Scilab Textbook Companion for Thermal Engineering by A. V. Arasu[1]

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

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Chapter 1

Fuels and Combustion

Scilab code Exa 1.1 Minimum mass of air required

```scilab
1 //Chapter-1, Illustration 1, Page 15
2 //Title: Fuels and Combustion
3 //
    =======================================================================
4 clc
5 clear
6
7 //INPUT DATA
8 C=0.91;//Percentage composition of Carbon
9 H=0.03;//Percentage composition of Hydrogen
10 O=0.02;//Percentage composition of Oxygen
11 N=0.008;//Percentage composition of Nitrogen
12 S=0.008;//Percentage composition of Sulphur
13
14 //CALCULATIONS
15 m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Mass of air
    per kg of coal in kg
16
17 //OUTPUT
18 mprintf('Minimum mass of air per kg of coal is %3.2f
```

```
      kg ' ,m)
19
20
21
22
23
24  //==============================END OF PROGRAM
      ==========================
```

Scilab code Exa 1.2 Theoretical volume of air required

```
1  //Chapter −1, Illustration  2, Page  16
2  //Title : Fuels  and  Combustion
3  //
     ====================================================
4  clc
5  clear
6
7  //INPUT DATA
8  C=0.86;//Percentage  composition  of  Carbon
9  H=0.12;//Percentage  composition  of  Hydrogen
10 O=0.01;//Percentage  composition  of  Oxygen
11 S=0.01;//Percentage  composition  of  Sulphur
12 v=0.773;//Specific  volume  of  air  at  N.T.P in  (m^3)/
     kg
13
14 //CALCULATIONS
15 m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Theoretical
     mass  of  air  per  kg  of  coal  in  kg
16 vth=m*v;//Theoretical  volume  of  air  at  N.T.P per  kg
     fuel  in  (m^3)/kg of  fuel
17
18 //OUTPUT
19 mprintf('Theoretical  volume  of  air  at  N.T.P per  kg
```

```
    fuel  is  %3.2 f  (mˆ3)/kg  of  fuel ' ,vth)
20
21
22
23
24
25 //════════════════════════════════END OF PROGRAM
     ══════════════════════════════
```

_____

Scilab code Exa 1.3 Minimum quantity of air and Total mass of products of combusti

```
 1 //Chapter −1,  Illustration  3,  Page  16
 2 //Title :  Fuels  and  Combustion
 3 //
     ══════════════════════════════════════════════════
 4 clc
 5 clear
 6
 7 //INPUT DATA
 8 C=0.78;//Percentage  composition  of  Carbon
 9 H=0.06;//Percentage  composition  of  Hydrogen
10 O=0.078;//Percentage  composition  of  Oxygen
11 N=0.012;//Percentage  composition  of  Nitrogen
12 S=0.03;//Percentage  composition  of  Sulphur
13
14 //CALCULATIONS
15 m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Minimum
     quantity  of  air  required  in  kg
16 mt=((11*C)/3)+(9*H)+(2*S)+(8.32+N);//Total  mass  of
     products  of  combustion  in  kg
17
18 //OUTPUT
19 mprintf('Minimum  quantity  of  air  required  for
     complete  combustion  is  %3.2 f  kg  \n  Total  mass  of
```

```
    products of combustion is %3.3f kg',m,mt)
20
21
22
23
24
25 //===============================END OF PROGRAM
   ===============================
```

Scilab code Exa 1.4 Mass of dry flue gas

```
1  //Chapter −1, Illustration 4, Page 17
2  //Title: Fuels and Combustion
3  //
   ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  C=0.84;//Percentage composition of Carbon
9  H=0.09;//Percentage composition of Hydrogen
10 CO2=0.0875;//Volumetric composition of CO2
11 CO=0.0225;//Volumetric composition of CO
12 O2=0.08;//Volumetric composition of Oxygen
13 N2=0.81;//Volumetric composition of Nitrogen
14 M1=44;//Molecular mass of CO2
15 M2=28;//Molecular mass of CO
16 M3=32;//Molecular mass of O2
17 M4=28;//Molecular mass of N2
18
19 //CALCULATIONS
20 c1=CO2*M1;//Proportional mass of CO2
21 c2=CO*M2;//Proportional mass of CO
22 c3=O2*M3;//Proportional mass of O2
```

```
23  c4=N2*M4; //Proportional mass of N2
24  c=c1+c2+c3+c4; //Total proportional mass of
        constituents
25  m1=c1/c; //Mass of CO2 per kg of flue gas in kg
26  m2=c2/c; //Mass of CO per kg of flue gas in kg
27  m3=c3/c; //Mass of O2 per kg of flue gas in kg
28  m4=c4/c; //Mass of N2 per kg of flue gas in kg
29  d1=m1*100; //Mass analysis of CO2
30  d2=m2*100; //Mass analysis of CO
31  d3=m3*100; //Mass analysis of O2
32  d4=m4*100; //Mass analysis of N2
33  m=((3*m1)/11)+((3*m2)/7); //Mass of carbon in kg
34  md=C/m; //Mass of dry flue gas in kg
35
36  //OUTPUT
37  mprintf('Mass of dry flue gases per kg of coal burnt
        is %3.1f kg',md)
38
39
40
41
42
43  //=================================END OF PROGRAM
        ===============================
```

Scilab code Exa 1.5 Minimum air required and Mass of air actually supplied and Amo

```
1  //Chapter -1, Illustration 5, Page 17
2  //Title: Fuels and Combustion
3  //
        ====================================================
4  clc
5  clear
6
```

```
 7  //INPUT DATA
 8  C=0.624;//Percentage composition of Carbon
 9  H=0.042;//Percentage composition of Hydrogen
10  O=0.045;//Percentage composition of Oxygen
11  CO2=0.13;//Volumetric composition of CO2
12  CO=0.003;//Volumetric composition of CO
13  O2=0.06;//Volumetric composition of Oxygen
14  N2=0.807;//Volumetric composition of Nitrogen
15  M1=44;//Molecular mass of CO2
16  M2=28;//Molecular mass of CO
17  M3=32;//Molecular mass of O2
18  M4=28;//Molecular mass of N2
19  mw=0.378;//Mass of H2O in kg
20
21  //CALCULATIONS
22  m=(11.5*C)+(34.5*(H-(O/8)));//Minimum air required
        in kg
23  c1=CO2*M1;//Proportional mass of CO2
24  c2=CO*M2;//Proportional mass of CO
25  c3=O2*M3;//Proportional mass of O2
26  c4=N2*M4;//Proportional mass of N2
27  c=c1+c2+c3+c4;//Total proportional mass of
        constituents
28  m1=c1/c;//Mass of CO2 per kg of flue gas in kg
29  m2=c2/c;//Mass of CO per kg of flue gas in kg
30  m3=c3/c;//Mass of O2 per kg of flue gas in kg
31  m4=c4/c;//Mass of N2 per kg of flue gas in kg
32  d1=m1*100;//Mass analysis of CO2
33  d2=m2*100;//Mass analysis of CO
34  d3=m3*100;//Mass analysis of O2
35  d4=m4*100;//Mass analysis of N2
36  mC=((3*m1)/11)+((3*m2)/7);//Mass of carbon in kg
37  md=C/mC;//Mass of dry flue gas in kg
38  mact=(md+mw)-(C+H+O);//Actual air supplied per kg of
        fuel in kg
39  me=mact-m;//Mass of excess air per kg of fuel in kg
40
41  //OUTPUT
```

```
42  mprintf ('Minimum air required to burn 1 kg of coal
       is %3.2f kg \n Mass of air actually supplied per
       kg of coal is %3.3f kg \n Amount of excess air
       supplied per kg of coal burnt is %3.3f kg',m,mact
       ,me)
43
44
45
46
47
48  //═══════════════════════════════════END OF PROGRAM
       ════════════════════════════════
```

Scilab code Exa 1.6 Mass of air to be supplied and Mass of gaseous products

```
1   //Chapter−1, Illustration 6, Page 19
2   //Title: Fuels and Combustion
3   //
        ════════════════════════════════════════════════════
4   clc
5   clear
6
7   //INPUT DATA
8   C=0.78;//Percentage composition of Carbon
9   H=0.03;//Percentage composition of Hydrogen
10  O=0.03;//Percentage composition of Oxygen
11  S=0.01;//Percentage composition of Sulphur
12  me=0.3;//Mass of excess air supplied
13
14  //CALCULATIONS
15  m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Mass of air
       per kg of coal in kg
16  mec=me*m;//Excess air supplied per kg of coal in kg
17  mact=m+mec;//Actual mass of air supplied per kg of
```

```
        coal in kg
18  mCO2=(11*C)/3;//Mass of CO2 produced per kg of coal
        in kg
19  mHw=9*H;//Mass of H2O produced per kg of coal in kg
20  mSO2=2*S;//Mass of SO2 produced per kg of coal in kg
21  mO2=0.232*mec;//Mass of excess O2 produced per kg of
        coal in kg
22  mN2=0.768*mact;//Mass of N2 produced per kg of coal
        in kg
23
24  //OUTPUT
25  mprintf('Mass of air to be supplied is %3.2f kg \n
        Mass of CO2 produced per kg of coal is %3.2f kg \
        n Mass of H2O produced per kg of coal is %3.2f kg
         \n Mass of SO2 produced per kg of coal is %3.2f
        kg \n Mass of excess O2 produced per kg of coal
        is %3.2f kg \n Mass of N2 produced per kg of coal
         is %3.2f kg \n',m,mCO2,mHw,mSO2,mO2,mN2)
26
27
28
29
30  //===============================END OF PROGRAM
        ===================================
```

Scilab code Exa 1.7 Total mass of dry flue gases and Percentage composition of dry

```
1  //Chapter-1, Illustration 7, Page 20
2  //Title: Fuels and Combustion
3  //
        ===================================
4  clc
5  clear
6
```

```scilab
 7  //INPUT DATA
 8  C=0.9;//Percentage composition of Carbon
 9  H=0.033;//Percentage composition of Hydrogen
10  O=0.03;//Percentage composition of Oxygen
11  N=0.008;//Percentage composition of Nitrogen
12  S=0.009;//Percentage composition of Sulphur
13  M1=44;//Molecular mass of CO2
14  M2=64;//Molecular mass of SO2
15  M3=32;//Molecular mass of O2
16  M4=28;//Molecular mass of N2
17
18  //CALCULATIONS
19  m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Minimum mass
        of air per kg of coal in kg
20  mCO2=(11*C)/3;//Mass of CO2 produced per kg of coal
        in kg
21  mHw=9*H;//Mass of H2O produced per kg of coal in kg
22  mSO2=2*S;//Mass of SO2 produced per kg of coal in kg
23  mt=11.5*1.5;//Total mass of air supplied per kg of
        coal in kg
24  me=mt-m;//Excess air supplied in kg
25  mO2=0.232*me;//Mass of excess O2 produced per kg of
        coal in kg
26  mN2=0.768*mt;//Mass of N2 produced per kg of coal in
         kg
27  mtN2=mN2+N;//Total mass of Nitrogen in exhaust in kg
28  md=mCO2+mSO2+mO2+mtN2;//Total mass of dry flue gases
         per kg of fuel in kg
29  CO2=(mCO2/md)*100;//Percentage composition of CO2 by
         mass in percent
30  SO2=(mSO2/md)*100;//Percentage composition of SO2 by
         mass in percent
31  O2=(mO2/md)*100;//Percentage composition of O2 by
        mass in percent
32  N2=(mN2/md)*100;//Percentage composition of N2 by
        mass in percent
33  c1=CO2/M1;//Proportional volume of CO2
34  c2=SO2/M2;//Proportional volume of SO2
```

```
35  c3=O2/M3;//Proportional volume of O2
36  c4=N2/M4;//Proportional volume of N2
37  c=c1+c2+c3+c4;//Total proportional volume of
        constituents
38  m1=c1/c;//Volume of CO2 in 1 (m^3) of flue gas
39  m2=c2/c;//Volume of SO2 in 1 (m^3) of flue gas
40  m3=c3/c;//Volume of O2 in 1 (m^3) of flue gas
41  m4=c4/c;//Volume of N2 in 1 (m^3) of flue gas
42  d1=m1*100;//Volume analysis of CO2
43  d2=m2*100;//Volume analysis of SO2
44  d3=m3*100;//Volume analysis of O2
45  d4=m4*100;//Volume analysis of N2
46
47  //OUTPUT
48  mprintf('Minimum mass of air required is %3.1f kg \n
        Total mass of dry flue gases per kg of fuel is
      %3.2f kg \n Percentage composition of CO2 by
      volume is %3.2f percent \n Percentage composition
       of SO2 by volume is %3.3f percent \n Percentage
      composition of O2 by volume is %3.1f percent \n
      Percentage composition of N2 by volume is %3.2f
      percent ',m,md,d1,d2,d3,d4)
49
50
51
52
53
54
55  //================================END OF PROGRAM
        ==============================
```

Scilab code Exa 1.8 Mass of air actually supplied and Percentage of excess air sup

```
1  //Chapter −1, Illustration 8, Page 21
2  //Title: Fuels and Combustion
```

```
 3 //
    ═══════════════════════════════════════════════════

 4 clc
 5 clear
 6
 7 //INPUT DATA
 8 C=0.88;//Percentage composition of Carbon
 9 H=0.036;//Percentage composition of Hydrogen
10 O=0.048;//Percentage composition of oxygen
11 CO2=0.109;//Volumetric composition of CO2
12 CO=0.01;//Volumetric composition of CO
13 O2=0.071;//Volumetric composition of Oxygen
14 N2=0.81;//Volumetric composition of Nitrogen
15 M1=44;//Molecular mass of CO2
16 M2=28;//Molecular mass of CO
17 M3=32;//Molecular mass of O2
18 M4=28;//Molecular mass of N2
19
20 //CALCULATIONS
21 m=(11.5*C)+(34.5*(H-(O/8)));//Theoretical air
     required in kg
22 c1=CO2*M1;//Proportional mass of CO2
23 c2=CO*M2;//Proportional mass of CO
24 c3=O2*M3;//Proportional mass of O2
25 c4=N2*M4;//Proportional mass of N2
26 c=c1+c2+c3+c4;//Total proportional mass of
     constituents
27 m1=c1/c;//Mass of CO2 per kg of flue gas in kg
28 m2=c2/c;//Mass of CO per kg of flue gas in kg
29 m3=c3/c;//Mass of O2 per kg of flue gas in kg
30 m4=c4/c;//Mass of N2 per kg of flue gas in kg
31 mC=((3*m1)/11)+((3*m2)/7);//Mass of carbon in kg
32 md=C/mC;//Mass of dry flue gas in kg
33 hc=H*9;//Hydrogen combustion in kg of H2O
34 mair=(md+hc)-(C+H+O);//Mass of air supplied per kg
     of coal in kg
35 me=mair-m;//Excess air per kg of coal in kg
```

```
36  mN2=m4*md;//Mass of nitrogen per kg of coal in kg
37  mact=mN2/0.768;//Actual mass of air per kg of coal
       in kg
38  pe=(me/m)*100;//Perccentage excess air in percent
39
40  //OUTPUT
41  mprintf('Mass of air actually supplied per kg of
        coal is %3.2f kg \n Percentage of excess air is
        %3.2f percent',mact,pe)
42
43
44
45
46
47
48
49  //==============================END OF PROGRAM
        ===============================
```

Scilab code Exa 1.9 Mass of excess air supplied and air fuel ratio

```
1  //Chapter-1, Illustration 9, Page 22
2  //Title: Fuels and Combustion
3  //
        ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  C=0.84;//Percentage composition of Carbon
9  H=0.14;//Percentage composition of Hydrogen
10  O=0.02;//Percentage composition of oxygen
11  CO2=8.85;//Volumetric composition of CO2
12  CO=1.2;//Volumetric composition of CO
```

```
13  O2=6.8;//Volumetric composition of Oxygen
14  N2=83.15;//Volumetric composition of Nitrogen
15  M1=44;//Molecular mass of CO2
16  M2=28;//Molecular mass of CO
17  M3=32;//Molecular mass of O2
18  M4=28;//Molecular mass of N2
19  a=8/3;//O2 required per kg C
20  b=8;//O2 required per kg H2
21  mair=0.23;//Mass of air
22
23  //CALCULATIONS
24  c=C*a;//O2 required per kg of fuel for C
25  d=H*b;//O2 required per kg of fuel for H2
26  tO2=c+d+O;//Theoreticcal O2 required in kg/kg of
        fuel
27  tm=tO2/mair;//Theoretical mass of air in kg/kg of
        fuel
28  c1=CO2*M1;//Proportional mass of CO2 by Volume
29  c2=CO*M2;//Proportional mass of CO by Volume
30  c3=O2*M3;//Proportional mass of O2 by Volume
31  c4=N2*M4;//Proportional mass of N2 by Volume
32  c=c1+c2+c3+c4;//Total proportional mass of
        constituents
33  m1=c1/c;//Mass of CO2 per kg of flue gas in kg
34  m2=c2/c;//Mass of CO per kg of flue gas in kg
35  m3=c3/c;//Mass of O2 per kg of flue gas in kg
36  m4=c4/c;//Mass of N2 per kg of flue gas in kg
37  mC=((m1*12)/M1)+((m2*12)/M2);//Mass of carbon per kg
        of dry flue gas in kg
38  md=C/mC;//Mass of dry flue per kg of fuel in kg
39  p=(4*m2)/7;//Oxygen required to burn CO in kg
40  meO2=md*(m3-p);//Mass of excess O2 per kg of fuel in
        kg
41  me=meO2/mair;//Mass of excess air in kg/kg fuel
42  mt=tm+me;//Total air required per kg fuel
43
44  //OUTPUT
45  mprintf('Mass of excess air supplied per kg of fuel
```

```
       burnt is %3.1 f kg/kg of fuel \n Air-fuel ratio is
       %3.1 f :1 ',me,mt)
46
47
48
49
50
51  //===============================END OF PROGRAM
       =================================
```

Scilab code Exa 1.10 `Volume of air required`

```
1  //Chapter -1, Illustration 10, Page 23
2  //Title: Fuels and Combustion
3  //
       ================================================
4  clc
5  clear
6
7  //INPUT DATA
8  H2=0.27;//Percentage composition of H2 by volume
9  CO2=0.18;//Percentage composition of CO2 by volume
10 CO=0.125;//Percentage composition of CO by volume
11 CH4=0.025;//Percentage composition of CH4 by volume
12 N2=0.4;//Percentage composition of N2 by volume
13
14 //CALCULATIONS
15 v=(2.38*(H2+CO))+(9.52*CH4);//Volume of air required
       for complete combustion in (m^3)
16
17 //OUTPUT
18 mprintf('Volume of air required for complete
       combustion is %3.3 f (m^3)',v)
19
```

```
20
21
22
23
24
25 //==============================END OF PROGRAM
       ======================
```

Scilab code Exa 1.11 Air fuel ratio

```
1  //Chapter-1, Illustration 11, Page 24
2  //Title: Fuels and Combustion
3  //
       ==================================================================

4  clc
5  clear
6
7  //INPUT DATA
8  H2=0.5;//Percentage composition of H2 by volume
9  CO2=0.1;//Percentage composition of CO2 by volume
10 CO=0.05;//Percentage composition of CO by volume
11 CH4=0.25;//Percentage composition of CH4 by volume
12 N2=0.1;//Percentage composition of N2 by volume
13 pCO2=8;//Percentage volumetric analysis of CO2
14 pO2=6;//Percentage volumetric analysis of O2
15 pN2=86;//Percentage volumetric analysis of N2
16
17
18 //CALCULATIONS
19 v=(2.38*(H2+CO))+(9.52*CH4);//Volume of air required
       for complete combustion in (m^3)
20 vN2=v*0.79;//Volume of nitrogen in the air in m^3
21 a=CO+CH4+CO2;//CO2 formed per m^3 of fuel gas burnt
22 b=vN2+N2;//N2 formed per m^3 of fuel gas burnt
```

```
23  vt=a+b;//Total volume of dry flue gas formed in m^3
24  ve=(pO2*vt)/(21-pO2);//Excess air supplied in m^3
25  V=v+ve;//Total quantity of air supplied in m^3
26
27  //OUTPUT
28  mprintf('Air-fuel ratio by volume is %3.3f:1',V)
29
30
31
32
33  //==============================END OF PROGRAM
        ================================
```

Scilab code Exa 1.12 Volume and analysis of products of combustion

```
1  //Chapter-1, Illustration 12, Page 24
2  //Title: Fuels and Combustion
3  //
        ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  H2=0.14;//Percentage composition of H2 by volume
9  CO2=0.05;//Percentage composition of CO2 by volume
10 CO=0.22;//Percentage composition of CO by volume
11 CH4=0.02;//Percentage composition of CH4 by volume
12 O2=0.02;//Percentage composition of O2 by volume
13 N2=0.55;//Percentage composition of N2 by volume
14 e=0.4;//Excess air supplied
15 //CALCULATIONS
16 v=(2.38*(H2+CO))+(9.52*CH4)-(4.76*O2);//Volume of
       air required for complete combustion in (m^3)
17 ve=v*e;//Volume of excess air supplied in m^3
```

25

```
18  vtN2=v-(v*0.21);//Volume of N2 in theoretical air in
        m^3
19  veN2=ve-(ve*0.21);//Volume of N2 in excess air in m
        ^3
20  vt=vtN2+veN2;//Total volume of N2 in air supplied in
        m^3
21  vCO2=CO+CH4+CO2;//CO2 formed per m^3 of fuel gas
22  vN2=vt+N2;//N2 formed per m^3 of fuel gas
23  veO2=ve*0.21;//Volume of excess O2 per m^3 of fuel
        gas
24  vT=vCO2+vN2+veO2;//Total volume of dry combustion
        products
25  pCO2=(vCO2*100)/vT;//Percentage volume of CO2
26  pN2=(vN2*100)/vT;//Percentage volume of N2
27  pO2=(veO2*100)/vT;//Percentage volume of O2
28
29  //OUTPUT
30  mprintf('Volume of air required for complete
        combustion is %3.3f (m^3) \n Volume of CO2 per m
        ^3 of gas fuel is %3.2f m^3/m^3 of gas fuel \n
        Volume of N2 per m^3 of gas fuel is %3.3f m^3/m^3
         of gas fuel \n Volume of excess O2 per m^3 of
        gas fuel is %3.2f m^3/m^3 of gas fuel \n Total
        volume of dry combustion products is %3.3f m^3/m
        ^3 of gas fuel \n Percentage volume of CO2 is %3
        .1f percent \n Percentage volume of N2 is %3.2f
        percent \n Percentage volume of O2 is %3.2f
        percent',v,vCO2,vN2,veO2,vT,pCO2,pN2,pO2)
31
32
33
34
35
36
37
38
39
40  //========================================END OF PROGRAM
```

