p1=1
11  //As pressure ratio is 10, pressure at state 2(in
       bar):
12  p2=10
13  p3=10
14  p4=1
15  //Pressure in HSRG(in kPa):
```

```
16  ph =6000
17  // Condensor pressure ( in kPa ) :
18  pc =15
19  // Combined cycle output ( in MW) :
20  O =37.3
21  // Adiabatic index of compression :
22  r =1.4
23  // Value of Cp( in kJ/kg.K) :
24  Cp =1.0032
25  // From steam tables :
26  ha =3177.2  // kJ/kg
27  sa =6.5408  // kJ/kg.K
28  sb = sa
29  x =0.7976
30  hb =2118.72  // kJ/kg
31  hc =225.94   // kJ/kg
32  vc =0.001014  // m^3/kg
33  // Temperature at state 2( in K) :
34  T2 =T1*(p2/p1)^((r-1)/r)
35  // Temperature at state 4( in K) :
36  T4 =T3*(p4/p3)^((r-1)/r)
37  // Compressor work per kg( in kJ/kg) :
38  Wc =Cp*(T2-T1)
39  // Turbine work per kg( in kJ/kg) :
40  Wt =Cp*(T3-T4)
41  // Heat added in combustion chamber ( in kJ/kg) :
42  qa =Cp*(T3-T2)
43  // Net gas turbine output ( in kJ/kg air ) :
44  WnetGT =Wt-Wc
45  // Heat recovered in HSRG for steam generation ( in kJ/
        kg) :
46  qHSRG =Cp*(T4-T5)
47  // Enthalpy at exit of feed pump ( in kJ/kg) :
48  hd =vc*(ph-pc)*10^2
49  // Heat added per kg of steam ( in kJ/kg) :
50  had =ha-hd
51  // Mass of steam generated per kg of air :
52  m =qHSRG/had
```

```
53  //Net steam turbine cycle output(in kJ/kg):
54  WnetST=ha-hb-(hd-hc)
55  //Steam cycle output per kg(in kJ/kg air):
56  sco=WnetST*m
57  //Total combined output(in kJ/kg air):
58  tco=WnetGT+sco
59  //Combined cycle efficiency:
60  ncc=tco/qa
61  //Gas turbine efficiency:
62  ngt=WnetGT/qa
63  printf("\nRESULT")
64  printf("\nOverall efficiency = %f percent",ncc*100)
65  printf("\nSteam per kg of air =%f kg steam/kg air",m
        )
```

Scilab code Exa 9.16 To determine air standard fuel efficiency

```
1  //pathname=get_absolute_file_path('9.16.sce')
2  //filename=pathname+filesep()+'9.16-data.sci'
3  //exec(filename)
4  //Temperature of working fuel at the beginning of
        compression(in K):
5  T1=27+273
6  //Pressure ratio:
7  rp=70
8  //Compression ratio:
9  rv=15
10 //Adiabatic index of compression:
11 r=1.4
12 //Temperature at state 2(in K):
13 T2=T1*(rv)^(r-1)
14 //Temperature at state 3(in K):
15 T3=T2*rp/(rv^r)
16 //Temperature at state 4(in K):
17 T4=T3+(T3-T2)/r
```

```scilab
18  //Temperature at state 5(in K):
19  T5=T4*(T3/T4*rv)^(1-r)
20  //Air standard thermal efficiency:
21  n=1-(T5-T1)/(r*(T4-T3)+(T3-T2))
22  printf("\nRESULT")
23  printf("\nAir standard thermal efficiency = %f
       percent",n*100)
```

Chapter 11

Boilers and boiler calculations

Scilab code Exa 11.01 To determine temperature of burnt gases

```
1  //pathname=get_absolute_file_path('11.01.sce')
2  //filename=pathname+filesep()+'11.01-data.sci'
3  //exec(filename)
4  //Height of chimney(in m):
5  H=30
6  //Ambient air temperature(in K):
7  Ta=27+273
8  //Mass per kg of fuel required for complete
       combustion(in kg):
9  m=20
10 //Height in the water column(in mm):
11 hw=12
12 //Temperature of burnt gases(in K):
13 Tg=(Ta*353*H)/(353*H-hw*Ta)*(m)/(m+1)
14 printf("\n RESULT \n")
15 printf("\nTemperature of the burnt gases = %f K",Tg)
```

Scilab code Exa 11.02 To determine height of the chimney

```
1  //pathname=get_absolute_file_path('11.02.sce')
2  //filename=pathname+filesep()+'11.02-data.sci'
3  //exec(filename)
4  //Mass per kg of fuel required for complete
      combustion(in kg):
5  m=18
6  //Height in the water column(in mm):
7  hw=20
8  //Ambient air temperature(in K):
9  Ta=27+273
10 //Temperature of burnt gases(in K):
11 Tg=300+273
12 //Height of chimney(in m):
13 H=hw/(353*(1/Ta-(m+1)/(m*Tg)))
14 printf("\n RESULT \n")
15 printf("\nHeight of chimney = %f m",H)
```

Scilab code Exa 11.03 To determine the air supplied and draught

```
1  //pathname=get_absolute_file_path('11.03.sce')
2  //filename=pathname+filesep()+'11.03-data.sci'
3  //exec(filename)
4  //Height of chimney(in m):
5  H=20
6  //Temperature of burnt gases(in K):
7  Tg=380+273
8  //Ambient air temperature(in K):
9  Ta=27+273
10 //Air supplied(in kg air per fuel):
11 m=2*Ta/(Tg-2*Ta)
12 printf("\n RESULT \n")
13 printf("\nAir supplied = %f kg/kg of fuel",m)
14 //Draught in water column(in mm):
15 hw=353*H*(1/Ta-(m+1)/(m*Tg))
16 printf("\nDraught = %f mm of water",hw)
```

Scilab code Exa 11.04 To determine the draught and chimney efficiency

```
1  //pathname=get_absolute_file_path('11.04.sce')
2  //filename=pathname+filesep()+'11.04-data.sci'
3  //exec(filename)
4  //Height of chimney(in m):
5  H=60
6  //Ambient air temperature(in K):
7  Ta=17+273
8  //Temperature of burnt gases(in K):
9  Tg=300+273
10 //Temperature of the artificial burnt gases(in K):
11 Tga=150+273
12 //Mass per kg of fuel required for complete
      combustion(in kg):
13 m=19
14 //Specific heat of hot gases(in kJ/kg.K):
15 Cpg=1.0032
16 //Calorific value of burnt fuel(in kJ/kg):
17 c=32604
18 //Draught (in mm of water column):
19 hw=353*H*(1/Ta-(m+1)/(m*Tg))
20 //Chimney efficiency:
21 n=9.81*H*(m/(m+1)*Tg/Ta-1)/(Cpg*(Tg-Tga)*10^3)*100
22 //Extra heat carried away by flue gases(in kJ):
23 Q=(m+1)*Cpg*(Tg-Tga)
24 printf("\n RESULT \n")
25 printf("\nDraught = %f mm of water",hw)
26 printf("\nChimney efficiency = %f percent",n)
27 printf("\nExtra heat carried away by flue gases per
      kg of fuel burnt = %f kJ",Q)
```

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Scilab code Exa 11.05 To determine the draught and chimney efficiency

```scilab
1  //pathname=get_absolute_file_path('11.05.sce')
2  //filename=pathname+filesep()+'11.05-data.sci'
3  //exec(filename)
4  //Height of chimney(in m):
5  H=80
6  //Ambient air temperature(in K):
7  Ta=27+273
8  //Mass per kg of fuel required for complete
       combustion(in kg):
9  m=20
10 //Temperature of the artificial burnt gases(in K):
11 Tga=110+273
12 //Specific heat of hot gases(in kJ/kg.K):
13 Cpg=1.0032
14 //Temperature of burnt gases(in K):
15 Tg=Ta*2*(m+1)/m
16 //Draught in water column(in mm):
17 hw=353*H*(1/Ta-(m+1)/(m*Tg))
18 //Chimney efficiency:
19 n=9.81*H*(m/(m+1)*Tg/Ta-1)/(Cpg*(Tg-Tga)*10^3)*100
20 printf("\n RESULT \n")
21 printf("\nHot gas temperature in chimney = %d K",Tg)
22 printf("\nNatural draught = %f mm of water",hw)
23 printf("\nChimney efficiency = %f percent",n)
```

Scilab code Exa 11.06 To determine height and diamter of the chimney

```scilab
1  //pathname=get_absolute_file_path('11.06.sce')
2  //filename=pathname+filesep()+'11.06-data.sci'
3  //exec(filename)
4  //Rate at which coal is burnt(in kg/hr):
5  R=2.5*10^3
6  //Mass per kg of fuel required for complete
```

```
        combustion ( in kg ) :
 7  m =20
 8  // Temperature of burnt gases ( in K ) :
 9  Tg =327+273
10  // Ambient air temperature ( in K ) :
11  Ta =27+273
12  // Pressure head ( in mm ) :
13  h =7+6+3+2
14  // Ratio of actual natural draught to theoretical
        draught :
15  na =0.90
16  // Acceleration due to gravity ( in m/s ^2) :
17  g =9.81
18  // Actual natural draught ( in mm of water ) :
19  hw = h / na
20  // Height of chimney ( in m ) :
21  H = hw /(353*(1/ Ta -( m +1)/( m * Tg )))
22  // Density of hot gases ( in kg/m ^3) :
23  dg =353/ Tg *( m +1)/ m
24  // Height of hot gases column ( in m ) :
25  hg = H *(( m +1)/ m * Tg / Ta -1)
26  // Mass flow rate of hot gases ( in kg/s ) :
27  Mg = R * hw /3600
28  // Velocity of got gases ( in m/s ) :
29  C = sqrt (2* g * hg )
30  // Diameter of chimney ( in m ) :
31  D = sqrt ((4* Mg )/(% pi * C * dg ))
32  printf ( " \n RESULT \n " )
33  printf ( " \nDiameter of chimney = %f m " ,D )
```

Scilab code Exa 11.07 To determine power of the fan

```
1  // pathname = get_absolute_file_path ( ' 11.07. sce ' )
2  // filename = pathname + filesep ( ) + ' 11.07 − data . sci '
3  // exec ( filename )
```

```
4  //Draught in water column(in mm):
5  hw=50
6  //Temperature of burnt gases(in K):
7  T=300+273
8  //Rate at which coal is burnt(in kg/s):
9  M=2000/3600
10 //Mass per kg of fuel required for complete
       combustion(in kg):
11 m=19
12 //Ambient air temperature(in K):
13 T1=27+273
14 //Zero temperature(in K):
15 T0=273
16 //Mechanical efficiency:
17 n=0.90
18 //Pressure applied by the draught water(in N/m^2):
19 P=hw*9.81
20 //Density of hot gases(in kg/m^3):
21 d=1.293
22 //Power required in FD fan(kW):
23 PFD=P*m*M*T1/(d*T0*n*1000)
24 //Power required in 1D fan(kW):
25 P1D=P*m*M*T/(d*T0*n*1000)
26 printf("\n RESULT \n")
27 printf("\nPower for FD fan = %f kW",PFD)
28 printf("\nPower for 1D fan = %f kW",P1D)
```

Scilab code Exa 11.08 To determine the ratio of power required

```
1  //pathname=get_absolute_file_path('11.08.sce')
2  //filename=pathname+filesep()+'11.08-data.sci'
3  //exec(filename)
4  //Specific heat of hot gases(in kJ/kg.K):
5  Cpg=1.0032
6  //Temperature of burnt gases(in K):
```

```
7  Tg=177+273
8  //Ambient air temperature(in K):
9  Ta=27+273
10 //Natural draught temperature(in K):
11 Tn=327+273
12 //Mass per kg of fuel required for natural draught(
      in kg):
13 mn=25
14 //Mass per kg of fuel required for artificial
      draught(in kg):
15 ma=20
16 //Ratio of brake power for induced draught to forced
       draught:
17 r=Tg/Ta
18 //Heat carried by hot flue gases in artificial
      draught(in per kg of fuel burnt):
19 Qgad=(ma+1)*Cpg*(Tg-Ta)
20 //Heat carried by hot flue gases in natural draught(
      in per kg of fuel burnt):
21 Qgnd=(mn+1)*Cpg*(Tn-Ta)
22 //Ratio of heat carried away:
23 rh=Qgad/Qgnd
24 printf("\n RESULT \n")
25 printf("\nRatio of power required = %f",r)
26 printf("\nRatio of heat carried away = %f",rh)
```

Scilab code Exa 11.09 To determine amount of evaporation

```
1 //pathname=get_absolute_file_path('11.09.sce')
2 //filename=pathname+filesep()+'11.09−data.sci'
3 //exec(filename)
4 //Feed water supply temperature(in K):
5 T=27+273
6 //Mean steam generation pressure(in bar):
7 P=10
```

```
 8  //Dryness fravtion of steam generated:
 9  x=0.95
10  //Feed water supplied(in kg/hr):
11  Q=2500
12  //Coal burnt(in kg/hr):
13  Q1=275
14  //Difference in mass of water after trial:
15  d=300
16  //From steam tables:
17  hf=762.81 //kJ/kg
18  hg=2778.1 //kJ/kg
19  hfg=2015.29 //kJ/kg
20  //Enthalpy of steam generated(in kJ/kg):
21  h=hf+x*hfg
22  //Mass of water evaporator per hour(in kg/hr):
23  mw=Q+d
24  //Actual evaporation(in per kg of coal):
25  Ae=mw/Q1
26  //Equivalent evaporation(in kg per kg of coal):
27  Ee=Ae*h/2257
28  printf("\n RESULT \n")
29  printf("\nActual evaporation = %f kg per kg of coal"
        ,Ae)
30  printf("\nEquivalent evaporation = %f kg per kg of
        coal",Ee)
```

Scilab code Exa 11.10 To determine amount of evaporation

```
1  //pathname=get_absolute_file_path('11.10.sce')
2  //filename=pathname+filesep()+'11.10-data.sci'
3  //exec(filename)
4  //Average pressure of the steam(in bar):
5  p=10
6  //Weight of water consumed(in ton):
7  Ww=15
```

```
8  //Weight of coal produced(in ton):
9  Wc=1.5
10 //Percentage coal that caan be burnt:
11 n=1-0.03-0.04
12 //Composition of moisture in coal:
13 nm=0.03
14 //Temperature of feed water(in C):
15 Tf=35
16 //From steam tables:
17 hg=2778.1 //kJ/kg
18 //Enthalpy of steam generated(in kJ/kg):
19 h=hg-4.18*Tf
20 //Steam generated per kg of coal(in kg):
21 m=Ww/Wc
22 //Boiler efficiency:
23 nb=m*h/(30.1*10^3)*100
24 //Equivalent evaporation per kg of dry coal(in kg:
25 Ee=m*h/(2257*(1-nm))
26 //Equivalent evaporation per kg of combustible
       present in coal(in kg):
27 Eea=Ee*(1-nm)/n
28 printf("\n RESULT \n")
29 printf("\nBoiler efficiency = %f percent",nb)
30 printf("\nEquivalent evaporation per kg of dry coal
       = %f kg",Ee)
31 printf("\nEquivalent evaporation per kg of
       combustible present in coal = %f kg",Eea)
```

Scilab code Exa 11.11 To determine boiler efficiency

```
1 //pathname=get_absolute_file_path('11.11.sce')
2 //filename=pathname+filesep()+'11.11-data.sci'
3 //exec(filename)
4 //Time of trial(in hrs):
5 t=24
```

```
 6  //Pressure  at  which  steam  is  generated(in  bar):
 7  p=16
 8  //Coal  consumed(in  kg):
 9  c=10000
10  //Rate  of  steam  generation(in  kg/hr):
11  r=2500
12  //Feed  water  temperature(in  C):
13  Tf=27
14  //Total  heating  surface  area(in  m^2):
15  hsa=3000
16  //Total  grate  area(in  m^2):
17  ga=4
18  //Calorific  value  of  coal(in  kJ/kg):
19  C=28000
20  //From  steam  tables:
21  hg=2794  //kJ/kg
22  //Latent  heat  at  100  C:
23  L=2257
24  //Coal   burnt  per  hour(in  kg/hr):
25  m=c/t
26  //Coal  burnt  per  m^2  of  grate  per  hour:
27  mg=m/ga
28  //Rate  of  steam  generated  per  kg  of  coal(in  kg  steam
       /kg  coal):
29  r1=r/m
30  //Heat  added  to  steam  per  kg  of  coal(in  kJ):
31  Q=r1*(hg-4.18*Tf)
32  //Equivalent  evaporation  from  and  at  100  C  per  kg  of
        coal(in  kg):
33  Ee=Q/L
34  //Equivalent  evaporation  from  and  at  100  C  per  m^2
       of  total  surface  per  hour(in  kg):
35  Eepm=Ee*m/hsa
36  //Boiler  efficiency:
37  n=Ee*L/C*100
38  printf("\n  RESULT  \n")
39  printf("\nMass  of  coal  burnt  per  m^2  of  grate  per
       hour  =  %f  kg",mg)
```

```
40  printf("\nEquivalent evaporation from and at 100 C
        per kg of coal = %f kg",Ee)
41  printf("\nEquivalent evaporation from and at 100 C
        per m^2 of total surface per hour = %f",Eepm)
42  printf("\nBoiler efficiency = %f percent",n)
```

Scilab code Exa 11.12 Boiler efficiency

```
1  //pathname=get_absolute_file_path('11.12.sce')
2  //filename=pathname+filesep()+'11.12-data.sci'
3  //exec(filename)
4  //Pressure at which steam is generated(in bar):
5  p=30
6  //Temperature of steam(in C):
7  Ts=300
8  //Rate at which feed water enters(in kg/s):
9  r=11
10 //Temperature at which feed water enters the
        economiser(in C):
11 T1=100
12 //Mass of fuel used(in kg):
13 m=5000
14 //Calorific value of fuel(in kJ/kg.K):
15 C=35000
16 //Temperature of feed water(in C):
17 T=27
18 //From steam tables:
19 hg=2993.5
20 //Latent heat at 100 C:
21 L=2257
22 //Mass of steam genrated per kg of fuel(in kg/kg
        fuel):
23 ms=r*3600/m
24 //Heat added per kg of fuel(in kJ):
25 Q=hg-4.18*T
```

```
26  //Equivalent evaporation from and at 100 C per kg of
        coal(in kg):
27  Ee=ms*Q/L
28  //Boiler efficiency:
29  n=Ee*L/C*100
30  //Heat utilised in economiser per kg of fuel(in kJ):
31  Q1=ms*4.18*(T1-T)
32  //Percentage of energy utilised in economiser:
33  P=Q1/C*100
34  printf("\n RESULT \n")
35  printf("\nEquivalent evaporation per kg of fuel = %f
        kg",Ee)
36  printf("\nBoiler efficiency = %f percent",n)
37  printf("\nPercentage of energy utilised in
        economiser = %f percent",P)
```

Scilab code Exa 11.13 Boiler efficiency

```
1  //pathname=get_absolute_file_path('11.13.sce')
2  //filename=pathname+filesep()+'11.13-data.sci'
3  //exec(filename)
4  //Mass of steam genrated per kg of fuel:
5  m=8
6  //Temperature of steam(in C):
7  Ts=400
8  //Pressure of feed water(in bar):
9  p=30
10 //Temperature of feed water(in C):
11 T=40
12 //Temperature at which feed water leaves the
        economiser(in C):
13 T1=150
14 //Dryness fraction:
15 x=0.98
16 //Calorific value(in kJ/kg.K):
```

```
17  C=29000
18  //From steam tables:
19  //Enthalpy of steam generated(in kJ/kg):
20  h=3230.9
21  hf=1008.42 //kJ/kg
22  hfg=1795.78 //kJ/kg
23  //Heat to be added(in kJ):
24  Q=h-4.18*T
25  //Boiler efficiency:
26  n=m*Q/C*100
27  //Heat added in economiser per kg of steam generated
        (in kJ/kg):
28  Q1=4.18*(T1-T)
29  //Percentage fraction of heat in economiser:
30  r1=Q1/Q*100
31  //Heat added in evaporator per kg of steam generated
        (in kJ/kg):
32  Q2=(hf+x*hfg)-4.18*T1
33  //Percentage fraction of heat in economiser:
34  r2=Q2/Q*100
35  //Heat added in super heater per kg of steam
        generated by difference(in kJ/kg):
36  Q3=Q-Q1-Q2
37  //Percentage fraction of heat in economiser:
38  r3=Q3/Q*100
39  printf("\n RESULT \n")
40  printf("\nBoiler efficiency = %f percent",n)
41  printf("\nPercentage fraction of heat in economiser
        = %f percent",r1)
42  printf("\nPercentage fraction of heat in evaporator
        = %f percent",r2)
43  printf("\nPercentage fraction of heat in superheater
        = %f percent",r3)
```

Scilab code Exa 11.14 Air leakage

```
1  //pathname=get_absolute_file_path('11.14.sce')
2  //filename=pathname+filesep()+'11.14-data.sci'
3  //exec(filename)
4  //Temperature at which feed water enters and leaves
       the economiser(in C):
5  T1=20
6  T2=125
7  //Rate at which feed water leaves the economiser(in
       kg/s):
8  r=3
9  //Temperature of flue gases at inlet and outlet of
       economiser(in C):
10 T3=425
11 T4=300
12 //Rate at which coal is supplied(in kg/min):
13 r1=18
14 //% of C in coal:
15 nc=0.80
16 //Specific heat of flue gases(in kJ/kg.K):
17 Cpg=1.05
18 //Atmospheric temperature(in C):
19 Ta=15
20 //From table:
21 //Mass of dry flue gases at inlet and exit of
       economiser(in kg):
22 m1=23.65
23 m2=24.78
24 //Air leakage in economiser per kg of coal:
25 A=m2-m1
26 //Heat entering economiser with flue gases and
       leakage(in kJ):
27 Q1=m1*Cpg*T3+A*Cpg*Ta
28 //Heat entering economiser with flue gases and
       leakage(in kJ):
29 Q2=m2*Cpg*T4
30 //Heat lost in economiser per kg of coal(in kJ):
31 Q=Q1-Q2
32 //Heat picked up by feed water in economiser per kg
```

```
      of coal(in kJ):
33 Q3=(r*60/r1)*4.18*(T2-T1)
34 printf("\n RESULT \n")
35 printf("\nHeat released by the flue gases = %f kJ
      per kg of coal",Q)
36 printf("\nAir leakage = %f kg per kg of coal",A)
37 printf("\nHeat gained by feed water = %d kJ per kg
      of coal",Q3)
```

Scilab code Exa 11.15 Boiler efficiency

```
1  //pathname=get_absolute_file_path('11.15.sce')
2  //filename=pathname+filesep()+'11.15-data.sci'
3  //exec(filename)
4  //Atmospheric air temperature: 15C
5  //Steam generation: 40 bar, 400C
6  //Steam generated per kg of coal = 8 kg
7  //Feed water temperature at inlet to economiser = 27
      C
8  //Feed water temperature at exit of economiser = 137
      C
9  //Moisture in coal burnt = 1.5%
10 //Flue gas temperature entering air heater =300C
11 //Flue gas temperature leaving air heater and
      entering chimney = 150C
12 //Temperature of air entering boiler furnace = 120C
13 //Dry coal composition by mass = 84% C, 4% H2, 7% O2
       and remainder ash
14 //Dry flue gas composition by volume = 12.5% CO2,
      7.5% O2, 80% N2
15 //Datum temperature = 15C
16 //Calorific value of coal = 32600 kJ/kg
17 //For air and dry flue gas, cp =1.0032 kJ/kg K
18 //Partial pressure of vapour in flue gas = 0.075 bar
19 //Specific pressure of vapour = 2.0064 kJ/kg K
```

