

Scilab Textbook Companion for
Fundamentals Of Internal Combustion Engines
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April 27, 2014

¹Funded by a grant from the National Mission on Education through ICT, <http://spoken-tutorial.org/NMEICT-Intro>. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website <http://scilab.in>

Book Description

Title: Fundamentals Of Internal Combustion Engines

Author: H. N. Gupta

Publisher: Prentice Hall of India Pvt Ltd, New Delhi

Edition: 1

Year: 2006

ISBN: 812032854X

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 2

Air Standard Cycles and Their Analysis

Scilab code Exa 2.1 The Ideal power developed

```
1  clc
2  clear
3  //Input data
4  d=20; //Cylinder bore diameter in cm
5  L=25; //Stroke length in cm
6  Vc=1570; //The clearance volume in cm3
7  P1=1; //Pressure at the beginning of the compression
      in bar
8  T1=300; //Temperature at the beginning of the
      compression in K
9  T3=1673; //The maximum temperature of the cycle in K
10 pi=3.141; //Mathematical constant value of pi
11 Cv=0.718; //specific heat at constant volume for air
      in kJ/kgK
12 R=0.287; //Real gas constant in kJ/kgK
13 g=1.4; //Isentropic index
14 c=500; //Number of cycles per minute
15
16 //Calculations
```



```

17 Vs=(pi/4)*d^2*L;//Swept volume in cm^3
18 V1=Vs+Vc;//According to pv diagram Total volume i.e
    sum of swept and clearance volume in cm^3
19 V2=Vc;//Volume according to pv diagram in cm^3
20 r=V1/V2;//Compression ratio
21 T2=T1*r^(g-1);//In isentropic process , Temperature
    at point 2 in degree centigrade
22 P2=P1*r^g;//In isentropic process , Pressure at point
    2 in bar
23 P3=P2*(T3/T2);//In constant volume, process Pressure
    at point 3 in bar
24 T4=T3*(1/r)^(g-1);//In isentropic process ,
    Temperature at point 4 in degree centigrade
25 P4=P3*(1/r)^(g);//In isentropic process , Pressure at
    point 4 in bar
26 no=(1-(1/r)^(g-1))*100;//Air standard efficiency of
    otto cycle
27 Q1=Cv*(T3-T2);//Heat supplied in kJ/kg
28 Q2=Cv*(T4-T1);//Heat rejected in kJ/kg
29 W=Q1-Q2;//Work done per unit mass in kJ/kg
30 m=[(P1*10^5*V1*10^-6)/(R*T1)]/1000;//The amount of
    mass in kg
31 W1=W*m;//Work done in kJ
32 pm=[(W1*10^3)/(Vs*10^-6)]/10^5;//Mean effective
    pressure in N/m^2
33 P=W1*(c/60);//Power developed in kW
34
35 //Output
36 printf('Temperature at point 2 = %3.1f K \n Pressure
    at point 2 = %3.3f bar \n Pressure at point 3 =
    %3.2f bar \n Temperature at point 4 = %3.0f K \n
    Pressure at point 4 = %3.3f bar \n Air standard
    efficiency of otto cycle = %3.4f percent \n Work
    done = %3.2f kJ \n Mean effective pressure = %3.3
    f bar \n Power developed = %3.1f kW ',T2,P2,P3,T4
    ,P4 ,no ,W1 ,pm ,P)

```

Scilab code Exa 2.2 The specific fuel consumption

```
1  clc
2  clear
3  //Input data
4  CV=42000; //The calorific value of the fuel in kJ/kg
5  pa=5 //Percentage of compression
6  Pa=1.2; //Pressure in the cylinder at 5% compression
   stroke
7  pb=75 //Percentage of compression
8  Pb=4.8; //Pressure in the cylinder at 75% compression
   stroke
9  g=1.3; //polytropic index
10 g1=1.4 //Isentropic index
11 n=0.6; //Air standard efficiency
12
13
14 // Calculations
15 V=(Pb/Pa)^(1/1.3); //Ratio of volumes
16 r=(V*(pb/100)-(pa/100))/((1-(pa/100))-(V*(1-(pb/100)
   ))) //Compression ratio
17 n1=((1-(1/r)^(g1-1)))*100 //Relative efficiency
18 nthj=n*(n1/100) //Indicated thermal efficiency
19 x=(1/(CV*nthj))*3600 //Specific fuel consumption in
   kg/kW.h
20
21 //Output
22 printf('The compression ratio of the engine is %3.1f
   \n The specific fuel consumption is %3.3f kg/kW.
   h',r,x)
```

Scilab code Exa 2.4 Diesel cycle

```

1  clc
2  clear
3  //Input data
4  d=0.2; //The diameter of the cylinder bore in m
5  L=0.3; //The length of the stroke in m
6  P1=1; //The pressure at the beginning of the
      compression in bar
7  T1=300; //The temperature at the beginning of the
      compression in K
8  r=16; //Compression ratio
9  V=0.08; //Cut off takes place at 8% of the stroke
10 pi=3.141; //Mathematical constant value of pi
11 R=0.287; //Real gas constant in kJ/kgK
12 g=1.4; //Isentropic index
13 Cp=1.005; //Specific heat at constant pressure in kJ/
      kgK
14 Cv=0.718; //specific heat at constant volume for air
      in kJ/kgK
15
16 // Calculations
17 Vs=(pi/4)*d^2*L; //Swept volume in m^3
18 Vc=Vs/(r-1); //Clearance volume in m^3
19 V2=Vc; //Volume at point 2 in m^3
20 V1=Vs+Vc; //Volume at point 1 in m^3
21 m=(P1*10^5*V1)/(R*T1); //The amount of mass in kg
22 P2=P1*(r^g); //Pressure at point 2 in bar
23 P3=P2; //Pressure at point 3 in bar
24 T2=T1*r^(g-1); //Temperature at point 2 in K
25 V3=(V*Vs)+V2; //Volume at point 3 in m^3
26 C=V3/V2; //Cut off ratio
27 T3=C*T2; //Temperature at point 3 in K
28 P4=P3*(C/r)^g; //Pressure at the point 4 in bar
29 T4=T3*(C/r)^(g-1); //Temperature at point 4 in K
30 V4=V1; //Volume at point 4 in m^3
31 Q1=[m*Cp*(T3-T2)]/1000; //Heat supplied in kJ
32 Q2=[m*Cv*(T4-T1)]/1000; //Heat rejected in kJ
33 W=[Q1-Q2]; //Work done per cycle in kJ
34 na=(W/Q1)*100; //Air standard efficiency

```

```

35 Pm=[W*1000/Vs]/10^5; //Mean effective pressure in bar
36
37 //Output
38 printf('(a) Volume at point 2 = %3.6f m^3 \n Volume
    at point 1 = %3.6f m^3 \n Pressure at point 2 =
    %3.1f bar \n Temperature at point 2 = %3.1f K \n
    Temperature at point 3 = %3.0f K \n Pressure at
    point 4 = %3.3f bar \n Temperature at point 4 =
    %3.1f K \n Volume at point 4 = %3.6f m^3 \n (b)
    cut off ratio = %3.2f \n (c) Work done per cycle
    = %3.3f kJ \n (d) air standard efficiency = %3.2f
    percent \n (e)Mean effective pressure = %3.2f
    bar ',V2,V1,P2,T2,T3,P4,T4,V4,C,W,na,Pm)

```

Scilab code Exa 2.5 Diesel cycle

```

1  clc
2  clear
3  //Input data
4  Pm=7; //The mean effective pressure of a diesel cycle
    in bar
5  r=12; //The compression ratio
6  P1=1; //Initial pressure in bar
7  g=1.4; //Isentropic index
8
9  //Calculations
10 function [f] = F(x); //function definition
11     f = 45.4*x - 12*x^1.4 - 64.2;
12 endfunction
13 x = 1; //Initial guss
14 function [z] = D(x) //Derivative
15     z = 3*x^2 - 3;
16 endfunction
17 y = fsolve(x,F, D);
18 C=y; //The cut off ratio

```

```

19 na=[1-(1/(r^(g-1)))*(((C^g)-1)/(g*(C-1)))]*100; // Air
    standard efficiency
20
21 //Output
22 printf('The cut off ratio = %3.1f \n The air
    standard efficiency = %3.2f percent ',C,na)

```

Scilab code Exa 2.6 The Ideal efficiency

```

1  clc
2  clear
3  //Input data
4  m=30; //The air fuel ratio by mass
5  T1=300; //The temperature of air at the beginning of
    the compression in K
6  r=16; //The compression ratio
7  CV=42000; //The calorific value of the fuel in kJ/kg
8  g=1.4; //Isentropic index
9  Cp=1.005; //Specific heat at constant prassure in kJ/
    kgK
10
11 //Calculations
12 T2=T1*(r^(g-1)); //Temperature at point 2 in K
13 T3=[(1/m)*(CV/Cp)]+T2; //Temperature at point 3 in K
14 C=T3/T2; //The cut off ratio
15 n=(1-[(1/r^(g-1))*(((C^g)-1)/(g*(C-1)))])*100; //The
    ideal efficiency of the engine based on the air
    standard cycle
16
17 //Output
18 printf(' The ideal efficiency of the engine based on
    the air standard cycle = %3.1f percent ',n)

```

Scilab code Exa 2.7 The air standard efficiency

```
1 clc
2 clear
3 //Input data
4 p1=1//Inlet pressure in bar
5 p2=32.425//Pressure at the end of isentropic
   compression in bar
6 r=6//Ratio of expansion
7 r1=1.4//Isentropic index
8
9 //Calculations
10 rc=(p2/p1)^(1/r1)//Compression ratio
11 b=(rc/r)//cut-off ratio
12 n=(1-((b^r1-1)/(rc^(r1-1)*r1*(b-1))))*100//Air-
   standard efficiency
13 pm=((p1*rc^r1*n/100*r1*(b-1))/((r1-1)*(rc-1)))//Mean
   effective pressure in bar
14
15 //Output
16 printf('Air-standard efficiency is %3.2f percent \n
   Mean effective pressure is %3.3f bar',n,pm)
```

Scilab code Exa 2.8 Air standard Dual cycle

```
1 clc
2 clear
3 //Input data
4 rc=15//Compression ratio
5 p1=1//Pressure at which compression begins in bar
6 T1=27+273//Temperature in K
7 pm=60//Maximum pressure in bar
8 h=2//Heat transfered to air at constant volume is
   twice that at constant pressure
9 g=1.4;//Isentropic index
```

```

10 Cv=0.718; //specific heat at constant volume for air
    in kJ/kgK
11 Cp=1.005; //specific heat at constant pressure for
    air in kJ/kgK
12 R=0.287; //Real gas constant in kJ/kgK
13
14 // Calculations
15 T2=(T1*rc^(g-1)) //Temperature in K
16 p2=(p1*rc^g) //Pressure in bar
17 T3=(T2*(pm/p2)) //Temperature in K
18 T4=(Cv*(T3-T2))/(2*Cp)+T3 //Temperature in K
19 b=(T4/T3) //Cut-off ratio
20 T5=(T4*(b/rc)^(g-1)) //Temperature in K
21 p5=(p1*(T5/T1)) //Pressure in bar
22 Q1=(Cv*(T3-T2))+(Cp*(T4-T3)) //Heat supplied per unit
    mass in kJ/kg
23 Q2=Cv*(T5-T1) //Heat rejected per unit mass in kJ/kg
24 W=(Q1-Q2) //Workdone in kJ/kg
25 n=(W/Q1)*100 //Air standard efficiency
26 Vs=((1*R*1000*T1)/(p1*10^5))*(1-1/rc) //Swept volume
    in m^3/kg
27 pmean=((W*1000)/Vs)/10^5 //Mean-effective pressure in
    bar
28
29 //Output
30 printf('(a) The pressures and temperatures at the
    cardinal points of the cycle are \n T2 = %3.0f K
    p2 = %3.1f bar \n T3 = %3.0f K p3 = %3.0f bar \
n T4 = %3.0f K p4 = %3.0f bar \n T5 = %3.0f K
    p5 = %3.2f bar \n (b) The cycle efficiency is %3
    .0f percent \n (c) The mean effective pressure of
    the cycle is %3.2f bar ', T2, p2, T3, pm, T4, pm, T5, p5,
    n, pmean)