26

Chapter 2

Gas Power Cycles

Scilab code Exa 2.1 Maximum pressure and temperature of cycle and Cycle efficiency

```scilab
1 //Chapter −2, Illustration 1, Page 55
2 //Title: Gas Power Cycles
3 //
    =============================================================
4 clc
5 clear
6
7 //INPUT DATA
8 P1=0.1;//Pressure of air supplied in MPa
9 T1=308;//Temperature of air supplied in K
10 rv=8;//Compression ratio
11 q1=2100;//Heat supplied in kJ/kg
12 Cp=1.005;//Specific heat at constant pressure in kJ/
    kg−K
13 Cv=0.718;//Specific heat at constant volume in kJ/kg
    −K
14 R=0.287;//Universal gas constant in kJ/kg−K
15
16 //CALCULATIONS
17 y=Cp/Cv;//Ratio of specific heats
```

```
18  n=(1-(1/(rv^(y-1))))*100;//Cycle efficiency
19  v1=(R*T1)/(P1*1000);//Specific volume at point 1 in
        (m^3)/kg
20  v2=v1/rv;//Specific volume at point 2 in (m^3)/kg
21  T2=T1*(rv^(y-1));//Temperature at point 2 in K
22  T3=(q1/Cv)+T2;//Temperature at point 3 in K
23  P2=P1*(rv^y);//Pressure at point 2 in MPa
24  P3=P2*(T3/T2);//Pressure at point 3 in MPa
25  wnet=(q1*n)/100;//Net workdone in J/kg
26  MEP=(wnet/(v1-v2))/1000;//Mean effective pressure in
        MPa
27
28  //OUTPUT
29  mprintf('Maximum pressure of the cycle is %3.3f MPa
        \n Maximum temperature of the cycle is %3.0f K \n
         Cycle efficiency is %3.1f percent \n Mean
        effective pressure is %3.3f MPa',P3,T3,n,MEP)
30
31
32
33
34
35  //================================END OF PROGRAM
        ================================
```

Scilab code Exa 2.2 Relative efficiency of engine

```
1  //Chapter-2, Illustration 2, Page 57
2  //Title: Gas Power Cycles
3  //
      =====================================================
4  clc
5  clear
6
```

```
7  //INPUT DATA
8  d=80;//Bore in mm
9  L=85;//Stroke in mm
10 Vc=0.06;//Clearance volume in litre
11 n=0.22;//Actual thermal efficiency
12 y=1.4;//Ratio of specific heats
13
14 //CALCULATIONS
15 Vs=(3.147/4)*(d^2)*L;//Stroke volume in mm^3
16 Vt=Vs+(Vc*(10^6));//Total volume in mm^3
17 rv=Vt/(Vc*(10^6));//Compression ratio
18 ni=(1-(1/(rv^(y-1))));//Ideal thermal efficiency
19 nr=(n/ni)*100;//Relative efficiency
20
21 //OUTPUT
22 mprintf('Relative efficiency of the engine is %3.1f
      percent',nr)
23
24
25
26
27
28
29
30 //================================END OF PROGRAM
   ===================================
```

Scilab code Exa 2.3 Air standard efficiency

```
1  //Chapter-2, Illustration 3, Page 57
2  //Title: Gas Power Cycles
3  //
   =========================================================
4  clc
```

```
5 clear
6
7 //INPUT DATA
8 d=0.137;//Bore in m
9 L=0.13;//Stroke in m
10 Vc=280*(10^-6);//Clearance volume in m^3
11 y=1.4;//Ratio of specific heats
12
13 //CALCULATIONS
14 Vs=(3.147/4)*(d^2)*L;//Stroke volume in m^3
15 rv=(Vc/Vs)*100;//Compression ratio
16 rvf=(Vs+Vc)/Vc;//final compression ratio
17 n=(1-(1/rvf^(y-1)))*100;//Cycle efficiency
18
19 //OUTPUT
20 mprintf('Clearance volume is %3.1f percent of swept
     volume \n Otto cycle efficiency is %3.2f percent'
     ,rv,n)
21
22
23
24
25
26
27 //===============================END OF PROGRAM
     ===========================
```

Scilab code Exa 2.4 Highest temperature and pressure in cycle and Amount of heat t

```
1 //Chapter −2, Illustration 4, Page 58
2 //Title: Gas Power Cycles
3 //
     ================================================
4 clc
```

```scilab
 5  clear
 6
 7  //INPUT DATA
 8  rv=9.5;//Compression ratio
 9  P1=100;//Air pressure in kPa
10  T1=290;//Air temperature in K
11  V1=600*(10^-6);//Volume of air in m^3
12  T4=800;//Final temperature in K
13  R=287;//Universal gas constan in J/kg.K
14  Cv=0.718;//Specific heat at constant volume in kJ/kg
        .K
15  y=1.4;//Ratio of specific heats
16
17  //CALCULATIONS
18  T3=T4*(rv^(y-1));//Temperature at the end of
        constant volume heat addition in K
19  P2=P1*(rv^y);//Pressure at point 2 in kPa
20  T2=T1*(rv^(y-1));//Temperature at point 2 in K
21  P3=P2*(T3/T2);//Pressure at point 3 in kPa
22  m=(P1*1000*V1)/(R*T1);//Specific mass in kg/s
23  Q=m*Cv*(T3-T2);//Heat transferred in kJ
24  n=(1-(1/rv^(y-1)))*100;//Thermal efficiency
25  Wnet=(n*Q)/100;//Net workdone in kJ
26  MEP=Wnet/(V1*(1-(1/rv)));//Mean effective pressure
        in kPa
27
28  //OUTPUT
29  mprintf('Maximum pressure of the cycle is %3.2f kPa
        \n Maximum temperature of the cycle is %3.1f K \n
         Amount of heat transferred is %3.2f kJ \n
        Thermal efficiency is %3.1f percent \n Mean
        effective pressure is %3.1f kPa',P3,T3,Q,n,MEP)
30
31
32
33
34
35
```

36
37 //═══════════════════════════════════END OF PROGRAM
═════════════════════════════════

───

Scilab code Exa 2.5 Pressure and Temperature at the end of heat addition process a

```
1  //Chapter -2, Illustration 5, Page 60
2  //Title: Gas Power Cycles
3  //
      ══════════════════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  rv=8;//Compression ratio
9  P1=95;//Pressure at point 1 in kPa
10 T1=300;//Temperature at point 1 in K
11 q23=750;//Heat transferred during constant volume
      heat addition process in kJ/kg
12 y=1.4;//Ratio of specific heats
13 Cv=0.718;//Specific heat at constant volume in kJ/kg
      -K
14 R=287;//Universal gas constant in J/kg-K
15
16 //CALCULATIONS
17 T2=T1*(rv^(y-1));//Temperature at point 2 in K
18 P2=P1*(rv^y);//Pressure at point 2 in kPa
19 T3=(q23/Cv)+T2;//Temperature at point 3 in K
20 P3=P2*(T3/T2);//Pressure at point 3 in kPa
21 nth=(1-(1/(rv^(y-1))))*100;//Thermal efficiency
22 Wnet=(nth*q23)/100;//Net work output in kJ/kg
23 v1=(R*T1)/(P1*1000);//Speific volume at point 1 in (
      m^3)/kg
24 MEP=Wnet/(v1*(1-(1/rv)));//Mean effective pressure
```

33

```
        in  kPa
25
26  //OUTPUT
27  mprintf ( ' Pressure  at  the  end  of  heat  addition
        process  is  %3.1 f  kPa  \n  Temperature  at  the  end  of
         heat  addition  process  is  %3.1 f  K  \n  Net  work
        output  is  %3.2 f  kJ/kg  \n  Thermal  efficiency  is  %3
        .2 f  percent  \n  Mean  effective  pressure  is  %3.0 f
        kPa ' , P3 , T3 , Wnet , nth , MEP )
28
29
30
31
32
33
34
35  //═══════════════════════════════════════END  OF  PROGRAM
        ═══════════════════════════════════
```

Scilab code Exa 2.6 `Air standard efficiency`

```
 1  // Chapter −2,  Illustration  6,  Page  61
 2  // Title :  Gas  Power  Cycles
 3  //
        ═══════════════════════════════════════════════════════════

 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  rv =14; // Compression  ratio
 9  c =0.06; // Cut−off  percentage
10  y =1.4; // Ratio  of  specific  heats
11
12  //CALCULATIONS
```

34

```
13  rc=1.78;//Cut-off ratio
14  nth=(1-(((rc^y)-1)/((rv^(y-1))*y*(rc-1))))*100;//
       Thermal efficiency
15
16  //OUTPUT
17  mprintf('Air standard efficiency is %3.1f percent',
       nth)
18
19
20
21
22
23
24
25  //===============================END OF PROGRAM
       ================================
```

Scilab code Exa 2.7 Cutoff ratio and Heat supplied and Cycle efficiency and MEP

```
1  //Chapter-2, Illustration 7, Page 62
2  //Title: Gas Power Cycles
3  //
       ==================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  rv=16;//Compression ratio
9  P1=0.1;//Pressure at point 1 in MPa
10 T1=288;//Temperature at point 1 in K
11 T3=1753;//Temperature at point 3 in K
12 y=1.4;//Ratio of specific heats
13 Cp=1.005;//Specific heat at constant pressure in kJ/
       kg-K
```

```
14  R=0.287;//Universal gas constant in kJ/kg-K
15
16  //CALCULATIONS
17  T2=T1*(rv^(y-1));//Temperature at point 2 in K
18  rc=T3/T2;//Cut-off ratio
19  q1=Cp*(T3-T2);//Heat supplied in kJ/kg
20  nth=(1-(((rc^y)-1)/((rv^(y-1))*y*(rc-1))))*100;//
       Cycle efficiency
21  wnet=(q1*nth)/100;//Net work done in kJ/kg
22  v1=(R*T1)/(P1*1000);//Speific volume at point 1 in (
       m^3)/kg
23  v2=v1/rv;//Speific volume at point 2 in (m^3)/kg
24  MEP=wnet/(v1-v2);//Mean effective pressure in kPa
25
26  //OUTPUT
27  mprintf('Cut-off ratio is %3.2f \n Heat supplied is
       %3.1f kJ/kg \n Cycle efficiency is %3.1f percent
       \n Mean effective pressure is %3.2f kPa',rc,q1,
       nth,MEP)
28
29
30
31
32  //===============================END OF PROGRAM
       =============================
```

Scilab code Exa 2.8 Air standard efficiency and percentage loss in efficiency

```
1  //Chapter-2, Illustration 8, Page 64
2  //Title: Gas Power Cycles
3  //
    ===================================================
4  clc
5  clear
```

```scilab
 6
 7  //INPUT DATA
 8  d=0.15;//Bore in m
 9  L=0.25;//Stroke in m
10  Vc=400*(10^-6);//Clearance volume in m^3
11  V2=Vc;//Clearance volume in m^3
12  c1=0.05;//Cut-off percentage 1
13  c2=0.08;//Cut-off percentage 2
14  y=1.4;//Ratio of specific heats
15
16  //CALCULATIONS
17  Vs=(3.147/4)*(d^2)*L;//Stroke volume in m^3
18  V31=V2+(c1*Vs);//Volume at the point of cut-off in m
       ^3
19  rc1=V31/V2;//Cut-off ratio 1
20  rv=(Vc+Vs)/Vc;//Compression ratio
21  nth1=(1-(((rc1^y)-1)/((rv^(y-1))*y*(rc1-1))))*100;//
       Air standard efficiency 1
22  V32=V2+(c2*Vs);//Volume at the point of cut-off in m
       ^3
23  rc2=V32/V2;//Cut-off ratio 2
24  nth2=(1-(((rc2^y)-1)/((rv^(y-1))*y*(rc2-1))))*100;//
       Air standard efficiency 2
25  pl=nth1-nth2;//Percentage loss in efficiency
26
27  //OUTPUT
28  mprintf('Air standard efficiency at 5 percent cut-
       off is %3.2f percent \n Air standard efficiency
       at 8 percent cut-off is %3.2f percent \n
       Percentage loss in efficiency is %3.2f percent',
       nth1,nth2,pl)
29
30
31
32
33
34  //===============================END OF PROGRAM
       ================================
```

Scilab code Exa 2.9 Maximum temperature and Thermal efficiency of cycle

```
1  //Chapter -2, Illustration 9, Page 65
2  //Title: Gas Power Cycles
3  //
4  clc
5  clear
6
7  //INPUT DATA
8  e=7.5;//Expansion ratio
9  c=15;//Compression ratio
10 P1=98;//Pressure at point 1 in kN/(m^2)
11 P4=258;//Pressure at point 4 in kN/(m^2)
12 T1=317;//Temperature at point 1 in K
13 y=1.4;//Ratio of specific heats
14
15 //CALCULATIONS
16 T4=T1*(P4/P1);//Temperature at point 4 in K
17 T3=T4*(e^(y-1));//Temperature at point 3 in K
18 t3=T3-273;//Temperature at point 3 in oC
19 T2=T1*(c^(y-1));//Temperature at point 2 in K
20 n=(1-((T4-T1)/(y*(T3-T2))))*100;//Thermal efficiency
21
22 //OUTPUT
23 mprintf('Maximum temperature attained during the
       cycle is %3.1f oC \n Thermal efficiency of the
       cycle is %3.1f percent',t3,n)
24
25
26
27
28
```

29
30 //══END OF PROGRAM
════════════════════════════════════

_____

Scilab code Exa 2.10 Thermal efficiency and MEP

```
1  //Chapter -2, Illustration 10, Page 66
2  //Title: Gas Power Cycles
3  //
    ══════════════════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  rv=20;//Compression ratio
9  P1=95;//Pressure at point 1 in kPa
10 T1=293;//Temperature at point 1 in K
11 T3=2200;//Temperature at point 3 in K
12 y=1.4;//Ratio of specific heats
13 R=287;//Universal gas constant in J/kg-K
14 Cp=1.005;//Specific heat at constant pressure in kJ/
    kg-K
15
16 //CALCULATIONS
17 P2=P1*(rv^y);//Pressure at point 2 in kPa
18 T2=T1*(rv^(y-1));//Temperature at point 2 in K
19 v2=(R*T2)/(P2*1000);//Specific volume at point 2 in
    (m^3)/kg
20 v3=v2*(T3/T2);//Specific volume at point 3 in (m^3)/
    kg
21 rc=v3/v2;//Cut-off ratio
22 nth=(1-(((rc^y)-1)/((rv^(y-1))*y*(rc-1))))*100;//
    Thermal efficiency
23 q23=Cp*(T3-T2);//Heat flow between points 2 and 3 in
```

```
        kJ/kg
24  wnet=(nth*q23)/100;//Net workdone in kJ/kg
25  MEP=wnet/(v2*(rv-1));//Mean effective pressure in
        kPa
26
27  //OUTPUT
28  mprintf('Thermal efficiency is %3.1f percent \n Mean
        effective pressure is %3.2f kPa',nth,MEP)
29
30
31
32
33
34
35  //===============================END OF PROGRAM
        ================================
```

Scilab code Exa 2.11 Cutoff ratio and air standard efficiency

```
1  //Chapter-2, Illustration 11, Page 68
2  //Title: Gas Power Cycles
3  //
        =================================================
4  clc
5  clear
6
7  //INPUT DATA
8  rv=21;//Compression ratio
9  re=10.5;//Expansion ratio
10  y=1.4;//Ratio of specific heats
11
12  //CALCULATIONS
13  rc=rv/re;//Cut-off ratio
14  nth=(1-(((rc^y)-1)/((rv^(y-1))*y*(rc-1))))*100;//Air
```

```
        standard efficiency
15
16 //OUTPUT
17 mprintf('Cut−off ratio is %3.0f \n Air standard
       efficiency is %3.2f percent',rc,nth)
18
19
20
21
22
23
24
25
26 //==============================END OF PROGRAM
       ==================================
```

Scilab code Exa 2.12 Ideal efficiency of cycle

```
1 //Chapter−2, Illustration 12, Page 69
2 //Title: Gas Power Cycles
3 //
       ================================================
4 clc
5 clear
6
7 //INPUT DATA
8 rv=16;//Compression ratio
9 rp=1.5;//Pressure ratio
10 y=1.4;//Ratio of specific heats
11 cp=8;//Cut−off percentage
12
13 //CALCULATIONS
14 rc=2.2;//Cut−off ratio
15 ntd=(1-((rp*(rc^y)-1)/((rv^(y-1)*((rp-1)+(y*rp*(rc
```

```
       -1)))))))*100;//Dual  cycle  efficiency
16
17  //OUTPUT
18  mprintf('Ideal  efficiency  of  engine  is  %3.1f  percent
       ',ntd)
19
20
21
22
23
24
25  //=============================END  OF  PROGRAM
       ==================================
```

_____

Scilab code Exa 2.13 Ideal efficiency of engine

```
1  //Chapter −2,  Illustration  13,  Page  69
2  //Title:  Gas  Power  Cycles
3  //
       ==================================================
4  clc
5  clear
6
7  //INPUT DATA
8  d=0.2;//Bore  in  m
9  L=0.5;//Stroke  in  m
10 c=0.06;//Cut−off  percentage
11 y=1.4;//Ratio  of  specific  heats
12 rv=15;//Compression  ratio
13 rp=1.4;//Pressure  ratio
14
15 //CALCULATIONS
16 Vs=(3.147/4)*(d^2)*L;//Stroke  volume  in  m^3
17 DV=c*Vs;//Difference  in  volumes  at  points  4  and  3
```

```
18  V3=Vs/(rv-1);//Specific volume at point 3 in m^3
19  V4=V3+DV;//Specific volume at point 4 in m^3
20  rc=V4/V3;//Cut-off ratio
21  ntd=(1-((rp*(rc^y)-1)/((rv^(y-1)*((rp-1)+(y*rp*(rc
       -1)))))))*100;//Ideal efficiency
22
23  //OUTPUT
24  mprintf('Ideal efficiency of the engine is %3.1f
       percent',ntd)
25
26
27
28
29
30  //================================END OF PROGRAM
       =============================
```

Scilab code Exa 2.14 Amount of heat added and rejected and Work done and Thermal e

```
1  //Chapter-2, Illustration 14, Page 70
2  //Title: Gas Power Cycles
3  //
       ================================================
4  clc
5  clear
6
7  //INPUT DATA
8  d=0.2;//Bore in m
9  L=0.3;//Stroke in m
10  c=0.04;//Cut-off percentage
11  y=1.4;//Ratio of specific heats
12  rv=8;//Compression ratio
13  P1=1;//Pressure at point 1 in bar
14  P3=60;//Pressure at point 3 in bar
```

```scilab
15  T1=298;//Temperature at point 1 in K
16  R=287;//Universal gas constant in J/kg
17  Cv=0.718;//Speific heat at constant volume in kJ/kg-
       K
18  Cp=1.005;//Speific heat at constant pressure in kJ/
       kg-K
19
20  //CALCULATIONS
21  Vs=(3.147/4)*(d^2)*L;//Stroke volume in m^3
22  V2=Vs/(rv-1);//Specific volume at point 2 in m^3
23  V3=V2;//Specific volume at point 3 in m^3
24  V1=V2+Vs;//Specific volume at pont 1 in m^3
25  V5=V1;//Specific volume at pont 5 in m^3
26  P2=P1*(rv^y);//Pressure at point 2 in bar
27  T2=T1*(rv^(y-1));//Temperature at point 2 in K
28  T3=T2*(P3/P2);//Temperature at point 3 in K
29  V4=V3+(c*(V1-V2));//Specific volume at point 4 in m
       ^3
30  T4=T3*(V4/V3);//Temperature at point 4 in K
31  T5=T4*((V4/V5)^(y-1));//Temperature at point 5 in K
32  q1=(Cv*(T3-T2))+(Cp*(T4-T3));//Heat added in kJ/kg
33  q2=Cv*(T5-T1);//Heat rejected in kJ/kg
34  nth=(1-(q2/q1))*100;//Thermal efficiency
35  m=(P1*V1*(10^5))/(R*T1);//Mass of air supplied in kg
36  W=m*(q1-q2);//Workdone in kJ/cycle
37
38  //OUTPUT
39  mprintf('Amount of heat added is %3.1f kJ/kg \n
       Amount of heat rejected is %3.2f kJ/kg \n
       Workdone per cycle is %3.2f kJ/cycle \n Thermal
       efficiency is %3.2f percent',q1,q2,W,nth)
40
41
42
43
44
45
46
```

//================================END OF PROGRAM
=====================================
_____

Scilab code Exa 2.15 MEP and Thermal efficiency

```
1  //Chapter -2, Illustration  15, Page  72
2  //Title:  Gas  Power  Cycles
3  //
      ==================================================

4  clc
5  clear
6
7  //INPUT DATA
8  P1=1;//Pressure  at  point  1  in  bar
9  P3=70;//Pressure  at  point  3  in  bar
10 T1=310;//Temperature  at  point  1  in  K
11 rv=10;//Compression  ratio
12 y=1.4;//Ratio  of  specific  heats
13 qin=2805;//Heat  added  in  kJ/kg
14 m=1;//Mass  of  air  in  kg
15 R=287;//Universal  gas  constant  in  J/kg
16 Cv=0.718;//Speific  heat  at  constant  volume  in  kJ/kg−
      K
17 Cp=1.005;//Speific  heat  at  constant  pressure  in  kJ/
      kg−K
18
19 //CALCULATIONS
20 V1=(m*R*T1)/(P1*(10^5));//Volume  at  point  1  in  m^3
21 T2=T1*(rv^(y-1));//Temperature  at  point  2  in  K
22 P2=P1*(rv^y);//Pressure  at  point  2  in  K
23 T3=T2*(P3/P2);//Temperature  at  point  3  in  K
24 q23=Cv*(T3-T2);//Heat  supplied  at  constant  volume  in
       kJ/kg
25 q34=qin-q23;//Heat  supplied  at  constant  pressure  in
```

```
          kJ/kg
26  T4=(q34/Cp)+T3;//Temperature at point 4 in K
27  V2=V1/rv;//Volume at point 2 in m^3
28  V4=V2*(T4/T3);//Volume at point 4 in m^3
29  V5=V1;//Volume at point 5 in m^3
30  T5=T4*((V4/V5)^(y-1));//Temperature at point 5 in K
31  qout=Cv*(T5-T1);//Heat rejected in kJ/kg
32  nth=(1-(qout/qin))*100;//Thermal efficiency
33  W=qin-qout;//Workdone in kJ/kg
34  Vs=V1*(1-(1/rv));//Swept volume in (m^3)/kg
35  MEP=(W/Vs)/100;//Mean effective pressure in bar
36
37  //OUTPUT
38  mprintf('Mean effective pressure is %3.2f bar \n
        Thermal efficiency is %3.2f percent',MEP,nth)
39
40
41
42
43
44
45  //===============================END OF PROGRAM
        =================================
```