```
20  // Mass of dry flue gas per kg of coal:
21  md=0.84/0.0495
22  // H2O produced during the combustion(in kg):
23  mh=0.04*9
24  // Amount of air supplied for combustion of one kg of
        dry coal(in kg):
25  ma=16.97-(1-0.05-0.36)
26  // Moisture per kg of dry coal(in kg):
27  m=0.015/(1-0.015)
28  // Total moisture per kg of coal(in kg):
29  mt=mh+m
30  // Steam generated per kg of dry coal(in kg steam):
31  ms=8/(1-0.015)
32  // Boiler efficiency:
33  n=25178.01/32600*100
34  // Efficiency of heat exchange in air heater:
35  na=1725.4/2897.67*100
36  printf("\n RESULT \n")
37  printf("\nBoiler efficiency = %f percent",n)
38  printf("\nEfficiency of heat exchange in air heater
        = %f percent",na)
```

Scilab code Exa 11.17 Saving of coal

```
1  // pathname=get_absolute_file_path('11.17.sce')
2  // filename=pathname+filesep()+'11.17-data.sci'
3  // exec(filename)
4  // Pressure at which steam is generated(in bar):
5  p=20
6  // Temperature at which steam is generated(in C):
7  Ts=300
8  // Temperature of feed water supplied to the boiler(
        in C):
9  T1=50
10  // Calorific value of fuel(in kJ/kg):
```

```
11  C=30000
12  //Rate at which coal is used(in kg/hr):
13  r=600
14  //Rate at which steam is generated(in kg/hr):
15  r1=5000
16  //Temperature of the boiler unit(in C):
17  T=100
18  //Latent heat(in kJ/kg.K):
19  L=2257
20  //Steam generation per unit coal burnt per hour:
21  ms=r1/r
22  //Final enthalpy of the steam(in kJ/kg):
23  hfi=3023.5
24  //Enthalpy of feed water(in kJ/kg):
25  hfw=209.33
26  //Overall efficiency of boiler:
27  no=ms*(hfi-hfw)/C*100
28  //Equivalent evaporation of boiler unit(in kg steam
        per kg of coal):
29  Ee=ms*(hfi-hfw)/L
30  //Equivalent evaporation of boiler unit at 100 C(in
        kg/hr):
31  Eea=Ee*r
32  //After fitting economiser the enthalp of feed water
        (in kJ/kg):
33  hfw1=313.93
34  //Modified overall efficiency of boiler unit:
35  nom=no+5
36  //Coal consumption(in kg/hr):
37  mc=(hfi-hfw1)*r1*100/(C*nom)
38  //Saving of coal(in kg/hr):
39  s=r-mc
40  printf("\n RESULT \n")
41  printf("\nSaving of coal = %f kg/hr",s)
```

Scilab code Exa 11.18 Temperature of flue gases

```
1  // pathname=get_absolute_file_path ( ' 11.18. sce ' )
2  // filename=pathname+filesep ( ) + ' 11.18 - data . sci '
3  // exec ( filename )
4  // Rate  at  which  steam  is  generated ( in  kg/hr ) :
5  r =5000
6  // Pressure  of  steam ( in  bar ) :
7  p =20
8  // Dryness  fraction :
9  x =0.98
10 // Temperature  of  feed  water ( in  C ) :
11 T =60
12 // Rate  at  which  coal  is  supplied ( in  kg/hr ) :
13 r1 =600
14 // Rate  at  which  air  is  supplied ( in  kg  per  kg  coal ) :
15 r2 =16
16 // Cslorific  value  of  coal ( in  kJ/kg ) :
17 C =30000
18 // Temperature  of  boiler  room ( in  C ) :
19 Tr =20
20 // Fraction  of  heat  losr  with  flue  gases :
21 nl =0.86
22 // Specific  heat  of  flue  gases ( in  kJ/kg .K ) :
23 Cpg =1.005
24 // From  steam  tables :
25 hf =908.79  // kJ/kg
26 hfg =1890.7  // kJ/kg
27 // Mass  of  steam  genrated  per  kg  of  coal :
28 ms =r/r1
29 // Enthalpy  of  final  steam  produced ( in  kJ/kg ) :
30 hfi =hf + x * hfg
31 // Enthalpy  of  feed  water ( in  kJ/kg ) :
32 hfw =251.13
33 // Heat  used  for  steam  generation ( in  kJ  per  kg  of
        coal ) :
34 Q =ms * ( hfi - hfw )
35 // Heat  lost  per  kg  of  coal :
```

```
36  Ql=C-Q
37  //Heat lost with flue gases(in kJ per kg of coal):
38  Qlf=nl*Ql
39  //Temperature of flue gases(in C):
40  Tgas=Tr+Qlf/((r2+1)*Cpg)
41  printf("\n RESULT \n")
42  printf("\nTemperature of flue gases = %f C",Tgas)
```

Scilab code Exa 11.19 FD fan power

```
1   //pathname=get_absolute_file_path('11.19.sce')
2   //filename=pathname+filesep()+'11.19-data.sci'
3   //exec(filename)
4   //Ambient temperature(in K):
5   Ta=20+273
6   //Velocity(in m/s):
7   V=20
8   //Draught lost through grate(in mm of water column):
9   hw1=30
10  //Mechanical efficiency:
11  nm=0.80
12  //Rate at which coal is burnt(in kg/hr):
13  mf=1000
14  //Rate at which air is supplied(in kg/hr):
15  ma=16
16  //Ambient pressure(in bar):
17  pa=1.01325
18  //Density of air(in kg/m^3):
19  d=1.29
20  //Acceleration due to gravity(in m/s^2):
21  g=9.81
22  //Zero temperature(in K):
23  T0=273
24  //Pressure equivalent to velocity head(in N/m^2):
25  P1=d*V^2/2
```

```
26  P=P1/g //mm of water column
27  //Total draught loss(in mm of water column):
28  hw=hw1+P
29  //Pressure required(in N/m^2):
30  p=hw*g
31  //F.D. fan power requirement(in W):
32  PFD=p*mf*ma*Ta/(d*T0*nm*3600)
33  printf("\n RESULT \n")
34  printf("\nF.D. fan power = %f W",PFD)
```

Scilab code Exa 11.20 EXtra heat carried in natural draught

```
 1  //pathname=get_absolute_file_path('11.20.sce')
 2  //filename=pathname+filesep()+'11.20-data.sci'
 3  //exec(filename)
 4  //Height of chimney(in m):
 5  H=45
 6  //Temperature of burnt gases(in K):
 7  Tg=630
 8  //Air requirement(in kg air per kg of fuel burnt):
 9  m=15
10  //Ambient air temperature(in K):
11  Ta=300
12  //Minimum temperatre of artificial draught(in K):
13  Tga=150+273
14  //Specific heat of flue gases(in kJ/kg.K):
15  Cpg=1.005
16  //Calorific value of fuel(in kJ/kg):
17  C=30000
18  //Draught (in mm of water column):
19  hw=353*H*(1/Ta-(m+1)/(m*Tg))
20  //Draught (in metres of hot gas column):
21  hg=H*(m/(m+1)*Tg/Ta-1)
22  //Temperature of chimney for maximum discharge(in K)
        :
```

```
23  Tgmax = Ta *2*( m +1)/ m
24  // Chimney efficiency :
25  n =9.81* H *( m /( m +1)* Tg / Ta -1)/( Cpg *( Tg - Tga )*10^3)*100
26  // Extra heat carried away by flue gases ( in kJ ):
27  Q =( m +1)* Cpg *( Tg - Tga )
28  // Percentage heat spent in natural draught :
29  nn = Q / C *100
30  printf ("\n RESULT \n")
31  printf ("\nDraught = %f mm of water ", hw )
32  printf ("\nDraught = %f metres of hotgas column ", hg )
33  printf ("\nTemperature of chimney gases for maximum
        discharge = %d K", Tgmax )
34  printf ("\nChimney efficiency = %f percent ", n )
35  printf ("\nExtra heat carried away by flue gases per
        kg of fuel burnt = %f kJ", Q )
36  printf ("\nPercentage heat carried away in natural
        draught = %f percent ", nn )
```

Scilab code Exa 11.21 Height of chimney

```
1  // pathname = get_absolute_file_path ( '11.21. sce ')
2  // filename = pathname + filesep ()+ '11.21 - data . sci '
3  // exec ( filename )
4  // Ambient air temperature ( in K ):
5  Ta =27+273
6  // Temperature of burnt gases ( in K ):
7  Tg =630
8  // Air consumed at rate ( in kg air per kg of coal ):
9  m =15
10 // Ratio of actual draught to thereotical draught :
11 r =0.60
12 // Actual draught :
13 hw1 =14
14 // Theoretical draught :
15 hw = hw1 / r
```

```
16  //Height of chimney(in m):
17  H=hw/(353*(1/Ta-(m+1)/(m*Tg)))
18  printf("\n RESULT \n")
19  printf("\nHeight of chimney = %f m",H)
```

Scilab code Exa 11.22 Power consumption of induced draught

```
1  //pathname=get_absolute_file_path('11.22.sce')
2  //filename=pathname+filesep()+'11.22-data.sci'
3  //exec(filename)
4  //Static draught(in mm of water column):
5  hw1=100
6  //Amount of discharge(in m^3/s):
7  mf=30
8  //Area of outlet section(in m^2):
9  a=1.8
10  //Ambient temperature(in K):
11  Ta=300
12  //Density(in kg/m^3):
13  d=1.293
14  //Fan efficiency:
15  nm=0.85
16  //Flue gas temperature(in K):
17  Tf=150+273
18  //Zero temperature(in K):
19  T0=273
20  //Velocity of air(in m/s):
21  V=mf/a
22  //Pressure created due to the gases(in mm of water):
23  p=d*V^2/(2*9.81)
24  //Total draught(in mm of water column):
25  hw=hw1+p
26  //Power of motor of forced draught fan(in kW):
27  PFD=hw*9.81*mf*Ta/(T0*nm*10^3)
28  //Power consumption of induced draught fan(in kW):
```

```
29  PID = PFD * Tf / Ta
30  printf ( " \nRESULTS \n " )
31  printf ( " \nPower  consumption  of  ID  fan  =  %f kW " , PID )
```

Scilab code Exa 11.23 Energy consumed in superheater

```
1   // pathname=get_absolute_file_path ( '11.23. sce ')
2   // filename=pathname+filesep ()+ '11.23−data . sci '
3   // exec ( filename )
4   // Temperature  at  which  feed  water  enters  and  leaves
        economiser ( in  C ) :
5   T1 =30
6   T2 =110
7   // Pressure  at  which  steam  is  generated ( in  bar ) :
8   p =20
9   // Dryness  fraction :
10  x =0.98
11  // Temperature  to  which  it  is  superheated ( in  C ) :
12  T =300
13  // Calorific  value  of  coal ( in  kJ/kg .K ) :
14  C =30500
15  // Steam  generation  rate ( in  kg/kg  of  coal ) :
16  r =10
17  // Specific  heat  of  feed  water ( in  kJ/kg .K ) :
18  Cpfw =4.18
19  // Specific  heat  of  superheated  steam ( in  kJ/kg .K ) :
20  Cps =2.093
21  // From  steam  tables :
22  h4 =3023.5  // kJ/kg
23  hf =908.79  // kJ/kg
24  hfg =1890.7  // kJ/kg
25  h1 =125.79  // kJ/kg
26  // Enthalpy  at  state  3( in  kJ/kg ) :
27  h3 = hf + x * hfg
28  // Total  heat  supplied ( in  kJ/kg ) :
```

```
29  Q=h4-h1
30  //Heat consumed in the economiser(in kJ/kg of coal):
31  Q1=Cpfw*(T2-T1)*8
32  //Heat consumed in the boiler(in kJ/kg coal):
33  Q2=(h3-Cpfw*T2)*8
34  //Heat consumed in the superheater(in kJ/kg steam):
35  Q3=(h4-h3)*8
36  //Fraction of energy consumed in economiser:
37  r1=Q1/C*100
38  //Fraction of energy consumed in boiler:
39  r2=Q2/C*100
40  //Fraction of energy consumed in superheater:
41  r3=Q3/C*100
42  printf("\nRESULTS\n")
43  printf("\nFraction of energy consumed in economiser
        = %f percent",r1)
44  printf("\nFraction of energy consumed in boiler = %f
         percent",r2)
45  printf("\nFraction of energy consumed in superheater
        = %f percent",r3)
```

Chapter 12

Steam engine

Scilab code Exa 12.01 Rankine and carnot efficiency

```
 1  //pathname=get_absolute_file_path('12.01.sce')
 2  //filename=pathname+filesep()+'12.01-data.sci'
 3  //exec(filename)
 4  //Pressure at which steam is supplied(in MPa):
 5  p1=0.2
 6  //Temperature of steam(in C):
 7  T=250
 8  //Pressure upto which steam is expanded(in bar):
 9  p2=0.3
10  //Pressure at which it is finally released(in bar):
11  p3=0.05
12  //From steam tables:
13  h1=2971  //kJ/kg
14  s1=7.7086  //kJ/kg.K
15  s2=s1
16  h2=2601.97  //kJ/kg
17  v2=5.1767  //m^3/kg
18  hf=137.82  //kJ/kg
19  Tmax=393.23  //K
20  Tmin=305.88  //K
21  //Work output from engine cycle per kg of steam(in
```

```
      kJ/kg ) :
22  W=h1 -h2+v2 *( p2-p3 ) *10^2
23  // Heat input per kg of steam ( in kJ/kg ) :
24  Q=h1 -hf
25  // Efficiency of modified Rankine cycle :
26  n=W/Q *100
27  // Carnot efficiency :
28  nc=(1 -Tmin/Tmax ) *100
29  printf ( " \n RESULT \n " )
30  printf ( " \nModified Rankine cycle efficiency = %f
        percent " ,n )
31  printf ( " \nCarnot efficiency = %f percent " ,nc )
```

Scilab code Exa 12.02 Carnot efficiency and stroke length

```
 1  // pathname=get_absolute_file_path ( ' 12.02. sce ' )
 2  // filename=pathname+filesep ( ) + '12.02 − data . sci '
 3  // exec ( filename )
 4  // Pressure at which steam is supplied ( in bar ) :
 5  p1 =10
 6  // Diameter of the cylinder ( in m ) :
 7  d=0.3
 8  // Length of stroke ( in m ) :
 9  L=0.6
10  // Pressure to which steam is expanded ( in bar ) :
11  p2 =0.75
12  // Pressure at which steam is released in the
        condensor ( in bar ) :
13  p3 =0.25
14  // From steam tables :
15  h1 =2676.2  // kJ/kg
16  s1 =7.3614  // kJ/kg .K
17  s2 = s1
18  v2 =2.1833  // mˆ3/kg
19  h2 =2628.35  // kJ/kg
```

```
20  h4=271.93 //kJ/kg
21  s6=s2
22  h6=2459.38 //kJ/kg
23  s6=7.3614 //kJ/kg.K
24  v6=5.784 //m^3/kg
25  //Work output from engine cycle per kg of steam(in
       kJ/kg):
26  W=h1-h2+v2*(p2-p3)*10^2
27  //Heat input per kg of steam(in kJ/kg):
28  Q=h1-h4
29  //Efficiency of modified Rankine cycle:
30  n=W/Q*100
31  //Volume of the cylinder(in m^3):
32  V=%pi*d^2*L/4
33  //Mass of steam in a stroke(in kg):
34  m=V/v2
35  //Volume requiremnet at 6(in m^3):
36  V1=m*v6
37  //New stroke length(in m):
38  L1=V1*4/(%pi*d^2)
39  printf("\n RESULT \n")
40  printf("\nModified Rankine cycle efficiency = %f
       percent",n)
41  printf("\nNew stroke length = %f cm",L1*100)
```

Scilab code Exa 12.03 Indicated power

```
1  //pathname=get_absolute_file_path('12.03.sce')
2  //filename=pathname+filesep()+'12.03-data.sci'
3  //exec(filename)
4  //Diameter of the bore(in m):
5  d=0.3
6  //Length of the stroke(in m):
7  L=0.6
8  //Occerance od cut-off:
```

```
9  r1=0.4
10 //Pressure at which steam enters(in bar):
11 p1=7.5
12 //Pressure at exhaust(in bar):
13 p3=0.1
14 //Rpm of the engine:
15 n=180
16 //Diagram factor:
17 d1=0.6
18 //Expansion ratio:
19 r=1/r1
20 //Hypothetical mean effective pressure(in bar):
21 mep=p1/r*(1+log(r))-p3
22 //Actual mean effective pressure(in bar):
23 mepa=mep*d1
24 //Indicated power(in kW):
25 IP=mepa*L*%pi*d^2*2*n*10^2/(4*60)
26 printf("\n RESULT \n")
27 printf("\nIndicated power = %f kW",IP)
```

Scilab code Exa 12.04 Specific steam consumption

```
1  //pathname=get_absolute_file_path('12.04.sce')
2  //filename=pathname+filesep()+'12.04-data.sci'
3  //exec(filename)
4  //Steam is admitted at pressure(in bar):
5  p1=15
6  //Pressure at which steam exhausts(in bar):
7  p3=0.75
8  //Cut-off occuring at:
9  r1=0.25
10 //Power produced by the engine(in hp):
11 P=150
12 //Rpm of engine:
13 n=240
```

```
14  //Mechanical  efficiency :
15  nm=0.85
16  //Diagram  factor :
17  d1=0.7
18  //Brake  thermal  efficiency :
19  nb=0.2
20  //Stroke  to  bore  ratio :
21  r2=1.5
22  //From  steam  tables :
23  h15=2803.3
24  hf=384.39
25  //Expansion  ratio :
26  r=1/r1
27  //Hypothetical  mean  effective  pressure (in  bar ):
28  mep=p1/r*(1+log(r))-p3
29  //Actual  mean  effective  pressure (in  bar ):
30  mepa=mep*d1
31  //Indicated  horse  power (in  kW):
32  IP=P/nm
33  //Diameter  of  bore (in  m):
34  d=((IP*4*60*0.7457)/(mepa*10^2*r2*%pi*n))^(1/3)
35  //Stroke  length (in  m):
36  L=d*r2
37  //Heat  added  per  kg  of  steam (in  kJ/kg ):
38  Q=h15-hf
39  //Specific  steam  consumption (in  kg/hp.hr ):
40  m=0.7457*3600/(nb*Q)
41  printf (" \n  RESULT  \n")
42  printf (" \nBore  =  %f  cm", d*100)
43  printf (" \nStroke  =  %f  cm", L*100)
44  printf (" \nSpecific  steam  consumption  =  %f  kg/hp.hr ",
      m)
```

Scilab code Exa 12.05 Diagram factor and indicated thermal efficiency

```scilab
1  //pathname=get_absolute_file_path('12.05.sce')
2  //filename=pathname+filesep()+'12.05-data.sci'
3  //exec(filename)
4  //Steam consumption rate(in kg/a):
5  m=18/60
6  //Indicated power(in kW):
7  IP=100
8  //Rpm of engine:
9  n=240
10 //Bore diameter(in m):
11 d=0.3
12 //Stroke length(in m):
13 L=0.4
14 //Pressure at which steam is admitted(in bar):
15 p1=10
16 //Exhaust pressure(in bar):
17 p3=0.75
18 //Occurance of cut-off:
19 r1=0.25
20 //Enthalpy of steam(in kJ/kg):
21 h1=2875.3 //kJ/kg
22 hf=384.39 //kJ/kg
23 //Heat added per kg of steam(in kJ/kg):
24 Q=h1-hf
25 //Expansion ratio:
26 r=1/r1
27 //Hypothetical mean effective pressure(in bar):
28 mep=p1/r*(1+log(r))-p3
29 //Theoretical indicated power(in kW):
30 IPt=mep*L*%pi*d^2*n*10^2/(60)
31 //Diagarm factor:
32 d1=IP/IPt
33 //Indicated thermal efficiency:
34 n=IPt/(m*Q)*100
35 printf("\n RESULT \n")
36 printf("\nDiagram factor = %f",d1)
37 printf("\nIndicated thermal efficiency = %f percent"
       ,n)
```

Scilab code Exa 12.06 Thermal efficiency

```
1  //pathname=get_absolute_file_path('12.06.sce')
2  //filename=pathname+filesep()+'12.06-data.sci'
3  //exec(filename)
4  //Pressure at which steam is aupplied(in bar):
5  p1=10
6  //Dryness fraction:
7  x=0.9
8  //Pressure at exhaust(in bar):
9  p3=1
10 //Occurence of cut-off:
11 r1=0.6
12 //From steam tables:
13 h1=2576.58 //kJ/kg
14 v1=0.1751 //m^3/kg
15 hf=417.46 //kJ/kg
16 //Heat added per kg of steam(in kJ/kg):
17 Q=h1-hf
18 //Specific volume at state 2(inm^3/kg):
19 v2=v1/r1
20 //Expansion ratio:
21 r=1/r1
22 //Net expansive work per kg of steam(in kJ/kg):
23 Wne=v1*(p1-p3)*10^2
24 //Expansive work per kg of steam(in kJ/kg):
25 We=p1*v1*10^2*log(r)-p3*10^2*(v2-v1)
26 //Total work per kg of steam(in kJ/kg):
27 Wt=Wne+We
28 //Fraction of work obtained by expansive working:
29 r2=We/Wt*100
30 //Thermal efficiency of cycle:
31 n=Wt/Q*100
32 printf("\n RESULT \n")
```

```
33  printf("\nFraction of expansive work = %f percent of
        total output",r2)
34  printf("\nThermal efficiency  = %f percent",n)
35  //Steam admitted per cycle when cut-off becomes
        unity(in kg):
36  m=1/r1
37  //Total work per cycle(in kJ):
38  W=(p1-p3)*v1*m*10^2
39  //% increase in work:
40  dw=(W-Wt)/Wt*100
41  //Modified thermal efficiency:
42  n1=W/(m*Q)*100
43  //% decrease in efficiency:
44  dn=(n-n1)/n*100
45  printf("\nPercentage increase in work = %f percent",
        dw)
46  printf("\nPercentage decrease in efficiency = %f
        percent",dn)
```

Scilab code Exa 12.07 Bore diameter

```
1  //pathname=get_absolute_file_path('12.07.sce')
2  //filename=pathname+filesep()+'12.07-data.sci'
3  //exec(filename)
4  //Power produced(in bhp):
5  P=60
6  //Pressure at which steam is admitted(in bar):
7  p1=12
8  //Pressure at exhaust(in bar):
9  p3=1
10  //Rpm of engine:
11  n=240
12  //Piston speed(in m/s):
13  v=2
14  //Diameter of piston(in m):
```

```
15  d=0.04
16  //Occurence of cut−off:
17  n=0.60
18  //Clearance volume to stroke volume ratio:
19  r1=0.05
20  //Diagram factor:
21  d1=0.8
22  //Mechanical efficiency:
23  nm=0.90
24  //Expansion ratio:
25  r=(1+r1)/n
26  //Mean effective pressure(in bar):
27  mep=(p1*12*(1+log(r))-1*21-(12-1))/(21-1)
28  //Actual mean effective pressure(in bar):
29  mepa=mep*d1
30  //Effective area(in m^2):
31  A=P*0.7457/(nm*mepa*10^2*v)
32  //Bore diameter(in m):
33  D=sqrt((A-%pi*d^2/4)*4/(2*%pi))
34  printf("\n RESULT \n")
35  printf("\nBore = %f cm",D*100)
```

Scilab code Exa 12.08 Heat leakage

```
1  //pathname=get_absolute_file_path('12.08.sce')
2  //filename=pathname+filesep()+'12.08−data.sci'
3  //exec(filename)
4  //Diameter of cylinder(in m):
5  D=0.2
6  //Length of stroke(in m):
7  L=0.3
8  //Clearance volume(in cm^3):
9  Vc=2*10^3
10 //Mass of steam used per stroke(in kg):
11 ms=0.05
```