```

Scilab code Exa 2.9 Dual combustion cycle

```

1  clc
2  clear
3  //Input data
4  r=12; //Compression ratio
5  B=1.615; //Cut off ratio
6  p3=52.17; //Maximum pressure in bar
7  p4=p3; //Maximum pressure in bar
8  p1=1; //Initial pressure in bar
9  T1=(62+273); //Initial temperature in K
10 n=1.35; //Indices of compression and expansion
11 g=1.4; //Adiabatic exponent
12 mR=0.287; //Real gas constant in kJ/kgK
13 Cv=0.718; //specific heat at constant volume for air
    in kJ/kgK
14 Cp=1.005; //specific heat at constant pressure for
    air in kJ/kgK
15
16 //Calculations
17 T2=T1*r^(n-1); //The temperature at point 2 in K
18 p2=p1*(r)^n; //The pressure at point 2 in bar
19 T3=T2*(p3/p2); //The temperature at point 3 in K
20 T4=T3*B; //The temperature at point 4 in K
21 T5=T4*(B/r)^(n-1); //The temperature at point 5 in K
22 Q12=[(g-n)/(g-1)]*mR*[(T1-T2)/(n-1)]; //Heat transfer
    during the process 1-2 for unit mass in kJ/kg
23 Q23=Cv*(T3-T2); //Heat transfer during the process
    2-3 for unit mass in kJ/kg
24 Q34=Cp*(T4-T3); //Heat transfer during the process
    3-4 for unit mass in kJ/kg
25 Q45=((g-n)/(g-1))*mR*((T4-T5)/(n-1)); //Heat transfer
    during the process 4-5 for unit mass in kJ/kg
26 Q51=Cv*(T1-T5); //Heat transfer during the process
    5-1 for unit mass in kJ/kg
27 Q1=Q23+Q34+Q45; //Heat supplied in kJ/kg
28 Q2=-Q12+(-Q51); //Heat rejected in kJ/kg
29 W=Q1-Q2; //Work done in kJ/kg
30 E=[W/Q1]*100; //Efficiency in percentage
31 Vs=[(mR*T1)/p1]*(r-1)/r; //Swept volume for unit mass

```



```

    in m3/kg
32 pm=[W*1000/Vs]/103; //Mean effective pressure in bar
33
34 //Output
35 printf(' (a)The temperature at cardinal points ,\n
        T2 = %3.0f K\n      T3 = %3.0f K \n      T4 =
        %3.0f K \n      T5 = %3.0f K \n (b) The cycle
        efficiency = %3.1f percent \n (c) The mean
        effective pressure of the cycle = %3.3f bar ',T2,
        T3,T4,T5,E,pm)

```

Scilab code Exa 2.10 Atkinson cycle

```

1  clc
2  clear
3  //Input data
4  p1=1//Inlet pressure in bar
5  T1=27+273//Temperature in K
6  p2=4//pressure at point 2 in bar
7  p3=16//Maximum pressure in bar
8  Cv=0.573//specific heat at constant volume for gas
    in kJ/kgK
9  Cp=0.761//specific heat at constant pressure for gas
    in kJ/kgK
10
11 //Calculations
12 g=(Cp/Cv)//Adiabatic index
13 T2=(T1*(p2/p1)^((g-1)/g))//Temperature in K
14 T3=(p3/p2)*T2//Temperature in K
15 T4=T3*(p1/p3)^((g-1)/g)//Temperature in K
16 Q1=Cv*(T3-T2)//Heat supplied in kJ/kg
17 Q2=Cp*(T4-T1)//Heat rejected in kJ/kg
18 W=Q1-Q2//Workdone in kJ/kg
19 n=(W/Q1)*100//Efficiency of cycle
20 r=(p2/p1)^(1/g)//Compression ratio

```

```

21 R=(Cp-Cv)//Universal gas constant in kJ/kg.K
22 Vs=(R*1000*T1*(r-1))/(p1*10^5*r)//Swept volume in m
    ^3/kg
23 pm=(W/(Vs*100))//Mean effective pressure in bar
24
25 //Output
26 printf('(a) The work done per kg of gas is %3.1f kJ/
    kg \n (b) The efficiency of the cycle is %3.1f
    percent \n (c) Mean effective pressure is %3.2f
    bar ',W,n,pm)

```

Chapter 3

Reactive Systems

Scilab code Exa 3.1 Volume of air

```
1  clc
2  clear
3  //Input data
4  E=20; //Methanol burned with excess air in percentage
5  p=1; //Pressure of air in bar
6  t=27; //Temperature of air in degree centigrade
7  O=32; //The molecular weight of oxygen
8  N=28; //The molecular weight of nitrogen
9  R=8314; //Universal gas constant in Nm/kmolK
10 C=32; //Molecular weight of methanol
11 CO=44; //Molecular weight of the carbondioxide
12 H=18; //Molecular weight of the water
13
14 //Calculations
15 S=[(1.8*O)+(6.768*N)]/C; //Stoichiometric air/fuel
    ratio
16 A=[(1.8*O)+(6.768*N)]/C; //Actual air/fuel ratio
17 M=1.8+6.768; //1 kmole of fuel reacts with air in
    kmole
18 V=(M*R*(t+273))/(p*10^5); //Volume of air in m^3/
    kmole fuel
```

```

19 T=(1+1.8+6.768); //The total number of moles in the
    reactants when excess air is supplied in moles
20 Cm=(1/T); //Mole fraction of the methanol
21 Om=(1.8/T); //Mole fraction of the oxygen
22 Nm=(6.768/T); //Mole fraction of the nitrogen
23 Mr=(Cm*C)+(Om*O)+(Nm*N); //Molecular weight of
    reactants
24 Tp=(1+2+6.768+0.3); //Total number of moles in the
    products in moles
25 COm=(1/Tp); //Mole fraction of the carbondioxide
26 Hp=(2/Tp); //Mole fraction of the water
27 Np=(6.768/Tp); //Mole fraction of the nitrogen
28 Op=(0.3/Tp); //Mole fraction of the oxygen
29 Mp=(COm*CO)+(Hp*H)+(Np*N)+(Op*O); //Molecular weight
    of products
30 Pp=(Hp*p); //Partial pressure of water vapour in bar
31 D=60; //The dew point is the saturation temp
    corresponding to partial pressure in degree
    centigrade
32
33 //Output
34 printf(' (a) The volume of air supplied per kmole of
    fuel = %3.1f m^3/kmole fuel \n (b) The molecular
    weight of the reactants = %3.2f \n The molecular
    weight of the products = %3.2f \n (c) The dew
    point of the products = %3.0f degree centigrade ',
    V,Mr,Mp,D)

```

Scilab code Exa 3.2 Mass of exhaust gases

```

1 clc
2 clear
3 //Input data
4 C1=40; //The content of C7H16 in the fuel in
    percentage

```

```

5 C2=60; //The content of C8H18 in the fuel in
    percentage
6 d=0.12; //The diameter of the bore in m
7 l=0.145; //The length of the bore in m
8 r=8.5; //Compression ratio
9 p=1.1; //Pressure at exhaust stroke in bar
10 T=720; //The temperature at the exhaust stroke in K
11 pi=3.141; //Mathematical constant pi
12 O=32; //The molecular weight of oxygen
13 N=28; //The molecular weight of nitrogen
14 C3=100; //Molecular weight of C7H16
15 C4=114; //The molecular weight of C8H18
16 R=8314; //Universal gas constant in Nm/kmolK
17 CO2=44; //Molecular weight of the carbondioxide
18 C5=28; //Molecular weight of the carbonmonoxide
19 H=18; //Molecular weight of the water
20
21 //Calculations
22 N2=100-(12+1.5+2.5); //Percentage of nitrogen in the
    dry products of combustion
23 Y=84/3.76; //The number of moles oxygen is supplied
24 X=13.5/7.6; //Moles of carbon
25 Z=(22.34-15.25)*2; //The number of moles of hydrogen
26 H1=(6.4+10.8)/2; //Number of moles of hydrogen on L.H
    .S
27 Hr=7.98; //Number of moles of hydrogen on R.H.S
28 Hd=H1-Hr; //Difference of hydrogen moles
29 A=[[12.58*(O+(3.76*N))]/[((C1/100)*C3)+((C2/100)*C4)
    ]]; //The Air/fuel ratio
30 Vs=(pi/4)*d^2*l; //Swept volume of the cylinder in m
    ^3
31 Vc=Vs/(r-1); //Clearance volume in m^3
32 M=[(6.757*CO2)+(0.8446*C5)+(1.408*O)+(47.3*N)+(8.6*H
    )]/[6.757+0.8446+1.408+47.3+8.6]; //Molecular
    weight of the product
33 R1=R/M; //Gas constant in J/kgK
34 m=[(p*10^5)*Vc]/[R1*T]; //Mass of the exhaust gases
    in the clearance space in kg

```

```

35
36 //Output
37 printf('(a)The air/fuel ratio =%3.2f \n (b)The mass
    of the exhaust gases in the clearance space =%3.7
    f kg ',A,m)

```

Scilab code Exa 3.3 Volumetric analysis

```

1  clc
2  clear
3  //Input data
4  C=0.86; //The amount of carbon content in the 1kg of
    fuel by weight in kg
5  H=0.05; //The amount of hydrogen content in the 1kg
    of fuel by weight in kg
6  O=0.02; //The amount of oxygen content in the 1kg of
    fuel by weight in kg
7  S=0.005; //The amount of sulphur content in the 1kg
    of fuel by weight in kg
8  N=0.065; //The amount of nitrogen content in the 1kg
    of fuel by weight in kg
9  E=25; //The amount of excess air supplied in
    percentage
10 o=32; //Molecular weight of the oxygen
11 co=44; //Molecular weight of the carbondioxide
12 c=12; //Molecular weight of the carbon
13 s=32; //Molecular weight of the sulphur
14 so=64; //Molecular weight of sulphur dioxide
15 n=28; //Molecular weight of the nitrogen
16
17 //Calculations
18 o1=(o/c)*C; //The amount of oxygen required for 0.86
    kg of carbon in kg
19 coa=(co/c)*C; //The amount of carbondioxide produced
    for 0.86 kg of carbon in kg