Scilab code Exa 2.16 Cycle efficiency and Heat supplied and rejected and Work outp

```
1  //Chapter-2, Illustration 16, Page 74
2  //Title: Gas Power Cycles
3  //
        ===================================================
4  clc
5  clear
6
7  //INPUT DATA
```

```
 8  P1=1;//Pressure at point 1 in bar
 9  T1=298;//Temperature at point 1 in K
10  P2=3;//Pressure at point 2 in bar
11  T3=923;//Temperature at point 3 in K
12  y=1.4;//Ratio of specific heats
13  Cp=1.005;//Speific heat at constant pressure in kJ/
        kg-K
14
15  //CALCULATIONS
16  x=(y-1)/y;//Ratio
17  rp=P2/P1;//Pressure ratio
18  nth=(1-(1/(rp^x)))*100;//Cycle efficiency
19  T2=T1*(rp^x);//Temperature at point 2 in K
20  q1=Cp*(T3-T2);//Heat supplied in kJ/kg
21  Wout=(nth*q1)/100;//Work output in kJ/kg
22  q2=q1-Wout;//Heat rejected in kJ/kg
23  T4=T3*((1/rp)^x);//Temperature at point 4 in K
24
25  //OUTPUT
26  mprintf('Cycle efficiency is %3.2f percent \n Heat
        supplied to air is %3.1f kJ/kg \n Work available
        at the shaft is %3.2f kJ/kg \n Heat rejected in
        the cooler is %3.2f kJ/kg \n Turbine exit
        temperature is %3.2f K',nth,q1,Wout,q2,T4)
27
28
29
30
31
32
33  //=============================END OF PROGRAM
        ===============================
```

Scilab code Exa 2.17 Pressure ratio and Maximum net specific work output and Therm

47

```
1  //Chapter-2, Illustration 17, Page 75
2  //Title: Gas Power Cycles
3  //
      _____

4  clc
5  clear
6
7  //INPUT DATA
8  T1=283;//Temperature at point 1 in K
9  T3=1353;//Temperature at point 3 in K
10 y=1.41;//Ratio of specific heats
11 Cp=1.007;//Specific heat constant pressure in kJ/kg-
      K
12
13 //CALCULATIONS
14 x=(y-1)/y;//Ratio
15 rpmax=((T3/T1)^(1/x));//Maximum pressure ratio
16 rpopt=sqrt(rpmax);//Optimum pressure ratio
17 T2=T1*(rpopt^x);//Temperature at point 2 in K
18 T4=T2;//Maximum temperature at point 4 in K
19 Wmax=Cp*((T3-T4)-(T2-T1));//Maximum net specific
      work output in kJ/kg
20 nth=(Wmax/(Cp*(T3-T2)))*100;//Thermal efficiency
21 WR=nth/100;//Work ratio
22 nc=((T3-T1)/T3)*100;//Carnot efficiency
23
24 //OUTPUT
25 mprintf('Optimum pressure ratio is %3.2f \n Maximum
       net specific work output %3.0f kJ/kg \n Thermal
       efficiency %3.0f percent \n Work ratio is %3.2f \
      n Carnot efficiency is %3.0f percent',rpopt,Wmax,
      nth,WR,nc)
26
27
28
29
30
```

```
31
32 //═══════════════════════════════════════END OF PROGRAM
      ══════════════════════════════════════
```

Scilab code Exa 2.18 Maximum work output and Cycle efficiency and Comparison with

```
1 //Chapter −2, Illustration 18, Page 76
2 //Title: Gas Power Cycles
3 //
      ═══════════════════════════════════════════════════════════

4 clc
5 clear
6
7 //INPUT DATA
8 Tmin=300;//Minimum temperature in K
9 Tmax=1073;//Maximum temperature in K
10 Cp=1.005;//Specific heat at constant pressure in kJ/
      kg−K
11
12 //CALCULATIONS
13 Wmax=Cp*((sqrt(Tmax)-sqrt(Tmin))^2);//Maximum work
      output in kJ/kg
14 nB=(1-sqrt(Tmin/Tmax))*100;//Brayton cycle
      efficiency
15 nC=(1-(Tmin/Tmax))*100;//Carnot efficiency
16 r=nB/nC;//Ratio of brayton cycle efficiency to
      carnot efficieny
17
18 //OUTPUT
19 mprintf('Maximum work per kg of air is %3.2f kJ/kg \
      n Cycle efficiency is %3.0f percent \n Ratio of
      brayton cycle efficiency to carnot efficieny is
      %3.3f',Wmax,nB,r)
20
```

```
21
22
23
24
25
26  //════════════════════════════END OF PROGRAM
        ═══════════════════════════════
```

Scilab code Exa 2.19 Net power output and Thermal efficiency and Work ratio

```
1  //Chapter-2, Illustration 19, Page 77
2  //Title: Gas Power Cycles
3  //
        ════════════════════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  T1=291;//Temperature at point 1 in K
9  P1=100;//Pressure at point 1 in kN/(m^2)
10 nC=0.85;//Isentropic efficiency of compressor
11 nT=0.88;//Isentropic effficiency of turbine
12 rp=8;//Pressure ratio
13 T3=1273;//Temperature at point 3 in K
14 m=4.5;//Mass flow rate of air in kg/s
15 y=1.4;//Ratio of speciifc heats
16 Cp=1.006;//Specific heat at constant pressure in kJ/
        kg-K
17
18 //CALCULATIONS
19 x=(y-1)/y;//Ratio
20 T2s=T1*(rp^x);//Temperature at point 2s in K
21 T2=T1+((T2s-T1)/nC);//Temperature at point 2 in K
22 t2=T2-273;//Temperature at point 2 in oC
```

50

```
23 T4s=T3*((1/rp)^x);//Temperature at point 4s in K
24 T4=T3-((T3-T4s)*nT);//Temperature at point 4 in K
25 t4=T4-273;//Temperature at point 4 in oC
26 W=m*Cp*((T3-T4)-(T2-T1));//Net power output in kW
27 nth=(((T3-T4)-(T2-T1))/(T3-T2))*100;//Thermal
       efficiency
28 WR=W/(m*Cp*(T3-T4));//Work ratio
29
30 //OUTPUT
31 mprintf('Net power output of the turbine is %3.0f kW
        \n Thermal efficiency of the plant is %3.0f
       percent \n Work ratio is %3.3f',W,nth,WR)
32
33
34
35
36
37
38 //==============================END OF PROGRAM
       ==============================
```

Scilab code Exa 2.20 Percentage increase in cycle efficiency

```
1 //Chapter−2, Illustration 20, Page 79
2 //Title: Gas Power Cycles
3 //
       ==================================================================
4 clc
5 clear
6
7 //INPUT DATA
8 P1=0.1;//Pressure at point 1 in MPa
9 T1=303;//Temperature at point 1 in K
10 T3=1173;//Temperature at point 3 in K
```

```
11  rp=6;//Pressure ratio
12  nC=0.8;//Compressor efficiency
13  nT=nC;//Turbine efficiency
14  e=0.75;//Regenerator effectiveness
15  y=1.4;//Ratio of specific heats
16  Cp=1.005;//Specific heat at constant pressure in kJ/
        kg-K
17
18  //CALCULATIONS
19  x=(y-1)/y;//Ratio
20  T2s=T1*(rp^x);//Temperature at point 2s in K
21  T4s=T3/(rp^x);//Temperature at point 4s in K
22  DTa=(T2s-T1)/nC;//Difference in temperatures at
        point 2 and 1 in K
23  DTb=(T3-T4s)*nT;//Difference in temperatures at
        point 3 and 4 in K
24  wT=Cp*DTb;//Turbine work in kJ/kg
25  wC=Cp*DTa;//Compressor work in kJ/kg
26  T2=DTa+T1;//Temperature at point 2 in K
27  q1=Cp*(T3-T2);//Heat supplied in kJ/kg
28  nth1=((wT-wC)/q1)*100;//Cycle efficiency without
        regenerator
29  T4=T3-DTb;//Temperature at point 4 in K
30  T5=T2+(e*(T4-T2));//Temperature at point 5 in K
31  q2=Cp*(T3-T5);//Heat supplied with regenerator in kJ
        /kg
32  nth2=((wT-wC)/q2)*100;//Cycle efficiency with
        regenerator
33  p=((nth2-nth1)/nth1)*100;//Percentage increase due
        to regeneration
34
35  //OUTPUT
36  mprintf('Percentage increase in the cycle efficiency
        due to regeneration is %3.2f percent',p)
37
38
39
40
```

```
41
42
43
44
45 //════════════════════════════════END  OF  PROGRAM
      ════════════════════════════════
```

_____

Scilab code Exa 2.21 Velocity of air leaving nozzle

```
1 //Chapter −2, Illustration  21,  Page  80
2 //Title:  Gas  Power  Cycles
3 //
      ════════════════════════════════════════════════════════════
4 clc
5 clear
6
7 //INPUT DATA
8 P1=1;//Pressure  at  point  1  in  atm
9 P3=5;//Pressure  at  point  3  in  atm
10 T1=288;//Temperature  at  point  1  in  K
11 T4=1143;//Temperature  at  point  4  in  K
12 y=1.4;//Ratio  of  specific  heats
13 Cp=1.005;//Specific  heat  at  constant  pressure  in  kJ/
      kg−K
14
15 //CALCULATIONS
16 rp=P3/P1;//Pressure  ratio
17 x=(y-1)/y;//Ratio
18 T3=T1*(rp^x);//Temperature  at  point  3  in  K
19 T5=T4-(T3-T1);//Temperature  at  point  5  in  K
20 T6=T4/(rp^x);//Temperature  at  point  6  in  K
21 C6=sqrt(2000*Cp*(T5-T6));//Velocity  of  air  leaving
      the  nozzle  in  m/s
22
```

```
23  //OUTPUT
24  mprintf('Velocity of air leaving the nozzle is %3.1f
        m/s',C6)
25
26
27
28
29
30
31  //======================================END OF PROGRAM
        ======================================
```

Scilab code Exa 2.22 Turbine exit pressure and Velocity of exhaust gases and Propu

```
1  //Chapter −2, Illustration  22, Page  81
2  //Title: Gas Power Cycles
3  //
        ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  C1=280;//Velocity of aircraft in m/s
9  P1=48;//Pressure at point 1 kPa
10 T1=260;//Temperature at point 1 in K
11 rp=13;//Pressure ratio
12 T4=1300;//Temperature at point 4 in K
13 Cp=1005;//Specific heat at constant pressure in J/kg
14 y=1.4;//Ratio of specific heats
15
16 //CALCULATIONS
17 x=(y-1)/y;//Ratio
18 T2=T1+((C1^2)/(2*Cp));//Temperature at point 2 in K
19 P2=P1*((T2/T1)^(1/x));//Pressure at point 2 in kPa
```

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```
20  P3=rp*P2;//Pressure at point 3 in kPa
21  P4=P3;//Pressure at point 4 in kPa
22  T3=T2*(rp^x);//Temperature at point 3 in K
23  T5=T4-T3+T2;//Temperature at point 5 in K
24  P5=P4*((T5/T4)^(1/x));//Pressure at point 5 in kPa
25  P6=P1;//Pressure at point 6 in kPa
26  T6=T5*((P6/P5)^x);//Temperature at point 6 in K
27  C6=sqrt(2*Cp*(T5-T6));//Velocity of air at nozzle
        exit in m/s
28  W=(C6-C1)*C1;//Propulsive power in J/kg
29  Q=Cp*(T4-T3);//Total heat transfer rate in J/kg
30  nP=(W/Q)*100;//Propulsive efficiency
31
32  //OUTPUT
33  mprintf('Pressure at the turbine exit is %3.1f kPa \
        n Velocity of exhaust gases are %3.1f m/s \n
        Propulsive efficiency is %3.1f percent',P5,C6,nP)
34
35
36
37
38
39
40
41
42
43
44
45  //==================================END OF PROGRAM
        ==================================
```

Chapter 3

Internal Combustion Engines

Scilab code Exa 3.1 Air standard efficiency and Indicated Power and Indicated ther

```
1  //Chapter-3, Illustration 1, Page 139
2  //Title: Internal Combustion Engines
3  //
    ================================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  d=200;//diameter of cylinder in mm
9  L=300;//stroke of cylinder in mm
10 Vc=1.73;//Clearance volume in litres
11 imep=650;//indicated mean effective pressure in kN/(
    m^2)
12 g=6.2;//gas consumption in (m^3)/h
13 CV=38.5;//Calorific value in MJ/(m^3)
14 y=1.4;//Ratio of specific heats
15 N=150;//No. of firing cycles per minute
16
17 //CALCULATIONS
18 Vs=((3.1415/4)*(d^2)*L)*(10^-6);//Stroke volume in
```

```
        litres
19  Vt=Vs+Vc;//Total volume in litres
20  rv=(Vt/Vc);//Compression ratio
21  n=(1-(1/rv^(y-1)))*100;//Air standard efficiency
22  IP=imep*(Vs*10^-3)*(N/60);//Indicated power in kW
23  F=(g*CV*1000)/3600;//Fuel energy input in kW
24  nT=(IP/F)*100;//Indicated thermal efficiency
25
26  //OUTPUT
27  mprintf('Air Standard Efficiency is %3.1f percent \n
        Indicated Power is %3.1f kW \n Indicated thermal
        efficiency is %3.0f percent',n,IP,nT)
28
29
30
31
32  //======================================END OF PROGRAM
        ===========================
```

Scilab code Exa 3.2 Relative efficiency of engine

```
1  //Chapter-3, Illustration 2, Page 140
2  //Title: Internal Combustion Engines
3  //
        =======================================================

4  clc
5  clear
6
7  //INPUT DATA
8  Vs=0.0008;//Swept volume in m^3
9  Vc=0.00015;//Clearance volume in m^3
10 CV=38;//Calorific value in MJ/(m^3)
11 v=0.45;//volume in m^3
12 IP=81.5;//Indicated power in kW
```

```
13  y =1.4; //Ratio  of  specific  heats
14
15  //CALCULATIONS
16  rv =(Vs+Vc)/Vc; //Compression  ratio
17  n =(1 -(1/rv^(y-1))); //Air  standard  efficiency
18  Ps =(v*CV*1000)/60; //Power  supplied  in  kW
19  nact =IP/Ps; //Actual  efficiency
20  nr =(nact/n)*100; //Relative  efficiency
21
22  //OUTPUT
23  mprintf('Relative  Efficiency  is  %3.2f  percent ',nr)
24
25
26
27  //=============================END  OF  PROGRAM
       ============================
```

Scilab code Exa 3.3 Indicated power and Brake power and and Brake thermal efficien

```
1  //Chapter -3,  Illustration  3,  Page  141
2  //Title:  Internal  Combustion  Engines
3  //
       ===============================================================
4  clc
5  clear
6
7  //INPUT DATA
8  n =6; //No.  of  cylinders
9  d =0.61; //Diameter  in  m
10  L =1.25; //Stroke  in  m
11  N =2; //No.of  revolutions  per  second
12  m =340; //mass  of  fuel  oil  in  kg
13  CV =44200; //Calorific  value  in  kJ/kg
14  T =108; //Torque  in  kN-m
```

```
15  imep=775; //Indicated mean efective pressure in kN/(m
        ^2)
16
17  //CALCULATIONS
18  IP=(imep*L*3.1415*(d^2)*N)/(8); //Indicated power in
        kW
19  TotalIP=(n*IP); //Total indicated power in kW
20  BP=(2*3.1415*N*T); //Brake power in kW
21  PI=(m*CV)/3600; //Power input in kW
22  nB=(BP/PI)*100; //Brake thermal efficiency
23  bmep=(BP*8)/(n*L*3.1415*(d^2)*2); //Brake mean
        effective pressure in kN/(m^2)
24  nM=(BP/TotalIP)*100; //Mechanical efficiency
25  bsfc=m/BP; //Brake specific fuel consumption in kg/
        kWh
26
27  //OUTPUT
28  mprintf('Total Indicated Power is %3.1f kW \n Brake
        Power is %3.1f kW \n Brake thermal efficiency is
        %3.1f percent \n Brake mean effective pressure is
         %3.1f kN/(m^2) \n Mechanical efficiency is %3.1f
         percent \n Brake specific fuel consumption is %3
        .3f kg/kW.h',TotalIP,BP,nB,bmep,nM,bsfc)
29
30
31
32  //══════════════════════════════════END OF PROGRAM
        ════════════════════════════════
```

Scilab code Exa 3.4 Indicated power and Brake output and Mechanical efficiency and

```
1  //Chapter −3, Illustration 4, Page 142
2  //Title: Internal Combustion Engines
3  //
```

```
 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  Hm=21;//Mean height of indicator diagram in mm
 9  isn=27;//indicator spring number in kN/(m^2)/mm
10  Vs=14;//Swept volume in litres
11  N=6.6;//Speed of engine in rev/s
12  Pe=77;//Effective brake load in kg
13  Re=0.7;//Effective vrake radius in m
14  mf=0.002;//fuel consumed in kg/s
15  CV=44000;//Calorific value of fuel in kJ/kg
16  mc=0.15;//cooling water circulation in kg/s
17  Ti=311;//cooling water inlet temperature in K
18  To=344;//cooling water outlet temperature in K
19  C=4.18;//specific heat capacity of water in kJ/kg-K
20  Ee=33.6;//Energy to exhaust gases in kJ/s
21  g=9.81;//Acceleration due to geravity in m/(s^2)
22
23  //CALCULATIONS
24  imep=isn*Hm;//Indicated mean efective pressure in kN
        /(m^2)
25  IP=(imep*Vs*N)/(2000);//Indicated Power in kW
26  BP=(2*3.1415*N*g*Pe*Re)/1000;//Brake Power in kW
27  nM=(BP/IP)*100;//Mechanical efficiency
28  Ef=mf*CV;//Eneergy from fuel in kJ/s
29  Ec=mc*C*(To-Ti);//Energy to cooling water in kJ/s
30  Es=Ef-(BP+Ec+Ee);//Energy to surroundings in kJ/s
31  p=(BP*100)/Ef;//Energy to BP in %
32  q=(Ec*100)/Ef;//Energy to coolant in %
33  r=(Ee*100)/Ef;//Energy to exhaust in %
34  w=(Es*100)/Ef;//Energy to surroundings in %
35
36  //OUTPUT
37  mprintf('Indicated Power is %3.1f kW \n Brake Power
        is %3.0f kW \n Mechanical Efficiency is %3.0f
        percent \n \nENERGY BALANCE                    kJ
```

```
         /s         Percentage \nEnergy  from  fuel
                        %3.0 f              100\nEnergy  to  BP
                           %3.0 f            %3.0 f \nEnergy
      to  coolant                         %3.01 f         %3.1 f \
      nEnergy  to  exhaust                      %3.1 f
      %3.1 f \nEnergy  to  surroundings ,  etc          %3.1 f
             %3.1 f ' , IP , BP , nM , Ef , BP , p , Ec , q , Ee , r , Es , w )
38
39
40
41
42  //=============================END  OF  PROGRAM
      =================================
```

Scilab code Exa 3.5 Brake power and Brake specific fuel consumption and Indicated

```
1  //Chapter −3 ,  Illustration  5 ,  Page  143
2  //Title :  Internal  Combustion  Engines
3  //
      ================================================
4  clc
5  clear
6
7  //INPUT DATA
8  t =30; // duration  of  trial  in  minutes
9  N =1750; // speed  in  rpm
10  T =330; // brake  torque  in  Nm
11  m =9.35; // mass  of  fuel  in  kg
12  CV =42300; // Calorific  value  in  kJ/kg
13  mj =483; // jacket  cooling  water  circulation  in  kg
14  Ti =290; // inlet  temperature  in  K
15  T0 =350; // outlet  temperature  in  K
16  ma =182; // air  consumption  in  kg
17  Te =759; // exhaust  temperature  in  K
```

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```scilab
18  Ta=256;//atmospheric temperature in K
19  nM=0.83;//Mechanical efficiency
20  ms=1.25;//mean specific heat capacity of exhaust gas
        in kJ/kg-K
21  Cw=4.18;//specific heat capacity of water in kJ/kg-K
22
23  //CALCULATIONS
24  BP=(2*3.1415*T*N)/(60*1000);//Brake power in kW
25  sfc=(m*2)/BP;//specific fuel consumption in kg/kWh
26  IP=BP/nM;//Indicated power in kW
27  nIT=((IP*3600)/(m*CV*2))*100;//Indicated thermal
        efficiency
28  Ef=(m*CV)/t;//Eneergy from fuel in kJ/min
29  EBP=BP*60;//Energy to BP in kJ/min
30  Ec=(mj*Cw*(T0-Ti))/t;//Energy to cooling water in kJ
        /min
31  Ee=((ma+m)*ms*(Te-Ti))/30;//Energy to exhaust in kJ/
        min
32  Es=Ef-(EBP+Ec+Ee);//Energy to surroundings in kJ/min
33
34  //OUTPUT
35  mprintf('Brake power is %3.1f kW \n Specific fuel
        consumption is %3.3f kg/kWh \n Indicated thermal
        efficiency is %3.1f percent \n Energy from fuel
        is %3.0f kJ/min \n Energy to BP is %3.0f kJ/min \
        n Energy to cooling water is %3.0f kJ/min \n
        Energy to exhaust is %3.0f kJ/min \n Energy to
        surroundings is %3.0f kJ/min',BP,sfc,nIT,Ef,EBP,
        Ec,Ee,Es)
36
37
38
39
40
41
42  //===============================END OF PROGRAM
        ===========================
```

Scilab code Exa 3.6 Indicated power and Mechanical efficiency of engine

```
1  //Chapter -3, Illustration 6, Page 144
2  //Title: Internal Combustion Engines
3  //
    _____

4  clc
5  clear
6
7  //INPUT DATA
8  BP0=12;//Brake Power output in kW
9  BP1=40.5;//Brake Power in trial 1 in kW
10 BP2=40.2;//Brake Power in trial 2 in kW
11 BP3=40.1;//Brake Power in trial 3 in kW
12 BP4=40.6;//Brake Power in trial 4 in kW
13 BP5=40.7;//Brake Power in trial 5 in kW
14 BP6=40.0;//Brake Power in trial 6 in kW
15
16 //CALCULATIONS
17 BPALL=BP0+BP6;//Total Brake Power in kW
18 IP1=BPALL-BP1;//Indicated Power in trial 1 in kW
19 IP2=BPALL-BP2;//Indicated Power in trial 2 in kW
20 IP3=BPALL-BP3;//Indicated Power in trial 3 in kW
21 IP4=BPALL-BP4;//Indicated Power in trial 4 in kW
22 IP5=BPALL-BP5;//Indicated Power in trial 5 in kW
23 IP6=BPALL-BP6;//Indicated Power in trial 6 in kW
24 IPALL=IP1+IP2+IP3+IP4+IP5+IP6;//Total Indicated
       Power in kW
25 nM=(BPALL/IPALL)*100;//Mechanical efficiency
26
27 //OUTPUT
28 mprintf('Indicated Power of the engine is %3.1f kW \
       n Mechanical efficiency of the engine is %3.1f
```

63

```
     percent ', IPALL ,nM)
29
30
31
32  //═══════════════════════════════════════END OF PROGRAM
      ═══════════════════════════════
```