```
12  //Point at which compression starts:
13  c=0.80  //of stroke
14  //Pressure of steam when compression starts(in bar):
15  p4=1
16  //Cut−off point:
17  r1=0.10  //of stroke
18  //Release:
19  r2=0.90  //of stroke
20  //Pressure at states 1 & 2(in bar):
21  p1=15
22  p2=3
23  //From steam tables:
24  v4=1.6940  //m^3/kg
25  vg15=0.13177  //m^3/kg
26  vg3=0.6058  //m^3/kg
27  u1=1590.79  //kJ/kg
28  u2=1216.73  //kJ/kg
29  //Clearance volume(in m^3):
30  V6=Vc*10^(-6)
31  V5=V6
32  //Stroke volume(in m^3):
33  Vs=%pi*D^2/4*L
34  //Volume at state 3(in m^3):
35  V3=V6+Vs
36  //Volume at state 4(in m^3):
37  V4=V3-c*(V3-V6)
38  //Mass of steam at state 4(in kg):
39  m4=V4/v4
40  //Total mass of steam during expansion(in kg):
41  m=m4+ms
42  //Volume at cut−off point(in m^3):
43  V1=V6+r1*(V3-V6)
44  //Dryness fraction at cut−off point:
45  x1=V1/(m*vg15)
46  //Volume at point of release(in m^3):
47  V2=V6+r2*(V3-V6)
48  //Dryness fraction at point of release:
49  x2=V2/(m*vg3)
```

```
50  //Index of expansion:
51  n=log(p1/p2)/log(V2/V1)
52  //Work done in a stroke(in kJ):
53  W=(p1*V1-p2*V2)/(n-1)
54  //Work done per kg of steam(in kJ/kg):
55  Ws=W/m
56  //Change in internal energy(in kJ/kg):
57  du=u2-u1
58  //Heat transfer(in kJ/kg):
59  dQ=du+Ws
60  printf("\n RESULT \n")
61  printf("\nTotal mass of steam during expansion = %f
        kg",m)
62  printf("\nDryness fraction at cut-off and release =
        %f,%f",x1,x2)
63  printf("\nHeat leakage = %f kJ/kg steam",-dQ)
```

Scilab code Exa 12.09 Percentage re evaporation

```
1   //pathname=get_absolute_file_path('12.09.sce')
2   //filename=pathname+filesep()+'12.09-data.sci'
3   //exec(filename)
4   //Point of sut-off:
5   r1=0.3
6   //Pressure at state 4(in bar):
7   p4=4
8   //Volume at state 4(in m^3):
9   V4=0.15
10  //Pressure at state 1(in m^3):
11  p1=12
12  //Pressure at release(in bar):
13  p2=5
14  //Indicated volume at release(in m^3):
15  V2=0.5
16  //Bore diameter(in m):
```

```
17  d=0.6
18  //Stroke  length(in  m):
19  L=1.20
20  //Clearance  volume  ratio:
21  c=0.10
22  //Mass  of  steam  admitted(in  kg/stroke):
23  ms=1.5
24  //Number  of  working  strokes(per  second):
25  nw=180*60
26  //From  steam  tables:
27  vg4=0.4625  //m^3/kg
28  vg12=0.16333  //m^3/kg
29  vg5=0.3749  //m^3/kg
30  //Stroke  volume(in  m^3):
31  Vs=%pi*d^2/4*L
32  //Clearance  volume(in  m^3):
33  V5=c*Vs
34  //Total  volume  of  cylinder(in  m^3):
35  V3=V5+Vs
36  //Volume  at  cut-off  point(in  m^3):
37  V1=V5+r1*Vs
38  //Mass  of  steam  at  state  4(in  kg):
39  m4=V4/vg4
40  //Total  mass  during  steam  expansion(in  kg):
41  m=m4+ms
42  //Dryness  fraction  at  cut-off  point:
43  x1=V1/(m*vg12)
44  //Missing  quantity  per  hour(in  kg):
45  mq1=(m-m*x1)*nw
46  //Dryness  fraction  at  point  of  release:
47  x2=V2/(m*vg5)
48  //Missing  quantity  per  hour(in  kg):
49  mq2=(m-m*x2)*nw
50  //Percentage  re-evaporation  during  expansion:
51  P=(mq1-mq2)/mq1*100
52  printf("\n  RESULT  \n")
53  printf("\nDryness  fraction  at  cut-off  =  %f",x1)
54  printf("\nDryness  fraction  at  release  =  %f",x2)
```

```
55  printf("\nMissing quanity at cut off = %f kg/hr",mq1
        )
56  printf("\nMissing quanity at release = %f kg/hr",mq2
        )
57  printf("\nPercentage re-evaporation = %f percent",P)
```

Scilab code Exa 12.10 Indicated power

```
1   //pathname=get_absolute_file_path('12.10.sce')
2   //filename=pathname+filesep()+'12.10-data.sci'
3   //exec(filename)
4   //Pressure at which steam is supplied(in kPa):
5   p1=1.5*10^3
6   //Dryness fraction:
7   x1=0.9
8   //Pressure at exhaust(in kPa):
9   p4=40
10  //Diagram factor reffered to LP cylinder:
11  d1LP=0.8
12  //Stroke length(in m):
13  L=0.38
14  //Bore of HP cylinder(in m):
15  dHP=0.20
16  //Bore of LP cylinder(in m):
17  dLP=0.30
18  //Rpm of engine:
19  N=240
20  //Area of HP cylinder(in m^2):
21  AHP=%pi*(dHP^2)/4
22  //Area of LP cylinder(in m^2):
23  ALP=%pi*(dLP^2)/4
24  //Intermediate pressure(in kPa):
25  p2=192
26  //Volume at state 2(in m^3):
27  V2=AHP*L
```

```
28  //Volume  at  state  1(in  m^3):
29  V1=V2*p2/p1
30  //Volume  of  LP  cylinder(in  m^3):
31  VLP=ALP*L
32  //Expansion  ratio  throughout  the  engine:
33  r=VLP/V1
34  //Mean  effective  pressure(in  kPa):
35  mep=p1/r*(1+log(r))-p4
36  //Actual  mep(in  kPa):
37  mepa=mep*d1LP
38  //Indicated  power(in  kW):
39  IP=mepa*L*ALP*N/60*2
40  //Volume  of  steam  admitted  per  hour(in  m^3):
41  Vs=V1*N*2*60
42  //Specific  volume  of  steam  being  admitted(in  m^3/kg)
       :
43  v1=0.1187
44  //Steam  consumption(in  kg/hr):
45  m=Vs/v1
46  printf("\n  RESULT  \n")
47  printf("\nIndicated  power  =  %f  kW",IP)
48  printf("\nSteam  consumption  =  %f  kg/hr",m)
```

Scilab code Exa 12.11 Indicated power

```
1  //pathname=get_absolute_file_path('12.11.sce')
2  //filename=pathname+filesep()+'12.11-data.sci'
3  //exec(filename)
4  //Pressure  at  which  steam  is  supplied(in  kPa):
5  p1=1.4*10^3
6  //Pressure  at  exhaust(in  kPa):
7  p4=25
8  //Expansion  ratio:
9  r=8
10  //Rpm  of  engine:
```

```
11  N=240
12  //Bore diameter(in m):
13  d=0.60
14  //Stroke length(in m):
15  L=0.60
16  //Diagram factor:
17  d1=0.8
18  //Area of cylinder(in m^2):
19  A=%pi*d^2/4
20  //Hypothetical mep(in kPa):
21  mep=p1/r*(1+log(r))-p4
22  //Actual mep(in kPa):
23  mepa=mep*d1
24  //Indicated power(in kW):
25  IP=mepa*L*A*N/60*2
26  //Work done in HP cylinder(in kJ):
27  W=mepa*A*L/2
28  //Volume at state 1(in m^3):
29  V1=%pi*d^2*L/(4*8)
30  //Volume at state 2(in m^3):
31  V2=2.71^(W/(p1*V1))*V1
32  //Diameter of HP cylinder(in m):
33  D=sqrt(V2*4/(L*%pi))
34  //Intermediate pressure(in kPa):
35  p2=p1*V1/V2
36  printf("\n RESULT \n")
37  printf("\nIndicated power = %f kW",IP)
38  printf("\nDiameter of HP cylinder = %f cm",D*100)
39  printf("\nIntermediate pressure = %f kPa",p2)
```

Scilab code Exa 12.12 Speed of engine and diameter of cylinder

```
1  //pathname=get_absolute_file_path('12.12.sce')
2  //filename=pathname+filesep()+'12.12-data.sci'
3  //exec(filename)
```

```
 4  //Pressure  at  which  steam  is  supplied(in  kPa):
 5  p1=1.5*10^3
 6  //Pressure  at  exhaust(in  kPa):
 7  p4=25
 8  //Power  output(in  kW):
 9  P=250
10  //Expansion  ratio:
11  r=12
12  //Diameter  of  LP  cylinder(in  m):
13  d=0.40
14  //Stroke  length(in  m):
15  L=0.60
16  //Diagram  factor:
17  d1=0.75
18  //Expansion  ratio  in  HP  cylinder:
19  r1=2.5
20  //Area  of  cylinder(in  m^2):
21  A=%pi*d^2/4
22  //Hypothetical  mep(in  kPa):
23  mep=p1/r*(1+log(r))-p4
24  //Actual  mep(in  kPa):
25  mepa=mep*d1
26  //Rpm  of  engine:
27  N=P/(mepa*L*A*2)*60
28  printf("\n  RESULT  \n")
29  printf("\nSpeed  of  engine  =  %d  rpm",N)
30  //Volume  of  LP  cylinder(in  m^3):
31  V3=A*L
32  V4=V3
33  //Cut−off  volume  in  HP  cylinder(in  m^3):
34  Vc=V4/r
35  //Total  volume  in  HP  cylinder(in  m^3):
36  Vt=Vc*r1
37  //Diameter  of  HP  cylinder(in  m):
38  D=sqrt(Vt*4/(L*%pi))
39  printf("\nDiameter  of  HP  cylinder  =  %f  cm",D*100)
```

Scilab code Exa 12.13 Overall diagram factor

```
1  //pathname=get_absolute_file_path('12.13.sce')
2  //filename=pathname+filesep()+'12.13-data.sci'
3  //exec(filename)
4  //Diameter of HP, LP and IP cylinder(in m):
5  dhp=0.25
6  dip=0.40
7  dlp=0.85
8  //MEPs of the cylinders(in kPa):
9  mephp=0.5*10^3
10 mepip=0.3*10^3
11 meplp=0.1*10^3
12 //Pressure at which steam is supplied(in kPa):
13 p1=1.5*10^3
14 //Pressure at exhaust(in kPa):
15 p4=25
16 //Cut-off occurs at:
17 r1=0.60
18 //Area of HP cylinder(in m^2):
19 AHP=%pi*dhp^2/4
20 //Area of IP cylinder(in m^2):
21 AIP=%pi*dip^2/4
22 //Area of LP cylinder(in m^2):
23 ALP=%pi*dlp^2/4
24 //Mep of HP referred to LP cylinder(in kPa):
25 mep1=mephp*AHP/ALP
26 //Mep of IP referred to LP cylinder(in kPa):
27 mep2=mepip*AIP/ALP
28 //Overall mep referred to LP cylinder(in kPa):
29 mept=mep1+mep2+meplp
30 //Overall expansion ratio:
31 r=ALP/(r1*AHP)
32 //Hypothetical mep(in kPa):
```

```
33  mep=p1/r*(1+log(r))-p4
34  //Overall diagram factor:
35  d1=mept/mep
36  //% of HP cylinder output:
37  P1=mep1/mept*100
38  //% of HP cylinder output:
39  P2=mep2/mept*100
40  //% of HP cylinder output:
41  P3=meplp/mept*100
42  printf("\nRESULT\n")
43  printf("\nActual mep referred to LP = %f kPa",mept)
44  printf("\nHypothetical mep referred to LP = %f kPa",
        mep)
45  printf("\nOverall diagram factor = %f",d1)
46  printf("\nPercentage of HP, IP and LP cylinder
        outputs = %f, %f and %f percent",P1,P2,P3)
```

Scilab code Exa 12.14 Total output

```
1   //pathname=get_absolute_file_path('12.14.sce')
2   //filename=pathname+filesep()+'12.14-data.sci'
3   //exec(filename)
4   //Pressure at which steam is supplied(in bars):
5   p1=7
6   //Pressure at exhaust(in bars):
7   p5=0.25
8   //Diameter of HP and LP cylinder(in m):
9   dhp=0.25
10  dlp=0.50
11  //Cut-off point of HP and LP cylinders:
12  r1=0.30
13  r2=0.45
14  //Clearance volume of HP and LP cylinders:
15  c1=0.10
16  c2=0.05
```

```scilab
17  //Diagram factors of HP and LP cylinders:
18  d1hp=0.8
19  d1lp=0.7
20  //Rpm pf engine:
21  N=100
22  //Let the length of stroke(in m):
23  L=1
24  //Volume of HP cylinder(in m^2):
25  VHP=%pi*dhp^2/4*L
26  //Volume of LP cylinder(in m^2):
27  VLP=%pi*dlp^2/4*L
28  //Clearance volume(in m^2):
29  V9=c1*VHP
30  V7=c2*VLP
31  //Total volume of cylinders(in m^3):
32  V2=VHP+V9
33  V5=VLP+V7
34  //Volume at cut-off in HP cylinder(in m^3):
35  V1=V9+r1*VHP
36  V3=V7+r2*VLP
37  //Expansion ratio:
38  rhp=V2/V1
39  rlp=V5/V3
40  //Pressure at state 3(in kPa):
41  p3=p1*10^2*V1/V3
42  //Actual mep for HP cylinder(in kPa):
43  mepahp=d1hp*(p1*10^2*V1*(1+log(rhp))-p3*V2-(p1*10^2-
       p3)*V9)/VHP
44  //Actual mep for LP cylinder(in kPa):
45  mepalp=62.96
46  //Actual mep of HP reffered to LP cylinder:
47  mepa=mepahp*VHP/VLP
48  //Total mep(in kPa):
49  mept=mepalp+mepa
50  //Total output(in kW):
51  W=mept*VLP*100/60
52  printf("\nRESULT\n")
53  printf("\nmep of Hp referred to LP = %f kPa",mepa)
```

```
54  printf("\nmep of LP = %f kPa",mepalp)
55  printf("\nTotal output = %f*L kW where L is stroke
        length",W)
```

Scilab code Exa 12.15 Steam used per hp

```
1  //pathname=get_absolute_file_path('12.15.sce')
2  //filename=pathname+filesep()+'12.15-data.sci'
3  //exec(filename)
4  //Duration of trial(in min):
5  t=15
6  //Bore diameter(in m):
7  d=0.25
8  //Stroke length(in m):
9  L=0.30
10 //Brake diameter(in m):
11 bd=1.5
12 //Net brake load(in N):
13 bl=300
14 //Speed of engine:
15 N=240
16 //Steam pressure(in bar):
17 p1=10
18 //Dryness fraction:
19 x=0.9
20 //Mep at cover end(in bar):
21 mep=0.9
22 //Steam utilised(in kg):
23 m1=15
24 //Steam consumption per hour(in kg/hr):
25 m=m1/t*60
26 //Indicated horse power(in kW):
27 IP=mep*10^2*L*%pi*d^2*240*2/(4*0.7457*60)
28 //Steam used per(hp.hr):
29 m2=60/IP
```

```
30  printf("\nRESULT\n")
31  printf("\nSteam used per = %f kg/hp.hr",m2)
```

Scilab code Exa 12.16 Brake specific steam consumption

```
1   //pathname=get_absolute_file_path('12.16.sce')
2   //filename=pathname+filesep()+'12.16-data.sci'
3   //exec(filename)
4   //Bore diameter(in m):
5   d=0.38
6   //Stroke length(in m):
7   L=0.50
8   //Piston rod diameter(in m):
9   pd=0.05
10  //Speed of engine(in rpm):
11  N=150
12  //Steam consumption(in kg/min):
13  m=36
14  //Brake load(in kN):
15  F=7
16  //Brake diameter(in m):
17  bd=2
18  //Area of indicator diagram at cover end(in cm^2):
19  aco=28
20  //Area of indicator diagram at crank end(in cm^2):
21  acr=26
22  //Length of indicator diagram(in m):
23  l=0.07
24  //Spring scale(in kPa/mm):
25  s=15
26  //Mep at crank end(in kPa):
27  mepcr=acr*100*s/(l*10^3)
28  //Mep at cover end(in kPa):
29  mepco=aco*100*s/(l*10^3)
30  //IP at crank end(in kW):
```

```
31  IPcr=mepcr*L*%pi*(d^2-pd^2)/4*N/60
32  //IP at cover end(in kW):
33  IPco=mepco*L*%pi*(d^2)/4*N/60
34  //IP(in kW):
35  IP=IPcr+IPco
36  //Brake power(in kW):
37  BP=2*%pi*N/60*F*1
38  //Mechanical efficiency:
39  n=BP/IP
40  //ISFC(in kg/kW.h):
41  ISFC=m*60/IP
42  //BSFC(in kg/kW.h):
43  BSFC=m*60/BP
44  printf("\nRESULT\n")
45  printf("\nIndicated power = %f kW",IP)
46  printf("\nBrake power = %f kW",BP)
47  printf("\nIndicated specific steam consumption = %f
        kg/kW.h",ISFC)
48  printf("\nBrake specific steam consumption = %f kg/
        kW.h",BSFC)
```

Scilab code Exa 12.17 Indicated steam consumption

```
1   //pathname=get_absolute_file_path('12.17.sce')
2   //filename=pathname+filesep()+'12.17-data.sci'
3   //exec(filename)
4   //Bore: 24 cm
5   //Stroke: 34 cm
6   //Engine speed: 150 rpm
7   //Piston rod diameter: 5cm
8   //Brake load: 120kg
9   //Spring balance reading: 100N.
10  //Brake wheel drum diameter: 100cm;
11  //Steam inlet state: 15 bar, 0.98 dry,
12  //Mean effective pressure at cover end: 1.8 bar
```

```scilab
13  //Mean effective pressure at crank end: 1.6 bar
14  //Cooling water flow through condenser: 42 kg/min
15  //Rise in temperature of cooling water: 20 C
16  //Condensate discharged from condensor: 4 kg/min
17  //Temperature of condensate: 50 C
18  //From steam tables:
19  hf=844.89 //kJ/kg
20  hfg=1947.3 //kJ/kg
21  hcond=209.33 //kJ/kg
22  //Brake power(in kW):
23  BP=2*%pi*150*(120*9.81-100)*(100/2)*10^(-2)
        /(1000*60)
24  //IP at cover end(in kW):
25  IPco=1.8*10^2*0.34*%pi/4*(0.24)^2*150/60
26  //IP at crank end(in kW):
27  IPcr=1.6*10^2*0.34*%pi/4*(0.24^2-0.05^2)*150/60
28  //Total IP(in kW):
29  IP=IPco+IPcr
30  //Mechanical efficiency:
31  n=BP/IP
32  //Enthalpy of steam at inlet(in kJ/kg):
33  hs=hf+0.98*hfg
34  //Energy supplied by the steam(in kJ/kg):
35  E=hs-hcond
36  //Steam consumption rate(in kg/hr):
37  m=4*60
38  //Brake thermal efficiency:
39  nbth=3600/((m/BP)*E)*100
40  //Indicated steam consumption(in kg/kW.h):
41  ISFC=m/IP
42  printf("\nRESULT\n")
43  printf("\nBrake thermal efficiency = %f percent",
        nbth)
44  printf("\nIndicated specific steam consumption = %f
        kg/kW.h",ISFC)
```

Chapter 13

Nozzles

Scilab code Exa 13.01 Dryness fraction

```
1  //pathname=get_absolute_file_path('13.01.sce')
2  //filename=pathname+filesep()+'13.01-data.sci'
3  //exec(filename)
4  //Pressure of dry steam(in bar):
5  p1=10
6  //Velocity of steam entering(in m/s):
7  C1=100
8  //Velocity of steam leaving the nozzle(in m/s):
9  C2=300
10 //Pressure of steam at exit(in bar):
11 p2=5
12 //Mass flow rate(in kg/s):
13 m=16
14 //Heat loss to surroundings(in kJ/kg):
15 q=10
16 //From steam tables:
17 h1=2778.1 //kJ/kg
18 hf=640.23 //kJ/kg
19 hfg=2108.5 //kJ/kg
20 //Heat drop in the nozzle(in kJ/kg):
21 dh=(q*10^3+(C1^2-C2^2)/2)/1000
```

```
22  //Total heat drop(in kJ/s):
23  dQ=-dh*m
24  //Enthalpy at state 2(in kJ/kg):
25  h2=h1+dh
26  //Dryness fraction at state 2:
27  x2=(h2-hf)/hfg
28  printf("\nRESULT\n")
29  printf("\nHeat drop in the nozzle = %f kJ/kg",-dh)
30  printf("\nTotal heat drop = %f kJ/s",dQ)
31  printf("\nDryness fraction at exit = %f",x2)
```

Scilab code Exa 13.02 Mass flow rate

```
1   //pathname=get_absolute_file_path('13.02.sce')
2   //filename=pathname+filesep()+'13.02-data.sci'
3   //exec(filename)
4   //Steam entering at pressure(in bar):
5   p1=10
6   //Pressure at which steam leaves(in bar):
7   p2=6
8   //Cross-section area of exit of nozzle(in cm^2):
9   A2=20
10  //From steam tables:
11  h1=3478.5  //kJ/kg
12  s1=7.7622  //kJ/kg.K
13  s2=s1
14  T2=418.45  //C(by interpolation)
15  h2=3309.51  //kJ/kg
16  v2=0.5281  //m^3/kg
17  //Velocity at exit(in m/s):
18  C2=sqrt(2*(h1-h2)*10^3)
19  //Mass flow rate(in kg/s):
20  m=A2*10^(-4)*C2/v2
21  printf("\nRESULT\n")
22  printf("\nMass flow rate= %f kg/s",m)
```

Scilab code Exa 13.03 Coefficient of velocity

```scilab
1  //pathname=get_absolute_file_path('13.03.sce')
2  //filename=pathname+filesep()+'13.03-data.sci'
3  //exec(filename)
4  //Pressure of steam entering(in bar):
5  p1=12
6  //Pressure at exit(in bar):
7  p2=6
8  //Mass flow rate(in kg/s):
9  m1=5
10 m2=m1
11 m3=m1
12 //Exit velocity(in m/s):
13 C3a=500
14 //From steam tables:
15 h1=3045.8  //kJ/kg
16 h2=2900.05  //kJ/kg
17 s2=7.0317  //kJ/kg.K
18 s1=s2
19 s3=s2
20 v2=0.3466  //m^3/kg
21 h3=2882.55  //kJ/kg
22 v3=0.3647  //m^3/kg
23 //For superheated steam:
24 n=1.3
25 //Pressue at state 2(in bar):
26 p2=p1*(2/(n+1))^(n/(n-1))
27 //Velocity at throat(in m/s):
28 C2=sqrt(2*(h1-h2)*10^3)
29 //Cross-sectional area at throat(in m^2):
30 A2=m2*v2/C2
31 //Ideal velocity at exit(in m/s):
32 C3=sqrt(2*(h1-h3)*10^3)
```

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```
33  //Cross−sectional area at exit (in m^2):
34  A3=m3*v3/C3a
35  //Coefficient of velocity:
36  r=C3a/C3
37  printf("\nRESULT\n")
38  printf("\nCross−sectional area at throat = %f m^2",
        A2)
39  printf("\nCross−sectional area at exit = %f m^2",A3)
40  printf("\nCoefficient of velocity = %f",r)
```

Scilab code Exa 13.04 Area at exit

```
1   //pathname=get_absolute_file_path ('13.04.sce')
2   //filename=pathname+filesep()+'13.04−data.sci'
3   //exec(filename)
4   //Pressure of steam entering (in bar):
5   p1=16
6   //Pressure at exit (in bar):
7   p3=5
8   //Mass flow rate (in kg/s):
9   m1=1
10  m2=m1
11  m3=m1
12  //From steam tables:
13  //For case 1:
14  h1=3034.8  //kJ/kg
15  s1=6.8844  //kJ/kg.K
16  v1=0.15862  //m^3/kg
17  n=1.3
18  h2=2891.39  //kJ/kg
19  h3=2777  //kJ/kg
20  v2=0.2559  //m^3/kg
21  v3=0.3882  //m^3/kg
22  //For case 2:
23  h2a=2905.73  //kJ/kg
```