```

```

20 o2=(o/4)*H;//The amount of oxygen required for 0.05
    kg of hydrogen in kg
21 h2=(36/4)*H;//The amount of water produced for 0.05
    kg of hydrogen in kg
22 o3=(o/s)*S;//The amount of oxygen required for 0.005
    kg of sulphur in kg
23 s1=(so/s)*S;//The amount of sulphur dioxide produced
    for 0.005 kg of sulphur in kg
24 To=o1+o2+o3;//Total oxygen required for the complete
    combustion of fuel in kg
25 Tt=To-0;//The amount of oxygen required per kg of
    fuel for complete combustion theoretically in kg
26 As=(Tt*100)/23;//Stoichiometric air/fuel ratio
27 as=As*(1+(E/100));//The actual quantity of air
    supplied per kg of fuel in kg
28 o2a=0.23*(E/100)*As;//The oxygen in the excess air
    in kg
29 n2a=0.77*(1+(E/100))*As;//The nitrogen in the air in
    kg
30 n2e=n2a+N;//Total nitrogen in the exhaust in kg
31 Tw=coa+n2e+o2a;//Total weight in kg
32 pco=(coa/Tw)*100;//Percentage composition of
    carbondioxide
33 pn=(n2e/Tw)*100;//Percentage composition of nitrogen
34 po=(o2a/Tw)*100;//Percentage composition of oxygen
35 mco=(coa/co);//Moles of carbondioxide
36 mn=(n2e/n);//Moles of nitrogen
37 mo=(o2a/o);//Moles of oxygen
38 Tm=mco+mn+mo;//Total moles
39 vco=(mco/Tm)*100;//Volumetric analysis of
    carbondioxide in percentage
40 vn=(mn/Tm)*100;//Volumetric analysis of nitrogen in
    percentage
41 vo=(mo/Tm)*100;//Volumetric analysis of oxygen in
    percentage
42
43 //Output
44 printf(' (a)Stoichiometric air/fuel ratio = %3.2f \n

```

(b)The percentage of dry products of combustion by weight : \n CO2 = %3.2f percent \n N2 = %3.2f percent \n O2 = %3.2f percent \n (c)The percentage of dry products of combustion by volume : \n CO2 = %3.2f percent \n N2 = %3.2f percent \n O2= %3.2f percent ',As ,pco ,pn ,po , vco ,vn ,vo)

Scilab code Exa 3.4 Fuel consumption

```

1  clc
2  clear
3  //Input data
4  C0=12; //The composition of carbondioxide of
      combustion by volume in percentage
5  C=0.5; //The composition of carbonmoxide of
      combustion by volume in percentage
6  O=4; //The composition of oxygen of combustion by
      volume in percentage
7  N=83.5; //The composition of nitrogen of combustion
      by volume in percentage
8  o=32; //Molecular weight of the oxygen
9  co=44; //Molecular weight of the carbondioxide
10 c=12; //Molecular weight of the carbon
11 s=32; //Molecular weight of the sulphur
12 so=64; //Molecular weight of sulphur dioxide
13 n1=28; //Molecular weight of the nitrogen
14 h=2; //Molecular weight of the hydrogen
15
16 //Calculations
17 m=12+0.5; //Balancing carbon
18 x=N/3.76; //Balancing nitrogen
19 z=[x-(C0+(C/2)+O)]*2; //Balancing oxygen
20 n=z*h; //Balancing hydrogen
21 Af=[(x*o)+(N*n1)]/[(m*c)+(n)]; //Air/fuel ratio

```



```

22 As=[(18.46*o)+(69.41*n1)]/173.84; //Stoichiometric
    air/fuel ratio
23 Ta=(Af/As)*100; //Percent theoretical air
24 mc=[(m*c)/173.84]*100; //Composition of carbon on
    mass basis in percent
25 mh=(n/173.84)*100; //Composition of hydrogen on mass
    basis in percent
26
27 //Output
28 printf(' (a)The air/fuel ratio = %3.2f \n (b)The
    percent theoretical air = %3.1f percent \n (c)The
    percentage composition of fuel on a mass basis :
    \n    C = %3.1f percent \n    H = %3.1f percent ',
    Af ,Ta ,mc ,mh)

```

Scilab code Exa 3.5 Percentage analysis

```

1  clc
2  clear
3  //Input data
4  C=86; //The composition of carbon in the fuel by
    weight in percentage
5  H=14; //The composition of hydrogen in the fuel by
    weight in percentage
6  e=1.25; //Equivalent ratio
7  o=32; //Molecular weight of the oxygen
8  co=44; //Molecular weight of the carbondioxide
9  c=12; //Molecular weight of the carbon
10 s=32; //Molecular weight of the sulphur
11 so=64; //Molecular weight of sulphur dioxide
12 n=28; //Molecular weight of the nitrogen
13 h2=2; //Molecular weight of the hydrogen
14 Fc=0.86; //Fraction of C
15
16 //Calculations

```

```

17 Ra=1/Fc;//Relative air/fuel ratio
18 x=2*[1+(0.9765/2)-(1.488*0.8)];//By oxygen balance
19 Tm=0.5957+0.4043+4.476;//Total number of moles of
    dry exhaust gas
20 vc=(0.5957/Tm)*100;//Volumetric analysis of
    carbonmonoxide of combustion in percentage
21 vco=(0.4043/Tm)*100;//Volumetric analysis of
    carbondioxide of combustion in percentage
22 vn=(4.476/Tm)*100;//Volumetric analysis of nitrogen
    of combustion in percentage
23
24 //Calculations
25 printf(' The percentage analysis of dry exhaust gas
    by volume : \n      CO = %3.2f percent \n      CO2 =
    %3.2f percent \n      N2 = %3.2f percent ',vc,vco,
    vn)

```

Scilab code Exa 3.6 Heat transfer

```

1 clc
2 clear
3 //Input data
4 t=25;//The temperature of both reactants and
    products in degree centigrade
5 p=1;//The pressure of both reactants and products in
    bar
6
7 //Calculations
8 h=0;//Enthalpy of all elements at given temp and
    pressure
9 hf1=-103.85;//The enthalpy of the compound C3H8 in
    the reactants side at given temp and pressure in
    MJ/kmol
10 hf2=-393.52;//The enthalpy of carbondioxide for the
    given temp and pressure in MJ/kmol

```

```

11 hf3=-285.8; //The enthalpy of the water for the given
    temp and pressure in MJ/kmol
12 hf4=[3*hf2]+[4*hf3]; //Total enthalpy in the products
    side in MJ/kmol
13 Q=hf4-hf1; //The heat transfer per mole of fuel in MJ
    /kmol fuel
14
15 //Output
16 printf(' The heat transfer per mole of fuel = %3.2f
    kJ/mol fuel',Q)

```

Scilab code Exa 3.7 The work for a fuel rate

```

1  clc
2  clear
3  //Input data
4  t=25; //The temperature of the air entering the
    diesel engine in degree centigrade
5  T=600; //The temperature at which the products are
    released in K
6  Ta=200; //Theoretical air used in percentage
7  Q=-93; //Heat loss from the engine in MJ/kmol fuel
8  f=1; //The fuel rate in kmol/h
9
10 //Calculations
11 hfr=-290.97; //The enthalpy of C12H26 for the given
    conditions in the reactants side in MJ/kmol
12 h1=-393.52; //Enthalpy of carbondioxide at formation
    state in MJ/kmol
13 h11=12.916; //The change in enthalpy for the given
    temp of CO2 in MJ/kmol
14 hfc=h1+h11; //The enthalpy of the carbondioxide in MJ
    /kmol
15 h2=-241.82; //The enthalpy of water at formation
    state in MJ/kmol

```

```

16 h22=10.498; //The change in enthalpy for the given
    temp of water in MJ/kmol
17 hfh=h2+h22; //The enthalpy of the water in MJ/kmol
18 h3=0; //Enthalpy of the oxygen gas
19 h33=9.247; //The change in enthalpy for the given
    temp of oxygen in MJ/kmol
20 hfo=h3+h33; //The enthalpy of oxygen in MJ/kmol
21 h4=0; //The enthalpy of the nitrogen gas
22 h44=8.891; //The change in enthalpy of the nitrogen
    for the given temp in MJ/kmol
23 hfn=h4+h44; //The enthalpy of nitrogen in MJ/kmol
24 hfp=(12*hfc)+(13*hfh)+(18.5*hfo)+(139.12*hfn); //The
    total enthalpy on the products side in MJ/kmol
25 W=Q+hfr-hfp; //The work in MJ/kmol fuel
26 W1=(f*W*10^3)/3600; //The work in kW
27
28 //Output
29 printf('The work for a fuel rate of 1 kmol/h is %3.1
    f kW',W1)

```

Scilab code Exa 3.8 The fuel consumption

```

1 clc
2 clear
3 //Input data
4 P=600; //Power of an engine in kW
5 t=25; //Temperature at which fuel is used in degree
    centigrade
6 Ta=150; //Theoretical air used in percentage
7 T1=400; //The temperature at which air enters in K
8 T2=700; //The temperature at which the products of
    combustion leave in K
9 Q=-150; //The heat loss from the engine in kW
10 C=12; //Molecular weight of carbon
11 h=1; //Molecular weight of hydrogen

```

```

12
13 // Calculations
14 hfc=-259.28;//The enthalpy of the compound C8H18 for
    the given conditions in MJ/kmol fuel
15 hfo1=3.029;//The enthalpy of the oxygen gas in MJ/
    kmol fuel
16 hfn1=2.971;//The enthalpy of the nitrogen gas in MJ/
    kmol fuel
17 HR=(hfc)+(1.5*12.5*hfo1)+(1.5*12.5*3.76*hfn1);//The
    total enthalpy on the reactants side in MJ/kmol
    fuel
18 hfco=-393.52;//The enthalpy of carbondioxide for
    formation state in MJ/kmol fuel
19 hfco1=17.761;//The change in enthalpy of the
    carbondioxide for temp difference in MJ/kmol fuel
20 hfh=-241.82;//The enthalpy of water for formation
    state in MJ/kmol fuel
21 hfh1=14.184;//The change in the enthalpy of the
    water for temp difference in MJ/kmol fuel
22 hfo2=12.502;//The enthalpy of the oxygen gas in MJ/
    kmol fuel
23 hfn2=11.937;//The enthalpy of the nitrogen gas in MJ
    /kmol fuel
24 HP=(8*(hfco+hfco1))+(9*(hfh+hfh1))+(6.25*hfo2)
    +(70.5*hfn2);//The total enthalpy on the products
    side in MJ/kmol fuel
25 H=HP-HR;//The total change in enthalpy of reactants
    and products in MJ/kmol fuel
26 nf=( [Q-P]*3600)/[H*10^3]; //The fuel rate in kmol/s
27 M=(8*C)+(18*h); //Molecular weight of fuel
28 mf=nf*M; //The fuel consumption in kg/h
29
30 //Output
31 printf(' The fuel consumption for complete
    combustion is %3.2f kg/h',mf)

```

Scilab code Exa 3.9 The heat transfer

```
1  clc
2  clear
3  //Input data
4  t=25; //Temperature at which fuel is used for
      combustion in degree centigrade
5  p=1; //The pressure at which fuel is used in bar
6  T=400; //The temperature of the products of
      combustion in K
7  R=8.314*10^-3; // Universal gas constant
8
9  //Calculations
10 hfc=-103.85; //Enthalpy of the compound C3H8 in MJ/
      kmol fuel
11 HR=[1*(hfc-(R*(t+273)))]+[5*(-R*(t+273))]; //The
      total enthalpy of the reactants in MJ/kmol fuel
12 hfco=-393.52; //The enthalpy of the carbondioxide in
      MJ/kmol fuel
13 hfco1=4.008; //The change in enthalpy of the
      carbondioxide for the given conditions in MJ/kmol
      fuel
14 hfh=-241.82; //The enthalpy of the water in MJ/kmol
      fuel
15 hfh1=3.452; //The change in enthalpy of the water for
      the given conditions in MJ/kmol fuel
16 HP=[3*(hfco+hfco1-(R*T))]+[4*(hfh+hfh1-(R*T))]; //The
      total enthalpy of the products in MJ/kmol fuel
17 Q=HP-HR; //The total change in the enthalpy of
      reactans and products in MJ/kmol fuel
18 Q1=-Q; //Heat liberated in kJ/mol propane
19
20 //Output
21 printf('The heat transfer per mole of propane = %3.1
```

f kJ/mol propane ',Q1)