Scilab code Exa 3.7 Engine dimensions and Brake power

```
 1  //Chapter −3, Illustration 7, Page 145
 2  //Title: Internal Combustion Engines
 3  //
      ═══════════════════════════════════════════════════════════
```

```
 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  n=2;//No. of cylinders
 9  N=4000;//speed of engine in rpm
10  nV=0.77;//Volumetric efficiency
11  nM=0.75;//Mechanical efficiency
12  m=10;//fuel consumed in lit/h
13  g=0.73;//spcific gravity of fuel
14  Raf=18;//air−fuel ratio
15  Np=600;//piston speed in m/min
16  imep=5;//Indicated mean efective pressure in bar
17  R=281;//Universal gas constant in J/kg−K
18  T=288;//Standard temperature in K
19  P=1.013;//Standard pressure in bar
20
21  //CALCULATIONS
22  L=Np/(2*N);//Piston stroke in m
23  mf=m*g;//mass of fuel in kg/h
24  ma=mf*Raf;//mass of air required in kg/h
```

```
25  Va=(ma*R*T)/(P*60*(10^5));//volume of air required
        in (m^3)/min
26  D=sqrt((2*Va)/(nV*L*N*3.1415));//Diameter in m
27  IP=(2*imep*100*L*3.1415*(D^2)*N)/(4*60);//Indicated
        Power in kW
28  BP=nV*IP;//Brake Power in kW
29
30  //OUTPUT
31  mprintf('Piston Stroke is %3.3f m \n Bore diameter
        is %3.4f m \n Brake power is %3.1f kW',L,D,BP)
32
33
34
35  //================================END OF PROGRAM
        ================================
```

Chapter 4

Steam nozzles and Steam turbines

Scilab code Exa 4.1 Throat area and Exit area and Mach number at exit

```
1  //Chapter−4, Illustration 1, Page 161
2  //Title: Steam Nozzles and Steam Turbines
3  //
   ===============================================================
4  clc
5  clear
6
7  //INPUT DATA
8  P1=3.5;//Pressure at entry in MN/(m^2)
9  T1=773;//Temperature at entry in K
10 P2=0.7;//Pressure at exit in MN/(m^2)
11 ma=1.3;//mass flow rate of air in kg/s
12 y=1.4;//Ratio of specific heats
13 R=0.287;//Universal gas constant in KJ/Kg−K
14
15 //CALCULATIONS
16 c=y/(y-1);//Ratio
17 Pt=((2/(y+1))^c)*P1;//Throat pressure in MN/(m^2)
```

```
18  v1=(R*T1)/(P1*1000);//Specific volume at entry in (m
        ^3)/kg
19  Ct=((2*c*P1*v1*(1-((Pt/P1)^(1/c))))^0.5)*1000;//
        Velocity at throat in m/s
20  vt=v1*((P1/Pt)^(1/y));//Specific volume at throat in
        (m^3)/kg
21  At=((ma*vt)/Ct)*(10^6);//Area of throat in (mm^2)
22  C2=((2*c*P1*v1*(1-((P2/P1)^(1/c))))^0.5)*1000;//
        Velocity at exit in m/s
23  v2=v1*((P1/P2)^(1/y));//Specific volume at exit in (
        m^3)/kg
24  A2=((ma*v2)/C2)*(10^6);//Area of exit in (mm^2)
25  M=C2/Ct;//Mach number at exit
26
27  //OUTPUT
28  mprintf('Throat area is %3.0f (mm^2) \n Exit area is
        %3.0f (mm^2) \n Mach number at exit is %3.2f',At
        ,A2,M)
29
30
31
32
33
34
35  //=================================END OF PROGRAM
        =================================
```

Scilab code Exa 4.2 Increase in pressure and temperature and internal energy

```
1  //Chapter−4, Illustration 2, Page 163
2  //Title: Steam Nozzles and Steam Turbines
3  //
        ================================================
4  clc
```

```scilab
 5  clear
 6
 7  //INPUT DATA
 8  T1=273;//Temperature at section 1 in K
 9  P1=140;//Pressure at section 1 in KN/(m^2)
10  v1=900;//Velocity at section 1 in m/s
11  v2=300;//Velocity at section 2 in m/s
12  Cp=1.006;//Specific heat at constant pressure in kJ/
        kg-K
13  Cv=0.717;//Specific heat at constant volume in kJ/kg
        -K
14  y=1.4;//Ratio of specific heats
15
16  //CALCULATIONS
17  c=y/(y-1);//Ratio
18  R=Cp-Cv;//Universal gas constant in KJ/Kg-K
19  T2=T1-(((v2)^2-(v1)^2)/(2000*c*R));//Temperature at
        section 2 in K
20  DT=T2-T1;//Increase in temperature in K
21  P2=P1*((T2/T1)^c);//Pressure at section 2 in KN/(m
        ^2)
22  DP=(P2-P1)/1000;//Increase in pressure in MN/(m^2)
23  IE=Cv*(T2-T1);//Increase in internal energy in kJ/kg
24
25  //OUTPUT
26  mprintf('Increase in temperature is %3.0f K \n
        Increase in pressure is %3.2f MN/(m^2) \n
        Increase in internal energy is %3.0f kJ/kg',DT,DP
        ,IE)
27
28
29
30
31
32  //==============================END OF PROGRAM
        ================================
```

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Scilab code Exa 4.3 Throat area and exit area and Degree of undercooling at exit

```scilab
1  //Chapter−4, Illustration 3, Page 163
2  //Title: Steam Nozzles and Steam Turbines
3  //
   _____

4  clc
5  clear
6
7  //INPUT DATA
8  P1=2;//Pressure at entry in MN/(m^2)
9  T1=598;//Temperature at entry in K
10 P2=0.36;//Pressure at exit in MN/(m^2)
11 m=7.5;//mass flow rate of steam in kg/s
12 n=1.3;//Adiabatic gas constant
13 v1=0.132;//Volume at entry in (m^3)/kg from steam
      table
14 Ts=412.9;//Saturation temperature in K
15
16 //CALCULATIONS
17 c=n/(n-1);//Ratio
18 Pt=((2/(n+1))^c)*P1;//Throat pressure in MN/(m^2)
19 Ct=((2*c*P1*v1*(1-((Pt/P1)^(1/c))))^0.5)*1000;//
      Velocity at throat in m/s
20 vt=v1*((P1/Pt)^(1/n));//Specific volume at throat in
       (m^3)/kg
21 At=((m*vt)/Ct)*(10^6);//Area of throat in (mm^2)
22 C2=((2*c*P1*v1*(1-((P2/P1)^(1/c))))^0.5)*1000;//
      Velocity at exit in m/s
23 v2=v1*((P1/P2)^(1/n));//Specific volume at exit in (
      m^3)/kg
24 A2=((m*v2)/C2)*(10^6);//Area of exit in (mm^2)
25 T2=T1*((P2/P1)^(1/c));//Temperature at exit in K
```

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```
26  D=Ts-T2;//Degree of undercooling at exit in K
27
28  //OUTPUT
29  mprintf('Throat area is %3.0f (mm^2) \n Exit area is
        %3.0f (mm^2) \n Degree of undercooling at exit
        is %3.1f K',At,A2,D)
30
31
32
33
34  //==============================END OF PROGRAM
        ==============================
```

_____

Scilab code Exa 4.4 Throat and exit velocities and Throat and exit areas

```
1  //Chapter-4, Illustration 4, Page 165
2  //Title: Steam Nozzles and Steam Turbines
3  //
        ===========================================================
4  clc
5  clear
6
7  //INPUT DATA
8  P1=2.2;//Pressure at entry in MN/(m^2)
9  T1=533;//Temperature at entry in K
10 P2=0.4;//Pressure at exit in MN/(m^2)
11 m=11;//mass flow rate of steam in kg/s
12 n=0.85;//Efficiency of expansion
13 h1=2940;//Enthalpy at entrance in kJ/kg from Moiller
        chart
14 ht=2790;//Enthalpy at throat in kJ/kg from Moiller
        chart
15 h2s=2590;//Enthalpy below exit level in kJ/kg from
        Moiller chart
```

```
16  vt=0.16;//Throat volume in (m^3)/kg
17  v2=0.44;//Volume at exit in (m^3)/kg
18
19  //CALCULATIONS
20  Ct=(2000*(h1-ht))^0.5;//Throat velocity in m/s
21  h2=ht-(0.85*(ht-h2s));//Enthalpy at exit in kJ/kg
22  C2=(2000*(h1-h2))^0.5;//Exit velocity in m/s
23  At=((m*vt)/Ct)*(10^6);//Area of throat in (mm^2)
24  A2=((m*v2)/C2)*(10^6);//Area of exit in (mm^2)
25
26  //OUTPUT
27  mprintf('Throat velocity is %3.0f m/s \n Exit
        velocity is %3.0f m/s \n Throat area is %3.0f (mm
        ^2) \n Exit area is %3.0f (mm^2) \n',Ct,C2,At,A2)
28
29
30
31
32  //===============================END OF PROGRAM
        =================================
```

Scilab code Exa 4.5 Nozzle dimensions and Degree of undercooling and supersaturati

```
1  //Chapter-4, Illustration 5, Page 166
2  //Title: Steam Nozzles and Steam Turbines
3  //
        ===================================================

4  clc
5  clear
6
7  //INPUT DATA
8  P1=35;//Pressure at entry in bar
9  T1=573;//Temperature at entry in K
10 P2=8;//Pressure at exit in bar
```

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```scilab
11  Ts=443.4;//Saturation temperature in K
12  Ps=3.1;//Saturation pressure in bar
13  m=5.2;//mass flow rate of steam in kg/s
14  n=1.3;//Adiabatic gas constant
15  v1=0.06842;//Specific volume at entry in (m^3)/kg
       from steam table
16  v3=0.2292;//Specific volume at exit in (m^3)/kg from
        steam table
17  h1=2979;//Enthalpy in kJ/kg from Moiller chart
18  h3=2673.3;//Enthalpy in kJ/kg from Moiller chart
19
20  //CALCULATIONS
21  c=n/(n-1);//Ratio
22  C2=((2*c*P1*(10^5)*v1*(1-((P2/P1)^(1/c))))^0.5);//
       Velocity at exit in m/s
23  v2=v1*((P1/P2)^(1/n));//Specific volume at exit in (
       m^3)/kg
24  A2=((m*v2)/C2)*(10^4);//Area of exit in (cm^2)
25  a=((A2/18)^0.5)*10;//Length in mm
26  b=3*a;//Breadth in mm
27  T2=T1*((P2/P1)^(1/c));//Temperature at exit in K
28  D=Ts-T2;//Degree of undercooling in K
29  Ds=P2/Ps;//Degree of supersaturation
30  hI=h1-h3;//Isentropic enthalpy drop in kJ/kg
31  ha=(C2^2)/2000;//Actual enthalpy drop in kJ/kg
32  QL=hI-ha;//Loss in available heat in kJ/kg
33  DS=QL/Ts;//Increase in entropy in kJ/kg-K
34  C3=(2000*(h1-h3))^0.5;//Exit velocity from nozzle
35  mf=((A2*C3*(10^-4))/v3);//Mass flow rate in kg/s
36  Rm=m/mf;//Ratio of mass rate
37
38  //OUTPUT
39  mprintf('Cross section of nozzle is %3.1f mm * %3.1f
        mm \n Degree of undercooling is %3.1f K and
      Degree of supersaturation is %3.2f \n Loss in
      available heat drop due to irreversibility is %3
      .2f kJ/kg \n Increase in entropy is %3.5f kJ/kg-K
       \n Ratio of mass flow rate with metastable
```

```
   expansion to the thermal expansion is %3.3f',b,a,
   D,Ds,QL,DS,Rm)
40
41
42
43
44
45 //================================END OF PROGRAM
   =================================
```

Scilab code Exa 4.6 `Nozzle efficiency and Exit area and Throat velocity`

```
1  //Chapter−4, Illustration 6, Page 169
2  //Title: Steam Nozzles and Steam Turbines
3  //
   =================================================================

4  clc
5  clear
6
7  //INPUT DATA
8  m=14;//Mass flow rate of steam in kg/s
9  P1=3;//Pressure of Steam in MN/(m^2)
10 T1=300;//Steam temperature in oC
11 h1=2990;//Enthalpy at point 1 in kJ/kg
12 h2s=2630;//Enthalpy at point 2s in kJ/kg
13 ht=2850;//Enthalpy at point t in kJ/kg
14 n=1.3;//Adiabatic gas constant
15 C2=800;//Exit velocity in m/s
16 v2=0.4;//Specific volume at exit in (m^3)/kg
17
18 //CALCULATIONS
19 x=n/(n-1);//Ratio
20 Pt=((2/(n+1))^x)*P1;//Temperature at point t in MN/(
   m^2)
```

```
21  h2=h1-((C2^2)/2000);//Exit enthalpy in kJ/kg
22  nN=((h1-h2)/(h1-h2s))*100;//Nozzle efficiency
23  A2=((m*v2)/C2)*(10^6);//Exit area in (mm^2)
24  Ct=sqrt(2000*(h1-ht));//Throat velocity in m/s
25
26  //OUTPUT
27  mprintf('Nozzle efficiency is %3.1f percent \n Exit
        area is %3.0f (mm^2) \n Throat velocity is %3.0f
       m/s',nN,A2,Ct)
28
29
30
31
32  //==============================END OF PROGRAM
       ================================
```

Scilab code Exa 4.7 Areas at throat and exit and Steam quality at exit

```
1  //Chapter-4, Illustration 7, Page 170
2  //Title: Steam Nozzles and Steam Turbines
3  //
      =================================================

4  clc
5  clear
6
7  //INPUT DATA
8  P1=10;//Pressure at point 1 in bar
9  P2=0.5;//Pressure at point 2 in bar
10  h1=3050;//Enthalpy at point 1 in kJ/kg
11  h2s=2480;//Enthalpy at point 2s in kJ/kg
12  ht=2910;//Enthalpy at throat in kJ/kg
13  n=1.3;//Adiabatic gas constant
14  r=0.1;//Total available heat drop
15  v1=0.258;//Specific volume at point 1 in (m^3)/kg
```

```
16  h2f =340.6; //Enthalpy for exit pressure from steam
        tables in kJ/kg
17  hfg =2305.4; //Enthalpy for exit pressure from steam
        tables in kJ/kg
18  m=0.5; //Mass flow rate in kg/s
19
20  //CALCULATIONS
21  x=n/(n-1); //Ratio
22  Pt=((2/(n+1))^x)*P1; //Temperature at throat in bar
23  h2=h2s+(r*(h1-h2s)); //Enthalpy at point 2 in kJ/kg
24  vt=((P1/Pt)^(1/n))*v1; //Specific volume at throat in
         (m^3)/kg
25  v2=((P1/P2)^(1/n))*v1; //Specific volume at point 2
        in (m^3)/kg
26  Ct=sqrt(2000*(h1-ht)); //Throat velocity in m/s
27  At=((m*vt)/Ct)*(10^6); //Throat area in (mm^2)
28  C2=sqrt(2000*(h1-h2)); //Exit velocity in m/s
29  A2=((m*v2)/C2)*(10^6); //Exit area in (mm^2)
30  x2=((h2-h2f)/hfg)*100; //Steam quality at exit
31
32  //OUTPUT
33  mprintf('Throat area is %3.0f (mm^2) \n Exit area is
         %3.0f (mm^2) \n Steam quality at exit is %3.0f
        percent ',At,A2,x2)
34
35
36
37
38
39
40  //===============================END OF PROGRAM
        =============================
```

Scilab code Exa 4.8 Maximum discharge and Area of nozzle at exit

```
1  //Chapter-4, Illustration 8, Page 171
2  //Title: Steam Nozzles and Steam Turbines
3  //
   _____

4  clc
5  clear
6
7  //INPUT DATA
8  P1=3.5;//Dry saturated steam in bar
9  P2=1.1;//Exit pressure in bar
10 At=4.4;//Throat area in cm^2
11 h1=2731.6;//Enthalpy at P1 in kJ/kg
12 v1=0.52397;//Specific volume at P1 in m^3/kg
13 n=1.135;//Adiabatic gas constant
14 ht=2640;//Enthalpy at Pt in kJ/kg
15 vt=0.85;//Specific volume at throat in m^3/kg
16 h2=2520;//Enthalpy at P2 in kJ/kg
17 v2=1.45;//Specific volume at P2 in m^3/kg
18
19 //CALCULATIONS
20 x=n/(n-1);//Ratio
21 Pt=((2/(n+1))^x)*P1;//Throat pressure in bar
22 Ct=sqrt(2000*(h1-ht));//Throat velocity in m/s
23 mmax=((At*Ct*(10^-4))/vt)*60;//Maximum discharge in
       kg/min
24 C2=sqrt(2000*(h1-h2));//Exit velocity in m/s
25 A2=((mmax*v2)/(C2*60))*(10^6);//Exit area in mm^2
26
27 //OUTPUT
28 mprintf('Maximum discharge is %3.3f kg/min \n Exit
       area is %3.2f mm^2',mmax,A2)
29
30
31
32
33 //=============================END OF PROGRAM
   ===================================
```

Scilab code Exa 4.9 Type of nozzle and Minimum area of nozzle

```
1  //Chapter-4, Illustration 9, Page 172
2  //Title: Steam Nozzles and Steam Turbines
3  //
   ==============================================================
4  clc
5  clear
6
7  //INPUT DATA
8  P1=10;//Pressure at point 1 in bar
9  T1=200;//Temperature at point 1 in oC
10 P2=5;//Pressure at point 2 in bar
11 n=1.3;//Adiabatic gas constant
12 h1=2830;//Enthalpy at P1 in kJ/kg
13 ht=2710;//Enthalpy at point Pt in kJ/kg
14 vt=0.35;//Specific volume at Pt in m^3/kg
15 m=3;//Nozzle flow in kg/s
16
17 //CALCULATIONS
18 x=n/(n-1);//Ratio
19 Pt=((2/(n+1))^x)*P1;//Throat pressure in bar
20 Ct=sqrt(2000*(h1-ht));//Throat velocity in m/s
21 At=(m*vt)/Ct;//Throat area in m^2
22
23 //OUTPUT
24 mprintf('Since throat pressure is greater than exit
       pressure,nozzle used is convergent-divergent
       nozzle \n Minimum area of nozzle required is %3.5
       f m^2',At)
25
26
27
```

77

Scilab code Exa 4.10 Throat velocity and Mass flow rate of steam

```
1  //Chapter−4, Illustration 10, Page 173
2  //Title: Steam Nozzles and Steam Turbines
3  //
   ══════════════════════════════════════════════════════
4  clc
5  clear
6
7  //INPUT DATA
8  P1=10.5;//Pressure at point 1 in bar
9  x1=0.95;//Dryness fraction
10 n=1.135;//Adiabatic gas constant
11 P2=0.85;//Pressure at point 2 in bar
12 vg=0.185;//Specific volume in m^3/kg
13
14
15 //CALCULATIONS
16 c=n/(n-1);//Ratio
17 Pt=((2/(n+1))^c)*P1;//Throat pressure in MN/(m^2)
18 v1=x1*vg;//Specific volume at point 1 in m^3/kg
19 Ct=sqrt((2*n*P1*v1*(10^5)/(n+1)));//Velocity at
      throat in m/s
20 vt=((P1/Pt)*(v1^n))^(1/1.135);//Specific volume at
      throat in m^3/kg
21 m=Ct/vt;//Mass flow rate per unit throat area in kg
      /(m^2)
22
23 //OUTPUT
```

```
24  mprintf('Throat velocity is %3.2f m/s \n Mass flow
        rate of steam is %3.2f kg/(m^2)',Ct,m)
25
26
27
28
29
30  //==============================END OF PROGRAM
        =================================
```

Scilab code Exa 4.11 Degree of undercooling and supersaturation

```
1  //Chapter-4, Illustration 11, Page 174
2  //Title: Steam Nozzles and Steam Turbines
3  //
        =======================================
4  clc
5  clear
6
7  //INPUT DATA
8  P1=10;//Pressure at point 1 in bar
9  T1=452.9;//Temperature at point 1 in K
10  P2=4;//Pressure at point 2 in bar
11  n=1.3;//Adiabatic gas constant
12  Ps=0.803;//Saturation pressure at T2 in bar
13  Ts=143.6;//Saturation temperature at P2 in oC
14  //CALCULATIONS
15  x=(n-1)/n;//Ratio
16  T2=((P2/P1)^x)*T1;//Temperature at point 2 in K
17  Ds=P2/Ps;//Degree of supersaturation
18  Du=Ts-(T2-273);//Degree of undercooling
19
20  //OUTPUT
21  mprintf('Degree of supersaturation is %3.2f \n
```

```
      Degree  of  undercooling  %3.0 f  oC',Ds,Du)
22
23
24
25
26
27
28
29  //════════════════════════════════END  OF  PROGRAM
       ═══════════════════════════════════
```

Scilab code Exa 4.12 Quantity of steam used and Exit velocity of steam

```
 1  //Chapter−4,  Illustration  12,  Page  174
 2  //Title:  Steam  Nozzles  and  Steam  Turbines
 3  //
        ══════════════════════════════════════════════════════════════
 
 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  P1=9;//Pressure  at  point  1  in  bar
 9  P2=1;//Pressure  at  point  2  in  bar
10  Dt=0.0025;//Throat  diameter  in  m
11  nN=0.9;//Nozzle  efficiency
12  n=1.135;//Adiabatic  gas  consstant
13  h1=2770;//Enthalpy  at  point  1  in  kJ/kg
14  ht=2670;//Throat  enthlapy  in  kJ/kg
15  h3=2400;//Enthlapy  at  point  2  in  kJ/kg
16  x2=0.96;//Dryness  fraction  2
17  vg2=0.361;//Specific  volume  in  m^3/kg
18
19  //CALCULATIONS
20  x=n/(n-1);//Ratio
```

```
21  Pt=((2/(n+1))^x)*P1;//Throat pressure in bar
22  Ct=sqrt(2000*(h1-ht)*nN);//Throat velocity in m/s
23  At=(3.147*2*(Dt^2))/4;//Throat area in m^2
24  vt=x2*vg2;//Specific volume at throat in m^3/kg
25  m=(At*Ct)/vt;//Mass flow rate of steam in kg/s
26  hact=nN*(h1-h3);//Actual enthalpy drop in kJ/kg
27  C2=sqrt(2000*hact);//Exit velocity of steam in m/s
28
29  //OUTPUT
30  mprintf('Quantity of steam used per second is %3.3f
        kg/s \n Exit velocity of steam is %3.2f m/s',m,C2
        )
31
32
33
34
35  //==============================END OF PROGRAM
        =============================
```

Scilab code Exa 4.13 Blade angles and Tangential force and Axial thrust and Diagra

```
1  //Chapter −4, Illustration 13, Page 202
2  //Title : Steam Nozzles and Steam Turbines
3  //
        ================================================
4  clc
5  clear
6
7  //INPUT DATA
8  C1=1000;//Steam velocity in m/s
9  a1=20;//Nozzle angle in degrees
10  U=400;//Mean blade speed in m/s
11  m=0.75;//Mass flow rate of steam in kg/s
12  b1=33;//Blade angle at inlet from the velocity
```

```
        triangle in degrees
13  b2=b1;//Blade angle at exit from the velocity
        triangle in degrees
14  Cx=1120;//Change in whirl velocity from the velocity
         triangle in m/s
15  Ca=0;//Change in axial velocity from the velocity
        triangle in m/s
16
17  //CALCULATIONS
18  Fx=m*Cx;//Tangential force on blades in N
19  Fy=m*Ca;//Axial thrust in N
20  W=(m*Cx*U)/1000;//Diagram power in kW
21  ndia=((2*U*Cx)/(C1^2))*100;//Diagram efficiency
22
23  //OUTPUT
24  mprintf('Blade angles are %3.0f degrees ,%3.0f
        degrees \n Tangential force on blades is %3.0f N
        \n Axial thrust is %3.0f \n Diagram power is %3.0
        f kW \n Diagram efficiency %3.1f percent ',b1,b2,
        Fx,Fy,W,ndia)
25
26
27
28
29
30  //================================END OF PROGRAM
        ================================
```