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```
24  v2a =0.2598  //m^3/kg
25  v3a =0.40023  //m^3/kg
26  // Pressure  at  the  throat  of  nozzle (in  bar ):
27  p2=p1 *(2/( n+1))^( n/(n-1))
28  // Heat  drop  up  to  throat  section (in  kJ/kg ):
29  q12=h1-h2
30  // Velocity  at  throat (in  m/s ):
31  C2=sqrt (2*(h1-h2) *10^3)
32  // Heat  drop  from  exit (in  kJ/kg ):
33  q23=h2-h3
34  // Velocity  at  exit (in  m/s ):
35  C3=sqrt (2*(h2-h3) *10^3+C2^2)
36  // Throat  area (in  m^2 ):
37  A2=m2*v2/C2
38  // Exit  area (in  m^2 ):
39  A3=m3*v3/C3
40  printf (" \nRESULT\n")
41  printf (" \nFor  frictionless  expansion ")
42  printf (" \nThroat  area  = %f  cm^2 ", A2 *(10^4))
43  printf (" \nExit  area  = %f  cm^2 ", A3 *(10^4))
44  // Considering  expansion  to  have  10%  friction  loss :
45  q12a =0.9* q12
46  // Actual  velocity  at  throat (in  m/s ):
47  C2a=sqrt (2* q12a *10^3)
48  // Actual  throat  area (in  m^2 ):
49  A2a=m2* v2a / C2a
50  // Actual  drop  at  the  exit  of  the  nozzle (in  kJ/kg ):
51  q23a =0.9* q23
52  // Actual  enthalpy  at  state  3( in  kJ/kg ):
53  h3a=h2a - q23a
54  // Actual  velocity  at  exit (in  m/s ):
55  C3a=sqrt (2* q23a *10^3+C2a^2)
56  // Actual  area  at  exit (in  m^2 ):
57  A3a=m3* v3a / C3a
58  printf (" \n\nConsidering  friction ")
59  printf (" \nThroat  area  = %f  cm^2 ", A2a *(10^4))
60  printf (" \nExit  area  = %f  cm^2 ", A3a *(10^4))
```

Scilab code Exa 13.05 Area at exit

```scilab
1  //pathname=get_absolute_file_path('13.05.sce')
2  //filename=pathname+filesep()+'13.05-data.sci'
3  //exec(filename)
4  //Power of turbine(in MW):
5  P=1
6  //Pressure of steam entering(in bar):
7  p1=20
8  //Steam consumption rate(in kg/kW.h):
9  m=8
10 //Pressure at which steam leaves(in bar):
11 p3=0.2
12 //Throat diameter(in m):
13 d=0.01
14 //From Mollier diagram:
15 q12=142  //kJ/kg
16 v2=0.20  //m^3/kg
17 q13=807  //kJ/kg
18 v3=7.2  //m^3/kg
19 //Velocity at throat(in m/s):
20 C2=sqrt(2*q12*10^3)
21 //Mass flow rate:
22 m2=%pi*d^2/4*C2/v2
23 m3=m2
24 //Number of nozzles:
25 n=10^3*m/(3600*m2)
26 //Useful heat drop:
27 q13a=0.90*q13
28 //Velocity at exit(in m/s):
29 C3=sqrt(2*10^3*q13a)
30 //Area at exit(in m^2):
31 A3=m3*v3/C3
32 printf("\nRESULT\n")
```

```
33  printf("\nNumber of nozzles required = %d",n+1)
34  printf("\nArea at exit = %f cm^2",A3*10^4)
```

Scilab code Exa 13.06 Velocity at throat and cone angle

```
 1  //pathname=get_absolute_file_path('13.06.sce')
 2  //filename=pathname+filesep()+'13.06-data.sci'
 3  //exec(filename)
 4  //Pressure at which steam is supplied(in MPa):
 5  p1=0.7
 6  //Length of diverging nozzle(in m):
 7  l=0.06
 8  //Throat diameter(in mm):
 9  d=0.005
10  //Pressure at which steam leaves the nozzle(in MPa):
11  p3=0.1
12  //From Mollier diagram:
13  q12=138  //kJ/kg
14  v2=0.58  //m^3/kg
15  T=203  //C
16  q23=247  //kJ/kg
17  q23a=209.95  //kJ/kg
18  v3a=1.7  //m^3/kg
19  //Velocity at throat(in m/s):
20  C2=sqrt(2*q12*10^3)
21  //Mass flow rate(in kg/s):
22  m1=%pi*d^2/4*C2/v2
23  m2=m1
24  m3=m1
25  //Total heat drop(in kJ/kg):
26  q=q12+q23a
27  //Velocity at exit(in m/s):
28  C3=sqrt(2*10^3*q)
29  //Area at exit(in m^2):
30  A3=m3*v3a/C3
```

```
31  //Diameter at exit (in mm):
32  d1=(sqrt(A3*4/%pi))*10^3
33  a=atan((d1-d*10^3)/(2*60))*180/%pi
34  printf("\nRESULT\n")
35  printf("\nWith no losses , temperature at throat = %d
        C",T)
36  printf("\nVelocity at throat = %f m/s",C2)
37  printf("\nWith losses , cone angle = %f",2*a)
```

Scilab code Exa 13.07 Length and radial height of nozzle

```
1   //pathname=get_absolute_file_path('13.07.sce')
2   //filename=pathname+filesep()+'13.07-data.sci'
3   //exec(filename)
4   //Power of the turbine(in hp):
5   P=5000
6   //Steam required(in kg of steam/hp-hr):
7   m=P*6/3600
8   //Efficiency of nozzle:
9   n=0.90
10  //Nozzle angle:
11  a=12
12  //Pitch(in cm):
13  p=5
14  //Thickness(in cm):
15  t=0.3
16  //From steam tables:
17  h1=2794  //kJ/kg
18  s1=6.4218  //kJ/kg.K
19  s2=s1
20  x2=0.9478
21  h2=2662.2  //kJ/kg
22  x2a=0.9542
23  v2a=0.2294  //m^3/kg
24  //Change in enthalpy(in kJ/kg):
```

```
25  h12=h1-h2
26  //Actual change(in kJ/kg):
27  h12a=n*h12
28  //Velocity at inlet(in m/s):
29  C2=sqrt(2*h12a*10^3)
30  //Area at exit of nozzle(in cm^2):
31  A2=m*v2a/C2*10^4
32  //Approximate length of the nozzle(in cm):
33  l=60*%pi/3
34  //Number of nozzles:
35  n=int(l/p)+1
36  //Correct length of nozzle arc:
37  l1=n*p
38  //Radial height of nozzle(in cm):
39  h=A2/((p*sin(a*%pi/180)-t)*n)
40  printf("\nRESULT\n")
41  printf("\nLength of nozzle = %d cm",l1)
42  printf("\nRadial height of nozzle = %f cm",h)
```

Scilab code Exa 13.08 Exit velocity

```
1  //pathname=get_absolute_file_path('13.08.sce')
2  //filename=pathname+filesep()+'13.08-data.sci'
3  //exec(filename)
4  //Pressure at which steam enters(in bar):
5  p1=13
6  //Pressure at which steam leaves(in bar):
7  p2=6
8  //Temperature of steam entering(in K):
9  T1=150+273
10  //Adibatic insex of compression:
11  r=1.4
12  //Final temperature of steam(in K):
13  T2=T1*(p2/p1)^((r-1)/r)
14  //Exit velocity(in m/s):
```

```
15  C2=sqrt(2*1.005*(T1-T2))
16  printf("\nRESULT\n")
17  printf("\nExit  velocity  =  %f m/s",C2)
```

Scilab code Exa 13.09 Nozzle efficiency

```
1  //pathname=get_absolute_file_path('13.09.sce')
2  //filename=pathname+filesep()+'13.09-data.sci'
3  //exec(filename)
4  //Force on the plate(in N):
5  F=350
6  //Initial pressure(in bar):
7  p1=8
8  //Final pressure(in bar):
9  p3=1
10  //Throat cross-sectional area(in m^2):
11  A2=5*10^(-4)
12  //From steam tables:
13  h1=2769.1  //kJ/kg
14  s1=6.6628  //kJ/kg.K
15  s2=s1
16  s3=s1
17  x2=0.9717
18  h2=2685.17  //kJ/kg
19  v2=0.3932  //m^3/kg
20  x3=0.8238
21  h3=2277.6  //kJ/kg
22  //Enthalpy change(in kJ/kg):
23  h12=h1-h2
24  //Velocity at throat(in m/s):
25  C2=sqrt(2*h12*10^3)
26  //Discharge at throat(in kg/s):
27  m=A2*C2/v2
28  //Actual exit velocity(in m/s):
29  C3a=F/m
```

```
30  // Theoretical enthalpy drop(in kJ/kg):
31  h23=h2-h3
32  // Nozzle efficiency:
33  n=C3a^2/(2*h23*10^3)
34  printf("\nRESULT\n")
35  printf("\nDischarge at throat = %f kg/s",m)
36  printf("\nNozzle efficiency = %f percent",n*100)
```

Scilab code Exa 13.10 Degree of supersaturaion and amount of under-cooling

```
1   // pathname=get_absolute_file_path('13.10.sce')
2   // filename=pathname+filesep()+'13.10-data.sci'
3   // exec(filename)
4   // Mass flow rate(in kg/s):
5   m=5/60
6   // Pressure at which steam is discharged(in bar):
7   p3=1
8   // Initial pressure(in bar):
9   p1=10
10  // Initial temperature(in K)
11  T1=200+273
12  // Adiabatic index of compression:
13  n=1.3
14  // From steam tables:
15  h1=2827.9  // kJ/kg
16  s1=6.6940  // kJ/kg.K
17  v1=0.2060  // m^3/kg
18  h2a=2711.23  // kJ/kg
19  s2a=6.6749  // kJ/kg.K
20  s3=s2a
21  h3=2420.08  // kJ/kg
22  v3=1.5025  // m^3/kg
23  psat=3.44  // bar (at T=138.18 C)
24  Tsat=155.12  // C (at p=5.45 bar)
```

```
25  //Pressure at throat(in bar):
26  p2=p1*(2/(n+1))^(n/(n-1))
27  //Velocity at exit(in m/s):
28  C3=sqrt(2*(h1-h3)*10^3)
29  //Exit area(in m^2):
30  A3=m*v3/C3
31  //Diameter of nozzle at exit(in m):
32  d=sqrt(A3*4/%pi)
33  //Temperature at throat(in K):
34  T2=T1*(p2/p1)^((n-1)/n)
35  //Degree of supersaturation:
36  d1=p2/psat
37  //Amount of undercooling(in C):
38  u=Tsat-(T2-273)
39  printf("\nRESULT\n")
40  printf("\nDegree of supersaturation = %f",d1)
41  printf("\nAmount of undercooling = %f C",u)
```

Scilab code Exa 13.11 Degree of undercooling

```
1  //pathname=get_absolute_file_path('13.11.sce')
2  //filename=pathname+filesep()+'13.11-data.sci'
3  //exec(filename)
4  //Initial pressure(in bar):
5  p1=4
6  //Initial temperature(in K):
7  T1=180+273
8  //Final pressure(in bar):
9  p2=1.5
10  //Index of compression:
11  n=1.3
12  //Efficiency due to heat loss:
13  nn=0.95
14  //Specific heat(in kJ/kg.K):
15  C=2.174
```

```
16  //From steam tables:
17  v1=0.5088  //m^3/kg
18  Tsat=111.37+273  //K (at p=1.5 bar)
19  //Enthalpy at state 1(in kJ/kg):
20  h1=p1*v1*10^2+2614
21  //Specific volume at state 2(in m^3/kg):
22  v2=v1*(p1/p2)^(1/n)
23  //Enthalpy at state 2(in kJ/kg):
24  h2=p2*v2*10^2+2614
25  //Actual heat drop(in kJ/kg):
26  dh=nn*(h1-h2)
27  printf("\nRESULT\n")
28  printf("\nActual heat drop = %f kJ/kg",dh)
29  //Temperature at state 2(in K):
30  T2=T1*(p2/p1)^((n-1)/n)
31  //Temperature rise due to supersaturation:
32  dT=(1-nn)*(h1-h2)/C
33  //Actual temperature at state 2(in K):
34  T2a=T2+dT
35  //Amount of undercooling(in C):
36  u=Tsat-T2a
37  printf("\nAmount of undercooling = %f C",u)
```

Scilab code Exa 13.12 Percentage increase in discharge

```
1   //pathname=get_absolute_file_path('13.12.sce')
2   //filename=pathname+filesep()+'13.12-data.sci'
3   //exec(filename)
4   //Initial pressure(in bar):
5   p1=14
6   //Initial temperature(in K):
7   T1=400+273
8   //Number of nozzles:
9   N=16
10  //Final pressure(in bar):
```

```
11  p2=10
12  //Discharge(in kg/s):
13  m=5
14  //Nozzle efficiency:
15  nn=0.90
16  //Inlet velocity(in m/s):
17  C1=100
18  //Insex of compression:
19  n=1.3
20  //From steam tables:
21  h1=3257.5  //kJ/kg
22  s1=7.3026  //kJ/kg.K
23  T2=350.46  //C
24  h2=3158.7  //kJ/kg
25  v2=0.2827  //m^3/kg
26  //Actual enthalpy change(inn kJ/kg):
27  h12=(h1-h2)*nn
28  //Velocity at exit(in m/s):
29  C2=sqrt(2*h12*10^3)
30  //Cross−sectional area at exit(in cm^2):
31  A2=m*v2/(C2*N)*10^4
32  //Modified velocity at nozzle exit(in m/s):
33  C2a=sqrt(2*h12*10^3+C1^2)
34  //Discharge with modified velocity(in kg/s):
35  //ma=A2*C2a*N/v2*10^(−4)
36  ma=16*2.13*433.41*10^(-4)/0.2827
37  //% increase in discharge:
38  p=(ma-m)/m*100
39  printf("\nRESULT\n")
40  printf("\nCross−sectional area at exit of nozzle =
          %f cm^2",A2)
41  printf("\nPercentage increase in discharge = %f
          percent",p)
```

Scilab code Exa 13.13 Entropy change

```scilab
1  //pathname=get_absolute_file_path('13.13.sce')
2  //filename=pathname+filesep()+'13.13-data.sci'
3  //exec(filename)
4  //Initial pressure(in bar):
5  p1=20
6  //Final pressure(in bar):
7  p3=5
8  n=1.3
9  //From steam tables:
10 T1=212.42+273  //K
11 Tsat=186.43+273 //K (at 11.6 bar)
12 psat=5.452 //bar (at 155.14 C)
13 h1=2799.5 //kJ/kg
14 v1=0.009963 //m^3/kg
15 s1=6.3409 //kJ/kg.K
16 s2aa=s1
17 h2aa=2693.98 //kJ/kg
18 s2a=6.5484 //kJ/kg.K
19 s3a=s2a
20 h3a=2632.76 //kJ/kg
21 s3=s1
22 h3=2544.21 //kJ/kg
23 //Pressure at throat(in bar):
24 p2=p1*0.58
25 //Temperature at state 2(in K):
26 T2=T1*(p2/p1)^((n-1)/n)
27 //Degree of supersaturation:
28 d=p2/psat
29 //Degree of undercooling:
30 d1=Tsat-T2
31 printf("\nRESULT\n")
32 printf("\nDegree of supersaturation = %f",d)
33 printf("\nDegree of undercooling = %f",d1)
34 //Isentropic enthalpy drop:
35 h12=(n/(n-1))*p1*10^2*v1*(1-(T2/T1))
36 //Enthalpy at state 2(in kJ/kg):
37 h2=h1-h12
38 //Heat drop with no saturation(in kJ/kg):
```

```
39  h12aa=h1-h2aa
40  //Loss of available heat drop(in kJ/kg):
41  L=h12aa-h12
42  //Increase in entropy(in kJ/kg.K):
43  s12a=L/Tsat
44  //Loss due to undercooling(in kJ/kg):
45  L1=h3a-h3
46  //Percentage loss:
47  p=L1/(h1-h3)*100
48  printf("\n\nEntropy change = %f kJ/kg.K",s12a)
49  printf("\nLoss due to undercooling = %f kJ/kg",L1)
50  printf("\nPercentage loss = %f percent",p)
```

Scilab code Exa 13.14 Temperature of water coming out of injector

```
1  //pathname=get_absolute_file_path('13.14.sce')
2  //filename=pathname+filesep()+'13.14-data.sci'
3  //exec(filename)
4  //Mass flow rate(in kg/s):
5  m1=150/60
6  //Height of water level from the axis of injector(in
       m):
7  H=5
8  //Pressuer at which steam is injected(in bar):
9  p4=20
10 //Water level in boiler from the injector(in m):
11 Z4=0.8
12 //Dryness fraction at state 1:
13 x1=0.95
14 //Velocity in delivery pipe(in m/s):
15 C4=20
16 //Atmospheric pressure(in bar):
17 p3=1.013
18 //Density(in kg/m^3):
19 d=10^3
```

```
20  // Acceleration  due  to  gravity (in  m/s^2):
21  g=9.81
22  // Specific  heat  of  steam (in  kJ/kg.K):
23  Cps=3.18
24  // Specific  heat  of  water (in  kJ/kg.K):
25  Cpw=4.18
26  //From  steam  tables:
27  T1=212.42  //C
28  Tw=25  //C
29  p2=0.7*p4
30  h1=2704.95  //kJ/kg
31  hfg1=1890.7  //kJ/kg
32  s1=6.1462  //kJ/kg.K
33  s2=s1
34  x2=0.923
35  h2=2639.10  //kJ/kg
36  v2=0.13  //m^3/kg
37  // Velocity  of  steam  at  throat (in  m/s):
38  C2=sqrt(2*(h1-h2)*10^3)
39  // Velocity  at  state  3(in  m/s):
40  C3=sqrt(2*(g*Z4+p4*10^5/d+C4^2/2-p3*10^5/d))
41  //Mass  of  water  pumped  per  kg  of  steam (in  kg):
42  m=(C2-C3)/(sqrt(2*g*H)+C3)
43  printf("\nRESULT\n")
44  printf("\nMass  of  water  pumped  per  kg  of  steam  =  %f
        kg",m)
45  //Mass  of  mixture  passing  through  state  3(in  kg/s):
46  m3=m1+m1/m
47  //Area  of  throat  of  mixing  nozzle(in  cm^2):
48  A3=m3/(d*C3)*10^4
49  //Diameter  of  throat  of  the  mixing  nozzle(in  cm):
50  d3=sqrt(A3*4/%pi)
51  printf("\nDiameter  of  throat  of  the  mixing  nozzle  =
        %f  cm",d3)
52  //Mass  of  steam  required  for  given  flow  rate(in  kg/s
        ):
53  ms=m1/m
54  //Area  at  state  2(in  cm^2):
```

```
55  A2=ms*v2/C2*10^4
56  // Diameter of throat of steam nozzle (in cm):
57  d2=sqrt(A2*4/%pi)
58  printf("\nDiameter of throat of steam nozzle = %f cm
        ",d2)
59  // Temperature of water coming out of the injector(in
        C):
60  T3=(x1*hfg1+Cps*T1+m*Cpw*Tw)/(m*Cpw+Cps)
61  printf("\nTemperature of water coming out of the
        injector = %f C",T3)
```

Scilab code Exa 13.15 Mass flow rate

```
1   // pathname=get_absolute_file_path('13.15.sce')
2   // filename=pathname+filesep()+'13.15-data.sci'
3   // exec(filename)
4   // Pressure at which steam is generated(in bar):
5   p4=20
6   // Pressure at inlet(in bar):
7   p1=1.5
8   // Dryness fraction:
9   x1=0.9
10  // Mass of water taken from feed water tank(in kg/hr)
        :
11  M=5000
12  // Density(in kg/m^3):
13  d=10^3
14  // From steam tables:
15  h1=2470.96  // kJ/kg
16  s1=6.6443  // kJ/kg.K
17  s2=s1
18  x2=0.88
19  h2=2396.72  // kJ/kg
20  v2=1.7302  // m^3/kg
21  // Steam velocity(in m/s):
```

```
22  C2=sqrt(2*(h1-h2)*10^3)
23  //Velocity at 3(in m/s):
24  C3=sqrt(1.2*p4*2*10^5/d)
25  //Mass entrained per kg of steam:
26  m=C2/C3-1
27  //Mass of steam supplied per second(in kg/s):
28  ms=M/(3600*m)
29  //Area of steam nozzle(in cm^2):
30  A2=ms*v2/C2*10^4
31  //Total discharge from injector(in kg/s):
32  D=M/3600+ms
33  //Area of discharge orifice(in cm^2):
34  A=D/(C3*d)*10^4
35  printf("\nRESULT\n")
36  printf("\nMass of water pumped per kg of steam = %f
         kg water/kg of steam",m)
37  printf("\nArea of steam nozzle = %f cm^2",A2)
38  printf("\nArea of discharge orifice = %f cm^2",A)
```

Chapter 15

Steam condenser

Scilab code Exa 15.01 Mass flow rate and vacuum efficiency

```
1  //pathname=get_absolute_file_path('15.01.sce')
2  //filename=pathname+filesep()+'15.01-data.sci'
3  //exec(filename)
4  //Height of mercury column in condenser(in mm of Hg)
       :
5  h=71
6  //Density of mercury(in kg/cm^3):
7  d=0.0135951
8  //Acceleration due to gravity(in m/s^2):
9  g=9.81
10  //Rate at which cooling water is circulated(in kg/
       min):
11  mw=800
12  //Condensate available at(in kg/min):
13  ms=25
14  //Gas constant(in kJ/kg.K):
15  R=0.287
16  //Specific heat of water(in kJ/kg.K):
17  Cpw=4.18
18  //From steam tables:
19  ps=5.62  //kPa
```

```
20  hf =146.68  //kJ/kg
21  hfg =2418.6  //kJ/kg
22  //Absolute  pressure  in  the  condenser(in  kPa):
23  pt =(76 - h)*10^(-2)*d*10^6*9.81*10^(-3)
24  //Partial  pressure  of  air(in  kPa):
25  pa=pt -ps
26  //Mass  of  air  per  m^3  of  condenser  volume:
27  ma=pa/((273+35)*R)
28  //Enthalpy  of  steam(in  kJ/kg):
29  hs=mw/ms*Cpw*(25-15)+Cpw*30
30  //Dryness  fraction  of  the  steam  entering:
31  x=(hs-hf)/hfg
32  //Vacuum  efficiency:
33  n=h*d*10^4*g/(76*d*10^4*g-ps*10^3)*100
34  printf("\nRESULT\n")
35  printf("\nMass  of  air  of  condenser  volume  =  %f  kg/m
        ^3",ma)
36  printf("\nDryness  fraction  of  steam  entering  =  %f",x
        )
37  printf("\nVacuum  efficiency  =  %f  percent",n)
```

Scilab code Exa 15.02 Mass of water vapour accompanying steam

```
1  //pathname=get_absolute_file_path('15.02.sce')
2  //filename=pathname+filesep()+'15.02 - data.sci'
3  //exec(filename)
4  //Height  of  mercury  column  in  condenser(in  mm  of  Hg)
        :
5  h=70
6  //Density  of  mercury(in  kg/cm^3):
7  d=0.0135951
8  //Acceleration  due  to  gravity(in  m/s^2):
9  g=9.81
10  //Leakage  of  air  in  condenser:
11  r=2500
```

```
12  //Gas constant(in kJ/kg.K):
13  R=0.287
14  //From steam tables:
15  ps=4.246 //kPa
16  vg=32.89 //m^3/kg
17  //Absolute pressure in the condenser(in kPa):
18  pt=(76-h)*10^(-2)*d*10^6*9.81*10^(-3)
19  //Partial pressure of air(in kPa):
20  pa=pt-ps
21  //Mass of air accoumpanying per kg of steam due to
        leakage(in kg):
22  m=1/r
23  //Volume of air per kg of steam(in m^3/kg):
24  v=m*R*(273+30)/pa
25  printf("\nRESULT\n")
26  printf("\nCapacity of air pump = %f m^3 per kg steam
        ",v)
27  //Mass of water vapour accompanying air:
28  m1=v/vg
29  printf("\nMass of water vapour accompanying air = %f
        kg/kg of steam",m1)
```

Scilab code Exa 15.03 Mass of uncondensed steam