Scilab code Exa 3.10 The enthalpy of reaction

```
1  clc
2  clear
3  //Input data
4  T=1500; //The given temperature in K
5
6  //Calculations
7  hfco=-393.52; //The enthalpy of formation for
   carbondioxide in MJ/kmol
8  hf1=61.714; //The change in enthalpy for actual state
   and reference state in MJ/kmol
9  HP=hfco+hf1; //The total enthalpy in the products
   side in MJ/kmol
10 hf2=-110.52; //The enthalpy of formation for
   carbonmonoxide in MJ/kmol
11 hf2=38.848; //The change in enthalpy of CO for actual
   and reference state in MJ/kmol
12 hfo=0; //The enthalpy of formation for oxygen gas
13 hf3=40.61; //The change in enthalpy of oxygen for
   different states in MJ/kmol
14 HR=[hfc+hf2]+[0.5*(hfo+hf3)]; //The total enthalpy in
   the reactants side in MJ/kmol
15 H=HP-HR; //The enthalpy of combustion in MJ/kmol
16
17 //Output
18 printf(' The enthalpy of combustion is %3.3f MJ/
   kmol CO ',H)
```

Scilab code Exa 3.11 The heat transfer

```

1  clc
2  clear
3  //Input data
4  E=30; //The amount of excess air in percentage
5  tp=400; //The temperature at which propane enters in
      K
6  ta=300; //The temperature at which air enters in K
7  T=900; //The temperature at which products leave in K
8  m=83.7; //The average molar specific heat of propane
      at constant pressure in kJ/kmolK
9  Mp=44; //The molecular weight of propane
10
11 //Calculations
12 hfc=-393.52; //The enthalpy of formation for
      carbondioxide in MJ/kmol
13 hf1=28.041; //The change in enthalpy of CO2 for
      actual and reference state in MJ/kmol
14 hfh=-241.82; //The enthalpy of formation for water in
      MJ/kmol
15 hf2=21.924; //The change in enthalpy of water for
      actual and reference state in MJ/kmol
16 hfn=0; //The enthalpy of nitrogen gas
17 hf3=18.221; //The change in enthalpy of nitrgen for
      actual and reference state in MJ/kmol
18 hfo=0; //The enthalpy of oxygen gas
19 hf4=19.246; //The change in enthalpy of oxygen for
      actual and reference state in MJ/kmol
20 HP=[3*(hfc+hf1)]+[4*(hfh+hf2)]+[24.44*(hfn+hf3)
      ]+[1.5*(hfo+hf4)]; //The total enthalpy in the
      products side in MJ/kmol
21 hfp=-103.85; //The enthalpy of formation for propane
      in MJ/kmol
22 R=0.0837; //Universal gas constant
23 hfo1=0; //The enthalpy of oxygen gas
24 hf11=0.054; //The change in enthalpy of oxygen gas
      for actual and reference state in MJ/kmol
25 hfn1=0; //The enthalpy of nitrogen gas
26 hfn22=0.054; //The change in enthalpy of nitrogen for

```



```

    actual and reference state in MJ/kmol
27 HR=[1*(hfp+(R*(tp-ta)))]+[6.5*(hfo1+hf11)]+[24.44*(
    hfn1+hfn22)];//The total enthalpy on the
    reactants side in MJ/kmol
28 Q=HP-HR;//The amount of heat liberated in MJ/kmol
29 Q1=[-Q/Mp];//The amount of heat liberated in MJ/kg
30
31 //Output
32 printf(' The amount of heat transfer per kg of fuel
    is %3.0f MJ/kg ',Q1)

```

Scilab code Exa 3.12 The standard enthalpy

```

1  clc
2  clear
3  //Input data
4  Ta=150;//The presence of Theoretical air
5
6  //Calculations
7  hfc=-393.52;//The enthalpy of formation for
    carbondioxide in MJ/kmol
8  hfh=-285.8;//The enthalpy of formation for water in
    MJ/kmol
9  hfon=0;//The enthalpy of formation for oxygen and
    nitrogen gas
10 hfeh=-74.87;//The enthalpy of formation for methane
    in MJ/kmol
11 HP=[hfc]+[2*hfh];//The total enthalpy on the
    products side in MJ/kmol
12 HR=1*hfeh;//The total enthalpy on the reactants side
    in MJ/kmol
13 H=HP-HR;//The total change in enthalpy of reactants
    and products in MJ/kmol
14 np=2;//Number of moles of product
15 nr=4;//Number of moles of reactant

```

```

16 n=np-nr;//The difference in moles
17 R=8.314*10^-3;//Universal gas constant
18 t=298;//The temperature in K
19 U1=H-[n*R*t]);//The standard internal energy in MJ/
    kmol
20 hfh1=-241.82;//The enthalpy of formation for water
    in MJ/kmol
21 HP1=[1*hfc]+[2*hfh1]);//The total enthalpy on the
    products side in MJ/kmol
22 H1=HP1-HR;//The change in enthalpy for reactants and
    products in MJ/kmol
23 np1=4;//Number of moles of product
24 nr1=4;//Number of moles of reactant
25 n1=np1-nr1;//The difference in moles
26 U2=H1-[n1*R*t]);//The standard internal energy in MJ/
    kmol
27
28 //Output
29 printf(' (a)The water as liquid , \n    The standard
    enthalpy of combustion is %3.2f MJ/kmol \n
    The standard internal energy of combustion is %3
    .2f MJ/kmol \n (b)The water as a gas , \n    The
    standard enthalpy of combustion is %3.2f MJ/kmol
    \n    The standard internal energy of combustion
    is %3.2f MJ/kmol ',H,U1,H1,U2)

```

Scilab code Exa 3.13 The calorific value

```

1 clc
2 clear
3 //Input data
4 cv=44000;//The lower calorific value of liquid fuel
    in kJ/kg
5 C=84;//The carbon content present in the fuel in
    percentage

```

```

6 H=16; //The hydrogen content present in the fuel in
    percentage
7 t=25; //The temperature in degree centigrade
8 hfg=2442; //The enthalpy of vaporization for water in
    kJ/kg
9 c=12; //Molecular weight of carbon
10 h=2; //Molecular weight of hydrogen
11 co2=44; //Molecular weight of carbondioxide
12 h2o=18; //Molecular weight of water
13 o2=32; //Molecular weight of oxygen
14 R=8.314; //Universal gas constant in J/molK
15
16 //Calculations
17 CO2=[0.84*(co2/c)]; //The amount of carbondioxide
    present per kg of fuel in kg
18 H2O=[0.16*(h2o/h)]; //The amount of water present per
    kg of fuel in kg
19 cvd=H2O*hfg; //The difference in the higher and lower
    calorific value in kJ/kg fuel
20 HHV=cv+cvd; //The higher calorific value of the
    liquid fuel in kJ/kg fuel
21 np=3.08/co2; //number of moles of product in kmol/kg
    fuel
22 nr=3.52/o2; //The number of moles of reactant in kmol
    /kg fuel
23 n=np-nr; //The difference in the moles
24 HHVv=HHV+[n*R*(t+273)]; //The higher calorific value
    at constant volume in kJ/kg fuel
25 LHVv=cv+[n*R*(t+273)]; //The lower calorific value at
    constant volume in kJ/kg fuel
26
27 //Output
28 printf(' The higher calorific value at constant
    pressure = %3.0f kJ/kg fuel \n The higher
    calorific value at constant volume = %3.0f kJ/kg
    fuel \n The lower calorific value at constant
    volume = %3.0f kJ/kg fuel ',HHV,HHVv,LHVv)

```

Scilab code Exa 3.14 The adiabatic flame temperature

```
1  clc
2  clear
3  //Input data
4  E=100; //The amount of excess air in percent
5  T=298; //The temperature of reactants in K
6  nc=1; //Number of moles of propane
7
8  //Calculations
9  hfch=-103.85; //Enthalpy of formation for propane in
    MJ/kmol fuel
10 HR=nc*hfch; //Total enthalpy on the reactants side in
    MJ/kmol fuel
11 hfc=-393.52; //Enthalpy of formation for
    carbondioxide in MJ/kmol fuel
12 hfh=-241.82; //Enthalpy of formation for water in MJ/
    kmol fuel
13 hfon=0; //Enthalpy of formation for both oxygen and
    nitrogen gas
14 x=HR-[(3*hfc)+(4*hfh)+(5*hfon)+(37.6*hfon)]; //For
    adiabatic combustion enthalpy obtained for
    equating reactants and products in MJ/kmol fuel
15 hfn=x/37.6; //trail to get the change in enthalpy of
    nitrogen in MJ/kmol
16 T1=1500; //Assuming the products temperature for fist
    trail in K
17 hfc1=61.714; //The change in enthalpy for
    corbondioxide for trail temp in MJ/kmol fuel
18 hfh1=48.095; //The change in enthalpy for water for
    trail temp in MJ/kmol fuel
19 hfo1=40.61; //The change in enthalpy for oxygen for
    trail temp in MJ/kmol fuel
20 hfn1=38.405; //The change in enthalpy for nitrogen
```

```

    for trail temp in MJ/kmol fuel
21 HP1=(HR-x)+(3*hfc1)+(4*hfh1)+(5*hfo1)+(37.6*hfn1);//
    Total enthalpy of products for first trail in MJ/
    kmol fuel
22 T2=1600;//Assuming the products temperature for
    second trail in K
23 hfc2=67.58;//The change in enthalpy for
    corbondioxide for trail temp in MJ/kmol fuel
24 hfh2=52.844;//The change in enthalpy for water for
    trail temp in MJ/kmol fuel
25 hfo2=44.279;//The change in enthalpy for oxygen for
    trail temp in MJ/kmol fuel
26 hfn2=41.903;//The change in enthalpy for nitrogen
    for trail temp in MJ/kmol fuel
27 HP2=(HR-x)+(3*hfc2)+(4*hfh2)+(5*hfo2)+(37.6*hfn2);//
    Total enthalpy of products for second trail in MJ
    /kmol fuel
28 Te=[[(HR-HP1)/(HP2-HP1)]*(T2-T1)]+T1;//The eatimated
    adiabatic flame temperature in K
29
30 //Output
31 printf(' The adiabatic flame temperature for steady-
    flow process is %3.1f K',Te)

```

Scilab code Exa 3.15 The adiabatic flame temperature

```

1  clc
2  clear
3  //Input data
4  T=600;//The initial temperature of air in K
5  p=1;//The initial pressure of air in atm
6  R=8.314;//Universal gas constant in J/molK
7  Tr=298;//The temperature of reactants in K
8  a=4.503;//Given Constant
9  b=-8.965*10^-3;//Given Constant