Scilab code Exa 4.14 Power developed and Blade efficiency and Steam consumption

```
1  //Chapter−4, Illustration 14, Page 203
2  //Title: Steam Nozzles and Steam Turbines
3  //
        ================================================
```

```scilab
4  clc
5  clear
6
7  //INPUT DATA
8  D=2.5;//Mean diameter of blade ring in m
9  N=3000;//Speed in rpm
10 a1=20;//Nozzle angle in degrees
11 r=0.4;//Ratio blade velocity to steam velocity
12 Wr=0.8;//Blade friction factor
13 m=10;//Steam flow in kg/s
14 x=3;//Sum in blade angles in degrees
15 b1=32.5;//Blade angle at inlet from the velocity
       triangle in degrees
16 W1=626.7;//Relative velocity at inlet from the
       velocity triangle in m/s
17 Cx=967;//Change in whirl velocity from the velocity
       triangle in m/s
18
19 //CALCULATIONS
20 U=(3.147*D*N)/60;//Blade velocity in m/s
21 C1=U/r;//Steam velocity in m/s
22 b2=b1-x;//Blade angle at exit in degrees
23 W2=Wr*W1;//Relative velocity at outlet from the
       velocity triangle in m/s
24 W=(m*Cx*U)/1000;//Power developed in kW
25 ndia=((2*U*Cx)/(C1^2))*100;//Blade efficiency
26 sc=(m*3600)/W;//Steam consumption in kg/kWh
27
28 //OUTPUT
29 mprintf('Power developed is %3.0f kW \n Blade
       efficiency is %3.1f percent \n Steam consumed is
       %3.2f kg/kWh',W,ndia,sc)
30
31
32
33
34 //==============================END OF PROGRAM
       ================================
```

Scilab code Exa 4.15 Blading efficiency and Blade velocity coefficient

```
1  //Chapter −4, Illustration 15, Page 204
2  //Title: Steam Nozzles and Steam Turbines
3  //
4  clc
5  clear
6
7  //INPUT DATA
8  m=3;//Mass flow rate of steam in kg/s
9  C1=425;//Steam velocity in m/s
10 r=0.4;//Ratio of blade speed to jet speed
11 W=170;//Stage output in kW
12 IL=15;//Internal losses in kW
13 a1=16;//Nozzle angle in degrees
14 b2=17;//Blade angle at exit in degrees
15 W1=265;//Relative velocity at inlet from the
       velocity triangle in m/s
16 W2=130;//Relative velocity at outlet from the
       velocity triangle in m/s
17
18 //CALCULATIONS
19 U=C1*r;//Blade speed in m/s
20 P=(W+IL)*1000;//Total power developed in W
21 Cx=P/(m*W);//Change in whirl velocity in m/s
22 ndia=((2*U*Cx)/(C1^2))*100;//Blading efficiency
23 Wr=W2/W1;//Blade velocity co−efficient
24
25 //OUTPUT
26 mprintf('Blading efficiency is %3.1f percent \n
       Blade velocity co−efficient is %3.2f',ndia,Wr)
27
```

```
28
29
30
31 //================================END OF PROGRAM
        ================================
```

Scilab code Exa 4.16 Blade angles and Turbine power

```
1  //Chapter −4, Illustration  16, Page  205
2  //Title: Steam  Nozzles  and  Steam  Turbines
3  //
        =================================================
4  clc
5  clear
6
7  //INPUT DATA
8  C1=375;//Steam  velocity  in m/s
9  a1=20;//Nozzle  angle
10 U=165;//Blade  speed  in m/s
11 m=1;//Mass  flow  rate  of  steam  in  kg/s
12 Wr=0.85;//Blade  friction  factor
13 Ca1=130;//Axial  velocity  at  inlet  from  the  velocity
        triangle  in m/s
14 Ca2=Ca1;//Axial  velocity  at  outlet  in m/s
15 W1=230;//Relative  velocity  at  inlet  from  the
        velocity  triangle  in m/s
16 Cx=320;//Change  in  whirl  velocity  from  the  velocity
        triangle  in m/s
17
18 //CALCULATIONS
19 b2=41;//Blade  angle  at  exit  from  the  velocity
        triangle  in  degrees
20 b1=34;//Blade  angle  at  exit  from  the  velocity
        triangle  in  degrees
```

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```
21  W=(m*Cx*U)/1000;//Power developed by turbine in kW
22
23  //OUTPUT
24  mprintf('Blade angles assumed are %3.0f degrees ,%3.0
        f degrees \n Power developed by turbine is %3.1f
      kW',b1,b2,W)
25
26
27
28
29  //===============================END OF PROGRAM
        ================================
```

Scilab code Exa 4.17 Nozzle angle and Blade angle at entry and exit

```
1  //Chapter −4, Illustration 17, Page 206
2  //Title: Steam Nozzles and Steam Turbines
3  //
        ================================================
4  clc
5  clear
6
7  //INPUT DATA
8  m=2;//Mass flow rate of steam in kg/s
9  W=130;//Turbine power in kW
10 U=175;//Blade velocity in m/s
11 C1=400;//Steam velocity in m/s
12 Wr=0.9;//Blade friction factor
13 W1=240;//Realtive velocity at inlet from the
      velocity triangle in m/s
14
15 //CALCULATIONS
16 Cx1=(W*1000)/(m*U);//Whirl velocity at inlet in m/s
17 W2=Wr*W1;//Realtive velocity at outlet from the
```

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```
         velocity   triangle   in  m/ s
18  a1 =19; // Nozzle  angle  from  the  velocity  triangle  in
        degrees
19  b1 =33; // Blade  angle  at  inlet  from  the  velocity
        triangle  in  degrees
20  b2 =36; // Blade  angle  at  outlet  from  the  velocity
        triangle  in  degrees
21
22  // OUTPUT
23  mprintf ( ' Nozzle  angle  is  %3.0 f  degrees  \n  Blade
        angles  are  %3.0 f  degrees ,%3.0 f  degrees ' , a1 , b1 , b2 )
24
25
26
27
28
29  //=================================END  OF  PROGRAM
        ==================================
```

_____

Scilab code Exa 4.18 `Diagram efficiency`

```
 1  // Chapter −4,  I l l u s t r a t i o n   18 ,  Page   207
 2  // Title :  Steam  Nozzles  and  Steam  Turbines
 3  //
        ===============================================
 4  clc
 5  clear
 6
 7  // INPUT DATA
 8  U =150; // Blade  speed  in  m/ s
 9  m =3; // Mass  flow  rate  of  steam  in  kg/ s
10  P =10.5; // Pressure  in  bar
11  r =0.21; // Ratio  blade  velocity  to  steam  velocity
12  a1 =16; // Nozzle  angle  in  first  stage  in  degrees
```

```
13  b2=20;//Blade angle at exit in first stage in
        degrees
14  a3=24;//Nozzle angle in second stage in degrees
15  b4=32;//Blade angle at exit in second stage in
        degrees
16  Wr=0.79;//Blade friction factor for first stage
17  Wr2=0.88;//Blade friction factor for second stage
18  Cr=0.83;//Blade velocity coefficient
19  W1=570;//Relative velocity at inlet from the
        velocity triangle for first stage in m/s
20  C2=375;//Velocity in m/s
21  W3=185;//Relative velocity at inlet from the
        velocity triangle for second stage in m/s
22
23  //CALCULATIONS
24  C1=U/r;//Steam speed at exit in m/s
25  W2=Wr*W1;//Relative velocity at outlet for first
        stage in m/s
26  C3=Cr*C2;//Steam velocity at inlet for second stage
        in m/s
27  W4=Wr2*W3;//Relative velocity at exit for second
        stage in m/s
28  DW1=W1+W2;//Change in relative velocity for first
        stage in m/s
29  DW2=275;//Change in relative velocity from the
        velocity triangle for second stage in m/s
30  ndia=((2*U*(DW1+DW2))/(C1^2))*100;//Diagram
        efficiency
31
32  //OUTPUT
33  mprintf('Diagram efficiency is %3.1f percent',ndia)
34
35
36
37
38  //================================END OF PROGRAM
        ================================
```

Scilab code Exa 4.19 Blade speed and Blade tip angles and Diagram efficiency

```scilab
1  //Chapter -4, Illustration 19, Page 208
2  //Title: Steam Nozzles and Steam Turbines
3  //
   ==================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  b1=30; //Blade angle at inlet in first stage in
       degrees
9  b2=30; //Blade angle at exit in first stage in
       degrees
10 b3=30; //Blade angle at inlet in second stage in
       degrees
11 b4=30; //Blade angle at exit in second stage in
       degrees
12 t1=240; //Temperature at entry in oC
13 P1=11.5; //Pressure at entry in bar
14 P2=5; //Pressure in wheel chamber in bar
15 vl=10; //Loss in velocity in percent
16 h=155; //Enthalpy at P2 in kJ/kg
17 W4=17.3; //Relative velocity at exit from the
       velocity triangle for second stage in m/s
18 a4=90; //Nozzle angle in second stage in degrees
19 C3=33; //Steam velocity at inlet from the velocity
       triangle for second stage in m/s
20 W2=49; //Relative velocity at outlet from the
       velocity triangle for first stage in m/s
21 x=15; //Length of AB assumed for drawing velocity
       triangle in mm
22 y=67; //Length of BC from the velocity triangle in mm
```

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```
23
24  //CALCULATIONS
25  C1=sqrt(2000*h);//Velocity of steam in m/s
26  W3=W4/0.9;//Relative velocity at inlet for second
        stage in m/s
27  C2=C3/0.9;//Velocity in m/s
28  W1=W2/0.9;//Relative velocity at inlet for first
        stage in m/s
29  C1n=C1/y;//Velocity of steam in m/s
30  U=x*C1n;//Blade speed in m/s
31  a3=17;//Nozzle angle in second stage from the
        velocity triangle in degrees
32  a2=43;//Nozzle angle from the velocity triangle in
        degrees
33  DW1=731.5;//Change in relative velocity from the
        velocity triangle for first stage in m/s
34  DW2=257.5;//Change in relative velocity from the
        velocity triangle for second stage in m/s
35  ndia=((2*U*(DW1+DW2))/(C1^2))*100;//Diagram
        efficiency
36
37  //OUTPUT
38  mprintf('Blade speed is %3.1f m/s \n Blade tip
        angles of the fixed blade are %3.0f degrees and
        %3.0f degrees \n Diagram efficiency is %3.1f
        percent ',U,a3,a2,ndia)
39
40
41
42
43
44
45
46  //==============================END OF PROGRAM
        ==============================
```

Scilab code Exa 4.20 Blade speed and Turbine power

```scilab
1  //Chapter-4, Illustration 20, Page 210
2  //Title: Steam Nozzles and Steam Turbines
3  //
   _____

4  clc
5  clear
6
7  //INPUT DATA
8  C1=600;//Steam velocity in m/s
9  b1=30;//Blade angle at inlet in first stage in
       degrees
10 b2=30;//Blade angle at exit in first stage in
       degrees
11 b3=30;//Blade angle at inlet in second stage in
       degrees
12 b4=30;//Blade angle at exit in second stage in
       degrees
13 a4=90;//Nozzle angle in second stage in degrees
14 m=3;//Mass of steam in kg/s
15 x=15;//Length for drawing velocity triangle in mm
16 y=56;//Length of BC from the velocity triangle in mm
17
18 //CALCUALTIONS
19 C1n=C1/y;//Velocity of steam in m/s
20 U=x*C1n;//Blade speed in m/s
21 l=103;//Length from velocity triangle in mm
22 P=(m*l*C1n*U)/1000;//Power developed in kW
23
24 //OUTPUT
25 mprintf('Blade speed is %3.1f m/s \n Power developed
       by the turbine is %3.2f kW',U,P)
```

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32 `//`══════════════════════════════════END OF PROGRAM
   ══════════════════════════════════

_____

Scilab code Exa 4.21 Mean diameter of drum and Volume of steam

```
1  //Chapter−4, Illustration 21, Page 211
2  //Title: Steam Nozzles and Steam Turbines
3  //
     ════════════════════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  N=400; //Speed in rpm
9  m=8.33; //Mass of steam in kg/s
10 P=1.6; //Pressure of steam in bar
11 x=0.9; //Dryness fraction
12 W=10; //Stage power in kW
13 r=0.75; //Ratio of axial flow velocity to blade
      velocity
14 a1=20; //Nozzle angle at inlet in degrees
15 a2=35; //Nozzle angle at exit in degrees
16 b1=a2; //Blade tip angle at exit in degrees
17 b2=a1; //Blade tip angle at inlet in degrees
18 a=25; //Length of AB from velocity triangle in mm
19 vg=1.091; //Specific volume of steam from steam
      tables in (m^3)/kg
20
```

```
21  //CALCULATIONS
22  Cx=73.5;//Change in whirl velocity from the velocity
         triangle by measurement in mm
23  y=Cx/a;//Ratio of change in whirl velocity to blade
      speed
24  U=sqrt((W*1000)/(m*y));//Blade speed in m/s
25  D=((U*60)/(3.147*N))*1000;//Mean diameter of drum in
         mm
26  v=m*x*vg;//Volume flow rate of steam in (m^3)/s
27
28  //OUTPUT
29  mprintf('Mean diameter of drum is %3.0f mm \n Volume
         of steam flowing per second is %3.2f m^3/s',D,v)
30
31
32
33
34
35
36
37
38
39
40  //===============================END OF PROGRAM
      ==================================
```

Scilab code Exa 4.22 Drum diameter and Blade height

```
1  //Chapter −4, Illustration 22, Page 212
2  //Title: Steam Nozzles and Steam Turbines
3  //
      ===============================================================

4  clc
5  clear
```

```
6
7  //INPUT DATA
8  N=300;//Speed in rpm
9  m=4.28;//Mass of steam in kg/s
10 P=1.9;//Pressure of steam in bar
11 x=0.93;//Dryness fraction
12 W=3.5;//Stage power in kW
13 r=0.72;//Ratio of axial flow velocity to blade
       velocity
14 a1=20;//Nozzle angle at inlet in degrees
15 b2=a1;//Blade tip angle at inlet in degrees
16 l=0.08;//Tip leakage steam
17 vg=0.929;//Specific volume of steam from steam
       tables in (m^3)/kg
18
19 //CALCULATIONS
20 mact=m-(m*l);//Actual mass of steam in kg/s
21 a=(3.147*N)/60;//Ratio of blade velocity to mean dia
22 b=r*a;//Ratio of axial velocity to mean dia
23 c=46;//Ratio of change in whirl velocity to mean dia
24 D=sqrt((W*1000)/(mact*c*a));//Mean dia in m
25 Ca=b*D;//Axial velocity in m/s
26 h=((mact*x*vg)/(3.147*D*Ca))*1000;//Blade height in
       mm
27 D1=D-(h/1000);//Drum dia in m
28
29 //OUTPUT
30 mprintf('Drum diameter is %3.3f m \n Blade height is
       %3.0f mm',D1,h)
31
32
33
34
35
36
37
38
39
```

Scilab code Exa 4.23 Rotor blade angles and Flow coefficient and Blade loading coe

```
1  //Chapter −4, Illustration 23, Page 214
2  //Title: Steam Nozzles and Steam Turbines
3  //
    ═══════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  P0=800;//Steam pressure in kPa
9  P2=100;//Pressure at point 2 in kPa
10  T0=973;//Steam temperature in K
11  a1=73;//Nozzle angle in degrees
12  ns=0.9;//Steam efficiency
13  m=35;//Mass flow rate in kg/s
14  Cp=1.005;//Specific heat at constant pressure in kJ/
       kg−K
15  y=1.4;//Ratio of specific heats
16
17  //CALCULATIONS
18  b1=atand(tand(a1)/2);//Blade angle at inlet in
       degrees
19  b2=b1;//Blade angle at exit in degrees
20  p=2/tand(a1);//Flow coefficient
21  s=p*(tand(b1)+tand(b2));//Blade loading coefficient
22  Dh=ns*Cp*T0*(1-((P2/P0)^((y-1)/y)));//Difference in
       enthalpies in kJ/kg
23  W=(m*Dh)/1000;//Power developed in MW
24
25  //OUTPUT
```

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```
26  mprintf('Rotor blade angles are %3.2f degrees and %3
        .2f degrees \n Flow coefficient is %3.3f \n Blade
         loading coefficient is %3.0f \n Power developed
        is %3.1f MW',b1,b2,p,s,W)
27
28
29
30
31
32
33
34
35
36
37
38
39
40  //================================END OF PROGRAM
        ================================
```

_____

Scilab code Exa 4.24 Rotor blade angles and Power developed and Final state of ste

```
1  //Chapter −4, Illustration 24, Page 215
2  //Title: Steam Nozzles and Steam Turbines
3  //
        ================================================
4  clc
5  clear
6
7  //INPUT DATA
8  P0=100;//Steam pressure in bar
9  T0=773;//Steam temperature in K
10 a1=70;//Nozzle angle in degrees
11 ns=0.78;//Steam efficiency
```

```
12  m=100;//Mass flow rate of steam in kg/s
13  D=1;//Turbine diameter in m
14  N=3000;//Turbine speed in rpm
15  h0=3370;//Steam enthalpy from Moiller chart in kJ/kg
16  v2=0.041;//Specific volume at P2 from steam tables
        in (m^3)/kg
17  v4=0.05;//Specific volume at P4 from steam tables in
        (m^3)/kg
18
19  //CALCULATIONS
20  U=(3.147*D*N)/60;//Blade speed in m/s
21  C1=(2*U)/sind(a1);//Steam speed in m/s
22  b1=atand(tand(a1)/2);//Blade angle at inlet for
        first stage in degrees
23  b2=b1;//Blade angle at exit for first stage in
        degrees
24  b3=b1;//Blade angle at inlet for second stage in
        degrees
25  b4=b2;//Blade angle at exit for second stage in
        degrees
26  Wt=(4*m*(U^2))/(10^6);//Total workdone in MW
27  Dh=(2*(U^2))/1000;//Difference in enthalpies in kJ/
        kg
28  Dhs=Dh/ns;//Difference in enthalpies in kJ/kg
29  h2=h0-Dh;//Enthalpy at point 2 in kJ/kg
30  h2s=h0-Dhs;//Enthalpy at point 2s in kJ/kg
31  Dh2=(2*(U^2))/1000;//Difference in enthalpies in kJ/
        kg
32  Dh2s=Dh2/ns;//Difference in enthalpies in kJ/kg
33  h4=h2-Dh2;//Enthalpy at point 4 in kJ/kg
34  h4s=h2-Dh2s;//Enthalpy at point 4s in kJ/kg
35  Ca=C1*cosd(a1);//Axial velocity in m/s
36  hI=(m*v2)/(3.147*D*Ca);//Blade height at first stage
         in m/s
37  hII=(m*v4)/(3.147*D*Ca);//Blade height at second
        stage in m/s
38
39  //OUTPUT
```

```
40  mprintf ('Rotor blade angles for first stage are %3.2
        f degrees and %3.2 f degrees \n Rotor blade angles
         for second stage are %3.2 f degrees and %3.2 f
        degrees \n Power developed is %3.2 f MW \n Final
        state of steam at first stage is %3.2 f kJ/kg \n
        Final state of steam at second stage is %3.2 f kJ/
        kg \n Blade height at first stage is %3.4 f m \n
        Blade height at second stage is %3.4 f m',b1,b2,b3
        ,b4,Wt,h2s,h4s,hI,hII)
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55  //=================================END OF PROGRAM
        ======================================
```

_____

Scilab code Exa 4.25 Rotor blade angles and Power developed and Final state of ste

```
1  //Chapter −4, Illustration  25 , Page  218
2  // Title :  Steam  Nozzles  and  Steam  Turbines
3  //
        ==================================================
4  clc
5  clear
```

```
 6
 7  //INPUT DATA
 8  P0 =100; //Steam  pressure  in  bar
 9  T0 =773; //Steam  temperature  in  K
10  a1 =70; //Nozzle  angle  in  degrees
11  ns =0.78; //Steam  efficiency
12  m=100; //Mass  flow  rate  of  steam  in  kg/s
13  D=1; //Turbine  diameter  in  m
14  N=3000; //Turbine  speed  in  rpm
15  h0 =3370; //Steam  enthalpy  from  Moiller  chart  in  kJ/kg
16  P4 =27; //Pressure  at  point  4  in  bar
17  T4 =638; //Temperature  at  point  4  in  K
18  v4 =0.105; //Specific  volume  at  P4  from  mollier  chart
       in  (m^3)/kg
19  ns =0.65; //Stages  efficiency
20
21  //CALCULATIONS
22  U=(3.147*D*N)/60; //Blade  speed  in  m/s
23  C1 =(4*U)/sind(a1); //Steam  speed  in  m/s
24  Ca=C1*cosd(a1); //Axial  velocity  in  m/s
25  b1=atand((3*U)/Ca); //Blade  angle  at  inlet  for  first
       stage  in  degrees
26  b2=b1; //Blade  angle  at  exit  for  first  stage  in
       degrees
27  b4=atand(U/Ca); //Blade  angle  at  exit  for  second
       stage  in  degrees
28  b3=b4; //Blade  angle  at  inlet  for  second  stage  in
       degrees
29  WI=m*6*(U^2); //Power  developed  in  first  stage  in  MW
30  WII=m*2*(U^2); //Power  developed  in  second  stage  in
       MW
31  W=(WI+WII)/(10^6); //Total  power  developed  in  MW
32  Dh=(W*1000)/100; //Difference  in  enthalpies  in  kJ/kg
33  Dhs=(W*1000)/(ns*100); //Difference  in  enthalpies  in
       kJ/kg
34  h4=h0-Dh; //Enthalpy  at  point  4  in  kJ/kg
35  h4s=h0-Dhs; //Enthalpy  at  point  4s  in  kJ/kg
36  h=(m*v4)/(3.147*D*Ca); //Rotor  blade  height  in  m
```

```
37
38  //OUTPUT
39  mprintf('Rotor blade angles for first stage are %3.2
       f degrees and %3.2f degrees \n Rotor blade angles
        for second stage are %3.2f degrees and %3.2f
       degrees \n Power developed is %3.2f MW \n Final
       state of steam at first stage is %3.1f kJ/kg \n
       Final state of steam at second stage is %3.2f kJ/
       kg \n Rotor blade height is %3.4f m',b1,b2,b3,b4,
       W,h4,h4s,h)
40
41
42
43
44
45
46
47
48
49
50  //======================================END OF PROGRAM
       ===================================
```

Scilab code Exa 4.26 Rotor blade angles

```
1  //Chapter −4, Illustration  26, Page  221
2  //Title: Steam  Nozzles  and  Steam  Turbines
3  //
       ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  a1=30;//Nozzle  angle  in  degrees
```

```
9  Ca=180;//Axial velocity in m/s
10 U=280;//Rotor blade speed in m/s
11 R=0.5;//Degree of reaction
12
13 //CALCULATIONS
14 a1n=90-a1;//Nozzle angle measured from axial
      direction in degrees
15 Cx1=Ca*tand(a1n);//Whirl velocity in m/s
16 b1=atand((Cx1-U)/Ca);//Blade angle at inlet in
      degrees
17 b2=a1n;//Blade angle at exit in degrees
18
19 //OUTPUT
20 mprintf('Blade angle at inlet is %3.0f degrees \n
      Blade angle at exit is %3.0f degrees',b1,b2)
21
22
23
24
25
26
27
28
29
30 //==============================END OF PROGRAM
      ================================
```