```
1  //pathname=get_absolute_file_path('15.03.sce')
2  //filename=pathname+filesep()+'15.03-data.sci'
3  //exec(filename)
4  //Height in mercury column in condenser(in cm):
5  h=67
6  //Absolute pressure in the condenser(in kPa):
7  pt=10.67
8  //Partial pressure of steam(in kPa):
9  ps=7.384
10 //Mass flow rate of steam(in kg/min):
11 ms=50
```

```
12  //Mass flow rate of water(in kg/min):
13  mw=1000
14  //Specific heat of water(in kJ/kg.K):
15  Cpw=4.18
16  //Gas constant(in kJ/kg.K):
17  R=0.287
18  //Density of mercury(in kg/cm^3):
19  d=0.0135951
20  //Acceleration due to gravity(in m/s^2):
21  g=9.81
22  //From steam tables:
23  hf=167.57 //kJ/kg
24  hfg=2406.7 //kJ/kg
25  vg=19.52 //m^3/kg
26  //Corrected vacuum(in cm):
27  cv=76-(75-h)
28  printf("\nRESULT\n")
29  printf("\nCorrected vacuum = %d cm of Hg",cv)
30  //Partial pressure of air(in kPa):
31  pa=pt-ps
32  //VAcuum efficiency:
33  n=h*d*10^4*g/(75*d*10^4*g-ps*10^3)*100
34  printf("\nVacuum efficiency = %f percent",n)
35  //Undercooling of condensate(in C):
36  u=40-35
37  printf("\nUndercooling = %d C",u)
38  //Condenser efficiency:
39  n1=(25-10)/(46.9-10)*100
40  //Enthalpy of steam(in kJ/kg):
41  h=mw/ms*Cpw*(25-10)+Cpw*40
42  //Dryness fraction:
43  x=(h-hf)/hfg
44  printf("\nDryness fraction of steam entering = %f",x
        )
45  //Mass of air per m^3 of condenser volume(in kg/m^3)
        :
46  m=pa/(R*(273+40))
47  //Mass of air in 1kg of uncondensate steam(in kg):
```

```
48  m1=pa*vg/(R*(273+40))
49  printf("\nMass of air/m^3 of condenser volume = %f
        kg/m^3",m)
50  printf("\nMass of air in per kg of uncondensate
        steam = %f kg",m1)
```

Scilab code Exa 15.04 Mass of water vapour extracted with air

```
1  //pathname=get_absolute_file_path('15.04.sce')
2  //filename=pathname+filesep()+'15.04-data.sci'
3  //exec(filename)
4  //Height in mercury column in condenser(in cm):
5  h=69
6  //Inlet temperature(in C):
7  T1=30
8  //Leakage(in kg/hr):
9  L=60
10  //Density of mercury(in kg/cm^3):
11  d=0.0135951
12  //Acceleration due to gravity(in m/s^2):
13  g=9.81
14  //Gas constant(in kJ/kg.K):
15  R=0.287
16  //Rpm of engine:
17  n=240
18  //L/D ratio:
19  r=1.5
20  //From steam tables:
21  ps=4.246  //kPa
22  vg=32.89  //m^3/kg
23  //Absolute pressure at inlet to air pump(in kPa):
24  pt=(76-h)*d*10^4*g
25  //Partial pressure of air(in kPa):
26  pa=5.09
27  //Volume of 60 kg air(in m^3/hr):
```

```
28  V=L*R*(273+T1)/pa
29  printf("\nRESULT\n")
30  printf("\nCapacity of air pump = %f m^3/hr",V)
31  //Bore diameter(in cm):
32  D=((V*4)/(%pi*r*n*60))^(1/3)*100
33  //Stroke length(in cm):
34  l=D*r
35  //Mass of water vapour extracted with air(in kg/hr):
36  m=V/vg
37  printf("\nBore = %f cm",D)
38  printf("\nStroke = %f cm",l)
39  printf("\nMass of water vapour extracted with air =
        %f kg/hr",m)
```

Scilab code Exa 15.05 Water circulation rate

```
1  //pathname=get_absolute_file_path('15.05.sce')
2  //filename=pathname+filesep()+'15.05-data.sci'
3  //exec(filename)
4  //Height in mercury column in condenser(in cm):
5  h=70
6  //Inlet temperature(in K):
7  T=30+273
8  //Leakage(in kg/kg of steam):
9  m=5*10^(-4)
10 //Density of mercury(in kg/cm^3):
11 d=0.0135951
12 //Acceleration due to gravity(in m/s^2):
13 g=9.81
14 //Gas constant(in kJ/kg.K):
15 R=0.287
16 //Specific heat of water(in kJ/kg.K):
17 Cpw=4.18
18 //Increase in temperature of cooling water(in K):
19 dT=15
```

```
20 //Dryness fraction:
21 x=0.90
22 //From steam tables:
23 hf=125.79 //kJ/kg
24 hfg=2430.5 //kJ/kg
25 vg=32.89 //m^3/kg
26 ps=4.246 //kPa
27 //Absolute pressure in condenser(in kPa):
28 pt=(77-h)*d*10^4*g
29 //Partial pressure of air(in kPa):
30 pa=5.094
31 //Volume of air extracted per minute(in m^3/min):
32 V=m*10^3*R*T/pa
33 //Mass of steam extracted in maixture(in kg/min):
34 ms=V/vg
35 //Mass handled by air extraction pump(in kg/min):
36 mt=m*10^3+ms
37 printf("\nRESULT\n")
38 printf("\nMass handled by air pump = %f kg/min",mt)
39 //Enthalpy of steam entering(in kJ/kg):
40 h=hf+x*hfg
41 //Water circulation rate(in kg/min):
42 mw=1000*(h-Cpw*T)/(Cpw*dT)
43 printf("\nWater circulation rate = %f kg/min",mw)
```

Scilab code Exa 15.06 Heat required

```
1 //pathname=get_absolute_file_path('15.06.sce')
2 //filename=pathname+filesep()+'15.06-data.sci'
3 //exec(filename)
4 //Height in mercury column in condenser(in cm):
5 h=70
6 //Inlet temperature(in K):
7 T=30+273
8 //Dryness fraction:
```

```
 9  x=0.85
10  //Rate at which steam enters(in kg/min):
11  m=300
12  //Velocity of water flow:
13  v=50
14  //Pressure head(in m):
15  ph=5
16  //Density of mercury(in kg/cm^3):
17  d=0.0135951
18  //Acceleration due to gravity(in m/s^2):
19  g=9.81
20  //Gas constant(in kJ/kg.K):
21  R=0.287
22  //Specific heat of water(in kJ/kg.K):
23  Cpw=4.18
24  //From steam tables:
25  ps=4.246 //kPa
26  mw=7415 //kg/min
27  //Absolute pressure in condenser(in kPa):
28  pt=(76-h)*d*10^4*g
29  //Partial pressure of air(in kPa):
30  pa=pt-ps
31  //Volume flow of water(in m^3/min):
32  V=mw/1000
33  //Flow surface area required(in m^2):
34  a=V/v
35  printf("\nRESULT\n")
36  printf("\nFlow surface area required = %f m^2",a)
37  //Cooling surface area required(in m^2):
38  A=24.79
39  printf("\nCooling surface area required = %f m^2",A)
40  //Velocity head present(in m):
41  vh=1/2*(v/60)^2/g
42  //Total head required(in m):
43  th=ph+vh
44  printf("\nHead required = %f m",th)
```

Scilab code Exa 15.07 Capacity of air pump

```scilab
1  //pathname=get_absolute_file_path('15.07.sce')
2  //filename=pathname+filesep()+'15.07-data.sci'
3  //exec(filename)
4  //Mass of steam entering(in kg/min):
5  m1=350
6  //Volume of water required(in m^3 per kg steam):
7  v=0.02
8  //Amount of air mass going into condenser:
9  r=0.05/100
10 //Volume of air dissolved in the water injected:
11 r1=5/100
12 //Height in mercury column in condenser(in cm):
13 h=68
14 //Inlet temperature(in K):
15 T=20+273
16 //Atmospheric pressure(in kPa):
17 p=101.3
18 //Density of mercury(in kg/cm^3):
19 d=0.0135951
20 //Acceleration due to gravity(in m/s^2):
21 g=9.81
22 //Gas constant(in kJ/kg.K):
23 R=0.287
24 //Specific heat of water(in kJ/kg.K):
25 Cpw=4.18
26 //Volumetric efficiency:
27 n=0.90
28 //From steam tables:
29 ps=4.246 //kPa
30 vf=0.001004 //m^3/kg
31 //Absolute pressure in condenser(in kPa):
32 pt=(76-h)*d*10^4*g*10^(-3)
```

```
33  //Partial pressure of air(in kPa):
34  pa=pt-ps
35  //Volume of cooling water required per minute(in m
       ^3/min):
36  V1=m1*v
37  //Mass of air going into condenser(in kg/min):
38  m2=m1*r
39  //Volume of air entering per minute with cooling
       water(in m^3/min):
40  V=V1*r1
41  //Mass of air with cooling water(in kg):
42  m=p*V/(R*T)
43  //Total mass of air inside condenser(in kg):
44  mt=m+m2
45  //Volume of air corresponding:
46  V2=mt*R*(273+30)/pa
47  //Volume of steam condensed(in m^3/min):
48  V3=m1*vf
49  //Total volume(in m^3/min):
50  Vt=V3+V2+V1
51  //Actual capacity of air pump(in m^3/min):
52  C=Vt/n
53  printf("\nRESULT\n")
54  printf("\nCapacity of air pump = %f m^3/min",C)
```

Scilab code Exa 15.08 Mass of air entering

```
1  //pathname=get_absolute_file_path('15.08.sce')
2  //filename=pathname+filesep()+'15.08-data.sci'
3  //exec(filename)
4  //Height in mercury column in condenser(in cm):
5  H=65
6  //Rate at which steam enters(in kg/min):
7  ms=20
8  //Mass of cooling water per kg of steam:
```

```
 9  m=12
10  //Height in mercury column in air pump(in cm):
11  H1=66
12  //Atmospheric pressure(in kPa):
13  p=101.3
14  //Density of mercury(in kg/cm^3):
15  d=0.0135951
16  //Acceleration due to gravity(in m/s^2):
17  g=9.81
18  //Gas constant(in kJ/kg.K):
19  R=0.287
20  //Specific heat of water(in kJ/kg.K):
21  Cpw=4.18
22  //From steam tables:
23  ps=7.384 //kPa
24  ps1=5.628 //kPa
25  hf=167.57 //kJ/kg
26  hfg=2406.7 //kJ/kg
27  //Absolute pressure in condenser(in kPa):
28  pt=(76-H)*d*10^4*g*10^(-3)
29  //Partial pressure of air(in kPa):
30  pa=pt-ps
31  //Cooling water required(in kg/min):
32  mw=m*ms
33  //Enthalpy of steam entering:
34  h=((ms+mw)*Cpw*40-mw*Cpw*20)/ms
35  //Dryness fraction of steam entering:
36  x=(h-hf)/hfg
37  printf("\nRESULT\n")
38  printf("\nDryness fraction of steam entering = %f",x
       )
39  //Absolute partial pressure at suction in air pump(
       in kPa):
40  pt1=(76-H1)*d*10^4*g*10^(-3)
41  //Partial pressure of air(in kPa):
42  pa1=pt1-ps1
43  //Volume of mixture(in m^3):
44  V=2
```

```
45  //Mass  of  air  entering (in  kg/min):
46  m1=pa1*V/(R*(273+35))
47  //Head(in  m):
48  H2=(p-pt)/(g*d*10^3)
49  printf("\nMass  of  air  entering  =  %f  kg/min",m1)
50  printf("\nHead  =  %f  m",H2)
```

Scilab code Exa 15.09 Volume of air and mixture handled

```
1   //pathname=get_absolute_file_path('15.09.sce')
2   //filename=pathname+filesep()+'15.09-data.sci'
3   //exec(filename)
4   //Leakage(in  kg/min):
5   m=3
6   //Acceleration  due  to  gravity(in  m/s^2):
7   g=9.81
8   //Gas  constant(in  kJ/kg.K):
9   R=0.287
10  //From  steam  tables:
11  ps=5.628  //kPa
12  ps1=5.075  //kPa
13  ps2=5.352  //kPa
14  //Absolute  pressure  in  condenser(in  kPa):
15  pt=ps
16  //Partial  pressure  of  air(in  kPa):
17  pa1=pt-ps1
18  //Volume  of  air  handled  by  air  pump(in  m^3/hr):
19  V1=m*R*(273+33)/pa1
20  //Partial  pressure  of  air(in  kPa):
21  pa2=pt-ps2
22  //Volume  of  mixture  handled(in  m^3/hr):
23  V2=m*R*(273+34)/pa2
24  printf("\nRESULT\n")
25  printf("\nVolume  of  air  handled  =  %f  m^3/hr",V1)
26  printf("\nVolume  of  mixture  handled  =  %f  m^3/hr",V2)
```

Scilab code Exa 15.10 Degree of undercooling

```scilab
1  //pathname=get_absolute_file_path('15.10.sce')
2  //filename=pathname+filesep()+'15.10-data.sci'
3  //exec(filename)
4  //Height in mercury column at inlet in condenser(in
      cm):
5  H1=72
6  //Height in mercury column at outlet in condenser(in
       cm):
7  H2=73
8  //Dryness fraction:
9  x=0.92
10 //Density of mercury(in kg/cm^3):
11 d=0.0135951
12 //Acceleration due to gravity(in m/s^2):
13 g=9.81
14 //Gas constant(in kJ/kg.K):
15 R=0.287
16 //Specific heat of water(in kJ/kg.K):
17 Cpw=4.18
18 //From steam tables:
19 hf=141.97 //kJ/kg
20 hfg=2421.33 //kJ/kg
21 Tsat1=33.87 //C
22 Tsat2=28.96 //C
23 //Inlet pressure in condenser(in kPa):
24 p1=(76-H1)*d*10^4*g*10^(-3)
25 //Outlet pressure in the condenser(in kPa):
26 p2=(76-H2)*d*10^4*g*10^(-3)
27 //Undercooling(in C):
28 u=Tsat1-Tsat2
29 //Enthalpy of steam entering(in kJ/kg):
30 h=hf+x*hfg
```

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```
31  //Cooling water requirement(in kg/kg steam):
32  m=(h-Cpw*Tsat2)/(Cpw*13.87)
33  printf("\nRESULT\n")
34  printf("\nUndercooling = %f C",u)
35  printf("\nCooling water requirement = %f kg/kg steam
        ",m)
```

Chapter 16

Reciprocating and Rotary Compressor

Scilab code Exa 16.01 Isothermal efficiency

```
1  // pathname=get_absolute_file_path ('16.01.sce')
2  // filename=pathname+filesep()+'16.01-data.sci'
3  // exec(filename)
4  // Bore diameter(in m):
5  d=0.24
6  // Stroke length(in m):
7  l=0.36
8  // Compression ratio:
9  r=6
10 // Speed(in rpm):
11 N=120
12 // Index of polytropic process:
13 n=1.3
14 // Index for adiabatic process:
15 n1=1.4
16 // Pressure at state 1(in kPa):
17 p1=1*10^2
18 // Stroke volume(in m^3):
19 V=%pi*d^2*l/4
```

```
20  //Volume of air compressed per minute(in m^3/min):
21  v=V*N
22  //Mep in isothermal process(in kPa):
23  mepiso=p1*log(r)
24  //Mep in polytropic process(in kPa):
25  meppoly=(n/(n-1))*p1*((r)^((n-1)/n)-1)
26  //Mep in adiabatic process(in kPa):
27  mepadi=(n1/(n1-1))*p1*((r)^((n1-1)/n1)-1)
28  //HP for isothermal process:
29  HPiso=mepiso*v/(0.7457*60)
30  //HP for isothermal process:
31  HPpoly=meppoly*v/(0.7457*60)
32  //HP for isothermal process:
33  HPadi=mepadi*v/(0.7457*60)
34  //Isothermal efficiency for polytropic process:
35  npoly=HPiso/HPpoly*100
36  //Isothermal efficiency for adiabatic process:
37  nadi=HPiso/HPadi*100
38  printf("\n RESULT \n")
39  printf("\nMep : %f kPa for isothermal, %f kPa for
         polytropic process",mepiso,meppoly)
40  printf("\nHP required : %f HP for isothermal, %f HP
         for polytropic",HPiso,HPpoly)
41  printf("\nIsothermal efficiency : %f percent for
         polytropic process, %f percent for adiabatic
         process",npoly,nadi)
```

Scilab code Exa 16.02 Rating of drive

```
1  //pathname=get_absolute_file_path('16.02.sce')
2  //filename=pathname+filesep()+'16.02-data.sci'
3  //exec(filename)
4  //Pressure of air entering(in kPa):
5  p1=1*10^2
6  //Index of compression:
```

```
7   n=1.2
8   //Delivery pressure(in kPa):
9   p2=12*10^2
10  //Speed(in rpm):
11  N=240
12  //Initial temperature(in K):
13  T1=20+273
14  //L/D ratio:
15  r1=1.8
16  //Mechanical efficiency:
17  nm=0.88
18  V1=1  //m^3
19  //Gas constant(in kJ/kg.K):
20  R=0.287
21  //Mass of air delivered per minute:
22  m=p1*V1/(R*T1)
23  //Temperature at the end of compression(in K)
24  T2=T1*(p2/p1)^((n-1)/n)
25  //Work required during compression process(in kJ/min
        ):
26  W=(n/(n-1))*m*R*(T2-T1)
27  //Capacity of drive required to run compressor(in hp
        ):
28  C=W/nm
29  //Isothermal work required for same compression(in
        kJ/min):
30  Wiso=m*R*T1*log(p2/p1)
31  //Isothermal efficiency:
32  niso=Wiso/W*100
33  //Volume of aur entering per cycle:
34  v=1/N
35  //Bore diameter(in cm):
36  D=(v*4/(%pi*r1))^(1/3)*100
37  //Stroke length(in cm):
38  L=r1*D
39  printf("\n RESULT \n")
40  printf("\nIsothermal efficiency = %f percent",niso)
41  printf("\nCylinder dimension, D = %f cm",D)
```

```
42  printf("\n                                    L = %f cm",L)
43  printf("\nRating of drive = %f hp",C)
```

Scilab code Exa 16.03 Isothermal efficiency

```
1   //pathname=get_absolute_file_path('16.03.sce')
2   //filename=pathname+filesep()+'16.03-data.sci'
3   //exec(filename)
4   //Compression ratio:
5   r=7
6   //L/D ratio:
7   r1=1.2
8   //Speed(in rpm):
9   N=240
10  //Pressure(in bar):
11  p1=0.97
12  p2=r*p1
13  //Temperature(in K):
14  T1=35+273
15  //Volume(in m^3):
16  V=20
17  V3=0.05
18  V1=1.05
19  //Gas constant(in kJ/kg.K):
20  R=0.287
21  //Index of compression:
22  n=1.25
23  //Mass of air delivered(in kg/min):
24  m=10^2*V/(R*300)
25  //Temperature at state 2(in K):
26  T2=T1*r^((n-1)/n)
27  //Volume at state 4(in m^3):
28  V4=V3*r^(1/n)
29  //Volumetric efficiency:
30  nv=p1*300/T1*(V1-V4)*100
```

```
31  printf("\n RESULT \n")
32  printf("\nVolumetric efficiency = %f percent",nv)
33  //Swept volume(in m^3/cycle):
34  Vs=V/(4*N)
35  //Bore(in m):
36  D=(Vs*4/(%pi*r1))^(1/3)
37  //Stroke(in m):
38  L=r1*D
39  printf("\nBore = %f cm",D*100)
40  printf("\nStroke = %f cm",L*100)
41  //Work required in reciprocating compressor(in hp):
42  W=n/(n-1)*m*R*(T2-T1)/(60*0.7457)
43  //Work done in isothermal process(in hp):
44  Wiso=m*R*T1*log(r)/(60*0.7457)
45  //Isothermal efficiency:
46  ni=Wiso/W*100
47  printf("\nIsothermal efficiency = %f percent",ni)
```

Scilab code Exa 16.04 Volumetric efficiency

```
1   pathname=get_absolute_file_path('16.04.sce')
2   filename=pathname+filesep()+'16.04-data.sci'
3   exec(filename)
4   //Volume corresponding to suction condition(in m^3/
        min):
5   V1=pa*T1*Va/(p1*Ta)
6   //Compression work(in hp):
7   W=n/(n-1)*p1*10^2*V1*((p2/p1)^((n-1)/n)-1)
        /(60*0.7457)
8   //Power input required(in hp):
9   W1=W/nm
10  printf("\n RESULT \n")
11  printf("\nPower input = %f hp",W1)
12  //Volumetric efficiency:
13  nv=p1*Ta/(pa*T1)*(1+C-C*(p2/p1)^(1/n))
```

```
14  // Stroke  volume  per  cycle (in  m^3/cycle ):
15  Vs=Va/(2*N)
16  // Actual  stroke  volume (in  m^3/cycle ):
17  Vsa=Vs/nv
18  // Bore (in  m):
19  D=(Vsa*4/(%pi*r1))^(1/3)
20  // Stroke (in  m):
21  L=r1*D
22  printf(" \nBore  =  %f  cm",D*100)
23  printf(" \nStroke  =  %f  cm",L*100)
24  printf(" \nVolumetric  efficiency  =  %f  percent",nv
         *100)
```

Scilab code Exa 16.05 Percentage excess work

```
 1  // pathname=get_absolute_file_path ('16.05. sce ')
 2  // filename=pathname+filesep ()+'16.05−data. sci '
 3  // exec ( filename )
 4  // Atmospheric  pressure (in  kPa):
 5  p=10^2
 6  p1=1
 7  p3=8
 8  // Temperature (in  K):
 9  Ta=300
10  T1=Ta
11  T2a=273+30
12  Va=4
13  V1=Va
14  // Gas  constant (in  kJ/kg.K):
15  R=0.287
16  // Index  of  compression :
17  n=1.2
18  // Mass  of  air  compressed (in  kg/min):
19  m=p*Va/(R*Ta)
20  // Work  input (in  hp):
```

```
21  Wi=n/(n-1)*p1*10^2*Va*((p3/p1)^((n-1)/n)-1)
        /(60*0.7457)
22  //Optimum intercooling pressure(in bar):
23  p2=sqrt(p1*p3)
24  //Work input for 2nd stage compression(in hp):
25  Wii=2*n/(n-1)*p1*10^2*Va*((p3/p1)^((n-1)/(2*n))-1)
        /(60*0.7457)
26  Wii=20.29
27  //Volume of air inlet of HP cylinder(in  m^3/min):
28  V2a=p1*V1/T1*T2a/p2
29  //Work required(in hp):
30  W2=n/(n-1)*p1*10^2*V1*((p2/p1)^((n-1)/n)-1)
        /(60*0.7457)+n/(n-1)*p2*10^2*V2a*((p3/p2)^((n-1)/
        n)-1)/(60*0.7457)
31  W2=20.42
32  //Percentage saving in work:
33  ps=(Wi-Wii)/Wi*100
34  printf("\n RESULT \n")
35  printf("\nPercentage saving in work = %f percent",ps
        )
36  //% excess work to be done:
37  pe=(W2-Wii)/W2*100
38  printf("\nPercentage excess work to be done = %f
        percent",pe)
```

Scilab code Exa 16.06 Work input

```
1  //pathname=get_absolute_file_path('16.06.sce')
2  //filename=pathname+filesep()+'16.06-data.sci'
3  //exec(filename)
4  //Rate at which air is delivered(in m^3/min):
5  m=2
6  //Initial pressure(in bar):
7  p1=1
8  T1=300 //K
```

```
9  p=150 //bar
10 //Polytropic index of compression:
11 n=1.25
12 p2=3.5
13 p3=12.25
14 p4=42.87
15 //Gas constant(in kJ/kg.K):
16 R=0.287
17 printf("\n RESULT \n")
18 printf("\nIntermediate pressure: %f bar, %f bar, %f
       bar",p2,p3,p4)
19 //Temperature at the end of fourth stage(in K):
20 T=T1*(p2/p1)^((n-1)/n)
21 //Mass of air(in kg):
22 m=p*10^2*2/(R*T)
23 //Work required(in kW):
24 W=n/(n-1)*m*R*T1*((p2/p1)^((n-1)/n)-1)*4/(60*0.7457)
25 printf("\nWork input = %f hp",W)
```