```

```

10 c=37.38*10^-6; //Given Constant
11 d=-36.49*10^-9; //Given Constant
12 e=12.22*10^-12; //Given Constant
13
14 //Calculations
15 hfc=-393.52; //Enthalpy of formation for
    carbondioxide in MJ/kmol fuel
16 hfh=-241.82; //Enthalpy of formation for water in MJ/
    kmol fuel
17 hfn=0; //Enthalpy of formation for nitrogen gas
18 HP=[1*hfc]+[2*hfh]+[7.52*hfn]; //The enthalpy on the
    products side in MJ/kmol fuel
19 hch=[R*[(a*(T-Tr))+((b/2)*(T^2-Tr^2))+((c/3)*(T^3-Tr
    ^3))+((d/4)*(T^4-Tr^4))+((e/5)*(T^5-Tr^5))
    ]]/1000; //The change in enthalpy of the methane
    in MJ/kmol
20 hfc1=-74.87; //The enthalpy of formation for methane
    in MJ/kmol fuel
21 hfh1=9.247; //The change in enthalpy of the water in
    MJ/kmol
22 hfn1=8.891; //The change in enthalpy of nitrogen in
    MJ/kmol
23 HR=[(hfc1+hch)+(2*hfh1)+(7.52*hfn1)]; //The enthalpy
    on the reactants side in MJ/kmol
24 x=HR-HP; //The enthalpy for the remaining gases in
    the product side in MJ/kmol
25 hfn2=x/7.52; //The guess enthalpy for the nitrogen
    gas in MJ/kmol
26 Tc=3700; //The corresponding temperature for the
    enthalpy of guess nitrogen in K
27 T1=2800; //The temperature assumed for the first
    trail in K
28 hco1=140.444; //The change in enthalpy for the assume
    temp for carbondioxide in MJ/kmol
29 hh1=115.294; //The change in enthalpy for the assume
    temp for water in MJ/kmol
30 hn1=85.345; //The change in enthalpy for the assume
    temp for nitrogen in MJ/kmol

```

```

31 HP1=hco1+(2*hh1)+(7.52*hn1)+(HR-x); //The total
    enthalpy on the products side for first trail in
    MJ/kmol fuel
32 T2=2500; //The temperature assumed for the second
    trail in K
33 hco2=121.926; //The change in enthalpy for the assume
    temp for carbondioxide in MJ/kmol
34 hh2=98.964; //The change in enthalpy for the assume
    temp for water in MJ/kmol
35 hn2=74.312; //; //The change in enthalpy for the
    assume temp for nitrogen in MJ/kmol
36 HP2=hco2+(2*hh2)+(7.52*hn2)+(HR-x); //The total
    enthalpy on the products side for the second
    trail in MJ/kmol
37 T3=2600; //The temperature fo the third trail in K
38 hco3=128.085; //The change in enthalpy for the assume
    temp for carbondioxide in MJ/kmol
39 hh3=104.37; //The change in enthalpy for the assume
    temp for water in MJ/kmol
40 hn3=77.973; //The change in enthalpy for the assume
    temp for nitrogen in MJ/kmol
41 HP3=hco3+(2*hh3)+(7.52*hn3)+(HR-x); //The total
    enthalpy on the products side for the third trail
    in MJ/kmol
42 Ta1=[[(HR-HP2)/(HP3-HP2)]*(T3-T2)]+T2; //The
    adiabatic temperature for constant pressure
    process in K
43 UR1=HR-(10.52*R*10^-3*T); //The internal energy of
    reactant in MJ/kmol fuel
44 Tc1=3000; //Assume temperature for first trail in K
45 hcoa1=146.645; //The change in enthalpy for the
    assume temp for carbondioxide in MJ/kmol
46 hha1=120.813; //The change in enthalpy for the assume
    temp for carbondioxide in MJ/kmol
47 hna1=89.036; //The change in enthalpy for the assume
    temp for nitrogen in MJ/kmol
48 UP1=hcoa1+(2*hha1)+(7.52*hna1)+(HR-x)-(0.08746*Tc1);
    //The internal energy of products in MJ/kmol fuel

```

```

49 Tc2=3200; //Assume temperature for the second trail
    in K
50 hcoa2=165.331; //; //The change in enthalpy for the
    assume temp for carbondioxide in MJ/kmol
51 hha2=137.553; //The change in enthalpy for the assume
    temp for water in MJ/kmol
52 hna2=100.161; //The change in enthalpy for the assume
    temp for nitrogen in MJ/kmol
53 UP2=hcoa2+(2*hha2)+(7.52*hna2)+(HR-x)-(0.08746*Tc2);
    //The internal energy of products in MJ/kmol fuel
54 Tu=[[(UR1-UP1)/(UP2-UP1)]*(Tc2-Tc1)]+Tc1; //The
    adiabatic flame temperature at constant pressure
    process in K
55
56 //Output
57 printf('The adiabatic flame temperature at \n      (a
    )Constant pressure process is %3.0f K \n      (b)
    Constant volume process is %3.1f K',Ta1,Tu)

```

Scilab code Exa 3.16 The adiabatic flame temperature

```

1  clc
2  clear
3  //Input data
4  T=600; //Temperature at constant pressure process in
    K
5  p=1; //The pressure in atm
6  E=50; //The amount of excess air in percent
7  L=20; //The amount of less air in percent
8  cp=52.234; //Specific constant for methane in kJ/
    kmolK
9  T1=298; //Assume the normal temperature in K
10
11 //Calculations
12 hfch=-74.87; //The enthalpy of formation for

```



```

    carbondioxide in MJ
13 hch=cp*(T-T1)*10^-3;//The change in enthalpy of
    carbondioxide in MJ
14 ho=9.247;//The change in enthalpy of oxygen in MJ
15 hn=8.891;//The change in enthalpy of nitrogen in MJ
16 HR=hfch+hch+(3*ho)+(11.28*hn);//The total enthalpy
    on the reactants side in MJ
17 hfc1=-393.52;//The enthalpy of formation of
    carbondioxide in MJ
18 hfh1=-241.82;//The enthalpy of formation of water in
    MJ
19 HP=hfc1+(2*hfh1);//The enthalpy of products side in
    MJ
20 x=HR-HP;//The change in enthalpy for the remaining
    in MJ
21 hn2=x/11.28;//The enthalpy of nitrogen assumed to be
    in MJ/kmol
22 Tc=2800;//The corresponding temperature in K
23 T1=2000;//The temperature for first trail in K
24 hfc11=91.45;//The enthalpy for the assume temp for
    carbondioxide in MJ
25 hfh11=72.689;//The change in enthalpy for the assume
    temp for water in MJ
26 hfn11=56.141;//The change in enthalpy for the assume
    temp for nitrogen in MJ
27 hfo11=59.199;//;//The change in enthalpy for the
    assume temp for oxygen in MJ
28 HP1=hfc11+(2*hfh11)+(11.28*hfn11)+(hfo11)+(HR-x);//
    The total enthalpy on the products side for first
    trail in MJ
29 T2=2100;//The temperature for second trail in K
30 hfc22=97.5;//The enthalpy for the assume temp for
    carbondioxide in MJ
31 hfh22=77.831;//The change in enthalpy for the assume
    temp for water in MJ
32 hfn22=59.748;//The change in enthalpy for the assume
    temp for nitrogen in MJ
33 hfo22=62.986;//;//The change in enthalpy for the

```

```

    assume temp for oxygen in MJ
34 HP2=hfc22+(2*hfh22)+(11.28*hfn22)+(hfo22)+(HR-x); //
    The total enthalpy on the products side for
    second trail in MJ
35 Ta1=[[(HR-HP1)/(HP2-HP1)]*(T2-T1)]+T1; //The
    adiabatic temperature for constant pressure
    process in K
36 X=2*[2-1.6]; //By balance oxygen
37 hfchr=-74.87; //The enthalpy of formation for methane
    in MJ
38 hor=9.247; //The change in enthalpy for oxygen in MJ
39 hnr=8.891; //The change in enthalpy for nitrogen in
    MJ
40 HRr=hfchr+hch+(1.6*hor)+(6.01*hnr); //The total
    enthalpy on reactants side in MJ
41 hfco1=-110.52; //The formation of enthalpy for
    carbonmonoxide in MJ
42 hfco2=-393.52; //The formation of enthalpy for
    carbondioxide in MJ
43 hfhp=-241.82; //The formation of enthalpy for water
    in MJ
44 HPp=(0.8*hfco1)+(0.2*hfco2)+(2*hfhp); //The enthalpy
    on product side in MJ
45 Tp1=2000; //The temperature for first trail in K
46 hco11=56.739; //The change in enthalpy for CO in MJ
47 hco211=91.45; //The change in enthalpy for CO2 in MJ
48 hh11=72.689; //The change in enthalpy for water in MJ
49 hn11=56.141; //The change in enthalpy for nitrogen in
    MJ
50 HPp1=(0.8*hco11)+(0.2*hco211)+(2*hh11)+(6.016*hn11)-
    HPp; //The enthalpy on the products side for
    trail temp in MJ
51 Tp2=2400; //The temperature for second trail in K
52 hco22=71.34; //The change in enthalpy for CO in MJ
53 hco222=115.788; //The change in enthalpy for CO2 in
    MJ
54 hh22=93.604; //The change in enthalpy for water in MJ
55 hn22=70.651; //The change in enthalpy for nitrogen in

```

```

    MJ
56 HPp2=(0.8*hco22)+(0.2*hco222)+(2*hh22)+(6.016*hn22)+
    HPp;///The enthalpy on the products side for
    trail temp in MJ
57 Tp3=2300;///The temperature for first trail in K
58 hco33=67.676;///The change in enthalpy for CO in MJ
59 hco233=109.671;///The change in enthalpy for CO2 in
    MJ
60 hh33=88.295;///The change in enthalpy for water in MJ
61 hn33=67.007;///The change in enthalpy for nitrogen in
    MJ
62 HPp3=(0.8*hco33)+(0.2*hco233)+(2*hh33)+(6.016*hn33)+
    HPp;///The enthalpy on the products side for
    trail temp in MJ
63 Ta2=[[(HRr-HPp3)/(HPp2-HPp3)]*(Tp2-Tp3)]+Tp3;///The
    adiabatic temperature for constant pressure
    process in K
64 hccc=-283.022;///The only combustible substance is CO
    in MJ/kmol
65 Q=-0.8*hccc;///The thermal energy loss in MJ/kmol
    fuel
66
67 //Output
68 printf(' The adiabatic flame temperature having \n
    (a)50 percent excess air is %3.1f K \n      (b)
    20 percent less air is %3.1f K \n The loss of
    thermal energy due to incomplete combustion is %3
    .1f MJ/kmol fuel ',Ta1,Ta2,Q)

```

Scilab code Exa 3.18 Dissociation of carbondioxide

```

1 clc
2 clear
3 //Input data
4 T1=3000;///Given temperature in K

```

```

5 T2=4000; //Given temperature in K
6 p=1; //The pressure in atm
7 KP1=1.117; //Natural logarithm of equilibrium
  constant at 3000 K
8 KP2=-1.593; //Natural logarithm of equilibrium
  constant at 4000 K
9
10 // Calculations
11 Kp1=exp(KP1); //The value of equilibrium constant at
  3000 K
12 Kp2=exp(KP2); //The value of equilibrium constant at
  4000 K
13 a1=0.4; //The dissociation of 1 mole of CO2 for the
  first trail
14 a2=0.5; //The dissociation of 1 mole of CO2 for the
  second trail
15 K1=3.674; //The value of equilibrium constant for the
  first trail
16 K2=2.236; //The value of equilibrium constant for the
  second trail
17 a12=[[ (K1-Kp1)/(K1-K2) ]*(a2-a1)]+a1; //The
  approximate dissociation of 1 mole of CO2
18 A12=a12*100; //The amount of CO2 will dissociate in
  percent
19 a3=0.9; //The dissociation of 1 mole of CO2 for the
  first trail
20 a4=0.89; //The dissociation of 1 mole of CO2 for the
  second trail
21 K3=0.1995; //The value of equilibrium constant for
  the first trail
22 K4=0.2227; //The value of equilibrium constant for
  the second trail
23 a23=[[ (Kp2-K4)/(K3-K4) ]*(a3-a4)]+a4; //The
  approximate dissociation of 1 mole of CO2
24 A23=a23*100; //The amount of CO2 will dissociate in
  percent
25
26 //output