Scilab code Exa 4.27 Rotor blade angles and Power developed and Isentropic enthalp

```
1 //Chapter-4, Illustration 27, Page 222
2 //Title: Steam Nozzles and Steam Turbines
3 //
      ================================================

4 clc
```

```scilab
5  clear
6
7  //INPUT DATA
8  P0=800;//Steam pressure in kPa
9  T0=900;//Steam temperature in K
10 a1=70;//Nozzle angle in degrees
11 ns=0.85;//Steam efficiency
12 m=75;//Mass flow rate of steam in kg/s
13 R=0.5;//Degree of reaction
14 U=160;//Blade speed in m/s
15
16 //CALCULATIONS
17 C1=U/sind(a1);//Steam speed in m/s
18 Ca=C1*cosd(a1);//Axial velocity in m/s
19 b1=0;//Blade angle at inlet from velocity triangle
        in degrees
20 b2=a1;//Blade angle at exit in degrees
21 a2=b1;//Nozzle angle in degrees
22 W=(m*(U^2))/(10^6);//Power developed in MW
23 Dhs=(W*1000)/(ns*m);//Isentropic enthalpy drop in kJ
        /kg
24
25 //OUTPUT
26 mprintf('Rotor blade angles are %3.0f degrees and %3
        .0f degrees \n Power developed is %3.2f MW \n
        Isentropic enthalpy drop is %3.2f kJ/kg',b1,b2,W,
        Dhs)
27
28
29
30
31
32
33
34
35 //==============================END OF PROGRAM
        =================================
```

Chapter 5

Air Compressors

Scilab code Exa 5.1 Indicated power and Mass of air and Temperature delivered by c

```scilab
1  //Chapter -5, Illustration 1, Page 250
2  //Title: Air Compressors
3  //
      =====================================================================

4  clc
5  clear
6
7  //INPUT DATA
8  D=0.2;//Cylinder diameter in m
9  L=0.3;//Cylinder Stroke in m
10 P1=1;//Pressure at entry in bar
11 T1=300;//Temperature at entry in K
12 P2=8;//Pressure at exit in bar
13 n=1.25;//Adiabatic gas constant
14 N=100;//Speed in rpm
15 R=287;//Universal gas constant in J/kg-K
16
17 //CALCULATIONS
18 x=(n-1)/n;//Ratio
19 V1=(3.147*L*(D^2))/4;//Volume of cylinder in m^3/
```

```
         cycle
20  W=(P1*(10^5)*V1*(((P2/P1)^x)-1))/x;//Work done in J/
         cycle
21  Pc=(W*100)/(60*1000);//Indicated power of compressor
         in kW
22  m=(P1*(10^5)*V1)/(R*T1);//Mass of air delivered in
         kg/cycle
23  md=m*N;//Mass delivered per minute in kg
24  T2=T1*((P2/P1)^x);//Temperature of air delivered in
         K
25
26  //OUTPUT
27  mprintf('Indicated power of compressor is %3.2f kW \
         n Mass of air delivered by compressor per minute
         is %3.2f kg \n Temperature of air delivered is %3
         .1fK',Pc,md,T2)
28
29
30
31
32  //===============================END OF PROGRAM
         ==============================
```

Scilab code Exa 5.2 Size of cylinder

```
1  //Chapter -5, Illustration 2, Page 251
2  //Title: Air Compressors
3  //
         =============================================================
4  clc
5  clear
6
7  //INPUT DATA
8  IP=37;//Indicated power in kW
```

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```
 9  P1 =0.98; //Pressure  at  entry  in  bar
10  T1 =288; //Temperature  at  entry  in  K
11  P2 =5.8; //Pressure  at  exit  in  bar
12  n =1.2; //Adiabatic  gas  constant
13  N =100; //Speed  in  rpm
14  Ps =151.5; //Piston  speed  in  m/min
15  a =2; //For  double  acting  compressor
16
17  //CALCULATIONS
18  L=Ps /(2*N) ; //Stroke  length  in  m
19  x =(n -1)/n; //Ratio
20  r =(3.147*L)/4; //Ratio  of  volume  to  bore
21  D=sqrt((IP*1000*60*x)/(N*a*r*P1*(10^5)*(((P2/P1)^x)
       -1)) ); //Cylinder  diameter  in  m
22
23  //OUTPUT
24  mprintf('Stroke  length  of  cylinder  is  %3.4 f  m  \n
       Cylinder  diameter  is  %3.4 f  m',L,D)
25
26
27
28
29
30
31  //========================END  OF  PROGRAM
       ==================================
```

Scilab code Exa 5.3 Cylinder dimensions

```
1  //Chapter −5,  Illustration  3,  Page  251
2  //Title :  Air  Compressors
3  //
     ====================================================================
4  clc
```

```
5  clear
6
7  //INPUT DATA
8  IP=11;//Indicated power in kW
9  P1=1;//Pressure at entry in bar
10 P2=7;//Pressure at exit in bar
11 n=1.2;//Adiabatic gas constant
12 Ps=150;//Piston speed in m/s
13 a=2;//For double acting compressor
14 r=1.5;//Storke to bore ratio
15
16 //CALCULATIONS
17 x=(n-1)/n;//Ratio
18 y=3.147/(4*(r^2));//Ratio of volume to the cube of
       stroke
19 z=(P1*(10^2)*y*(((P2/P1)^x)-1))/x;//Ratio of
       workdone to the cube of stroke
20 L=(sqrt(IP/(z*Ps)))*1000;//Stroke in mm
21 D=(L/r);//Bore in mm
22
23 //OUTPUT
24 mprintf('Stroke length of cylinder is %3.0f mm \n
       Bore diameter of cylinder is %3.0f mm',L,D)
25
26
27
28
29
30
31 //===============================END OF PROGRAM
       ==============================
```

Scilab code Exa 5.4 Volumetric efficiency and Volumetric efficiency referred to at

```
1  //Chapter-5, Illustration 4, Page 252
```

```scilab
2  //Title: Air Compressors
3  //
      ================================================================

4  clc
5  clear
6
7  //INPUT DATA
8  x=0.05;//Ratio of clearance volume to swept volume
9  P1=1;//Pressure at point 1 in bar
10 T1=310;//Temperature at point 1 in K
11 n=1.2;//Adiabatic gas constant
12 P2=7;//Pressure at point 2 in bar
13 Pa=1.01325;//Atmospheric pressure in bar
14 Ta=288;//Atmospheric temperature in K
15
16 //CALCULATIONS
17 V1=1+x;//Ratio of volume of air sucked to stroke
      volume
18 V4=((P2/P1)^(1/n))/20;//Ratio of volume delivered to
       stroke volume
19 DV=V1-V4;//Difference in volumes
20 nv1=DV*100;//Volumetric efficiency
21 V=(P1*DV*Ta)/(T1*Pa);//Ratio of volumes referred to
      atmospheric conditions
22 nv2=V*100;//Volumetric efficiency referred to
      atmospheric conditions
23 W=(n*0.287*T1*((P2/P1)^((n-1)/n)-1))/(n-1);//Work
      required in kJ/kg
24
25 //OUTPUT
26 mprintf('Volumetric efficiency is %3.1f percent \n
      Volumetric efficiency referred to atmospheric
      conditions is %3.1f percent \n Work required is
      %3.1f kJ/kg',nv1,nv2,W)
27
28
29
```

```
30
31
32
33
34
35  //===========================END  OF  PROGRAM
        ==============================
```

Scilab code Exa 5.5 Theoretical volume of air taken

```
 1  //Chapter −5,  Illustration  5,  Page  253
 2  //Title:  Air  Compressors
 3  //
        =================================================
 
 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  D=0.2;//Bore  in  m
 9  L=0.3;//Stroke  in  m
10  lc=0.015;//Linear  clearance  in  m
11  P1=1;//Pressure  at  point  1  in  bar
12  P2=7;//Pressure  at  point  2  in  bar
13  n=1.25;//Adiabatic  gas  constant
14
15  //CALCULATIONS
16  V3=(3.147*(D^2)*lc)/4;//Clearance  volume  in  m^3
17  Vs=(3.147*(D^2)*L)/4;//Stoke  volume  in  m^3
18  C=V3/Vs;//Clearance  ratio
19  nv=(1+C-(C*((P2/P1)^(1/n))))*100;//Volumetric
        efficiency
20  DV=(nv*Vs)/100;//Volume  of  air  taken  in  (m^3)/stroke
21
22  //OUTPUT
```

```
23  mprintf('Theoretical volume of air taken in per
        stroke is %3.6f (m^3)/stroke',DV)
24
25
26
27
28
29
30
31
32  //═══════════════════════════════════════END OF PROGRAM
        ═══════════════════════════════════════
    _____
```

Scilab code Exa 5.6 Mean effective pressure and Power required

```
1  //Chapter −5, Illustration  6, Page  254
2  //Title: Air  Compressors
3  //
        ═══════════════════════════════════════════════════════════
4  clc
5  clear
6
7  //INPUT DATA
8  D=0.2;//Bore in m
9  L=0.3;//Stroke in m
10 r=0.05;//Ratio of clearance volume to stroke volume
11 P1=1;//Pressure at point 1 in bar
12 T1=293;//Temperature at point 1 in K
13 P2=5.5;//Pressure at point 2 in bar
14 n=1.3;//Adiabatic gas constant
15 N=500;//Speed of compressor in rpm
16
17 //CALCULATIONS
18 x=(n-1)/n;//Ratio
```

```
19  Vs=(3.147*L*(D^2))/4;//Stroke volume in m^3
20  Vc=r*Vs;//Clearance volume in m^3
21  V1=Vc+Vs;//Volume at point 1 in m^3
22  V4=Vc*((P2/P1)^(1/n));//Volume at point 4 in m^3
23  EVs=V1-V4;//Effective swept volume in m^3
24  W=(P1*(10^5)*EVs*(((P2/P1)^x)-1))/x;//Work done in J
        /cycle
25  MEP=(W/Vs)/(10^5);//Mean effective pressure in bar
26  P=(W*N)/(60*1000);//Power required in kW
27
28  //OUTPUT
29  mprintf('Mean effective pressure is %3.2f bar \n
        Power required is %3.2f kW',MEP,P)
30
31
32
33
34
35
36  //═══════════════════════════════END OF PROGRAM
        ═══════════════════════════════
```

Scilab code Exa 5.7 Free air delivered and Volumetric efficiency and Delivery temp

```
1  //Chapter −5, Illustration 7, Page 255
2  //Title: Air Compressors
3  //
        ═══════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  D=0.2;//Bore in m
9  L=0.3;//Stroke in m
```

```
10  r=0.05;//Ratio of clearance volume to stroke volume
11  P1=97;//Pressure at entry in kN/(m^2)
12  P4=P1;//Pressure at point 4 in kN/(m^2)
13  T1=293;//Temperature at point 1 in K
14  P2=550;//Compression Pressure in kN/(m^2)
15  P3=P2;//Pressure at point 3 in kN/(m^2)
16  n=1.3;//Adiabatic gas constant
17  N=500;//Speed of compressor in rpm
18  Pa=101.325;//Air pressure in kN/(m^2)
19  Ta=288;//Air temperature in K
20
21  //CALCULATIONS
22  x=(n-1)/n;//Ratio
23  DV=(3.147*L*(D^2))/4;//Difference in volumes in m^3
24  V3=r*DV;//Clearance volume in m^3
25  V1=V3+DV;//Volume at point 1 in m^3
26  V4=V3*((P3/P4)^(1/n));//Volume at point 4 in m^3
27  Vs=V1-V4;//Effective swept volume in m^3
28  EVs=Vs*N;//Effective swept volume per min
29  Va=(P1*EVs*Ta)/(Pa*T1);//Free air delivered in (m^3)
        /min
30  nV=((V1-V4)/(V1-V3))*100;//Volumetric effciency
31  T2=T1*((P2/P1)^x);//Air delivery temperature in K
32  t2=T2-273;//Air delivery temperature in oC
33  W=(n*P1*(V1-V4)*(((P2/P1)^x)-1))*N/((n-1)*60);//
        Cycle power in kW
34  Wiso=P1*V1*(log(P2/P1));//Isothermal workdone
35  P=(n*P1*V1*(((P2/P1)^x)-1))/(n-1);//Cycle power
        neglecting clearance
36  niso=(Wiso/P)*100;//Isothermal efficiency
37
38  //OUTPUT
39  mprintf('Free air delivered is %3.3f (m^3)/min \n
        Volumetric efficiency is %3.0f percent \n Air
        delivery temperature is %3.1f oC \n Cycle power
        is %3.0f kW \n Isothermal efficiency is %3.1f
        percent ',Va,nV,t2,W,niso)
40
```

41
42
43
44
45
46
47
48
49
50 //═══END OF PROGRAM
═══════════════════════════════════

Scilab code Exa 5.8 Mean effective pressure and Brake power

```scilab
1  //Chapter-5, Illustration  8,  Page  257
2  //Title: Air Compressors
3  //
        ════════════════════════════════════════════════════════════
4  clc
5  clear
6
7  //INPUT DATA
8  Ve=30;//Volume of air entering compressor per hour
       in m^3
9  P1=1;//Presure of air entering compressor in bar
10 N=450;//Speed in rpm
11 P2=6.5;//Pressure at point 2 in bar
12 nm=0.8;//Mechanical efficiency
13 nv=0.75;//Volumetric efficiency
14 niso=0.76;//Isothermal efficiency
15
16 //CALCULATIONS
17 Vs=Ve/(nv*3600);//Swept volume per sec in (m^3)/s
18 V=(Vs*60)/N;//Swept volume per cycle in m^3
```

112

```
19  V1=(Ve*60)/(3600*N);//Volume at point 1 in m^3
20  Wiso=P1*100*V1*log(P2/P1);//Isothermal workdone per
        cycle
21  Wact=Wiso/niso;//Actual workdone per cycle on air
22  MEP=(Wact/V)/100;//Mean effective pressure in bar
23  IP=(Wact*N)/60;//Indicated power in kW
24  BP=IP/nm;//Brake power in kW
25
26  //OUTPUT
27  mprintf('Mean effective pressure is %3.3f bar \n
        Brake power is %3.2f kW',MEP,BP)
28
29
30
31
32
33
34
35  //================================END OF PROGRAM
        ==============================
```

Scilab code Exa 5.9 Cylinder dimensions

```
1  //Chapter-5, Illustration 9, Page 258
2  //Title: Air Compressors
3  //
        ==================================================
4  clc
5  clear
6
7  //INPUT DATA
8  Va=15;//Volume of air in (m^3)/min
9  Pa=1.01325;//Pressure of air in bar
10 Ta=302;//Air temperature in K
```

```
11  P1=0.985;//Pressure at point 1 in bar
12  T1=313;//Temperature at point 1 in K
13  r=0.04;//Ratio of clearance volume to swept volume
14  y=1.3;//Ratio of stroke to bore diameter
15  N=300;//Speed in rpm
16  n=1.3;//Adiabatic gas constant
17  P2=7.5;//Pressure at point 2 in bar
18
19  //CALCULATIONS
20  x=((P2/P1)^(1/n))-1;//Ratio of volume at point 4 to
        clearance volume
21  a=x*r;//Ratio of volume at point 4 to swept volume
22  nv=1-a;//Volumetric efficiency
23  V1=(Pa*Va*T1)/(Ta*P1);//Volume at point 1 in (m^3)/
        min
24  Vs=V1/(nv*N*2);//Swept volume in m^3
25  D=((Vs*4)/(3.147*y))^(1/3);//Bore in m
26  L=y*D;//Stroke in m
27
28  //OUTPUT
29  mprintf('Cylinder bore in %3.3f m \n Cylinder stroke
        %3.3f m',D,L)
30
31
32
33
34
35
36  //==============================END OF PROGRAM
        ==============================
```

Scilab code Exa 5.10 Volumetric efficiency and Indicated power and Isothermal effi

```
1  //Chapter−5, Illustration 10, Page 259
2  //Title: Air Compressors
```

```scilab
 3 //
     ================================================================

 4 clc
 5 clear
 6
 7 //INPUT DATA
 8 P1=0.98;//Pressure at point 1 in bar
 9 P4=P1;//Pressure at point 4 in bar
10 P2=7;//Pressure at point 2 in bar
11 P3=P2;//Pressure at point 3 in bar
12 n=1.3;//Adiabatic gas constant
13 Ta=300;//Air temperature in K
14 Pa=1.013;//Air pressure in bar
15 T1=313;//Temperature at point 1 in K
16 c=0.04;//Ratio of clearance volume to swept volume
17 Va=15;//Volume of air delivered in m^3
18 R=0.287;//Universal gas constant in kJ/kg-K
19
20 //CALCULATIONS
21 x=(n-1)/n;//Ratio
22 r=(P2/P1)^(1/n);//Ratio of volumes
23 a=r*c;//Ratio of volume at point 4 to swept volume
24 DV=1+c-a;//Difference in volumes
25 V=(P1*DV*Ta)/(T1*Pa);//Volume of air delivered per
      cycle
26 nv=V*100;//Volumetric efficiency
27 DV1=(Pa*Va*T1)/(Ta*P1);//Difference in volumes
28 T2=T1*((P2/P1)^x);//Temperature at point 2 in K
29 ma=(Pa*100*Va)/(R*Ta);//Mass of air delivered in kg/
      min
30 IP=(ma*R*(T2-T1))/(x*60);//Indicated power in kW
31 Piso=(ma*R*T1*log(P2/P1))/60;//Isothermal indicated
      power in kW
32 niso=(Piso/IP)*100;//Isothermal efficiency
33
34 //OUTPUT
35 mprintf('Volumetric efficiency is %3.1f percent \n
```

115

```
            Indicated power is %3.2 f kW \n Isothermal
            efficiency is %3.0 f percent ',nv,IP,niso)
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50  //═══════════════════════════════════════END OF PROGRAM
         ═══════════════════════════════════
```

___

Scilab code Exa 5.11 Power required

```
1  // Chapter −5, Illustration 11, Page 261
2  // Title : Air Compressors
3  //
      ════════════════════════════════════════════════════
4  clc
5  clear
6
7  //INPUT DATA
8  V1=7*(10^-3); // Volume of air in (m^3)/s
9  P1=1.013; // Pressure of air in bar
10 T1=288; // Air temperature in K
11 P2=14; // Pressure at point 2 in bar
12 n=1.3; // Adiabatic gas constant
```

```
13  nm =0.82; //Mechanical efficiency
14
15  //CALCULATIONS
16  x=(n-1)/n; //Ratio
17  W=(P1*100*V1*(((P2/P1)^x)-1))/x; //Work done by
        compressor in kW
18  P=W/nm; //Power requred to drive compressor in kW
19
20  //OUTPUT
21  mprintf('Power requred to drive compressor is %3.2f
        kW',P)
22
23
24
25
26
27
28
29
30  //==============================END OF PROGRAM
        ==========================
```

Scilab code Exa 5.12 Theoretical volume efficiency and Volume of air delivered and

```
1  //Chapter-5, Illustration 12, Page 261
2  //Title: Air Compressors
3  //
        ===========================================================
4  clc
5  clear
6
7  //INPUT DATA
8  L=0.15; //Stroke in mm
9  D=0.15; //Bore in mm
```

```scilab
10  N=8; //Speed in rps
11  P1=100; //Pressure at point 1 in kN/(m^2)
12  P2=550; //Pressure at point 2 in kN/(m^2)
13  n=1.32; //Adiabatic gas constant
14  C=0.06; //Ratio of clearance volume to swept volume
15
16  //CALCULATIONS
17  x=(n-1)/n; //Ratio
18  nv=(1+C-(C*((P2/P1)^(1/n))))*100; //Volumetric
        efficiency
19  DV=(3.147*(D^2)*L)/4; //Difference in volumes at
        points 1 and 3
20  DV1=(nv*DV)/100; //Difference in volumes at points 1
        and 4
21  V2=DV1*((P1/P2)^(1/n))*N; //Volume of air delivered
        per second
22  W=(P1*DV1*(((P2/P1)^x)-1))*N/x; //Power of compressor
         in kW
23
24  //OUTPUT
25  mprintf('Theoretical volume efficiency is %3.1f
        percent \n Volume of air delivered is %3.5f (m^3)
        /s \n Power of compressor is %3.3f kW',nv,V2,W)
26
27
28
29
30
31
32
33
34
35  //=============================END OF PROGRAM
        ================================
```

Scilab code Exa 5.13 Minimum indicated power and Maximum temperature and Heat to b

```
1  //Chapter-5, Illustration 13, Page 262
2  //Title: Air Compressors
3  //
   _____

4  clc
5  clear
6
7  //INPUT DATA
8  V=16;//Volume of air compresssed in m^3
9  P1=1;//Pressure at point 1 in bar
10 P3=10.5;//Pressure at point 3 in bar
11 T1=294;//Temperature at point 1 in K
12 Tc=25;//Temperature of cooling water in oC
13 n=1.35;//Adiabatics gas constant
14 R=0.287;//Universal gas constant in kJ/kg-K
15 Cp=1.005;//Specific heat at constant pressure in kJ/
      kg-K
16 Cw=4.187;//Specific heat of water in kJ/kg-K
17
18 //CALCULATIONS
19 x=(n-1)/n;//Ratio
20 P2=sqrt(P1*P3);//Pressure at point 2 in bar
21 W1=(2*P1*100*V*(((P2/P1)^x)-1))/(x*60);//Indicated
      power of compressor from P1 to P2 in kW
22 W2=(P1*100*V*(((P3/P1)^x)-1))/(x*60);//Indicated
      power of compressor from P1 to P3 in kW
23 T4=T1*((P2/P1)^x);//Maximum temperature for two
      stage compression in K
24 T2=T1*((P3/P1)^x);//Maximum temperature for single
      stage compression in K
25 m=(P1*100*V)/(R*T1);//Mass of air compressed in kg/
      min
26 Q=m*Cp*(T4-T1);//Heat rejected by air in kJ/min
27 mc=Q/(Cw*Tc);//Mass of cooling water in kg/min
28
```

```
29  //OUTPUT
30  mprintf('Minimum indicated power required for 2
       stage compression is %3.1 f kW \n Power required
       for single stage compression is 18 percent more
       than that for two stage compression with perfect
       intercooling \n Maximum temperature for two stage
        compression is %3.1 f K \n Maximum temperature
       for single stage compression is %3.1 f K \n Heat
       rejected by air is %3.1 f kJ/min \n Mass of
       cooling water required is %3.1 f kg/min',W1,T4,T2,
       Q,mc)
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45  //===============================END OF PROGRAM
       ===============================
```

Scilab code Exa 5.14 Intermediate pressure and Total volume of each cylinder and C

```
1  //Chapter−5, Illustration 14, Page 264
2  //Title: Air Compressors
3  //
       ================================================
```