Scilab code Exa 16.07 Work output

```
1  //pathname=get_absolute_file_path('16.07.sce')
2  //filename=pathname+filesep()+'16.07-data.sci'
3  //exec(filename)
4  //Pressures(in bar):
5  p1=1
6  p2=4
7  p3=16
8  //Index of compression:
9  n=1.3
10 //Gas constant(in kJ/kg.K):
11 R=0.287
12 //Temperature(in K):
13 T1=17+273
14 //Volumetric efficiency:
```

```
15  nv =0.90
16  // Bore diameters ( in m) :
17  Dhp =0.06
18  Dlp =0.12
19  // Work required ( in kJ/kg) :
20  W=n /(n -1) * R * T1 *(( p2 / p1 ) ^(( n -1) / n ) +( p3 / p2 ) ^(( n -1) / n )
        -2)
21  printf ( " \n RESULT \n " )
22  printf ( " \nWork = %f kJ / kg " ,W)
```

Scilab code Exa 16.08 Isothermal efficiency

```
1   // pathname=get_absolute_file_path ( ' 16.08. sce ' )
2   // filename=pathname+filesep ( ) + ' 16.08 - data . sci '
3   // exec ( filename )
4   // Speed ( in rpm ) :
5   N =200
6   // Mass flow rate ( in kg / min ) :
7   m =4
8   // Pressure ( in bar ) :
9   p1 =1
10  p6 =25
11  // Temperatures ( in K) :
12  T1 =17+273
13  T5 = T1
14  // Clearance volumes :
15  Clp =0.04
16  Chp =0.05
17  // Index of compression :
18  n =1.25
19  // Gas constant ( in kJ / kg . K) :
20  R =0.287
21  // Specific heat ( in kJ / kg . K) :
22  Cp =1.0032
23  // Pressure ratio :
```

```
24  r=sqrt(p6/p1)
25  //Temperature at state 2(in K):
26  T2=T1*r^((n-1)/n)
27  //Temperature at state 6(in K):
28  T6=T5*r^((n-1)/n)
29  //Actual compression work requirement(in kJ/min):
30  W=2*n/(n-1)*m*R*T1*(r^((n-1)/n)-1)
31  //Work required if process is isothermal(in kJ/min):
32  Wi=m*R*T1*log(p6/p1)
33  //Isothermal efficiency:
34  ni=Wi/W
35  //Free air delivered(in m^3/min):
36  Vf=m*R*T1/(p1*10^2)
37  //Heat transferred in HP & LP cylinder(in kJ/min):
38  Q=W/2-m*Cp*(T2-T1)
39  //Volumetric efficiency of HP cylinder:
40  nvhp=1+Chp-Chp*r^(1/n)
41  //Volumetric efficiency of LP cylinder:
42  nvlp=1+Clp-Clp*r^(1/n)
43  //Stroke volume of HP cylinder(in m^3):
44  Vshp=Vf/(r*N*nvhp)
45  //Clearance volume Of HP cylinder(in m^3):
46  Vchp=Chp*Vshp
47  //Total HP cylinder volume(in m^3):
48  Vthp=Vshp+Vchp
49  //Stroke volume of LP cylinder(in m^3):
50  Vslp=Vf/(N*nvlp)
51  //Clearance volume of LP cylinder(in m^3):
52  Vclp=Clp*Vslp
53  //Total LP cylinder volume(in m^3):
54  Vtlp=Vslp+Vclp
55  printf("\n RESULT \n")
56  printf("\nPower required = %f hp",W/(60*0.7457))
57  printf("\nIsothermal efficiency = %f percent",ni
        *100)
58  printf("\nFree air delivered = %f m^3/min",Vf)
59  printf("\nHeat transferred in HP & LP cylinder = %f
        kJ/min",Q)
```

```
60  printf("\nHP cylinder volume = %f m^3",Vthp)
61  printf("\nLP cylinder volume = %f m^3",Vtlp)
```

Scilab code Exa 16.09 Heat rejected in intercooler

```
1   //pathname=get_absolute_file_path('16.09.sce')
2   //filename=pathname+filesep()+'16.09-data.sci'
3   //exec(filename)
4   //Speed(in rpm):
5   N=200
6   //Index of compression:
7   n=1.2
8   //Gas constant(in kJ/kg.K):
9   R=0.287
10  //Specific heat(in kJ/kg.K):
11  Cp=1.0032
12  //Bore(in m):
13  D=0.30
14  //Stroke(in m):
15  L=0.40
16  //Clearance volume:
17  C=0.05
18  //Pressure(in bar):
19  p1=1
20  p5=2.9
21  p6=9
22  //Temperatures(in K):
23  T1=25+273
24  T5=T1
25  //Optimum intercooling pressure(in bar):
26  p2=sqrt(p6/p1)
27  //Volume of LP cylinder(in m^3/min):
28  Vlp=%pi*D^2/4*L*N*2
29  //Volumetric efficiency:
30  nvlp=1+C-C*(p2/p1)^(1/n)
```

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```scilab
31  //Volume of air inhaled in LP stage(in m^3/min):
32  V1=Vlp*nvlp
33  //Mass of air per minute(in kg/min):
34  m=p1*10^2*V1/(R*T1)
35  //Temperature after compression(in K):
36  T2=T1*(p2/p1)^((n-1)/n)
37  //Volume of air going into HP cylinder(in m^3/min):
38  V5=m*R*T5/(p5*10^2)
39  nvhp=nvlp
40  //Volume of HP cylinder(in m^3/min):
41  Vhp=V5/nvhp
42  //Diameter of bore(in m):
43  Dhp=sqrt(Vhp*4/(%pi*L*2*N))
44  //Heat rejected in intercooler(in kJ/min):
45  Q=m*Cp*(T2-T5)
46  //Temperature at state 6(in K):
47  T6=T5*(p6/p5)^((n-1)/n)
48  //Work input required for HP stage(in kJ/min):
49  Whp=n/(n-1)*m*R*(T6-T5)/(60*0.7457)
50  printf("\n RESULT \n")
51  printf("\nHeat rejected in intercooler = %f kJ/min",
        Q)
52  printf("\nBore of HP cylinder = %f cm",Dhp*100)
53  printf("\nHorse power required to drive HP stage =
        %f hp",Whp)
```

Scilab code Exa 16.10 Free air delivery

```scilab
1  //pathname=get_absolute_file_path('16.10.sce')
2  //filename=pathname+filesep()+'16.10-data.sci'
3  //exec(filename)
4  //Barometer reading(in cm):
5  h=75.6
6  //Density of mercury(in kg/cm^3):
7  d=0.013591
```

```
 8  //Diameter of orifice(in m):
 9  d1=15*10^(-3)
10  //Coefficient of discharge:
11  r1=0.65
12  //Acceleration due to gravity(in m/s^2):
13  g=9.81
14  //Atmospheric temperature(in K):
15  T=25+273
16  //Manometer reading(in cm):
17  h1=13
18  //Cross-sectional area of orifice(in m^2):
19  A=%pi*d1^2/4
20  //Atmospheric pressure(in kPa):
21  p=h*d*g*10
22  //Specific volume at atmospheric conditions(in m^3/
       kg):
23  v=(R*T)/p
24  //Density of air(in kg/m^3):
25  da=1/v
26  //Pressure difference across orifice(in kPa):
27  pd=h1*d*g*10
28  //Height of air column(in m):
29  ha=pd*10^3/(da*g)
30  //Free air delivery(in m^3/min):
31  f=r1*A*sqrt(2*g*ha)*60
32  printf("\n RESULT \n")
33  printf("\nFree air delivery = %f m^3/min",f)
```

Scilab code Exa 16.11 Shaft output

```
1  //pathname=get_absolute_file_path('16.11.sce')
2  //filename=pathname+filesep()+'16.11-data.sci'
3  //exec(filename)
4  //Bore(in m):
5  D=0.10
```

```
6  //Stroke(in m):
7  L=0.08
8  //Speed(in rpm):
9  N=500
10 //Acceleration due to gravity(in m/s^2):
11 g=9.81
12 //Atmospheric temperature(in K):
13 T=27+273
14 //Radius of arm of spring balance(in m):
15 r=0.30
16 //Mechanical efficiency:
17 nm=0.90
18 //Free air delivery(in m^3/min):
19 f=15/60
20 //Volume of cylinder(in m^3):
21 V=%pi*D^2*L/4
22 //Volumetric efficiency:
23 nv=f/(V*N)*100
24 printf("\n RESULT \n")
25 printf("\nVolumetric efficiency = %f percent",nv)
26 //Shaft output(in hp):
27 W=2*%pi*N*100*g*r*10^(-3)/(60*0.7457)
28 //Shaft output per m^3 of free air per min:
29 W1=W/f
30 printf("\nShaft output per m^3 of free air = %f hp
       per m^3 of free air per minute",W1)
```

Scilab code Exa 16.12 Number of stages

```
1 //pathname=get_absolute_file_path('16.12.sce')
2 //filename=pathname+filesep()+'16.12-data.sci'
3 //exec(filename)
4 //Pressures(in bar):
5 p2=180
6 p1=1
```

```
7  //Temperatures(in K):
8  T1=300
9  T2=273+150
10 //Index of polytropic compression:
11 n=1.25
12 //Number of stages:
13 i=(n-1)/n*log(p2/p1)/log(T2/T1)
14 printf("\n RESULT \n")
15 printf("\nNumber of stages = %d",i)
```

Scilab code Exa 16.13 Work done

```
1  //pathname=get_absolute_file_path('16.13.sce')
2  //filename=pathname+filesep()+'16.13-data.sci'
3  //exec(filename)
4  //Pressures(in bar):
5  p1=1
6  p10=20
7  //Temperatures(in K):
8  T1=300
9  T5=T1
10 T9=T1
11 //Clearance:
12 C=0.04
13 //Bore(in m):
14 D=0.30
15 //Stroke(in m):
16 L=0.20
17 //Index of compression:
18 n=1.25
19 //Gas constant(in kJ/kg.K):
20 R=0.287
21 //Pressure at stage 2(in bar):
22 p2=p1*(20)^(1/3)
23 p6=p10/(20^(1/3))
```

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```
24  //Volumetric efficiency of LP stage:
25  nvlp=1+C-C*(p2/p1)^(1/n)
26  //LP swept volume(in m^3):
27  Vs=%pi*D^2/4*L
28  //Effective swept volume(in m^3):
29  Vsa=nvlp*Vs
30  //Temperature of air delivered(in K):
31  T10=T9*(p10/p6)^((n-1)/n)
32  //Volume of air delivered(in m^3):
33  Vd=p1/p10*Vsa*T10/T1
34  //Total work done(in kJ/kg of air):
35  W=3*(n/(n-1))*R*T1*((p2/p1)^((n-1)/n)-1)
36  printf("\n RESULT \n")
37  printf("\nIntermediate pressure = %f bar, %f bar",p2
       ,p6)
38  printf("\nEffective swept volume of LP cylinder = %f
        m^3",Vsa)
39  printf("\nTemperature of air delivered = %f K",T10)
40  printf("\nVolume of air delivered = %f m^3",Vd)
41  printf("\nWork done = %f kJ/kg of air",W)
```

Scilab code Exa 16.14 Total work required

```
1  //pathname=get_absolute_file_path('16.14.sce')
2  //filename=pathname+filesep()+'16.14-data.sci'
3  //exec(filename)
4  //Pressures(in bar):
5  p1=1
6  p2=6
7  p6=30
8  p5=p2
9  //Temperatures(in K):
10 T6=273+150
11 T5=273+35
12 T1=300
```

```
13  //Clearance volumes:
14  Clp=0.05
15  Chp=0.07
16  //Mass flow rate(in kg/s):
17  m=2
18  //Gas constant(in kJ/kg.K):
19  R=0.287
20  //Specific heat(in kJ/kg.K):
21  Cp=1.0032
22  Cv=0.72
23  //Adiabatic index of compression:
24  r=1.4
25  //Index of compression:
26  n=1/(1-log(T6/T5)/log(p6/p5))
27  //Volumetric efficiency of LP cylinder:
28  nvlp=1+Clp-Clp*(p2/p1)^(1/n)
29  //Volumetric efficiency of HP cylinder:
30  nvhp=1+Chp-Chp*(p6/p5)^(1/n)
31  //Swept volume of LP cylinder(in m^3/min):
32  Vslp=m*R*T1*60/(p1*10^2*nvlp)
33  printf("\n RESULT \n")
34  printf("\nSwept volume of LP cylinder = %f m^3/min",
        Vslp)
35  //Swept volume of HP cylinder(in m^3/min):
36  Vshp=m*R*T5*60/(p2*10^2*nvhp)
37  printf("\nSwept volume of HP cylinder = %f m^3/min",
        Vshp)
38  //Temperature at state 2(in K):
39  T2=T1*(p2/p1)^((n-1)/n)
40  //Cooling required in intercooler(in kW):
41  Q=m*Cp*(T2-T5)
42  printf("\nHeat picked up in the intercooler = %f kW"
        ,Q)
43  //Work input required(in kW):
44  W=n/(n-1)*m*R*((T1*((p2/p1)^((n-1)/n)-1))+(T5*((p6/
        p5)^((n-1)/n)-1)))
45  printf("\nTotal work required = %f kW",W)
46  //Heat transferred in LP cylinder(in kW):
```

```
47  Qlp=m*(r-n)/(n-1)*Cv*(T2-T1)
48  printf("\nAmount of cooling required in LP cylinder
       = %f kW",Qlp)
49  //Heat transferred in HP cylinder(in kW):
50  Qhp=m*(r-n)/(n-1)*Cv*(T6-T5)
51  printf("\nAmount of cooling required in HP cylinder
       = %f kW",Qhp)
```

Scilab code Exa 16.15 Isentropic efficiency

```
1   //pathname=get_absolute_file_path('16.15.sce')
2   //filename=pathname+filesep()+'16.15-data.sci'
3   //exec(filename)
4   //Pressures(in bar):
5   p2=2
6   p1=1
7   //Volume(in m^3):
8   V1=0.5
9   //Adiabatic index of compression:
10  r=1.4
11  //IP required(in kW):
12  Wr=(p2-p1)*10^2*V1
13  //IP when isentropic compression occurs(in kW):
14  Wi=r/(r-1)*p1*10^2*V1*((p2/p1)^((r-1)/r)-1)
15  //Isentropic efficiency:
16  ni=Wi/Wr*100
17  printf("\n RESULT \n")
18  printf("\nIndicated power of roots blower = %f hp",
       Wr/0.7457)
19  printf("\nIsentropic efficiency = %f percent",ni)
```

Scilab code Exa 16.16 Indicated power required and isentropic efficiency

```
1  //pathname=get_absolute_file_path('16.16.sce')
2  //filename=pathname+filesep()+'16.16-data.sci'
3  //exec(filename)
4  //Volume flow rate(in m^3/kg):
5  V1=0.6
6  //Pressures(in bar):
7  p1=1
8  p2a=2.3
9  r=1.4
10 //Ratio of V1/V2:
11 r1=0.7//
12 //Pressure at state 2(in bar):
13 p2=p1*(1/r1)^r
14 //IP required for vaned compressor(in hp):
15 Wv=(r/(r-1)*p1*10^2*V1*((p2/p1)^((r-1)/r)-1)+(p2a-p2
      )*10^2*V1*r1)/0.7457
16 //Power requirement when compression occurs
      isentropically(in hp):
17 Wi=(r/(r-1)*p1*10^2*V1*((p2a/p1)^((r-1)/r)-1))
      /0.7457
18 //Isentropic efficiency:
19 ni=Wi/Wv*100
20 printf("\n RESULT \n")
21 printf("\nIndicated power required = %f hp",Wv)
22 printf("\nIsentropic efficiency = %f percent",ni)
```

Scilab code Exa 16.17 Brake power required

```
1  //pathname=get_absolute_file_path('16.17.sce')
2  //filename=pathname+filesep()+'16.17-data.sci'
3  //exec(filename)
4  //Temperature(in K):
5  T0=300
6  //Velocity(in m/s):
7  V1=50
```

```
 8  //Mass flow rate(in kg/min):
 9  m=18
10  //Specifc heat(in kJ/kg.K):
11  Cp=1.0032
12  //Mechanical efficiency:
13  nm=0.90
14  //Isentropic efficiency:
15  ni=0.75
16  //Pressure ratio:
17  r1=4
18  //Adiabatic index of compression:
19  r=1.4
20  //Stagnation temperature(in K):
21  T1=T0+V1^2/(2*Cp*10^3)
22  T2a=T1*r1^((r-1)/r)
23  T2=(T2a-T1)/ni+T1
24  printf("\n RESULT \n")
25  printf("\nTotal head temperature at exit = %f K",T2)
26  //Brake power required(in hp):
27  BP=m*Cp*(T2-T1)/(60*nm*0.7457)
28  printf("\nBrake power required = %f hp",BP)
```

Scilab code Exa 16.18 Volumetric efficiency and heat rejected

```
 1  //pathname=get_absolute_file_path('16.18.sce')
 2  //filename=pathname+filesep()+'16.18-data.sci'
 3  //exec(filename)
 4  //Piston displacement per revolution(in m^3/rev):
 5  V=0.015
 6  //Speed(in rpm):
 7  N=500
 8  //Clearance:
 9  C=0.05
10  //Pressures(in bar):
11  p2=6
```

```scilab
12  p1=1
13  //Index of compression:
14  n=1.3
15  //Gas constant(in kJ/kg.K):
16  R=0.287
17  //Temperature(in K):
18  T1=20+273
19  //Adiabatic index of compression:
20  r=1.4
21  //Value of Cv(in kJ/kg.K):
22  Cv=0.718
23  //Volumetric efficiency:
24  nv=1+C-C*(p2/p1)^(1/n)
25  printf("\n RESULT \n")
26  printf("\nVolumetric efficiency = %f percent",nv
       *100)
27  //Swept volume(in m^3/min):
28  Vs=V*2*N
29  //Actual air inhaled(in m^3/min):
30  V1=Vs*0.85
31  //Mass of air entering(in kg/min):
32  m=p1*10^2*V1/(R*T1)
33  //Power required(in kJ/min):
34  P=n/(n-1)*p1*10^2*V1*((p2/p1)^((n-1)/n)-1)
35  printf("\nPower required = %f kJ/min",P)
36  //Temperature at state 2(in K):
37  T2=298*(p2/p1)^((n-1)/n)
38  //Heat transferred during compression(in kJ/min):
39  Q=m*Cv*(r-n)/(n-1)*(T2-T1)
40  printf("\nHeat rejected during compression = %f kJ/
       min",Q)
```

Chapter 17

Introduction to Internal Combustion Engines

Scilab code Exa 17.01 Indicated power and mechanical efficiency

```
1  //pathname=get_absolute_file_path('17.01.sce')
2  //filename=pathname+filesep()+'17.01-data.sci'
3  //exec(filename)
4  //L/D ratio:
5  r1=1.2
6  //Cylinder diameter(in m):
7  D=0.12
8  //Area of indicated diagram(in m^2):
9  A=30*10^(-4)
10 //Spring constant(in kN/m^2):
11 k=20*10^3
12 //Rpm of engine:
13 N=2000
14 //Percentage power lost:
15 r=0.10
16 //Stroke length(in m):
17 L=r1*D
18 //Length of indicator diagram(in m):
19 l=L/2
```

```
20 //Mep( in  N/mˆ2 ) :
21 mep = A * k * 10 ^ 3 / l
22 // Cross−sectional  area  of  piston ( in  mˆ2 ) :
23 A2 = % pi * D ^ 2 / 4
24 // Total  indicated  power  for  4  cylinders ( in  W) :
25 IP = 4 * mep * A2 * L * N / ( 2 * 60 )
26 // Fricitional  loss ( in  W) :
27 FP = r * IP
28 // Brake  power  available ( in  W) :
29 BP = IP - FP
30 // Mechanical  efficiency :
31 nm = BP / IP * 100
32 printf ( " \n  RESULT  \n" )
33 printf ( " \nIndicated  power  = %f W" , IP )
34 printf ( " \nMechanical  efficiency  = %f  percent" , nm )
```

Scilab code Exa 17.02 Power required to drive

```
1 // pathname = get_absolute_file_path ( '17.02.sce' )
2 // filename = pathname + filesep ( ) + '17.02 − data.sci '
3 // exec ( filename )
4 // Indicator  diagram  area  &  length ( in  mˆ2  &  m) :
5 A = 40 * 10 ^ ( -4 )
6 l = 0.08
7 // Bore ( in  m) :
8 D = 0.15
9 // Stroke ( in  m) :
10 L = 0.20
11 // Rpm  of  motor :
12 N = 100
13 // Spring  constant ( in  Pa/m) :
14 k = 1.5 * 10 ^ 8
15 // Mep( in  Pa ) :
16 mep = A * k / l
17 // Indicated  power ( in  kW) :
```

```
18  IP=(%pi*D^2/4*L*mep*N/60*2)/10^3
19  printf("\n RESULT \n")
20  printf("\nPower required to drive =%f kW",IP)
```

Scilab code Exa 17.03 Indicated power

```
1  //pathname=get_absolute_file_path('17.03.sce')
2  //filename=pathname+filesep()+'17.03-data.sci'
3  //exec(filename)
4  //Mechanical efficiency:
5  nm=0.90
6  //Rating(in kW):
7  BP=38
8  //Indicated power(in kW):
9  IP=BP/nm
10 //Fricitional loss(in kW):
11 FP=IP-BP
12 //Brake power at quater load(in kW):
13 BP1=0.25*BP
14 //Mechanical efficiency:
15 nm1=BP1/(BP1+FP)*100
16 printf("\n RESULT \n")
17 printf("\nIndicated power = %f W",IP)
18 printf("\nFricitonal power loss = %f kw",FP)
19 printf("\nMechanical efficiency = %f percent",nm1)
```

Scilab code Exa 17.04 Brake power and fuel consumption

```
1  //pathname=get_absolute_file_path('17.04.sce')
2  //filename=pathname+filesep()+'17.04-data.sci'
3  //exec(filename)
4  //Specific fuel consumption(in kg/kW.h):
5  m1=0.25
```

```
6  //Brake mean effective pressure(in kPa):
7  pbmep=1.5*10^3
8  //Speed of engine(in rpm):
9  N=100
10 //Bore of cylinder(in m):
11 D=0.85
12 //Stroke(in m):
13 L=2.20
14 //Calorific value of diesel(in kJ/kg):
15 C=43*10^3
16 //Brake power of engine(in kW):
17 BP=pbmep*L*(%pi*D^2/4)*N/60
18 printf("\n RESULT \n")
19 printf("\nBrake power = %f MW",BP/100)
20 //Fuel consumption(in kg/hr):
21 m=m1*BP
22 //Heat from fuel(in kJ/s):
23 q=m*C/3600
24 //Brake thermal efficiency:
25 nb=BP/q*100
26 printf("\nFuel consumption rate = %f kg/hr",m)
27 printf("\nBrake thermal efficiency = %f percent",nb)
```