```

```

27 printf('The percent dissociation of carbondioxide
    into carbonmonoxide and oxygen at \n    (a) at
    3000 K and 1 atm pressure = %3.1f percent \n    (
    b) at 4000 K and 1 atm pressure = %3.2f percent ',
    ,A12,A23)

```

Scilab code Exa 3.19 The mole fraction

```

1  clc
2  clear
3  //Input data
4  p=1;//Initial pressure in atm
5  T=300;//Initial temperature in K
6  Tc=2400;//To calculate the molefraction of the
    products at this temperature in K
7  KP1=3.866;//Natural logarithm of equilibrium
    constant at 2400 K for the equation
8
9  //Calculations
10 K1=exp(KP1);//The value of equilibrium constant at
    2400 K
11 nr=1+0.5;//The number of moles of reactants
12 Pp=(p*Tc)/(nr*T);//Pressure exercted on the products
    side per mole in atm/mole
13 a=0.098;//The dissociation of 1 mole of CO2
14 np=(a+2)/2;//The number of moles of products
15 xco=[2*(1-a)]/(2+a);//Mole fraction of CO2
16 xc=[2*a]/(2+a);//Mole fraction of CO
17 xo=a/(2+a);//Mole fraction of O2
18 PP=5.333*np;//Pressure of the product in bar
19
20 //output
21 printf('Mole fraction of the carbondioxide is %3.4f
    \n Mole fraction of the carbonmonoxide is %3.4f \
    n Mole fraction of oxygen is %3.4f \n Pressure of

```

the product is %3.3 f bar ',xco ,xc ,xo ,PP)

Scilab code Exa 3.20 The adiabatic flame temperature

```
1  clc
2  clear
3  //Input data
4  t=25; //The temperature of air in degree centigrade
5  p=1; //The pressure of air in atm
6  T1=2200; //Given first temperature in K
7  T2=2400; //Given second temperature in K
8  h1=59.86; //The change in enthalpy of hydrogen at
   2200 K in MJ/kmol
9  h2=66.915; //The change in enthalpy of hydrogen at
   2400 K in MJ/kmol
10 T=298; //The temperature of air in K
11
12 //Calculations
13 HR=0; //The total enthalpy on the reactants side
   since all the reactants are elements
14 Kp1=-6.774; //Natural logarithm of equilibrium
   constant at 2200 K for the equation
15 K1=exp(Kp1); //The value of equilibrium constant at
   2200 K
16 a1=0.02; //By trail and error method the degree of
   dissociation of H2O
17 hfh=-241.82; //The enthalpy of formation of water at
   both 2200 and 2400 K in MJ/kmol
18 hfh1=83.036; //The change in enthalpy of water at
   2200 K in MJ/kmol
19 hfd1=59.86; //The change in enthalpy of hydrogen at
   2200 K in MJ/kmol
20 hfo1=66.802; //The change in enthalpy of oxygen at
   2200 K in MJ/kmol
21 hfn1=63.371; //The change in enthalpy of nitrogen at
```

```

    2200 K in MJ/kmol
22 HP1=(0.98*(hfh+hfh1))+(0.02*hfd1)+(0.01*hfo1)+(1.88*
    hfn1);//The enthalpy on the products side in MJ/
    kmol
23 a2=0.04;//By trail and error method the degree of
    dissociation of H2O at 2400 K
24 hfh2=93.604;//The change in enthalpy of water at
    2400 K in MJ/kmol
25 hfd2=66.915;//The change in enthalpy of hydrogen at
    2400 K in MJ/kmol
26 hfo2=74.492;//The change in enthalpy of oxygen at
    2400 K in MJ/kmol
27 hfn2=70.651;//The change in enthalpy of nitrogen at
    2400 K in MJ/kmol
28 HP2=(0.96*(hfh+hfh2))+(0.04*hfd2)+(0.02*hfo2)+(1.88*
    hfn2);//The enthalpy on the products side in MJ/
    kmol
29 H1=HP1-HR;//The total change in enthalpy at 2200 K
    in MJ/kmol
30 H2=HP2-HR;//The total change in enthalpy at 2400 K
    in MJ/kmol
31 T1=[[(T2-T1)/[HP2-HP1]]*[HR-HP1]]+T1;//The required
    temperature in K
32
33 //Output
34 printf('The adiabatic flame temperature taking
    dissociation into account is %3.0f K',T1)

```

Chapter 4

Fuel Air Cycles and Their Analysis

Scilab code Exa 4.1 Efficiency

```
1  clc
2  clear
3  //Input data
4  r=8.5; //The compression ratio
5  sv=1.4; //The specific heat at constant volume in
        percent
6
7  //Calculations
8  n=1-(1/r)^(sv-1); //The efficiency of the otto cycle
9  ef=[((1-n)/n)*(sv-1)*(log(r))*(sv/100)]*100; //The
        percentage change in efficiency of an otto cycle
        and is negative
10
11 //Output
12 printf('The efficiency decreases by %3.3f percent ',
        ef)
```

Scilab code Exa 4.2 Efficiency

```
1  clc
2  clear
3  //Input data
4  r=18; //The compression ratio
5  l=6; //The cut off taking place corresponding of the
      stroke in percent
6  sc=2; //The specific heat at constant volume
      increases in percent
7  cv=0.717; //The specific heat at constant volume in
      kJ/kgK
8  R=0.287; //Gas constant in kJ/kgK
9
10 //Calculations
11 Vs=(r-1); //The ratio of swept volume and volume 2
12 B=((1/100)*Vs)+1; //The cut off ratio
13 cp=cv+R; //The specific heat at constant pressure in
      kJ/kgK
14 R1=cp/cv; //The ratio of specific heats
15 n=1-[[[(1/r)^(R1-1)]*(B^R1-1)]/(R1*(B-1))]]; //The
      efficiency of the diesel cycle
16 dn=[((1-n)/n)*[(R1-1)*((log(r))-((B^R1)*log(B))/(B^
      R1-1)))+(1/B)]*(sc/100)]*100; //The efficiency
      decrease in percent
17
18 //Output
19 printf('The efficiency decreases by %3.3f percent ',
      dn)
```

Scilab code Exa 4.3 Temperature

```
1  clc
2  clear
3  //Input data
```

```

4 r=8; //The compression ratio
5 af=15; //Air/fuel ratio
6 p1=1; //The pressure at the beginning of a
    compression stroke in bar
7 t=60; //The temperature at the beginning of a
    compression stroke in degree centigrade
8 cv=44000; //The calorific value of the fuel in kJ/kg
9 n=1.32; //The index of the compression
10 Cv=0.717; //specific heat at constant volume in kJ/
    kgK
11
12 // Calculations
13 T1=t+273; //The temperature at the beginning of a
    compression stroke in K
14 p2=p1*(r)^n; //The pressure at the end of a
    compression stroke in bar
15 T2=T1*r^(n-1); //The temperature at the end of a
    compression stroke in K
16 f=(1/(af+1)); //The amount of fuel present in 1 kg of
    mixture in kg
17 a=(af/(af+1)); //The amount of air present in 1 kg of
    mixture in kg
18 q23=cv/(af+1); //The heat transfer during process 2-3
    per kg of mixture in kJ/kg
19 T3=[[-10430+[(10430)^2+(4*494.8*10^5)]^(1/2)]]/2; //
    The temperature at point 3 in K
20 p3=(T3/T1)*(r)*p1; //The pressure at point 3 in bar
21 T31=(q23/Cv)+T2; //The pressure at point 3 in K
22 p31=(T31/T1)*r*p1; //The pressure at point 3 in bar
23
24 //Output
25 printf('(a) The Maximum temperature in the cylinder
    T3 = %3.0f K \n The Maximum pressure in the
    cylinder P3 = %3.0f bar \n (b)With constant value
    of Cv \n The Maximum temperature in the cylinder
    T3 = %3.0f K \n The Maximum pressure in the
    cylinder P3 = %3.1f bar ',T3,p3,T31,p31)

```

Scilab code Exa 4.4 The percentage of stroke

```
1
2 clc
3 clear
4 //Input data
5 r=21; //The compression ratio
6 af=29; //Air/fuel ratio
7 T=1000; //The temperature at the end of compression
   in K
8 cv=42000; //The calorific value of the in kJ/kg
9 R=0.287; //Gas constant in kJ/kgK
10
11 //Calculations
12 q23=cv/(af+1); //Heat transfer during the process 2-3
   per kg of mixture in kJ
13 T3=[-0.997+[((0.997)^2)+(4*2411*14*10^-6)]^(1/2)
   ]/(28*10^-6); //The temperature during the process
   2-3 in K
14 function y=f1(x),y=(0.997+(28*10^-6)*x),endfunction
15 I=intg(T,T3,list(f1)); //Integrating the above
   function
16 abs(I)
17 V3=(T3/T); //The ratio of volumes at 2 and 3 points
18 Vs=(r-1); //Swept volume in terms of V2
19 V=V3-1; //The difference in the volume at 2 and 3
   points
20 pc=(V/Vs)*100; //The percentage stroke during which
   the combustion is completed in percent
21
22 //Output
23 printf('The percentage of stroke at which combustion
   is complete = %3.3f percent ',pc)
```

Scilab code Exa 4.5 The pressure

```
1
2 clc
3 clear
4 //Input data
5 r=16; //The compression ratio
6 l=6; //The cut-off of the stroke in percent
7 p3=70; //The maximum pressure obtained in bar
8 p1=1; //The pressure at the beginning of compression
   in bar
9 T1=(100+273); //The temperature at the beginning of
   compression in K
10 R=0.287; //Gas constant in kJ/kgK
11 g=1.4; //Assume the isentropic index
12
13 //Calculations
14 T2=T1*(r)^(g-1); //The temperature at point 2 in K
15 function y=f1(x),y=(0.716+(125*10^-6)*x),endfunction
16 I=intg(373,1131,list(f1)); //Integrating the above
   function
17 abs(I)
18 Cv=(1/(1131-373))*I; //The specific heat at constant
   volume for the temp range T2 and T3 in kJ/kgK
19 Cp=Cv+R; //The specific heat at constant pressure in
   kJ/kgK
20 g1=Cp/Cv; //The ratio of specific heats
21 T21=T1*(r)^(g1-1); //The temperature at point 2 in K
22 function y=f1(x),y=(0.716+(125*10^-6)*x),endfunction
23 I1=intg(373,995,list(f1)); //Integrating the above
   function
24 abs(I1)
25 Cv1=(1/(995-373))*I1; //The specific heat at constant
   volume for the temp range T2 and T3 in kJ/kgK
```

```

26 Cp1=Cv1+R;//The specific heat at constant pressure
    in kJ/kgK
27 g2=Cp1/Cv1;//The ratio of specific heats
28 T2=T1*(r)^(g2-1);//The temperature at point 2 in K
29 p2=(T2/T1)*r*p1;//The pressure at point 2 in bar
30 T3=(p3/p2)*T2;//The temperature at point 3 in K
31 V=[(1/100)*(r-1)]+1;//The ratio of volumes at 3-4
    points
32 T4=(V)*T3;//The temperature at point 4 in K
33 p4=p3;//The pressure at point 4 in bar
34 g3=1.3;//Assume isentropic index
35 V5=r/V;//The ratio of volumes at 4-5 process
36 T5=T4*(1/V5)^(g3-1);//The temperature at point 5 in
    K
37 Cv2=[[0.716*(T5-T4)]+[62.5*10^-6*(T5^2-T4^2)]]/(T5-
    T4);//The specific heat at constant volume for
    the temp range T5 and T4 in kJ/kgK
38 Cp2=Cv2+R;//The specific heat at constant pressure
    in kJ/kgK
39 g4=Cp2/Cv2;//The ratio of specific heats
40 T51=T4*(1/V5)^(g4-1);//The temperature at point 5 in
    K
41 Cv3=[[0.716*(T51-T4)]+[62.5*10^-6*(T51^2-T4^2)]]/(
    T51-T4);//The specific heat at constant volume
    for the temp range T5 and T4 in kJ/kgK
42 Cp3=Cv3+R;//The specific heat at constant pressure
    in kJ/kgK
43 g5=Cp3/Cv3;//The isentropic index
44 T52=T4*(1/V5)^(g5-1);//The temperature at point 5 in
    K
45 p5=(T52/T1)*p1;//The pressure at point 5 in bar
46
47 //Output
48 printf('The pressure and temperature at all points
    of the cycle \n at point 2 , Temperature T2 = %3
    .0f K    and Pressure P2 = %3.2f bar \n at point
    3 , Temperature T3 = %3.0f K    and Pressure P3 =
    %3.0f bar \n at point 4 , Temperature T4 = %3.0f