```scilab
 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  V=0.2;//Air flow rate in (m^3)/s
 9  P1=0.1;//Intake pressure in MN/(m^2)
10  P3=0.7;//Final pressure in MN/(m^2)
11  T1=289;//Intake temperature in K
12  n=1.25;//Adiabatic gas constant
13  N=10;//Compressor speed in rps
14
15  //CALCULATIONS
16  x=(n-1)/n;//Ratio
17  P2=sqrt(P1*P3);//Intermediate pressure in MN/(m^2)
18  V1=(V/N)*1000;//Total volume of LP cylinder in
        litres
19  V2=((P1*V1)/P2);//Total volume of HP cylinder in
        litres
20  W=((2*P1*V*(((P2/P1)^x)-1))/x)*1000;//Cycle power in
         kW
21
22  //OUTPUT
23  mprintf('Intermediate pressure is %3.3f MN/(m^2) \n
        Total volume of LP cylinder is %3.0f litres \n
        Total volume of HP cylinder is %3.1f litres \n
        Cycle power is %3.0f kW',P2,V1,V2,W)
24
25
26
27
28
29
30
31
32  //===============================END OF PROGRAM
        ================================
```

Scilab code Exa 5.15 Power of compressor

```
1  //Chapter-5, Illustration 15, Page 265
2  //Title: Air Compressors
3  //
   _____

4  clc
5  clear
6
7  //INPUT DATA
8  P1=1;//Pressure at point 1 in bar
9  T1=290;//Temperature at point 1 in K
10 P3=60;//Pressure at point 3 in bar
11 P2=8;//Pressure at point 2 in bar
12 T2=310;//Temperature at point 2 in K
13 L=0.2;//Stroke in m
14 D=0.15;//Bore in m
15 n=1.35;//Adiabatic gas constant
16 N=200;//Speed in rpm
17
18 //CALCULATIONS
19 x=(n-1)/n;//Ratio
20 V1=(3.147*(D^2)*L)/4;//Volume at point 1 in m^3
21 V2=(P1*V1*T2)/(T1*P2);//Volume of air entering LP
      cylinder in m^3
22 W=((P1*(10^5)*V1*(((P2/P1)^x)-1))/x)+((P2*(10^5)*V2
      *(((P3/P2)^x)-1))/x);//Workdone by compressor per
       cycle in J
23 P=(W*N)/(60*1000);//Power of compressor in kW
24
25 //OUTPUT
26 mprintf('Power of compressor is %3.2f kW',P)
27
```

122

```
28
29
30
31
32
33
34
35 //═════════════════════════════════════════END OF PROGRAM
      ═══════════════════════════════════
```

Scilab code Exa 5.16 Heat rejected and Diameter of HP cylinder and Power required

```
 1 //Chapter −5, Illustration 16, Page 265
 2 //Title: Air Compressors
 3 //
      ════════════════════════════════════════════════════════
 4 clc
 5 clear
 6
 7 //INPUT DATA
 8 N=220;//Speed of compressor in rpm
 9 P1=1;//Pressure entering LP cylinder in bar
10 T1=300;//Temperature at point 1 in K
11 Dlp=0.36;//Bore of LP cylinder in m
12 Llp=0.4;//Stroke of LP cylinder in m
13 Lhp=0.4;//Stoke of HP cylinder in m
14 C=0.04;//Ratio of clearance volumes of both
      cylinders
15 P2=4;//Pressure leaving LP cylinder in bar
16 P5=3.8;//Pressure entering HP cylinder in bar
17 T3=300;//Temperature entering HP cylinder in K
18 P6=15.2;//Dicharge pressure in bar
19 n=1.3;//Adiabatic gas constant
20 Cp=1.0035;//Specific heat at constant pressure in kJ
```

123

```
        /kg–K
21  R=0.287;//Universal gas constant in kJ/kg–K
22  T5=T1;//Temperature at point 5 in K
23
24  //CALCULATIONS
25  x=(n-1)/n;//Ratio
26  Vslp=(3.147*(Dlp^2)*Llp*N*2)/4;//Swept volume of LP
        cylinder in m^3/min
27  nv=1+C-(C*((P2/P1)^(1/n)));//Volumetric efficiency
28  V1=nv*Vslp;//Volume of air drawn at point 1 in (m^3)
        /min
29  m=(P1*100*V1)/(R*T1);//Mass of air in kg/min
30  T2=T1*((P2/P1)^x);//Temperature at point 2 in K
31  QR=m*Cp*(T2-T5);//Heat rejected in kJ/min
32  V5=(m*R*T5)/(P5*100);//Volume of air drawn in HP
        cylinder M^3/min
33  Plp=P2/P1;//Pressure ratio of LP cylinder
34  Php=P6/P5;//Pressure ratio of HP cylinder
35  Vshp=V5/nv;//Swept volume of HP cylinder in m^3/min
36  Dhp=sqrt((Vshp*4)/(3.147*Lhp*N*2));//Bore of HP
        cylinder in m
37  P=(m*R*(T2-T1))/(x*60);//Power required for HP
        cylinder in kW
38
39  //OUTPUT
40  mprintf('Heat rejected in intercooler is %3.1f kJ/
        min \n Diameter of HP cylinder is %3.4f m \n
        Power required for HP cylinder is %3.0f kW',QR,
        Dhp,P)
41
42
43
44
45
46
47
48
49
```

Scilab code Exa 5.17 Ratio of cylinder diameters

```scilab
1  //Chapter -5, Illustration  17, Page  267
2  //Title: Air Compressors
3  //
         ════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  P1=1;//Pressure  at  point  1  in  bar
9  P3=30;//Pressure  at  point  3  in  bar
10 T1=300;//Temperature  at  point  1  in  K
11 n=1.3;//Adiabatics  gas  constant
12
13 //CALCULATIONS
14 P2=sqrt(P1*P3);//Intermediate  pressure  in  bar
15 rD=sqrt(P2/P1);//Ratio  of  cylinder  diameters
16
17 //OUTPUT
18 mprintf('Ratio  of  cylinder  diameters  is  %3.2f',rD)
19
20
21
22
23
24
25
26 //════════════════════════════════END OF PROGRAM
════════════════════════════
```

Scilab code Exa 5.18 Delivery pressures and Ratio of cylinder volumes and Temperat

```
1  //Chapter-5, Illustration 18, Page 268
2  //Title: Air Compressors
3  //
   _____

4  clc
5  clear
6
7  //INPUT DATA
8  P1=1.013;//Pressure at point 1 in bar
9  T1=288;//Temperaturea at point 1 in K
10 v1=8.4;//free air delivered by compressor in m^3
11 P4=70;//Pressure at point 4 in bar
12 n=1.2;//Adiabatic gas constant
13 Cp=1.0035;//Specific heat at constant pressure in kJ
      /kg-K
14
15 //CALCULATIONS
16 x=(n-1)/n;//Ratio
17 P2=P1*((P4/P1)^(1/3));//LP cylinder delivery
      pressure in bar
18 P3=P2*((P4/P1)^(1/3));//IP cylinder delivery
      pressure in bar
19 r=P2/P1;//Ratio of cylinder volumes
20 r1=P3/P2;//Ratio of cylinder volumes
21 r2=r*r1;//Ratio of cylinder volumes
22 V3=1;//Volume at point 3 in m^3
23 T4=T1*((P2/P1)^x);//Three stage outlet temperature
      in K
24 QR=Cp*(T4-T1);//Heat rejected in intercooler in kJ/
      kg of air
25 W=((3*P1*100*v1*(((P4/P1)^(x/3))-1))/(x*60));//Total
```

```
26
27 //OUTPUT
28 mprintf('LP cylinder delivery pressure is %3.3f bar
       \n IP cylinder delivery pressure is %3.2f bar \n
       Ratio of cylinder volumes is %3.2f:%3.1f:%3.0f \n
        Temperature at end of each stage is %3.2f K \n
       Heat rejected in each intercooler is %3.1f kJ/kg
       of air \n Total indicated power is %3.2f kW',P2,
       P3,r2,r1,V3,T4,QR,W)
29
30
31
32
33
34
35
36
37
38
39
40
41 //================================END OF PROGRAM
       ==============================
```

Scilab code Exa 5.19 Intermediate pressures and Effective swept volume and Tempera

```
1 //Chapter−5, Illustration 19, Page 269
2 //Title: Air Compressors
3 //
       ================================================
4 clc
5 clear
6
```

```scilab
 7  //INPUT DATA
 8  D=0.45;//Bore in m
 9  L=0.3;//Stroke in m
10  C=0.05;//Ratio of clearance volume to swept volume
11  P1=1;//Pressure at point 1 inn bar
12  T1=291;//Temperature at point 1 in K
13  P4=15;//Pressure at point 4 in bar
14  n=1.3;//Adiabatic gas constant
15  R=0.29;//Universal gas constant in kJ/kg-K
16
17  //CALCULATIONS
18  x=(n-1)/n;//Ratio
19  k=(P4/P1)^(1/3);//Pressure ratio
20  P2=k*P1;//Pressure at point 2 in bar
21  P3=k*P2;//Pressure at point 1 in bar
22  Vslp=(3.147*(D^2)*L)/4;//Swept volume of LP cylinder
23  V7=C*Vslp;//Volume at point 7 in m^3
24  V1=Vslp+V7;//Volume at point 1 in m^3
25  V8=V7*(k^(1/n));//Volume at point 8 in m^3
26  EVs=(V1-V8)*1000;//Effective swept volume in litres
27  T4=T1*(k^x);//Temperature at point 4 in K
28  t4=T4-273;//Delivery temperature in oC
29  DV=((P1*T4*(V1-V8))/(P4*T1))*1000;//Delivery volume
        per stroke in litres
30  W=(3*R*T1*((k^x)-1))/x;//Workdone per kg of air in
        kJ
31
32  //OUTPUT
33  mprintf('Intermediate pressures are %3.3f bar and %3
        .3f bar \n Effective swept volume of LP cylinder
        is %3.2f litres \n Temperature of air delivered
        per stroke is %3.1f oC \n Volume of air delivered
         per stroke is %3.2f litres \n Work done per kg
        of air is %3.1f kJ',P2,P3,EVs,t4,DV,W)
34
35
36
37
```

45 `//`═════════════════════════════END OF PROGRAM ══════════════════════════════

___

Scilab code Exa 5.20 Number of stages and Exact stage pressure ratio and Intermedi

```
1  //Chapter-5, Illustration 20, Page 271
2  //Title: Air Compressors
3  //
    ══════════════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  P1=1;//Pressure at point 1 in bar
9  Pns=100;//Maximum pressure in bar
10 p=4;//Pressure ratio
11
12 //CALCULATIONS
13 Ns=log(Pns)/log(p);//Number of stages
14 y=ceil(Ns);//Rounding off to next higher integer
15 ps=(Pns/P1)^(1/y);//Exact stage pressure ratio
16 P2=ps*P1;//Pressure at point 2 in bar
17 P3=ps*P2;//Pressure at point 3 in bar
18 P4=ps*P3;//Pressure at point 4 in bar
19
20 //OUTPUT
21 mprintf('Number of stages are %3.0f \n Exact stage
```

```
        pressure ratio is %3.3f \n Intermediate pressures
         are %3.3f bar,%3.2f bar,%3.2f bar',y,ps,P2,P3,P4
        )
22
23
24
25
26
27
28
29
30  //══════════════════════════════END OF PROGRAM
        ══════════════════════════════
```

Chapter 6

Refrigeration Cycles

Scilab code Exa 6.1 Claim is correct or not

```
1  //Chapter-6, Illustration 1, Page 308
2  //Title: Refrigeration cycles
3  //
    =========================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  COP=8.5;//Co-efficient of performance
9  T1=300;//Room temperature in K
10 T2=267;//Refrigeration temperature in K
11
12 //CALCULATIONS
13 COPmax=T2/(T1-T2);//Maximum COP possible
14
15 //OUTPUT
16 mprintf('Maximum COP possible is %3.2f \n Since the
       COP claimed by the inventor is more than the
       maximum possible COP his claim is not correct',
       COPmax)
```

```
17
18
19
20  //==================================END OF PROGRAM
        ================================
```

Scilab code Exa 6.2 Weight of ice formed and Minimum power required

```
1  //Chapter −6, Illustration  2, Page  309
2  //Title: Refrigeration  cycles
3  //
        ========================================================
4  clc
5  clear
6
7  //INPUT DATA
8  TL=268; //Low  temperature  in  K
9  TH=293; //High  temperature  in  K
10 t=24; //time  in  hrs
11 C=2100; //Capacity  of  refrigerator  in  kJ/s
12 Tw=10; //Water  temperature  in  oC
13 L=335; //Latent  heat  of  ice  in  kJ/kg
14
15 //CALCULATIONS
16 COP=TL/(TH-TL); //Co−efficient  of  performance
17 Pmin=C/COP; //Minimum  power  required  in  kW
18 Qr=(4.187*(Tw-0))+L; //Heat  removed  from  water  in  kJ/
        kg
19 m=C/Qr; //mass  of  ice  formed  in  kg/s
20 W=(m*t*3600)/1000; //Weight  of  ice  formed  in  tons
21
22 //OUTPUT
23 mprintf('Minimum  power  required  is  %3.2f  kW  \n
        Weight  of  ice  formed  in  24  hours  is  %3.2f  tons',
```

```
    Pmin ,W)
24
25
26
27
28
29
30 //==============================END OF PROGRAM
     ===============================
```

Scilab code Exa 6.3 `Mass of ice formed`

```
1  //Chapter−6, Illustration 3, Page 309
2  //Title: Refrigeration cycles
3  //
     ============================================================

4  clc
5  clear
6
7  //INPUT DATA
8  TL=-10;//Temperature of brine in oC
9  TH=20;//Temperature of water in oC
10 L=335;//Latent heat of ice in kJ/kg
11
12 //CALCULATIONS
13 Qr=(4.187*(TH-0))+L;//Heat removed from water in kJ/
     kg
14 COP=(TL+273)/(TH-TL);//Co−efficient of performance
15 mi=(COP*3600)/Qr;//mass of ice formed per kWh in kg
16
17 //OUTPUT
18 mprintf('Mass of ice formed per kWh is %3.1f kg',mi)
19
20
```

25 //═══END OF PROGRAM
    ═══════════════════════════════════════

_____

Scilab code Exa 6.4 Rate of heat removed and Power input to compreesor and Rate of

```
1  //Chapter-6, Illustration 4, Page 310
2  //Title: Refrigeration cycles
3  //
   ═══════════════════════════════════════════════════════

4  clc
5  clear
6
7  //INPUT DATA
8  P1=1.2;//Pressure at point 1 in bar
9  P2=7;//Pressure at point 2 in bar
10 m=0.05;//mass flow rate of refrigerant in kg/s
11 h1=340.1;//Enthalpy at point 1 from refrigerant-12
     tables in kJ/kg
12 s1=1.57135;//Entropy at point 1 from refrigerant-12
     tables in kJ/kg-K
13 s2=1.57135;//Entropy at point 2 from refrigerant-12
     tables in kJ/kg-K
14 h2=372;//Enthalpy at point 2 from refrigerant-12
     tables in kJ/kg
15 h3=226.575;//Enthalpy at point 3 from refrigerant-12
      tables in kJ/kg
16 h4=226.575;//Enthalpy at point 4 from refrigerant-12
      tables in kJ/kg
17
18 //CALCULATIONS
```

```
19  Q2=m*(h1-h4);//Rate of heat removed from the
       refrigerated space in kW
20  W=m*(h2-h1);//Power input to the compressor in kW
21  Q1=m*(h2-h3);//Rate of heat rejection to the
       environment in kW
22  COP=Q2/W;//Co-efficient of performance
23
24  //OUTPUT
25  mprintf('Rate of heat removed from the refrigerated
       space is %3.2f kW \n Power input to the
       compressor is %3.3f kW \n Rate of heat rejection
       to the environment is %3.2f kW \n Co-efficient of
        performance is %3.2f',Q2,W,Q1,COP)
26
27
28
29
30  //==================================END OF PROGRAM
       ==================================
```

Scilab code Exa 6.5 COP of system

```
1  //Chapter-6, Illustration 5, Page 311
2  //Title: Refrigeration cycles
3  //
       ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  T2=40;//Temperature at point 2 in oC
9  T1=-10;//Temperature at point 1 in oC
10 h2=367.155;//Enthalpy at point 2 from refrigerant-12
        tables in kJ/kg
```

```
11  s2=1.54057; //Entropy  at  point  2  from  refrigerant −12
        tables  in  kJ/kg−K
12  s1=1.54057; //Entropy  at  point  1  from  refrigerant −12
        tables  in  kJ/kg−K
13  sg=1.56004; //Entropy  from  refrigerant −12  tables  in
        kJ/kg−K
14  sf=0.96601; //Entropy  from  refrigerant −12  tables  in
        kJ/kg−K
15  hf=190.822; //Enthalpy  from  refrigerant −12  tables  in
        kJ/kg−K
16  hfg=156.319; //Enthalpy  from  refrigerant −12  tables  in
        kJ/kg−K
17  h3=238.533; //Enthalpy  at  point  3  from  refrigerant −12
        tables  in  kJ/kg−K
18  h4=h3; //Enthalpy  at  point  4  from  refrigerant −12
        tables  in  kJ/kg−K
19
20  //CALCULATIONS
21  x1=(s1-sf)/(sg-sf); //Quality  factor
22  h1=hf+(x1*hfg); //Enthalpy  at  point  1  from
        refrigerant −12  tables  in  kJ/kg
23  COP=(h1-h4)/(h2-h1); //Co−efficient  of  performance
24
25  //OUTPUT
26  mprintf('COP  of  the  system  is  %3.2f',COP)
27
28
29
30  //═════════════════════════════════END  OF  PROGRAM
        ═════════════════════════════
```

Scilab code Exa 6.6 Capacity of refrigeration plant and Mass flow rate of refriger

```
1  //Chapter −6,  Illustration  6,  Page  311
2  //Title:  Refrigeration  cycles
```

```
 3  //
        ════════════════════════════════════════════════════════════════════

 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  Tc=35;//Temperature of condenser in oC
 9  Te=-15;//Temperature of evaporator in oC
10  m=10;//Mass of ice per day in tons
11  Tw=30;//Temperature of water in oC
12  Ti=-5;//Temperature of ice in oC
13  nv=0.65;//Volumetric efficiency
14  N=1200;//Speed in rpm
15  x=1.2;//Stroke to bore ratio
16  na=0.85;//Adiabatic efficiency
17  nm=0.95;//Mechanical efficiency
18  S=4.187;//Specific heat of water in kJ/kg
19  L=335;//Latent heat of ice in kJ/kg
20  h1=1667.24;//Enthalpy at Te from Ammonia chart in kJ
        /kg
21  h2=1925;//Enthalpy at Te from Ammonia chart in kJ/kg
22  h4=586.41;//Enthalpy at Tc from Ammonia chart in kJ/
        kg
23  v1=0.508;//Specific humidity at Te from Ammonia
        chart in (m^3)/kg
24
25  //CALCULATIONS
26  Qr=(((m*1000)/24)*((S*(Tw-0))+L+(1.94*(0-Ti))))
        /3600;//Refrigerating capacity in kW
27  mr=Qr/(h1-h4);//Refrigerant mass flow rate in kg/s
28  T2=112;//Discharge temperature in oC
29  D=((mr*v1*4*60)/(nv*3.14*x*N))^(1/3);//Cylinder
        diameter in m
30  L=x*D;//Stroke length in m
31  W=(mr*(h2-h1))/(na*nm);//Compressor motor power in
        kW
32  COPth=(h1-h4)/(h2-h1);//Theoretical COP
```

```
33  COPact=Qr/W;//Actual COP
34
35  //OUTPUT
36  mprintf('Refrigerating capacity of plant is %3.2f kW
        \n Refrigerant mass flow rate is %3.4f kg/s \n
        Discharge temperature is %3.0f oC \n Cylinder
        diameter is %3.3f m \n Stroke length is %3.3f m \
        n Compressor motor power is %3.2f kW \n
        Theoretical COP is %3.2f \n Actual COP is %3.2f',
        Qr,mr,T2,D,L,W,COPth,COPact)
37
38
39
40
41  //==============================END OF PROGRAM
        ==============================
```

Scilab code Exa 6.7 Circulation rate of ammonia and Power required and COP

```
1  //Chapter-6, Illustration 7, Page 313
2  //Title: Refrigeration cycles
3  //
      =====================================================
4  clc
5  clear
6
7  //INPUT DATA
8  T1=-5;//Temperature at point 1 in oC
9  T2=30;//Temperature at point 2 in oC
10  m=13500;//mass of ice per day in kg
11  Tw=20;//Temperature of water in oC
12  COP=0.6;//Co-efficient of performance
13  h2=1709.33;//Enthalpy at point 2 in kJ/kg
14  s2=6.16259;//Entropy at point 2 in kJ/kg-K
```

```
15  s1=6.16259;//Entropy at point 1 in kJ/kg-K
16  sf=1.8182;//Entropy in kJ/kg-K
17  sg=6.58542;//Entropy in kJ/kg-K
18  hf=400.98;//Enthalpy in kJ/kg
19  hfg=1278.35;//Enthalpy in kJ/kg
20  h4=562.75;//Enthalpy at point 4 in kJ/kg
21  S=4.187;//Specific heat of water in kJ/kg
22  L=336;//Latent heat of ice in kJ/kg
23
24  //CALCULATIONS
25  x1=(s1-sf)/(sg-sf);//Quality factor
26  h1=hf+(x1*hfg);//Enthalpy at point 1 from
        refrigerant-12 tables in kJ/kg
27  COPi=(h1-h4)/(h2-h1);//Ideal COP
28  COPact=COP*COPi;//Actual COP
29  Qr=((m*S*(Tw-0))+(m*L))/(24*3600);//Total amount of
        heat removed in kJ/s
30  mr=Qr/(h1-h4);//Circulation rate of ammonia in kg/s
31  W=mr*(h2-h1);//Power required in kW
32
33  //OUTPUT
34  mprintf('Circulation rate of ammonia is %3.3f kg/s \
        n Power required is %3.3f kW \n COP is %3.3f',mr,
        W,COPact)
35
36
37
38
39
40  //==============================END OF PROGRAM
        ================================
```

Scilab code Exa 6.8 Refrigerating effect and Mass flow rate of refrigerant and The

```
1  //Chapter-6, Illustration 8, Page 314
```

```
2  //Title: Refrigeration cycles
3  //
                _____

4  clc
5  clear
6
7  //INPUT DATA
8  Tc=20;//Temperature of condenser in oC
9  Te=-25;//Temperature of evaporator in oC
10 m=15;//Mass of ice per day in tons
11 Ts=5;//Subcooled temperature in oC
12 Tsh=10;//Superheated temperature in oC
13 n=6;//No. of cylinders
14 N=950;//Speed of compressor in rpm
15 x=1;//Stroke to bore ratio
16 h1=402;//Enthalpy at point 1 from R-22 tables in kJ/
       kg
17 h2=442;//Enthalpy at point 2 from R-22 tables in kJ/
       kg
18 h3=216;//Enthalpy at point 3 from R-22 tables in kJ/
       kg
19 h4=216;//Enthalpy at point 4 from R-22 tables in kJ/
       kg
20 v1=2.258;//Specific volume at point 1 in (m^3)/min
21
22 //CALCULATIONS
23 Re=h1-h4;//Refrigerating effect in kJ/kg
24 mr=(m*14000)/(Re*60);//Mass flow of refrigerant in
       kg/min
25 Pth=(mr*(h2-h1))/60;//Theoretical power in kW
26 COP=(h1-h4)/(h2-h1);//Co-efficient of performance
27 Dth=v1/n;//Theoretical displacement per cylinder
28 D=(((Dth*4)/(3.147*N))^(1/3))*1000;//Theoretical
       bore of compressor in mm
29 L=D;//Theoretical stroke of compressor in mm
30
31 //OUTPUT
```