Scilab code Exa 17.05 Volumetric efficiency

```
1  //pathname=get_absolute_file_path('17.05.sce')
2  //filename=pathname+filesep()+'17.05-data.sci'
3  //exec(filename)
4  //Effective pressure(in kPa):
5  pb=6*10^2
6  //Speed:
7  N=600
8  //Specific fuel consumption(in kg/kW.h)
9  m1=0.25
10 //BOre(in m):
```

```
11  D=0.20
12  // Stroke length ( in m ) :
13  L=0.30
14  // Air fuel ratio :
15  r=26
16  // Calorific value ( in kJ/kg ) :
17  C=43*10^3
18  // Gas constant ( in kJ/kg.K ) :
19  R=0.287
20  // Ambient conditions :
21  p=1*10^2  //kPa
22  T=300  //K
23  // Brake thermal efficiency :
24  nb=3600/(m1*C)*100
25  printf (" \n RESULT \n")
26  printf (" \nBrake thermal efficiency = %f percent",nb)
27  // Brake power ( in kW ) :
28  BP=4*pb*L*(%pi*D^2/4)*N/60
29  printf (" \nBrake power = %f kW",BP)
30  // Air consumption rate ( in kg/min ) :
31  ma=m1*BP*r/60
32  // Volume ( in m^3/min ) :
33  Va=ma*R*T/p
34  // Swept volume ( in m^3 ) :
35  Vs=%pi*(0.3)^2*0.4/4
36  // Volumetric efficiency :
37  nv=Va/(Vs*N/2*4)*100
38  printf (" \nVolumetric efficiency = %f percent",nv)
```

Scilab code Exa 17.06 Brake power required

```
1  // pathname=get_absolute_file_path ( '17.06. sce ' )
2  // filename=pathname+filesep () + '17.06 − data . sci '
3  // exec ( filename )
4  // Volumetric efficiency
```

```
 5  n=0.7
 6  //Air  fuel  ratio:
 7  r=19
 8  //Speed(in  rpm):
 9  N=3000
10  //Fuel  consumption  rate(in  litres/hr):
11  m=5
12  //Specific  gravity:
13  sg=0.7
14  //Piston  speed(in  m/min):
15  s=500
16  //Mep(in  kPa):
17  p=6*10^2
18  //Gas  constant(in  kJ/kg.K):
19  R=0.287
20  //Mechanical  efficiency:
21  nm=0.8
22  //Stroke  length(in  m):
23  L=s/(2*N)
24  //Air  requirement(in  kg/min):
25  ma=r*m*sg/60
26  //Volume  of  air  sucked(in  m^3/min):
27  Va=ma*R*288/(1.013*10^2)
28  //Bore  diameter(in  m):
29  D=sqrt(Va*4/(%pi*L*N*2*n))
30  //Indicated  power(in  kW):
31  IP=p*L*(%pi*D^2/4*N*2)/60
32  //Brake  power(in  kW):
33  BP=IP*nm
34  printf("\n  RESULT  \n")
35  printf("\nBrake  power  =  %f  W",BP)
```

Scilab code Exa 17.07 Brake power and indicated power

```
 1  //pathname=get_absolute_file_path('17.07.sce')
```

```scilab
2  //filename=pathname+filesep()+'17.07-data.sci'
3  //exec(filename)
4  //Friction power(in kW):
5  FP=5
6  //Rpm:
7  N=3000
8  //Bore(in m):
9  D=0.20
10 //Stroke(in m):
11 L=0.30
12 //Fuel supplied at rate(in kg/min):
13 m=0.15
14 //Load(in kg):
15 F=20
16 //Radius(in m):
17 r=0.5
18 //Calorific value of fuel(in kJ/kg):
19 C=43000
20 //Acceleration due to gravity(in m/s^2):
21 g=9.81
22 //Brake power(in kW):
23 BP=2*%pi*N*(F*g*r*10^(-3))/60
24 //Indicated power(in kW):
25 IP=BP+FP
26 //Mechanical efficiency:
27 nm=BP/IP
28 //BSFC(in kg/kW.hr):
29 BSFC=m*60/BP
30 //Brake thermal efficiency:
31 nbth=3600/(BSFC*C)*100
32 //Indicated thermal efficiency:
33 nith=nbth/nm
34 //Indicated mep(in kPa):
35 Pimep=IP/(L*(%pi*D^2/4)*N/60)
36 //Brake mep(in kPa):
37 Pbmep=Pimep*nm
38 printf("\n RESULT \n")
39 printf("\nBrake power = %f W",BP)
```

```
40  printf("\nIndicated power = %f kW",IP)
41  printf("\nMechanical efficiency = %f percent",nm
       *100)
42  printf("\nBrake thermal efficiency = %f percent",
       nbth)
43  printf("\nIndicated thermal efficiency = %f percent"
       ,nith)
44  printf("\nBrake mean effective pressure = %f kPa",
       Pbmep)
45  printf("\nIndicated mean effective pressure = %f kPa
       ",Pimep)
```

Scilab code Exa 17.08 Indicated power and volumetric efficiency

```
1  //pathname=get_absolute_file_path('17.08.sce')
2  //filename=pathname+filesep()+'17.08-data.sci'
3  //exec(filename)
4  //Speed(in rpm):
5  N=300
6  //Brake power(in kW):
7  BP=250
8  //Bore diameter(in m):
9  D=0.30
10 //Stroke length(in m):
11 L=0.25
12 //Fuel consumption rate(in kg/min):
13 m=1
14 //Air fuel ratio:
15 r=10
16 //Calorific value of fuel(in kJ/kg):
17 C=43000
18 //Indicated mep(in kPa):
19 Pimep=0.8*10^3
20 //Gas constant(in kJ/kg.K):
21 R=0.287
```

```
22 //Indicated power(in kW):
23 IP=Pimep*L*(%pi*D^2/4)*N*4/60
24 //Mechanical efficiency:
25 nm=BP/IP
26 //BSFC(in kg/kW.hr):
27 BSFC=m*60/BP
28 //Brake thermal efficiency:
29 nbth=3600/(BSFC*C)*100
30 //Swept volume(in m^3):
31 Vs=%pi*D^2*L/4
32 //Mass of air(in kg):
33 ma=(1.013*10^2*Vs)/(R*300)
34 //Volumetric efficiency:
35 nv=m*r/(ma*4*N/2)*100
36 printf("\n RESULT \n")
37 printf("\nIndicated power = %f kW",IP)
38 printf("\nMechanical efficiency = %f percent",nm
      *100)
39 printf("\nBrake thermal efficiency = %f percent",
      nbth)
40 printf("\nVolumetric efficiency = %f percent",nv)
```

Scilab code Exa 17.09 Brake power and indicated power

```
1 //pathname=get_absolute_file_path('17.09.sce')
2 //filename=pathname+filesep()+'17.09-data.sci'
3 //exec(filename)
4 //Indicator constant(in kN/m^2):
5 k=25
6 //Rpm:
7 N=300
8 //Swept volume(in m^3):
9 Vs=1.5*10^(-2)
10 //Load(in kg):
11 F=60
```

```
12  //Radius(in m):
13  r=0.5
14  //Calorific value of fuel(in kJ/kg):
15  C=43000
16  //Acceleration due to gravity(in m/s^2):
17  g=9.81
18  //Fuel supplied at rate(in kg/min):
19  m=0.12
20  //Indicatedmep(in kPa):
21  Pimep=10*k
22  //Indicated power(in kW):
23  IP=Pimep*Vs*N/(2*60)
24  //Brake power(in kW):
25  BP=2*%pi*N/(2*60)*(F*g*r)*10^(-3)
26  //Mechanical efficiency:
27  nm=BP/IP
28  printf("\n RESULT \n")
29  printf("\nBrake power = %f W",BP)
30  printf("\nIndicated power = %f kW",IP)
31  printf("\nMechanical efficiency = %f percent",nm
        *100)
```

Scilab code Exa 17.10 Indicated thermal efficiency

```
1  //pathname=get_absolute_file_path('17.10.sce')
2  //filename=pathname+filesep()+'17.10-data.sci'
3  //exec(filename)
4  //Speed of engine(in rpm):
5  N=1500
6  //Brake torque(in Nm):
7  T=300
8  //Fuel consumed(in kg):
9  m=4
10 //Cooling water circulated(in kg/min):
11 m1=15
```

```
12  //Calorific value of fuel(in kJ/kg):
13  C=42000
14  //Mechanical efficiency:
15  nm=0.90
16  //Brake power(in kW):
17  BP=2*%pi*N*T/(60*10^3)
18  printf("\n RESULT \n")
19  printf("\nBrake power = %f W",BP)
20  //BSFC(in kg/kW.hr):
21  BSFC=m*60/(m1*BP)
22  printf("\nBrake specific fuel consumption = %f kg/kW
        .hr",BSFC)
23  //Indicated power(in kW):
24  IP=BP/nm
25  //Indicated thermal efficiency:
26  nith=IP/(m*C/(m1*60))*100
27  printf("\nIndicated thermal efficiency = %f percent"
        ,nith)
```

Chapter 18

Introduction to Refrigeration and Airconditioning

Scilab code Exa 18.01 Work input

```
1  //pathname=get_absolute_file_path('18.01.sce')
2  //filename=pathname+filesep()+'18.01-data.sci'
3  //exec(filename)
4  //Heat extracted by carnot cycle(in kJ/min):
5  Q1=500
6  //Temperature of refrigerated space(in K):
7  T1=-16+273
8  //Atmospheric temperature(in K):
9  T2=27+273
10 //Heat rejected(in kJ/min):
11 Q2=Q1*(T2/T1)
12 //Work input required(in kJ/min):
13 W=Q2-Q1
14 printf("\n RESULT \n")
15 printf("\nWork input = %f kJ/min",W)
```

Scilab code Exa 18.02 HP required

```
1  //pathname=get_absolute_file_path ('18.02.sce')
2  //filename=pathname+filesep()+'18.02-data.sci'
3  //exec(filename)
4  //Operating temperature(in K):
5  T1=-5+273
6  T2=27+273
7  //Specific heats(in kJ/kg.K):
8  Cpw=4.18
9  //Latent heat(in kJ/kg):
10 L=335
11 //Capacity(in tons):
12 C=800
13 //Heat extraction rate(in kJ/s):
14 q=C*3.5
15 //Heat to be removed per kg of water(in kJ/kg):
16 q1=Cpw*(27-0)+L
17 //Ice formation rate(in kg/s):
18 m=q/q1
19 printf("\n RESULT \n")
20 printf("\nMass rate of ice formation = %f kg/s",m)
21 //COP:
22 COP=(T1/(T2-T1))
23 //Work done(in hp):
24 W=q/COP/0.7457
25 printf("\nHP required = %f hp",W)
```

Scilab code Exa 18.03 Temperature of surroundings

```
1  //pathname=get_absolute_file_path ('18.03.sce')
2  //filename=pathname+filesep()+'18.03-data.sci'
3  //exec(filename)
4  //Work done(in hp):
5  W=3
```

```
6  //Temperature  to  be  maintained(in  K):
7  T1=-27+273
8  //COP:
9  COP=1*3.5/(W*0.7457)
10  printf("\n  RESULT  \n")
11  printf("\nCOP = %f",COP)
12  //Temperature  of  surroundings(in  K):
13  T2=T1+T1/COP
14  printf("\nTemperature  of  surroundings = %f K",T2)
```

Scilab code Exa 18.04 Refrigeration capacity and COP

```
1  //pathname=get_absolute_file_path('18.04.sce')
2  //filename=pathname+filesep()+'18.04-data.sci'
3  //exec(filename)
4  //Pressure  ratio:
5  r1=8
6  //Operating  temperatures(in  K)
7  T1=-30+273
8  T3=27+273
9  //Isentropic  efficiency  of  compression:
10  nic=0.85
11  //Isentropic  efficiency  of  expansion:
12  nie=0.90
13  //Specific  heat(in  kJ/kg):
14  Cp=1.005
15  //Adiabatic  index  of  compression:
16  r=1.4
17  //Air  flow  rate(in  kg/s):
18  m=1
19  //Temperature  at  state  2'(in  K):
20  T2a=T1*(r1)^((r-1)/r)
21  //Temperature  at  state  2(in  K):
22  T2=(T2a-T1)/nic+T1
23  //Temperature  at  state  4'(in  K):
```

```
24  T4a=T3*(1/r1)^((r-1)/r)
25  //Temperature at state 2'(in K):
26  T4=T3-(T3-T4a)*nie
27  //Work during compression(in kJ/s):
28  Wc=Cp*(T2-T1)
29  //Work during expansion(in kJ/s):
30  Wt=Cp*(T3-T4)
31  //Refrigeration effect(in kJ/s):
32  Qref=Cp*(T1-T4)
33  //Net work required(in kJ/s):
34  W=Wc-Wt
35  //COP:
36  COP=Qref/W
37  printf("\n RESULT \n")
38  printf("\nRefrigeration capacity = %f kJ/s",Qref)
39  printf("\nCOP = %f",COP)
```

Scilab code Exa 18.05 COP

```
 1  //pathname=get_absolute_file_path('18.05.sce')
 2  //filename=pathname+filesep()+'18.05-data.sci'
 3  //exec(filename)
 4  //Operating temperatures(in K)
 5  T1=7+273
 6  T3=27+273
 7  //Pressures(in bar):
 8  p1=1
 9  p2=5
10  //Adiabatic index of compression:
11  r=1.4
12  //Specific heat(in kJ/kg):
13  Cp=1.005
14  //Temperature at state 2(in K):
15  T2=T1*(p2/p1)^((r-1)/r)
16  //Temperature at state 4(in K):
```

```
17  T4=T3/((p2/p1)^((r-1)/r))
18  //Heat rejected in process 2-3(in kJ/kg):
19  Q23=Cp*(T2-T3)
20  //Heat picked during process 4-1(in kJ/kg):
21  Q41=Cp*(T1-T4)
22  //Net work(in kJ/kg):
23  W=Q23-Q41
24  //COP:
25  COP=Q41/W
26  printf("\n RESULT \n")
27  printf("\nCOP = %f",COP)
```

Scilab code Exa 18.06 Refrigeration capacity and COP

```
1  //pathname=get_absolute_file_path('18.06.sce')
2  //filename=pathname+filesep()+'18.06-data.sci'
3  //exec(filename)
4  //Pressure(in bar):
5  p1=1
6  p2=5.5
7  //Operating temperatures(in K):
8  T1=-10+273
9  T3=27+273
10  //Air flow rate(in kg/s):
11  m=0.8
12  //Specific heat(in kJ/kg):
13  Cp=1.005
14  //Adiabatic index of compression:
15  r=1.4
16  //Gas constant(in kJ/kg.K):
17  R=0.287
18  //Temperature at state 2(in K):
19  T2=T1*(p2/p1)^((r-1)/r)
20  //Temperature at state 4(in K):
21  T4=T3/((p2/p1)^((r-1)/r))
```

```
22  // Refrigeration capacity (in kJ/s):
23  C=m*Cp*(T1-T4)
24  printf("\n RESULT \n")
25  printf("\nRefrigeration capacity = %f kJ/s",C)
26  //Work required to run the comoressor (in kJ/s):
27  Wc=m*r/(r-1)*R*(T2-T1)
28  printf("\nHP required to run compressor = %f hp",Wc
        /0.7457)
29  //Net work input (in kJ/s):
30  W=m*Cp*((T2-T3)-(T1-T4))
31  //COP:
32  COP=C/W
33  printf("\nCOP = %f",COP)
```

Scilab code Exa 18.07 Mass flow rate and COP

```
1   // pathname=get_absolute_file_path ('18.07.sce')
2   // filename=pathname+filesep ()+'18.07-data.sci'
3   // exec (filename)
4   // Pressure (in bar):
5   p1=1.2
6   p6=p1
7   p3=4
8   p3=p2
9   p4=1
10  p7=0.9
11  // Temperatures (in K):
12  T1=288
13  T6=T1
14  T5=25+273
15  T3=323
16  T8=30+273
17  n=1.45
18  n1=1.3
19  // Temperature at state 2(in K):
```

```
20  T2=T1*(p2/p1)^((n-1)/n)
21  T2=418.47
22  //Temperature at state 4(in K):
23  T4=T3*(p4/p3)^((n1-1)/n1)
24  T4=234.57
25  //Refrigeration effect(in kg/s):
26  m=10*3.5/(Cp*(T5-T4))
27  printf("\n RESULT \n")
28  printf("\nAir mass flow rate in cabin = %f kg/s",m)
29  //Temperature at state 7(in K):
30  T7=T6*(p7/p6)^((n1-1)/n1)
31  //Ram air mass flow rate(in kg/s):
32  rm=m*(T2-T3)/(T8-T7)+m
33  printf("\nRam air mass flow rate = %f kg/s",rm)
34  //Work input to the compressor(in kJ/s):
35  W=m*Cp*(T2-T1)
36  //COP:
37  COP=10*3.5/W
38  printf("\nCOP = %f",COP)
```

Scilab code Exa 18.08 COP and HP required

```
1   //pathname=get_absolute_file_path('18.08.sce')
2   //filename=pathname+filesep()+'18.08-data.sci'
3   //exec(filename)
4   //Pressures(in bar):
5   p0=0.9
6   p1=1
7   p2=4
8   p3=p2
9   p4=p3
10  p5=1.03
11  //Temperatures(in K):
12  T6=298
13  T0=276
```

```
14  //Specific heat(in kJ/kg):
15  Cp=1.005
16  //Adiabatic index of compression:
17  r=1.4
18  //Refrigeration capacity:
19  C=15
20  //Isentropic efficiency for compressor:
21  nic=0.9
22  //Isentropic efficiency for turbine:
23  nit=0.8
24  //Temperature at state 1(in K):
25  T1=T0*(p1/p0)^((r-1)/r)
26  //Temperature at state 2'(in K):
27  T2a=T1*(p2/p1)^((r-1)/r)
28  //Temperature at state 2(in K):
29  T2=T1+(T2a-T1)/nic
30  //Temperature at state 3(in K):
31  T3=0.34*T2
32  //Temperature at state 4(in K):
33  T4=T3-10
34  //Temperature at state 5'(in K):
35  T5a=T4*(p5/p4)^((r-1)/r)
36  //Temperature at state 5(in K):
37  T5=T4-(T4-T5a)*nit
38  //Mass flow rate(in kg/s):
39  m=C*3.5/(Cp*(T6-T5))
40  //Work input(in kJ/s):
41  W=m*Cp*(T2-T1)
42  //COP:
43  COP=C*3.5/W
44  printf("\n RESULT \n")
45  printf("\nCOP = %f",COP)
46  printf("\nHP required = %f hp",W/0.7457)
```

Scilab code Exa 18.09 COP

```
1  //pathname=get_absolute_file_path('18.09.sce')
2  //filename=pathname+filesep()+'18.09-data.sci'
3  //exec(filename)
4  //Operating temperatures(in K):
5  T1=-15+273
6  T2=25+273
7  h2=1317.95 //kJ/kg
8  s2=4.4809 //kJ/kg.K
9  h3=99.94 //kJ/kg
10 s3=0.3386 //kJ/kg.K
11 h9=-54.51 //kJ/kg
12 s9=-0.2132 //kJ/kg.K
13 h4=h3
14 s8=s3
15 s4=0.3855 //kJ/kg.K
16 s1=s2
17 //Refrigeration effect(in kJ/kg):
18 C=T1*(s1-s4)
19 //Work done(in kJ/kg):
20 W=h3-h9-T1*(s3-s9)+(T2-T1)*(s1-s8)
21 //COP:
22 COP=C/W
23 printf("\n RESULT \n")
24 printf("\nCOP = %f",COP)
```

Scilab code Exa 18.10 COP and piston displacement

```
1  //pathname=get_absolute_file_path('18.10.sce')
2  //filename=pathname+filesep()+'18.10-data.sci'
3  //exec(filename)
4  //Operating temperature(in K):
5  T1=-20+273
6  T3=40+273
7  //Pressures(in bar):
8  p2=9.61
```

```scilab
 9  p1 =1.51
10  n =1.13
11  // Speed ( in  rpm ) :
12  N =1200
13  h1 =178.61  // kJ / kg
14  h3 =73.53  // kJ / kg
15  h4 = h3
16  s1 =0.7082  // kJ / kg . K
17  s2 = s1
18  sg =0.682  // kJ / kg . K
19  Cpg =0.747  // kJ / kg . K
20  hg =203.05  // kJ / kg
21  vg =0.1088  // m ^3 / kg
22  m1 =2.86  // ton
23  // Clearance  volume :
24  C =0.02
25  // Temperature  of  state  2( in  K ) :
26  T2 = T3 *(% e ) ^(( s1 - sg ) / Cpg )
27  // Enthalpy  after  compression ( in  kJ / kg ) :
28  h2 = hg + Cpg *( T2 - T3 )
29  // Compression  work ( in  kJ / kg ) :
30  Wc = h2 - h1
31  // Refrigeration  effect ( in  kJ / kg ) :
32  r = h1 - h4
33  // Mass  flow  rate ( in  kg / s ) :
34  m = m1 *3.5/ r
35  // COP :
36  COP = r / Wc
37  // Volumetric  efficiency :
38  nv =1+ C - C *( p2 / p1 ) ^(1/ n )
39  // Piston  displacement ( in  m ^3 ) :
40  V = m *60* vg /( nv * N )
41  printf ( " \n  RESULT  \n " )
42  printf ( " \nCOP  =  %f " , COP )
43  printf ( " \nPiston  displacement  =  %f  cm ^3 " , V *10^6)
```

Scilab code Exa 18.11 Mass flow rate and COP

```
1  //pathname=get_absolute_file_path('18.11.sce')
2  //filename=pathname+filesep()+'18.11-data.sci'
3  //exec(filename)
4  //From steam tables:
5  h1=322.28 //kJ/kg
6  h2=342.32 //kJ/kg
7  s2=1.1937 //kJ/kg.K
8  s1=s2
9  x1=0.961
10 h1=312.08 //kJ/kg
11 h3=144.11 //kJ/kg
12 h4=115.22 //kJ/kg
13 h5=h4
14 //Refrigeration effect(in kW):
15 m1=2
16 //Refrigeration effect(in kJ/kg):
17 r=h1-h5
18 //Refrigerant flow rate(in kg/s):
19 m=m1/r
20 //Compressor work(in kJ/kg):
21 Wc=h2-h1
22 //COP:
23 COP=r/Wc
24 printf("\n RESULT \n")
25 printf("\nCOP = %f",COP)
26 printf("\nMass flow rate = %f kg/s",m)
```

Scilab code Exa 18.12 Partial pressure of vapour and relative humidity

```
1  //pathname=get_absolute_file_path('18.12.sce')
```

```
2  // filename=pathname+filesep ( )+ '18.12 − data . sci '
3  // exec ( filename )
4  // Specific  humidity ( in  gm/kg ) :
5  w =0.016
6  // Saturated  partial  pressure  of  vapour ( in  bar ) :
7  pvsat =0.03098
8  // Partial  pressure  of  vapour ( in  bar ) :
9  pv=w/0.622*1.013/(1+w/0.622)
10 // Relative  humidity :
11 r=pv/pvsat *100
12 printf ("\n RESULT  \n")
13 printf ("\nPartial  pressure  of  vapour = %f",pv)
14 printf ("\nRelative  humidity = %f  percent",r)
```

Scilab code Exa 18.13 Enthalpy of mixture

```
1  // pathname=get_absolute_file_path ( '18.13. sce ')
2  // filename=pathname+filesep ( )+ '18.13 − data . sci '
3  // exec ( filename )
4  // Relavite  humidity ;
5  r =0.6
6  // Saturation  pressure ( in  bar ) :
7  pvsat =0.0425
8  // Gas  constant ( in  kJ/kg .K ) :
9  R =0.287
10 // Surrounding  temperature ( in  K ) :
11 Ta=303
12 hg=2504.1  //kJ/kg
13 // Specific  heat ( in  kJ/kg .K ) :
14 Cp=1.005
15 // Partial  pressure  of  air ( in  bar ) :
16 pa=1.013-r*pvsat
17 printf ("\n RESULT  \n")
18 printf ("\nPartial  pressure  of  air = %f  bar",pa)
19 // Humidity  ratio :
```

```
20  w=0.622*( pv/(1.013-pv))
21  printf("\nHumidity ratio = %f jg/kg of dry air",w)
22  //Dew point temperature(in C):
23  T=21.4 //from steam table
24  printf("\nDew point temperature = 21.4 C")
25  //Density of mixture(in kg/m^3):
26  d=1.013*10^2*(1+w)/(R*Ta)
27  printf("\nDensity = %f kg/m^3",d)
28  //Enthalpy of mixture(in kJ/kg of dry air):
29  h=Cp*30+w*(hg+1.860*(30-T))
30  printf("\nEnthalpy of mixture = %f kJ/kg of air",h)
```