```

K and Pressure $P_4 = 3.0$ bar \n at point 5 ,
 Temperature $T_5 = 3.0$ K and Pressure $P_5 = 3$
 $.2$ bar ', $T_{22}, p_2, T_3, p_3, T_4, p_4, T_{52}, p_5$)

Scilab code Exa 4.6 Molecular expansion

```

1  clc
2  clear
3  //Input data
4  r=8; //Compression ratio
5  lcv=44000; //The lower heating value of the fuel in
      kJ/kg
6  af=15; //The air/fuel ratio
7  Cv=0.71; //The specific heat at constant volume in kJ
      /kgK
8  p=1; //The pressure at the beginning of the
      compression in bar
9  t=60; //The temperature at the beginning of the
      compression in degree centigrade
10 Mo=32; //Molecular weight of oxygen
11 Mn=28.161; //Molecular weight of nitrogen
12 Mh=18; //Molecular weight of water
13 n=1.3; //Polytropic index
14
15 //Calculations
16 T1=(t+273); //The temperature at the beginning of the
      compression in K
17 sa=[12.5*[Mo+(3.76*Mn)]]/[(12*8)+(1*Mh)]; //The
      stoichiometric air fuel ratio
18 Y=af*([(12*8)+(1*Mh)]/(Mo+(3.76*Mn))); //To balance
      the oxygen and nitrogen
19 x=(12.5-Y)*2; //By oxygen balance
20 nb=1+Y+(Y*3.76); //Number of moles before combustion
21 na=x+7.8+9+46.624; //Number of moles after combustion
22 Me=[(na-nb)/nb]*100; //The percentage molecular

```

```

    expansion in percent
23 T2=T1*(r)^(n-1); //The temperature at point 2 in K
24 T3=[1cv/(af+1)]*(1/Cv)+(T2); //The temperature at
    point 3 in K
25 p3=r*(T3/T1)*p; //The pressure at point 3 in bar
26 p31=p3*(na/nb); //The pressure at point 3 with molar
    expansion in bar
27
28 //Output
29 printf('The percentage molecular expansion is %3.0f
    percent \n (a) Without considering the molecular
    expansion \n The maximum temperature is %3.0f K \n
    The maximum pressure is %3.0f bar \n (b) With
    molecular expansion \n The maximum temperature is
    %3.0f K \n The maximum pressure is %3.1f bar ',
    Me , T3 , p3 , T3 , p31)

```

Scilab code Exa 4.7 Residual air

```

1  clc
2  clear
3  //Input data
4  f=0.03; //The residual fraction of an engine
5  e=1.2; //The equivalence ratio
6
7  //Calculations
8  F=0.0795; //Fuel/air ratio for corresponding
    equivalence ratio
9  T=1+F; //Total mass in kg
10 fa=1-f; //Fresh air in kg
11 ff=F*(fa); //Fresh fuel in kg
12 ra=f; //Air in residual in kg
13 rf=ra*F; //Fuel in residual in kg
14
15 //Output

```

```

16 printf('Fresh air = %3.2f kg \n Fresh fuel = %3.6f
    kg \n Air in residual = %3.2f kg \n Fuel in
    residual = %3.6f kg ',fa,ff,ra,rf)

```

Scilab code Exa 4.8 Internal energy

```

1  clc
2  clear
3  //Input data
4  T=800;//The given temperature in K
5  e=1;//The equivalence ratio
6
7  //Calculations
8  hi=154.723;//Sensible Enthalpy for isooctane at 800
    K in MJ/kmol
9  ho=15.841;//Sensible Enthalpy for oxygen at 800 K in
    MJ/kmol
10 hn=15.046;//Sensible Enthalpy for nitrogen at 800 K
    in MJ/kmol
11 nc=0.00058;//Number of kmoles of C8H18 for
    equivalence ratio for 1 kg of air
12 no=0.00725;//Number of kmoles of oxygen for
    equivalence ratio for 1 kg of air
13 nn=0.0273;//Number of kmoles of nitrogen for
    equivalence ratio for 1 kg of air
14 Hs=(nc*hi)+(no*ho)+(nn*hn);//Total sensible enthalpy
    of reactants in MJ per kg of air
15 Hs1=Hs*1000;//Total sensible enthalpy of reactants
    in kJ per kg of air
16 R=8.314;//Gas constant in kJ/kgK
17 n=nc+no+nn;//Total number of kmoles for 1 kg of air
18 Us=Hs-(n*R*10^-3*(T-298));//sensible internal energy
    of reactants in MJ per kg of air
19 Us1=Us*1000;//sensible internal energy of reactants
    in kJ per kg of air

```



```

20
21 //Output
22 printf('Total sensible enthalpy of reactants = %3.1f
      kJ/kg air \n Sensible internal energy of
      reactants = %3.1f kJ/kg air ',Hs1,Us1)

```

Scilab code Exa 4.9 Fuel Air Cycles and Their Analysis

```

1  clc
2  clear
3  //Input data
4  T=500;//The given temperature in K
5  e=1;//Equivalence ratio
6
7  //Calculations
8  Ai=0.0662;//The amount of isooctane for 1 kg of air
      in kg
9  Ta=298;//Consider the ambient temperature in K
10 E=[[0.0662*[(0.44*log(T/Ta))+(3.67*10^-3*(T-Ta))
      ]]+[(0.921*log(T/Ta))+(2.31*10^-4*(T-Ta))]]*1000;
      //Isentropic compression function in J/kg air
11 R=8.314;//Gas constant in kJ/kgK
12 Ri=R/114;//Gas constant for isooctane in kJ/kgK
13 W=[0.5874-(0.662*Ri*log(T/Ta))-(0.287*log(T/Ta))
      ]*1000;//Gas constant for isooctane in kJ/kgK
14
15 //Output
16 printf('The isentropic compression functions at 500
      K for the unburned, \n isooctane-air mixture are
      %3.1f J/kg air and %3.1f J/kg air ',E,W)

```

Scilab code Exa 4.10 Work input

```

1  clc
2  clear
3  //Input data
4  r=7.8; //Compression ratio
5  p=1; //The pressure at the start of compression in
      atm
6  T1=335; //The temperature at the start of compression
      in K
7
8  //Calculations
9  W1=100; //Isentropic compression function for T1 in J
      /kg air K
10 W2=W1-(292*log(1/r)); //Isentropic compression
      function in J/kg air K
11 T2=645; //The temperature corresponding to isentropic
      compression function in J/kg air K
12 V1=(292*T1)/(p*10^5); //Volume at initial in m^3/kg
      air
13 p2=p*(T2/T1)*r; //The pressure at the end of
      compression stroke in atm
14 V2=V1/r; //The volume per unit mass of air at the end
      of the compression stroke in m^3/kg air
15 U1=35; //Internal energy corresponding to temp T1 in
      kJ/kg air
16 U2=310; //Internal energy corresponding to temp T2 in
      kJ/kg air
17 W=U2-U1; //Work input during compression in kJ/kg air
18 E1=120; //Isentropic compression function at T1
19 E2=910; //Isentropic compression function at T2
20 p21=[exp((E2-E1)/292)]; //The pressure at the end of
      compression stroke in atm
21
22 //Output
23 printf('(a)At the end of the compression stroke, \n
      The temperature is %3.0f K \n The pressure is %3
      .0f atm \n The volume per unit mass of air is %3
      .3f m^3/kg air \n The pressure is %3.0f atm \n (b
      )The work input during compression is %3.0f kJ/kg

```

```
air ',T2 ,p2 ,V2 ,p21 ,W)
```

Scilab code Exa 4.11 Work

```
1  clc
2  clear
3  //Input data
4  p=65; //The pressure in the cylinder in bar
5  r=10; //The compression ratio
6  V3=0.1; //The volume per unit mass of air at the
   start of expansion in m^3/kg air
7  p3=p*100; //The pressure in the cylinder after the
   completion of combustion in kN/m^2
8
9  //Calculations
10 T3=2240; //The temperature from the chart
   corresponding to p3,V3 in K
11 u3=-1040; //The energy from the chart in kJ/kg air
12 s3=8.87; //The entropy from the chart in kJ/kg air K
13 s4=s3; //Since the process is isentropic
14 V4=r*V3; //The volume per unit mass of air at the end
   of expansion stroke in m^3/kg air
15 T4=1280; //The temperature from the chart
   corresponding to p4,V4 in K
16 u4=-2220; //The energy from the chart in kJ/kg air
17 p4=4.25; //The pressure from the chart in bar
18 W=-(u4-u3); //Work of expansion in kJ/kg air
19
20 //Output
21 printf('(a)At the end of expansion stroke , \n The
   pressure is %3.2f bar \n The temperature is %3.0f
   K \n The volume is %3.1f m^3/kg air \n (b)The
   work during the expansion stroke is %3.0f kJ/kg
   air ',p4 ,T4 ,V4 ,W)
```

Scilab code Exa 4.13 The temperature and pressure

```
1  clc
2  clear
3  //Input data
4  Tu=645;//The temperature at the end of compression
    process in K
5  usu=310;//The internal energy at the end of
    compression process in kJ/kg air
6  pu=(15.4*1.013);//The pressure at the end of the
    compression process in bar
7  Vu=0.124;//The volume at the end of the compression
    process in m^3/kg air
8  e=1;//Equivalence ratio
9  f=0.065;//Burned gas fraction
10
11 //Calculations
12 ufu=-118.5-(2963*f);//Internal energy of formation
    in kJ/kg air
13 ub=usu-ufu;//The internal energy for constant volume
    adiabatic combustion in kJ/kg air
14 Vb=Vu;//The volume for constant volume adiabatic
    combustion in kJ/kg air
15 Tb=2820;//The temperature for constant volume
    adiabatic combustion corresponding to ub,Vb on
    the burnt gas chart in K
16 pb=6500;//The pressure for constant volume adiabatic
    combustion corresponding to ub,Vb on the burnt
    gas chart in kN/m^2
17 hfu=-129.9-(2958*f);//The enthalpy of formation in
    kJ/kg air
18 hsu=440;//The enthalpy from chart corresponding to
    temp Tu in kJ/kg air
19 hb=hsu+hfu;//The enthalpy for constant pressure
```

```

    adiabatic combustion in kJ/kg air
20 pb1=1560; //The pressure for constant pressure
    adiabatic combustion in kN/m^2
21 ub1=-700; //Trail and error along the pb internal
    energy in kJ/kg air
22 vb1=(118-ub1)/pb; //The volume in m^3/kg air
23 Tb1=2420; //The temperature for constant pressure
    adiabatic combustion corresponding to ub,Vb on
    the burnt gas chart in K
24
25 //Output
26 printf('(a)For constant volume adiabatic combustion
    ,\n The temperature is %3.0f K \n The pressure is
    %3.0f kN/m^2 \n (b)For constant pressure
    adiabatic combustion, \n The temperature is %3.0f
    K \n The pressure is %3.0f kN/m^2 ',Tb,pb,Tb1,pb1
    )