```
32  mprintf('Refrigerating effect is %3.0f kJ/kg \n Mass
         flow of refrigerant per minute is %3.2f kg/min \
      n Theoretical input power is %3.2f kW \n COP is
      %3.2f \n Theoretical bore of compressor is %3.2f
      mm \n Theoretical stroke of compressor is %3.2f
      mm',Re,mr,Pth,COP,D,L)
33
34
35
36
37
38
39
40  //===================================END OF PROGRAM
      =================================
```

_____

Scilab code Exa 6.9 COP when there is no subcooling and when there is subcooling

```
 1  //Chapter−6, Illustration 9, Page 316
 2  //Title: Refrigeration cycles
 3  //
       ============================================================

 4  clc
 5  clear
 6
 7  //INPUT DATA
 8  T2=40;//Temperature at point 2 in oC
 9  T1=-5;//Temperature at point 1 in oC
10  h2=367.155;//Enthalpy at point 2 from F−12 tables in
         kJ/kg
11  sg=1.55717;//Entropy from F−12 tables in kJ/kg−K
12  s1=1.54057;//Entropy at point 1 from F−12 tables in
         kJ/kg−K
13  sf=0.98311;//Entropy from F−12 tables in kJ/kg−K
```

```
14  hf =195.394;//Enthalpy from F−12 tables in kJ/kg
15  hfg =153.934;//Enthalpy from F−12 tables in kJ/kg
16  h4 =238.533;//Enthalpy at point 4 from F−12 tables in
        kJ/kg
17  h4s =218;//Enthalpy at point 4 with subcooling from F
        −12 tables in kJ/kg
18
19  //CALCULATIONS
20  x1 =( s1 - sf )/( sg - sf );//Quality factor
21  h1 =hf +( x1 * hfg );//Enthalpy at point 1 from
        refrigerant −12 tables in kJ/kg
22  COPns =( h1 - h4 )/( h2 - h1 );//Co−efficient of performance
        with no subcooling
23  COPs =( h1 - h4s )/( h2 - h1 );//Co−efficient of performance
        with subcooling
24
25  //OUTPUT
26  mprintf ('COP with no subcooling is %3.3f \n COP with
        subcooling is %3.3f ',COPns ,COPs )
27
28
29
30
31
32
33
34
35  //════════════════════════════END OF PROGRAM
        ════════════════════════════
```

Scilab code Exa 6.10 Ideal COP of system

```
1  //Chapter −6, Illustration 10, Page 309
2  //Title: Refrigeration cycles
3  //
```

```
  4 clc
  5 clear
  6
  7 //INPUT DATA
  8 Tg=470;//Heating temperature in K
  9 T0=290;//Cooling temperature in K
 10 TL=270;//Refrigeration temperature in K
 11
 12 //CALCULATIONS
 13 COP=((Tg-T0)/Tg)*(TL/(T0-TL));//Ideal COP of
       absorption refrigeration system
 14
 15 //OUTPUT
 16 mprintf('Ideal COP of absorption refrigeration
       system is %3.2f',COP)
 17
 18
 19
 20 //===============================END OF PROGRAM
    ===============================
```

Scilab code Exa 6.11 Maximum and minimum temperature in cycle and COP and Rate of

```
  1 //Chapter −6, Illustration 11, Page 317
  2 //Title: Refrigeration cycles
  3 //
    ===============================
  4 clc
  5 clear
  6
  7 //INPUT DATA
  8 T1=-18;//Temperature at point 1 in oC
```

```scilab
 9  T3=27;//Temperature at point 3 in oC
10  rp=4;//Pressure ratio
11  m=0.045;//mass flow rate in kg/s
12  y=1.4;//Ratio of specific heats
13  Cp=1.005;//Specific heat at constant pressure in kJ/
       kg-K
14
15  //CALCULATIONS
16  x=(y-1)/y;//Ratio
17  T2=(rp^x)*(273+T1);//Temperature at point 2 in K
18  Tmax=T2-273;//Maximum temperature in oC
19  T4=((1/rp)^x)*(273+T3);//Temperature at point 4 in K
20  Tmin=T4-273;//Minimum temperature in oC
21  qL=Cp*(T1-Tmin);//Heat rejected
22  Wcin=Cp*(Tmax-T1);//Compressor work
23  Wtout=Cp*(T3-Tmin);//Turbine work
24  Wnet=Wcin-Wtout;//Net work done
25  COP=qL/Wnet;//Co-efficient of performance
26  Qref=m*qL;//Rate of refrigeration in kW
27
28  //OUTPUT
29  mprintf('Maximum temperature in the cycle is %3.0foC
        \n Minimum temperature in the cycle is %3.0foC \
       n COP is %3.2f \n Rate of refrigeration is %3.2f
       kW',Tmax,Tmin,COP,Qref)
30
31
32
33
34
35  //==============================END OF PROGRAM
        ==============================
```

Scilab code Exa 6.12 Work developed and Refrigerating effect and COP

```scilab
1  //Chapter-6, Illustration 12, Page 318
2  //Title: Refrigeration cycles
3  //
   ==============================================================
4  clc
5  clear
6
7  //INPUT DATA
8  P1=1;//Pressure at point 1 in bar
9  T1=268;//Temperature at point 1 in K
10 P2=5;//Pressure at point 2 in bar
11 T3=288;//Temperature at point 3 in K
12 n=1.3;//Adiabatic gas constant
13 Cp=1.005;//Specific heat at constant pressure in kJ/
      kg-K
14
15 //CALCULATIONS
16 x=(n-1)/n;//Ratio
17 T2=((P2/P1)^x)*T1;//Temperature at point 2 in K
18 T4=((P1/P2)^x)*T3;//Temperature at point 4 in K
19 W=Cp*(T3-T4);//Work developed per kg of air in kJ/kg
20 Re=Cp*(T1-T4);//Refrigerating effect per kg of air
      in kJ/kg
21 Wnet=Cp*((T2-T1)-(T3-T4));//Net work output in kJ/kg
22 COP=Re/Wnet;//Co-efficient of performance
23
24 //OUTPUT
25 mprintf('Work developed per kg of air is %3.3f kJ/kg
       \n Refrigerating effect per kg of air is %3.3f
     kJ/kg \n COP of the cycle is %3.2f',W,Re,COP)
26
27
28
29
30
31 //============================END OF PROGRAM
   ==============================
```

145

Scilab code Exa 6.13 COP of refrigerator and Driving power required and Air mass f

```scilab
1  //Chapter-6, Illustration 13, Page 319
2  //Title: Refrigeration cycles
3  //
   ===========================================================
4  clc
5  clear
6
7  //INPUT DATA
8  T1=277;//Temperature at point 1 in K
9  T3=328;//Temperature at point 3 in K
10 P1=0.1;//Pressure at point 1 in MPa
11 P2=0.3;//Pressure at point 2 in MPa
12 nc=0.72;//Isentropic efficiency of compressor
13 nt=0.78;//Isentropic efficiency of turbine
14 y=1.4;//Adiabatic gas constant
15 Cp=1.005;//Specific heat at constant pressure in kJ/
      kg-K
16 m=3;//Cooling load in tonnes
17
18 //CALCULATIONS
19 x=(y-1)/y;//Ratio
20 T2s=T1*((P2/P1)^x);//Temperature at point 2s in K
21 T2=((T2s-T1)/nc)+T1;//Temerature at point 2 in K
22 T4s=T3*((P1/P2)^x);//Temperature at point 4s in K
23 T4=T3-((T3-T4s)*nt);//Temperature at point 4 in K
24 Re=Cp*(T1-T4);//Refrigerating effect in kJ/kg
25 Wnet=Cp*((T2-T1)-(T3-T4));//Net work output in kJ/kg
26 COP=Re/Wnet;//Co-efficient of performance
27 P=(m*3.52)/COP;//Driving power required in kW
28 ma=(m*3.52)/Re;//Mass flow rate of air in kg/s
29
```

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```
30  //OUTPUT
31  mprintf('COP of refrigerator is %3.2f \n Driving
        power required is %3.0f kW \n Mass flow rate of
        air is %3.3f kg/s',COP,P,ma)
32
33
34
35
36  //================================END OF PROGRAM
        ===============================
```

Scilab code Exa 6.14 Theoretical COP and Net cooling produced

```
1  //Chapter−6, Illustration 14, Page 321
2  //Title: Refrigeration cycles
3  //
      =================================================================

4  clc
5  clear
6
7  //INPUT DATA
8  P1=2.5;//Pressure at point 1 in bar
9  P3=9;//Pressure at point 3 in bar
10 COPr=0.65;//Ratio of actual COP to the theoretical
      COP
11 m=5;//Refrigerant flow in kg/min
12 T1=309;//Temperature at point 1 in K
13 T2s=300;//Temperature at point 2s in K
14 h1=570.3;//Enthalpy at P1 from the given tables in
      kJ/kg
15 h4=456.4;//Enthalpy at P3 from the given tables in
      kJ/kg
16 h2g=585.3;//Enthalpy at P3 from the given tables in
      kJ/kg
```

```
17  s2=4.76;//Entropy at P1 from the given tables in kJ/
        kg-K
18  s2g=4.74;//Entropy at P3 from the given tables in kJ
        /kg-K
19  Cp=0.67;//Specific heat at P3 in kJ/kg-K
20
21  //CALCULATIONS
22  T2=(2.718^((s2-s2g)/Cp))*T2s;//Temperature at point
        2 in K
23  h2=h2g+(Cp*(T2-T2s));//Enthalpy at point 2 in kJ/kg
24  COPR=(h1-h4)/(h2-h1);//Refrigerant COP
25  COPact=COPr*COPR;//Actual COP
26  qL=COPact*(h2-h1);//Heat rejected in kJ/kg
27  QL=((m*qL*60)/3600)/3.516;//Cooling produced per kg
        of refrigerant in tonnes of refrigeration
28
29  //OUTPUT
30  mprintf('Theoretical COP is %3.2f \n Net cooling
        produced per hour is %3.2f TR',COPR,QL)
31
32
33
34
35  //===============================END OF PROGRAM
        ===================================
```

Scilab code Exa 6.15 Theoretical COP of machine

```
1  //Chapter-6, Illustration 15, Page 322
2  //Title: Refrigeration cycles
3  //
        ====================================================
4  clc
5  clear
```

```
6
7  //INPUT DATA
8  T2=298;//Temperature at point 2 in K
9  T1=268;//Temperature at point 1 in K
10 hf1=-7.54;//Liquid Enthalpy at T1 in kJ/kg
11 x1=0.6;//Quality factor 1
12 hfg1=245.3;//Latent heat at T1 in kJ/kg
13 sf1=0.251;//Liquid Entropy at T1 in kJ/kg-K
14 s1=0.507;//Entropy at point 1 in kJ/kg-K
15 hfg2=121.4;//Latent heat at T2 in kJ/kg
16 hf2=81.3;//Liquid Enthalpy at T2 in kJ/kg
17 h4=hf2;//Enthalpy at point 4 in kJ/kg
18
19 //CALCULATIONS
20 h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
21 x2=((s1-sf1)*T2)/hfg2;//Quality factor 2
22 h2=hf2+(x2*hfg2);//Enthalpy at point 2 in kJ/kg
23 COP=(h1-h4)/(h2-h1);//COP of the machine
24
25 //OUTPUT
26 mprintf('COP of the machine is %3.2f',COP)
27
28
29
30
31 //===============================END OF PROGRAM
   ======================================
```

Scilab code Exa 6.16 Theoretical COP of refrigerator and Capacity of refrigerator

```
1 //Chapter-6, Illustration 16, Page 323
2 //Title: Refrigeration cycles
3 //
```

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```
 4 clc
 5 clear
 6
 7 //INPUT DATA
 8 P1=25;//Pressure at point 1 in bar
 9 P2=60;//Pressure at point 2 in bar
10 h2=208.1;//Vapour enthalpy at P2 in kJ/kg
11 h3=61.9;//Liquid enthalpy at P2 in kJ/kg
12 h4=h3;//Liquid enthalpy at P2 in kJ/kg
13 s2=0.703;//Vapour entropy at P2 in kJ/kg-K
14 sf1=-0.075;//Liquid entropy at P1 in kJ/kg-K
15 sfg1=0.971;//Entropy in kJ/kg-K
16 hf1=-18.4;//Liquid Enthalpy at P1 in kJ/kg
17 hfg1=252.9;//Latent heat at P1 in kJ/kg
18 m=5;//Refrigerant flow in kg/min
19
20 //CALCULATIONS
21 x1=(s2-sf1)/sfg1;//Quality factor 1
22 h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
23 COP=(h1-h4)/(h2-h1);//Co-efficient of performance
24 QL=(m*(h1-h4))/60;//Capacity of the refrigerator in
      kW
25
26 //OUTPUT
27 mprintf('COP of refrigerator is %3.2f \n Capacity of
      refrigerator is %3.2f kW',COP,QL)
28
29
30
31 //=====================================END OF PROGRAM
   ========================================
```
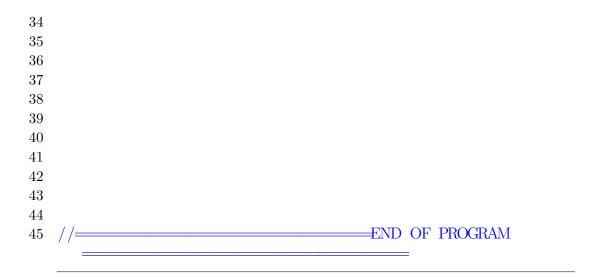
Scilab code Exa 6.17 COP and Theoretical power required

```
 1 //Chapter-6, Illustration 17, Page 324
```

```scilab
2  //Title: Refrigeration cycles
3  //
       ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  T1=271;//Temperature at point 1 in K
9  T=265;//Temperature at point 1' in K
10 Ta=303;//Temperature at point 2' in K
11 Cpv=0.733;//Specific heat of vapour in kJ/kg
12 Cpl=1.235;//Specific heat of liquid in kJ/kg
13 h=184.07;//Liquid enthalpy at T in kJ/kg
14 s=0.7;//Entropy at point 1' in kJ/kg-K
15 sa=0.685;//Vapour entropy at Ta in kJ/kg-K
16 ha=199.62;//Enthalpy at point 2' in kJ/kg
17 hfb=64.59;//Liquid enthalpy at Ta in kJ/kg
18 DT3=5;//Temperature difference in oC
19 Q=2532;//Refrigeration capacity in kJ/min
20
21 //CALCULATIONS
22 s2=s+(Cpv*((log(T1/T))/(log(2.718))));//Entropy at
       point 1 in kJ/kg-K
23 h1=h+(Cpv*(T1-T));//Enthalpy at point 1 in kJ/kg-K
24 T2=(2.718^((s2-sa)/Cpv))*Ta;//Temperature at point 2
       in K
25 h2=ha+(Cpv*(T2-Ta));//Enthalpy at point 2 in kJ/kg
26 h4=hfb-(Cpl*DT3);//Enthalpy at point 4 in kJ/kg
27 COP=(h1-h4)/(h2-h1);//Co-efficient of performance
28 m=Q/(h1-h4);//Mass flow rate of refrigerant in kJ/
       min
29 P=(m*(h2-h1))/(60*12);//Power required in kW/TR
30
31 //OUTPUT
32 mprintf('COP is %3.2f \n Theoretical power required
       per tonne of refrigeration is %3.3f kW/TR',COP,P)
33
```

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```
34
35
36
37
38
39
40
41
42
43
44
45  //═══════════════════════════════════END OF PROGRAM
       ═══════════════════════════════════
```

Chapter 7

Air Conditioning

Scilab code Exa 7.1 Heating capacity of coil and Surface temperature and Capacity

```
1  //Chapter −7, Illustration  1, Page  345
2  //Title: Air  Conditioning
3  //
     ================================================================
4  clc
5  clear
6
7  //INPUT DATA
8  DBTo =10; //Out door  Dry  bulb  temperature  in  oC
9  WBTo =8; //Out door  Wet  bulb  temperature  in  oC
10 DBTi =20; //In door  Dry  bulb  temperature  in  oC
11 RH =0.6; //Re−Heat  factor
12 a =0.3; //amount  of  air  circulated  in  (m^3)/min/person
13 S =50; //Seating  capacity  of  office
14 BPF =0.32; //ByPass  factor
15 ha =25; //Enthalpy  at  point  a  from  Psychrometric  chart
       shown  in  Page  346  in  kJ/kg
16 hb =42.5; //Enthalpy  at  point  b  from  Psychrometric
      chart  shown  in  Page  346  in  kJ/kg
17 hc =42.5; //Enthalpy  at  point  c  from  Psychrometric
```

```
        chart  shown  in  Page  346  in  kJ/kg
18  Wa=0.006;// Specific  humidity  at  point  a  from
        Psychrometric  chart  shown  in  Page  346  in  kg/kg
        dry  air
19  Wc=0.009;// Specific  humidity  at  point  c  from
        Psychrometric  chart  shown  in  Page  346  in  kg/kg
        dry  air
20  Tb=27;// Temperature  at  point  b  in  oC
21  na=0.81;// Specific  Volume  from  Psychrometric  chart
        shown  in  page  346  in  (m^3)/kg
22
23  //CALCULATIONS
24  ma=(a*S)/(na*60);// mass  of  air  circulated  per  second
         in  kg/s
25  Hc=ma*(hb-ha);// Heating  capacity  of  coil  in  kW
26  Ts=(Tb-(BPF*DBTo))/(1-BPF);// Heating  coil  surface
        temperature  in  oC
27  C=(ma*3600)*(Wc-Wa);// Capacity  of  humidifier  in  kg/
        hr
28
29  //OUTPUT
30  mprintf('Heating  capacity  of  coil  is  %3.2f kW \n
        Surface  temperature  of  coil  is  %3.0f oC \n
        Capacity  of  humidifier  is  %3.2f  kg/hr',Hc,Ts,C)
```

Scilab code Exa 7.2 Capacity of coils and Amount of water vapour removed and by pa

```
1  //Chapter −7,  Illustration  2,  Page  346
2  //Title :  Air  Conditioning
3  //
4  clc
5  clear
6
```

```scilab
 7  //INPUT DATA
 8  S=60;//No. of staff
 9  DBTo=30;//Out door Dry bulb temperature in oC
10  RHo=0.7;//Re-Heat factor at out-door
11  a=0.4;//amount of air circulated in (m^3)/min/person
12  DBTi=20;//In door Dry bulb temperature in oC
13  RHi=0.6;//Re-Heat factor at indoor
14  Td=25;//Heating coil surface temperature in oC
15  ha=82.5;//Enthalpy at point a from Psychrometric
        chart shown in Page 347 in kJ/kg
16  hb=34.5;//Enthalpy at point b from Psychrometric
        chart shown in Page 347 in kJ/kg
17  hc=42.5;//Enthalpy at point c from Psychrometric
        chart shown in Page 347 in kJ/kg
18  Wa=0.020;//Specific humidity at point a from
        Psychrometric chart shown in Page 347 in kg/kg
        dry air
19  Wb=0.009;//Specific humidity at point b from
        Psychrometric chart shown in Page 347 in kg/kg
        dry air
20  Tb=12;//Temperature at point b in oC
21  na=0.89;//Specific Volume from Psychrometric chart
        shown in page 346 in (m^3)/kg
22
23  //CALCULATIONS
24  ma=(a*S)/(na*60);//mass of air circulated per second
         in kg/s
25  Hc=(ma*(ha-hb))/3.5;//Heating capacity of cooling
        coil in tonnes
26  Hh=ma*(hc-hb);//Heating capacity of heating coil in
      kW
27  W=(ma*3600)*(Wa-Wb);//Amount of water vapour removed
         per hour in kg/hr
28  BPF=(Td-DBTi)/(Td-Tb);//By-Pass factor
29
30  //OUTPUT
31  mprintf('Capacity of cooling coil is %3.2f tonnes \n
        Capacity of heating coil is %3.1f kW \n Amount
```

Scilab code Exa 7.3 Supply air condition and Refrigeration load and Total refriger

```
1  //Chapter−7, Illustration 3, Page 347
2  //Title: Air Conditioning
3  //
4  clc
5  clear
6
7  //INPUT DATA
8  RSH=10;//Room sensible heat in kW
9  RLH=10;//Room latent heat in kW
10 td1=25;//Inside temperature in oC
11 RH1=0.5;//Inside Re−Heat factor
12 h1=50.4;//Enthalpy at point 1 in kJ/kg
13 td2=35;//Out door Dry bulb temperature in oC
14 tw2=28;//Out door Wet bulb temperature in oC
15 CR=4;//Cooling coil ratio
16 BPF=0.1;//Cooling coil bypass factor
17 tADP=10;//Apparatus dew point temperature in oC
18 RH3=0.55;//Re−Heat factor at point 3
19 h3=58.2;//Enthalpy at point 3 in kJ/kg
20 RH4=0.95;//Re−Heat factor at point 4
21 h4=32.2;//Enthalpy at point 4 in kJ/kg
22 RH5=0.81;//Re−Heat factor at point 5
23 h5=36.8;//Enthalpy at point 5 in kJ/kg
24 RH6=0.54;//Re−Heat factor at point 6
25 h6=43.1;//Enthalpy at point 5 in kJ/kg
26 td6=22;//Temperature at point 6 in oC
27
28 //CALCULATIONS
```

```
29  td3=((td2-td1)/5)+td1;//Temperature at point 3 from
       Psychrometric chart shown in Page 348 in oC
30  td4=(BPF*(td3-tADP))+tADP;//Temperature at point 4
       from Psychrometric chart shown in Page 348 in oC
31  td5=td4+((td1-td4)/5);//Temperature at point 5 from
       Psychrometric chart shown in Page 348 in oC
32  RSHF=RSH/(RSH+RLH);//Room Sensible Heat Factor
33  QR=h1-h6;//Total heat removed in kJ/kg
34  S=(RSH+RLH)/QR;//Supply air quantity in kg/s
35  R=(S*(h6-h5))/3.5;//Refrigeration load due to reheat
        in ton
36  D=(S*4)/5;//Dehumidified air quantity in kg/s
37  T=(D*(h3-h4))/3.5;//Total refrigerating capacity in
       ton
38  Q=(D/5)/1.2;//Quantity of fresh air supplied in (m
       ^3)/s
39
40  //OUTPUT
41  mprintf('Supply air condition to the room is %3.2f
       kg/s \n Refrigeration load due to reheat is %3.2f
        ton \n Total refrigerating capacity is %3.2f ton
        \n Quantity of fresh air supplied is %3.3f (m^3)
       /s',S,R,T,Q)
```