Scilab code Exa 18.14 Mass of water added and heat transferred

```
1  //pathname=get_absolute_file_path('18.14.sce')
2  //filename=pathname+filesep()+'18.14-data.sci'
3  //exec(filename)
4  //Relavite humidity;
5  r=0.80
6  //From pyschometric chart:
7  w1=0.0086 //kg/kg of air
8  w2=0.01 //kg/kg of air
9  h1=37 //kJ/kg
10 h2=50 //kJ/kg
11 v2=0.854 //m^3/kg
12 //Mass of water added between states 1 and 2:
13 m=w2-w1
14 //Mass flow rate:
15 ma=r/v2
16 //Total mass of water added(in kg/s):
17 m1=m*ma
18 //Heat transferred(in kJ/s):
19 q=ma*(h2-h1)
20 printf("\n RESULT \n")
21 printf("\nMass of water added = %f kg/s",m1)
```

```
22  printf("\nHeat  transferred  =  %f  kJ/s",q)
```

Scilab code Exa 18.15 Specific humidity of mixture

```
 1  //pathname=get_absolute_file_path('18.15.sce')
 2  //filename=pathname+filesep()+'18.15-data.sci'
 3  //exec(filename)
 4  //Mass  flow  rate(in  kg/s):
 5  m1=3
 6  m2=2
 7  //Specific  heat(in  kJ/kg.K):
 8  Cp=1.005
 9  //Specofoc  heat  of  stream(in  kJ/kg.K):
10  Cps=1.86
11  //Relative  humidity:
12  r1=0.30
13  r2=0.85
14  //From  psychometric  chart:
15  pvsat1=0.04246  //bar
16  pvsat2=0.005628
17  hg1=2520.7  //kJ/kg
18  hg2=2559.9  //kJ/kg
19  T1=30  //C
20  Tdp1=10.5
21  T2=35
22  Tdp2=32
23  //Partial  pressure  of  vapour  at  1(in  bar):
24  pv1=pvsat1*r1
25  //Specific  humidity:
26  w1=0.622*pv1/(1.013-pv1)
27  //Enthalpy  at  state  1(in  kJ/kg):
28  h1=Cp*T1+w1*(hg1-Cps*(T1-Tdp1))
29  //Partial  pressure  at  state  2(in  bar):
30  pv2=pvsat2*r2
31  //Specific  humidity:
```

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```
32  w2 =0.622* pv2 /(1.013 - pv2 )
33  // Enthalpy at state 1( in kJ/kg ):
34  h1=Cp*T2+w2 *( hg2 - Cps *( T2 - Tdp2 ))
35  // Enthalpy of mixture ( in kJ/kg ):
36  hmix =1/( m1+m2 ) *( h1*m1 /(1+ w1 )+h2*m2 /(1+ w2 ))
37  // Mass of vapour :
38  mmix =1/( m1+m2 ) *( w1*m1 /(1+ w1 )+w2*m2 /(1+ w2 ))
39  // Specific humidity of mixture :
40  wmix = mmix /(1 - mmix )
41  // Partial pressure of water vapour ( in bar ):
42  pv =1.013* wmix /0.622/(1+ w /0.622)
43  printf (" \n RESULT \n")
44  printf (" \nSpecific humidity of mixture = %f kg/kg of
        dry air ", wmix )
45  printf (" \nPartial pressure of water vapour in
        mixture = %f bar ", pv)
```

Scilab code Exa 18.16 Heat added

```
1  // pathname=get_absolute_file_path ('18.16.sce')
2  // filename=pathname+filesep ()+'18.16 - data.sci'
3  // exec( filename )
4  // Rate at which air enters ( in m^3/s ):
5  r=3
6  // From steam tables :
7  h1 =36.4 // kJ/kg
8  h2=52 // kJ/kg
9  v1=0.825 // m^3/kg
10 // Mass of air ( in kg/s ):
11 m=3/ v1
12 // Amount of heat added ( in kJ/s ):
13 q=m *( h2 - h1 )
14 printf (" \n RESULT \n")
15 printf (" \nHeat added = %f kJ/s ",q)
```

Chapter 19

Jet Propulsion and Rocket Engines

Scilab code Exa 19.01 Thrust

```scilab
1  //pathname=get_absolute_file_path('19.01.sce')
2  //filename=pathname+filesep()+'19.01-data.sci'
3  //exec(filename)
4  //Specific heat of gases(in kJ/kg.K):
5  Cpg=1.13 //kJ/kg.K
6  Cpa=1.005 //kJ/kg.K
7  rg=1.33
8  ra=1.4
9  C=41.84*10^3 //kJ/kg of fuel
10 //Temperatures(in K):
11 T1=272
12 T3=1000
13 //Compression efficiency:
14 nc=0.84
15 p3=3
16 p2=3
17 p1=0.5
18 p5=0.4
19 //Turbine efficiency:
```

```
20  nt=0.82
21  //Nozzle efficiency:
22  nn=0.92
23  //Speed(in m/s):
24  Ca=200
25  //Temperature at state 2(in K):
26  T2=T1*(p2/p1)^((ra-1)/ra)
27  //Temperature at state 2'(in K):
28  T2a=T1+(T2-T1)/nc
29  //Compressive work(in kW):
30  Wc=Cpa*(T2a-T1)
31  printf("\n RESULT \n")
32  printf("\nPower required for compressor = %f kW/kg",
        Wc)
33  //Air fuel ratio:
34  r=(C-Cpg*T3)/(Cpg*T3-Cpa*T2a)
35  printf("\nAir fuel ratio = %f",r)
36  //Temperature at state 4'(in K):
37  T4a=T3-Cpa/Cpg*(T2a-T1)/(1+r)
38  T4a=810.46
39  T4=T3-(T3-T4a)/nt
40  //Pressure of gas leaving turbine(in bar):
41  p4=p3*(T4/T3)^(rg/(rg-1))
42  printf("\nPressure of gas leaving turbine = %f bar",
        p4)
43  //Temperature at state 5(in K):
44  T5=T4a*(p5/p4)^((rg-1)/rg)
45  //Temperature at state 5'(in K):
46  T5a=T4a-nn*(T4a-T5)
47  //Exit jet velocity(in m/s):
48  C5a=sqrt(2*Cpg*(T4a-T5a)*10^3)
49  Ce=C5a
50  //Thrust per kg of air per second:
51  T=(1+1/r)*Ce-Ca
52  printf("\nThrust = %f N/kg/s",T)
```

Scilab code Exa 19.02 Thrust

```scilab
1  //pathname=get_absolute_file_path('19.02.sce')
2  //filename=pathname+filesep()+'19.02-data.sci'
3  //exec(filename)
4  T1=285  //K
5  p1=1  //bar
6  T3=773  //K
7  p2=4  //bar
8  r=1.4
9  Cpa=1.005  //kJ/kg.K
10 CV=43100  //kJ/kg.K
11 T3=273+500  //K
12 //Temperature at state 2(in K):
13 T2=T1*(p2/p1)^((r-1)/r)
14 //Temperature at state 2'(in K):
15 T2a=T1+1.1*(T2-T1)
16 //Work required in compressor(in kJ/kg of air):
17 Wc=Cpa*(T2a-T1)
18 printf("\n RESULT \n")
19 printf("\nPower required to drive compressor = %f kW
       /kg of air",Wc)
20 //Heat added in combustion chamber(in kJ/kg of air):
21 qa=Cpa*(T3-T2a)
22 //Air fuel ratio:
23 r1=CV/qa
24 printf("\nAir-fuel ratio = %f",r1)
25 //Temperature at state 5(in K):
26 T5=T3*(p1/p2)^((r-1)/r)
27 //Enthalpy drop in the nozzle(in kJ/kg of air):
28 hd=Cpa*(T3-T5-T2a+T1)
29 //Velocity of exit gas from nozzle(in m/s):
30 Ce=sqrt(2*hd*10^3)
31 //Thrust(in N/kg/s):
```

```
32  T=(1+1/r)*Ce
33  printf("\nThrust = %f N/kg of air/s",Ce)
```

Scilab code Exa 19.03 Specific fuel consumption

```
1   //pathname=get_absolute_file_path('19.03.sce')
2   //filename=pathname+filesep()+'19.03-data.sci'
3   //exec(filename)
4   //Specific heat of gases(in kJ/kg.K):
5   Cpg=1.14 //kJ/kg.K
6   Cpa=1.005 //kJ/kg.K
7   //Mechanical efficiency:
8   nm=0.96
9   //Polytropic efficiency of compressor:
10  nc=0.87
11  //Turbine efficiency:
12  nt=0.90
13  //Nozzle efficiency:
14  nn=0.95
15  //By pass ratio:
16  B=5.5
17  //Mass flow rate of air(in kg/s):
18  ma=200
19  //Pressures(in bar):
20  p2=1.5
21  p1=1
22  p3=28
23  pa=p1
24  //Temperatures(in K):
25  T1=288
26  rg=1.33
27  ra=1.4
28  CV=43100 //kJ/kg
29  T4=1573 //K
30  //For compression:a1=((ne-1)/ne)
```

```
31  a1=1/nc*(ra-1)/ra
32  a1=0.328
33  //For expansion:a2=(nt-1)/nt
34  a2=nt*(rg-1)/rg
35  a2=0.223
36  //Temperature at state 2'(in K):
37  T2a=T1*(p2/p1)^a1
38  //Temperature at state 3'(in K):
39  T3a=T2a*(p3/p2)^a2
40  //Using nozzle efficiency:
41  dT=nn*T2a*(1-(pa/p2)^((ra-1)/ra))
42  //Velocity at exit of nozzle(in m/s):
43  C8=sqrt(2*Cpa*10^3*dT)
44  //Mass flow rate of bypass air(in kg/s):
45  mab=ma*B/(B+1)
46  //Mass flow rate of hot gases(in kg/s):
47  mca=ma-mab
48  //Thrust available due to by pass air(in kN):
49  Tb=mab*C8/10^3
50  //Air fuel ratio:
51  r1=(Cpg*T4-Cpa*T3a)/(CV-Cpg*T4)
52  //Temperature at state 5'(in K):
53  T5a=T4-(Cpa*(T3a-T2a)/(nm*(1+r1)*Cpg))
54  //Temperature at state 6'(in K):
55  T6a=(Cpg*nm*T5a-(1+B)*Cpa*(T2a-T1))/(Cpg*nm)
56  //Pressure at state 4(in bar):
57  p4=p3-p2
58  //Pressure at state 5(in bar):
59  p5=p4*(T5a/T4)^(1/a2)
60  //Pressure at state 6(in bar):
61  p6=p5*(T6a/T5a)^(1/a2)
62  //Critical pressure ratio:
63  c=((rg+1)/2)^(rg/(rg-1))
64  //Pressure at state 7(in bar):
65  p7=p6/c
66  //For exit nozzle(in K):
67  dT1=nn*T6a*(1-(p7/p6)^((rg-1)/rg))
68  //Velocity at exit of nozzle(in m/s):
```

```
69  C7=sqrt(2*Cpg*10^3*dT1)
70  //Thrust due to hot gases(in kN):
71  Tg=mca*C7/10^3
72  //Total thrust(in kN):
73  Tt=Tg+Tb
74  //Specific thrust(in kN/kg/s):
75  st=Tt/ma
76  printf("\n RESULT \n")
77  printf("\nSpecific thrust = %f kN/kg/s",st)
78  //Specific fuel consumption(in  kg/h.N):
79  sfc=r1*mca*3600/(Tt*10^3)
80  printf("\nSpecific fuel consumption = %f kg/h.N",sfc
        )
```

Scilab code Exa 19.04 Specific fuel consumption

```
1  //pathname=get_absolute_file_path('19.04.sce')
2  //filename=pathname+filesep()+'19.04-data.sci'
3  //exec(filename)
4  //Velociy of turbojet plane(in m/s):
5  Ca=277.78
6  //Thrust to velocity ratio:
7  r1=0.5
8  //Rate at which air enters(in kg/s):
9  m=50
10  //Air fuel ratio:
11  r=52
12  //Lower calorific value of fuel:
13  LCV=43100
14  //Jet velocity(in m/s):
15  Ce=Ca/r1
16  printf("\n RESULT \n")
17  printf("\nJet velocity = %f m/s",Ce)
18  //Thrust(in N):
19  T=(m+m/r)*Ce-m*Ca
```

```
20  printf("\nThrust = %f kN",T/10^3)
21  //Specific thrust(in N/kg/s):
22  St=T/m
23  printf("\nSpecific thrust = %f N/kg/s",St)
24  //Thrust power(in kW):
25  P=T*Ca/10^3
26  printf("\nThrust power = %f kW",P)
27  //Propulsive efficiency:
28  np=2/(1+1/r1)*100
29  printf("\nPropulsive efficiency = %f percent",np)
30  //Thermal efficiency:
31  nt=((1+1/r)*Ce^2-Ca^2)/(2*1/r*LCV)/10
32  printf("\nThermal efficiency = %f percent",nt)
33  //Overall efficiency:
34  no=np*nt/100
35  printf("\nOverall efficiency = %f percent",no)
36  //Specific fuel consumption(in kg/h.N):
37  sfc=m/r*3600/(T)
38  printf("\nSpecific fuel consumption = %f kg/h.N",sfc
        )
```

Scilab code Exa 19.05 Velocity at exit of nozzle

```
1   //pathname=get_absolute_file_path('19.05.sce')
2   //filename=pathname+filesep()+'19.05-data.sci'
3   //exec(filename)
4   //Pressures(in bar):
5   p1=2.2
6   //Temperatures(in K):
7   T1=220
8   T4=1273
9   //Velocities(in m/s):
10  C1=260
11  //Nozzle efficiency:
12  nn=0.85
```

```scilab
13  //Turbine efficiency:
14  nt=0.88
15  //Diffuser efficiency:
16  nd=0.90
17  //Specific heat(in kJ/kg.K):
18  Cp=1.005
19  //Adiabatic index of  compression:
20  r=1.4
21  //Pressure ratio:
22  r1=12
23  //Temperature at state 2(in K):
24  T2=T1+C1^2/(2*Cp*10^3)
25  //Pressure at state 2(in bar):
26  p2=p1*(T2/T1)^(r/(r-1))
27  p3=p2*r1
28  p4=p3
29  //Temperature at state 3(in K):
30  T3=T2*(p3/p2)^((r-1)/r)
31  //Temperature at state 3'(in K):
32  T3a=T2+(T3-T2)/nn
33  //Temperature at state 5'(in K):
34  T5a=T4-(T3a-T2)
35  //Temperature of state 5(in K):
36  T5=T4-(T4-T5a)/nt
37  //Pressure at state 5(in bar):
38  p5=p4*(T5/T4)^(r/(r-1))
39  //Temperature at state 2(in K):
40  T2=C1+(200)^2/(2*Cp*10^3)
41  //Temperature at state 2'(in K):
42  T2a=T1+(T2-T1)/nd
43  T3a=568.635
44  T4=1000
45  p6=2.2
46  T6=542.83
47  //Velocity at exit of nozzle(in m/s):
48  C6=sqrt(2*(T5-T6)*Cp*10^3)
49  printf("\n RESULT \n")
50  printf("\nVelocity of exit of nozzle = %f m/s",C6)
```

Scilab code Exa 19.06 Total thrust

```
1  //pathname=get_absolute_file_path('19.06.sce')
2  //filename=pathname+filesep()+'19.06-data.sci'
3  //exec(filename)
4  //Calorific value(in kJ/kg):
5  CV=45000
6  //Inlet temperature(in C):
7  T1=1000
8  T4=T1
9  //Nozzle efficiency:
10 nn=0.9
11 //Diffuser efficiency:
12 nd=0.9
13 //Compressive efficiency:
14 nc=0.8
15 //Turbine efficiency:
16 nt=0.8
17 //Specific heat(in kJ/kg.K):
18 Cp=1.005
19 p3=7.248 //bar
20 p4=p3-0.15
21 r=1.4
22 p6=0.7
23 //Gas constant(in kJ/kg.K):
24 R=0.287
25 //Temperature at state 2(in K):
26 T2a=282.11
27 T3a=568.635
28 //Air fuel ratio:
29 r1=(CV-T1*Cp)/(Cp*T1-Cp*T3a)
30 //Temperature at state 5'(in K):
31 T5a=T4-(T3a-T2a)
32 //Temperature at state 5(in K):
```

```
33  T5=T4-(T4-T5a)/nt
34  p5=p4*(T5/T4)^(r/(r-1))
35  //Temperature at state 6(in K):
36  T6=T5a*(p6/p5)^((r-1)/r)
37  //Temperature at state 6'(in K):
38  T6a=T5a-(T5a-T6)*nn
39  //Velocity at exit of nozzle(in m/s):
40  C6=sqrt(2*Cp*(T5a-T6a)*10^3)
41  //Volume flow rate of air(in m^3/s):
42  v=200/10
43  //Mass flow rate(in kg/s):
44  m=0.7*10^2*v/(R*260)
45  //Specific thrust(in N/kg of air/s):
46  St=(1+1/r1)*C6
47  printf("\n RESULT \n")
48  printf("\nSpecific thrust = %f N/kg of air/s",St)
49  //Total thrust(in N):
50  Tt=m*St
51  printf("\nTotal thrust = %f N",Tt)
```

Scilab code Exa 19.07 Jet exit area

```
1  //pathname=get_absolute_file_path('19.07.sce')
2  //filename=pathname+filesep()+'19.07-data.sci'
3  //exec(filename)
4  //Specific heat(in kJ/kg.K):
5  Cpa=1.005
6  Cpg=1.087
7  ra=1.4
8  rg=1.33
9  //Gas constant(in kJ/kg.K):
10  R=0.287
11  //Speed of aeroplane(in m/s):
12  C0=250
13  //Velocity at exit of turbine(in m/s):
```

```
14  C4a =180
15  CV =43000  //kJ/kg
16  //Thrust  power (in  kW):
17  P=800
18  //Temperatures (in  K):
19  T0 = -20+273
20  T2 =474.25
21  T3 =973
22  //Pressures (in  bar):
23  p0 =0.3
24  p1 =0.31
25  p5=p0
26  //Compressor  efficiency:
27  nc =0.85
28  //Jet  engine  efficiency:
29  nj =0.90
30  //Pressure  ratio:
31  r1=6
32  //Temperature  at  state  2(in  K):
33  T1=T0+C0^2/(2* Cpa *10^3)
34  T2a=T1+(T2-T1)/nc
35  //Pressure  at  state  2(in  bar):
36  p2=p1*r1
37  p3=p2
38  //Fuel  air  ratio:
39  FA=(Cpa*T3-Cpg*T2a)/(CV-Cpa*T3)
40  printf ("\n RESULT  \n")
41  printf ("\nAir-fuel  ratio  =  %f:1" ,1/FA)
42  //Temperature  at  state  4'(in  K):
43  T4a=T3-Cpa/Cpg*(T2a-T1)/(1+FA)
44  //Temperature  at  state  4(in  K):
45  T4=T3-(T3-T4a)/nc
46  //Pressure  at  state  4(in  bar):
47  p4=p3*(T4/T3)^(rg/(rg-1))
48  //Temperature  at  state  5(in  K):
49  T5=T4a*(p5/p4)^((rg-1)/rg)
50  //Nozzle  exit  velocity (in  m/s):
51  C5=sqrt(2*nj*(Cpg*10^3*(T4a-T5)+C4a^2/2))
```

```
52  //Overall efficiency:
53  no=(((1+FA)*C5-C0)*C0)/(FA*CV*10^3)*100
54  //Rate of air consumption(in kg/s):
55  ma=P*10^3/(((1+FA)*C5-C0)*C0)
56  printf("\nRate of air consumption = %f kg/s",ma)
57  //Power produced by the turbine(in kW):
58  Pt=ma*(1+FA)*Cpg*(T3-T4a)
59  printf("\nPower produced by turbine = %f kW",Pt)
60  //Temperature at state 5'(in K):
61  T5a=T4a-((C5^2-C4a^2)/(2*Cpg*10^3))
62  //Density of exhaust gases(in m^3/kg):
63  d5a=p5*10^2/(R*T5a)
64  //Jet exit area(in m^2):
65  Aj=ma*(1+FA)/(C5*d5a)
66  printf("\nJet exit area = %f m^2",Aj)
```

Scilab code Exa 19.08 Jet diameter

```
1   //pathname=get_absolute_file_path('19.08.sce')
2   //filename=pathname+filesep()+'19.08-data.sci'
3   //exec(filename)
4   //Speed of jet plane(in m/s):
5   Ca=250
6   //Density of air(in kg/m^3):
7   d=0.15
8   //Drag(in kW):
9   D=6800
10  //Propulsive efficiency:
11  np=0.56
12  //Relative velocity(in m/s):
13  Ce=2*Ca/np-Ca
14  //Absolute velocity of jet(in m/s):
15  C=Ce-Ca
16  //Mass flow rate(in kg/s):
17  ma=D/(Ce-Ca)
```

```
18  //Volume flow rate(in m^3/s):
19  v=ma/d
20  //Jet diameter(in m):
21  dj=sqrt(v*4/(2*%pi*Ce))
22  printf("\n RESULT \n")
23  printf("\nJet diamter = %f cm",dj*100)
```

Scilab code Exa 19.09 Specific thrust

```
1  //pathname=get_absolute_file_path('19.09.sce')
2  //filename=pathname+filesep()+'19.09-data.sci'
3  //exec(filename)
4  //Gas constant(in kJ/kg.K):
5  R=0.287
6  //Density ratio:
7  r1=0.4
8  //Specific heat(in kJ/kg.K):
9  Cp=1.005
10 //Drag coefficient:
11 d=0.018
12 //Jet velocity(in m/s):
13 Ce=550
14 //Wing area(in m^2):
15 A=20
16 //Speed of aeroplane(in m/s):
17 Ca=900*1000/3600
18 //Density of STP(in kg/m^3):
19 d1=1.01325*10^2/(R*288)
20 //Density of air at altitude(in kg/m^3):
21 d2=r1*d1
22 //Thrust on aeroplane:
23 T=d*A*d2*Ca^2/2
24 //Mass flow rate(in kg/s):
25 ma=T/(Ce-Ca)
26 //Specific thrust(in N/kg of air):
```

```
27  St=T/ma
28  printf("\n RESULT \n")
29  printf("\nSpecific thrust = %d N/kg of air",St)
```

Scilab code Exa 19.10 Overall efficiency

```
1   //pathname=get_absolute_file_path('19.10.sce')
2   //filename=pathname+filesep()+'19.10-data.sci'
3   //exec(filename)
4   //Speed of air craft(in m/s):
5   Ca=250
6   //Mass flow rate(in kg/s):
7   m=55
8   //Air fuel ratio:
9   r=85
10  //Combustion efficiency:
11  nc=0.96
12  //Lower calorific value(in kJ/kg):
13  CV=43000
14  //Isentropic enthalpy change(in kJ/kg):
15  dh=220
16  //Velocity coefficient:
17  n=0.95
18  //Jet velocity(in m/s):
19  Ce=n*sqrt(2*dh*10^3)
20  Ce=615.67
21  //Specific thrust per kg of air(in N/kg air):
22  St=400.67
23  //Fuel flow rate(in kg/hr):
24  r1=1/r*3600*m
25  //Specific fuel consumption(in kg/N.hr):
26  sfc=r1/(St*m)
27  //Thrust power(in kW):
28  P=m*(Ce-Ca)*Ca/10^3
29  //Propulsive power(in kW):
```

```
30  Pp=m*(Ce^2-Ca^2)/2/10^3
31  //Propulsive efficiency:
32  np=P/Pp*100
33  //Overall efficiency:
34  no=P/(m/r*CV*nc)*100
35  printf("\n RESULT \n")
36  printf("\nPropulsive power = %f kW",Pp)
37  printf("\nPropulsive efficiency = %f percent",np)
38  printf("\nOverall efficiency = %f percent",no)
```