```

Scilab code Exa 4.14 The temperature and pressure

```

1  clc
2  clear
3  //Input data
4  r=8; //The compression ratio
5  T1=350; //The given temperature at the start of
    compression in K
6  p=1; //The given pressure at the start of compression
    in bar
7  f=0.08; //The exhaust residual fraction
8  cv=44000; //The calorific value in kJ/kg
9
10 //Calculations
11 W1=150; //Isentropic compression functions for
    corresponding temp T1 in J/kg air K
12 W2=W1-(292*log(1/r)); //Isentropic compression

```

```

function in J/kg air K
13 T2=682;//The temperature corresponding to isentropic
    compression function in K
14 V1=(292*T1)/(p*10^5);//The initial volume in m^3/kg
    air
15 p2=p*(T2/T1)*r;//The pressure at point 2 in atm
16 V2=V1/r;//The volume at point 2 in m^3/kg air
17 us2=350;//The internal energy corresponding to temp
    T2 in K
18 us1=40;//The internal energy corresponding to temp
    T1 in K
19 Wc=us2-us1;//Adiabatic compression work in kJ/kg air
20 ufu=-118.5-(2963*f);//The internal energy of
    formation in kJ/kg air
21 u3=us2+ufu;//The internal energy at point 3 in kJ/kg
    air
22 V3=V2;//The volume at point 3 in m^3/kg air
23 T3=2825;//The temperature at point 3 corresponding
    to u3,V3 on the burned gas chart in K
24 p3=7100;//The pressure at point 3 in kN/m^2
25 s3=9.33;//Entropy at point 3 in kJ/kg air K
26 s4=s3;//Entropy is same in kJ/kg air K
27 V4=V1;//The volume at point 4 in m^3/kg air
28 u4=-1540;//The internal energy at point 4
    corresponding to V4,s4 in kJ/kg air
29 p4=570;//The pressure at point 4 in kN/m^2
30 T4=1840;//The temperature at point 4 in K
31 We=u3-u4;//The expansion work in kJ/kg air
32 Wn=We-Wc;//The net work output in kJ/kg air
33 nth=[(Wn)/((1-f)*0.0662*cv)]*100;//The indicated
    thermal efficiency in percent
34 imep=((Wn*1000)/(V1-V2))/10^5;//The indicated mean
    effective pressure in bar
35 nv=[((1-f)*287*298)/(1.013*10^5*(1-0.125))]*100;//
    The volumetric efficiency in percent
36
37 //Output
38 printf('(a)At point 2, \n The temperature is %3.0f K

```

\n The pressure is %3.1f atm \n At point 3, \n
The temperature is %3.0f K \n The pressure is %3
.0f kN/m^2 \n At point 4, \n The temperature is
%3.0f K \n The pressure is %3.0f kN/m^2 \n (b)The
indicated thermal efficiency is %3.1f percent \n
(c)The indicated mean effective pressure is %3.0
f bar \n (d)The volumetric efficiency is %3.1f
percent ',T2,p2,T3,p3,T4,p4,nth,imep,nv)

Chapter 9

Carburettors and Fuel Injection in SI Engines

Scilab code Exa 9.1 The orifice diameter

```
1 clc
2 clear
3 //Input data
4 ma=5; //Mass flow rate of air per min for a simple
      jet carburettor in kg/min
5 mf=0.4; //Mass flow rate of fuel in kg/min
6 df=780; //Density of the fuel in kg/m^3
7 p1=1.013; //The initial pressure of air in bar
8 t1=27; //The initial temperature of air in degree
      centigrade
9 C2=90; //The air flow velocity in m/s
10 Cva=0.8; //The velocity coefficient for the venturi
11 Cdf=0.6; //The coefficient of discharge of the main
      fuel jet
12 Cpd=0.75; //The pressure drop across the fuel
      metering oriface
13 Cp=1005; //The specific heat of gas in J/kgK
14 g=1.4; //Adiabatic index
15 R=287; //Real gas constant in J/kgK
```



```

16 pi=3.141; //The mathematical constant of pi
17
18 //Calculations
19 p2=p1*[1-(C2^2/(Cva^2*2*Cp*(t1+273)))]^(g/(g-1)); //
    Throat pressure in bar
20 da1=((p1*10^5)/(R*(t1+273))); //The density of air at
    inlet in kg/m^3
21 da2=[(da1)*(p2/p1)^(1/g)]; //The density of air at
    the throat in kg/m^3
22 A2=[(ma/60)/(da2*C2)]*10^4; //The throat area in cm^2
23 d2=(4*A2/pi)^(1/2); //The throat diameter of the
    choke in cm
24 pv=p1-p2; //Pressure drop at venturi in bar
25 pj=Cpd*pv; //Pressure drop at jet in bar
26 Aj=[(mf/60)/(Cdf*(2*df*pj*10^5)^(1/2))]*10^6; //The
    area of the jet in mm^2
27 dj=(4*Aj/pi)^(1/2); //The oriface diameter in mm
28
29 //Output
30 printf('The throat diameter of the choke = %3.2f cm
    \n The oriface diameter = %3.1f mm ',d2,dj)

```

Scilab code Exa 9.2 Suitable choke

```

1 clc
2 clear
3 //Input data
4 Vs=0.002; //The swept volume in m^3
5 nv=75; //Volumetric efficiency in percent
6 N=4500; //The engine rpm
7 p1=1.013; //The initial pressure of air in bar
8 R=287; //Real gas constant in J/kgK
9 pi=3.141; //The mathematical constant of pi
10 t1=15; //The atmospheric temperature in degree
    centigrade

```

```

11 Cp=1005; //The specific heat of gas in J/kgK
12 g=1.4; //Adiabatic index
13 C2=100; //The air flow velocity at choke in m/s
14 Cda=0.85; //The velocity coefficient for the venturi
15 Cdf=0.66; //The coefficient of discharge of the main
    fuel jet
16 sf=0.75; //The specific gravity of fuel
17 d=0.4; //The ratio of the diameter to choke diameter
18 af=14; //The air fuel ratio
19 gf=9.81; //The gravitational force constant in m/s^2
20 Z=0.006; //The petrol surface below the choke in m
21 df=750; //The density of the fuel in kg/m^3
22
23 //Calculations
24 Va=((nv/100)*Vs*N)/(2*60); //The volume of air
    induced in m^3/s
25 V1=Va/2; //The carburator delivers an air flow in m
    ^3/s
26 ma=(p1*10^5*V1)/(R*(t1+273)); //The mass flow rate of
    air in kg/s
27 p2=p1*[1-(C2^2/(2*Cp*(t1+273)))]^(g/(g-1)); //The
    pressure at throat in bar
28 da1=[(p1*10^5)/(R*(t1+273))]; //The density of air in
    kg/m^3
29 da2=da1*(p2/p1)^(1/g); //Density of air at throat in
    kg/m^3
30 A2=[ma/(da2*C2*Cda)]*10^6; //The throat area in mm^2
31 D=[(A2*4)/(pi*0.84)]^(1/2); //The choke diameter in
    mm
32 mf=ma/af; //The mass flow rate of fuel in kg/s
33 pm=[p1-p2-(gf*Z*df/10^5)]*10^5; //The pressure
    difference across the main jet in N/m^2
34 Aj=(mf/(Cdf*(2*df*pm)^(1/2)))*10^6; //The area of the
    jet in mm^2
35 dj=(4*Aj/pi)^(1/2); //The diameter of the jet in mm
36
37 //Output
38 printf('The diameter of the choke = %3.2f mm \n The

```

diameter of the jet in = %3.2 f mm ',D,dj)

Scilab code Exa 9.3 The fuel flow rate

```
1  clc
2  clear
3  //Input data
4  d=0.08; //The diameter of the bore in m
5  L=0.09; //The length of the stroke in m
6  N=4000; //The engine rpm
7  C=84; //The carbon content in the fuel by mass in
    percent
8  H=16; //The hydrogen content in the fuel by mass in
    percent
9  nv=80; //The volumetric efficiency of the engine in
    percent
10 p1=1; //The pressure at ambient condition in bar
11 t1=25; //The temperature at ambient condition in
    degree centigrade
12 p=0.06; //The depression at venturi throat in bar
13 ma=0.95; //The actual quantity of air supplied
14 Ra=287; //Real gas constant in J/kgK
15 Rf=98; //Real gas constant in J/kgK
16 pi=3.141; //The mathematical constant of pi
17 n=4; //Number of cylinders
18 Cp=1005; //The specific heat of gas in J/kgK
19 g=1.4; //Adiabatic index
20
21 //Calculations
22 V=(pi/4)*d^2*L*(nv/100)*(N/(2*60))*n; //The volume of
    mixture supplied to the engine in m^3/s
23 Af=(100/23)*((C*(32/12))+(H*8))/100; //Stoichiometric
    air/fuel ratio
24 mfa=Af*ma; //The actual mass of air supplied per kg
    of fuel in kg/kg fuel
```

```

25 Aaf=mfa;//Actual air fuel ratio
26 da=(p1*10^5)/(Ra*(t1+273));//The density of air at
    one bar in kg/m^3
27 dv=(p1*10^5)/(Rf*(t1+273));//The density of fuel
    vapour in kg/m^3
28 ma1=V/((1/da)+(1/(mfa*dv)));//Mass flow rate of air
    in kg/s
29 mf1=ma1/mfa;//Mass flow rate of fuel in kg/s
30 p2=p1-p;//The pressure at the outlet in bar
31 C2=[2*Cp*(t1+273)*(1-(p2/p1)^((g-1)/g))]^(1/2);//
    Velocity of air at the throat in m/s
32 T2=(t1+273)*(p2/p1)^((g-1)/g);//The temperature at
    throat in K
33 d2=(p2*10^5)/(Ra*T2);//The density of the air at
    throat in kg/m^3
34 A2=[ma1/(d2*C2)]*10^4;//The cross sectional area of
    the venturi throat in cm^2
35 d2=(A2*4/pi)^(1/2);//The diameter of the venturi
    throat in cm
36
37 //Output
38 printf('The fuel flow rate = %3.6 f kg/s \n The
    velocity of air at throat = %3.1 f m/s \n The
    throat diameter = %3.2 f cm ',mf1,C2,d2)

```

Scilab code Exa 9.4 The depression at the throat

```

1 clc
2 clear
3 //Input data
4 d=0.1;//The diameter of the bore in m
5 L=0.12;//The length of the stroke in m
6 N=3000;//The engine rpm
7 d2=0.035;//The throat diameter of carburettor
    venturi in m

```

```

8  nv=80; //The volumetric efficiency of the engine in
    percent
9  Cda=0.82; //The coefficient of discharge of air flow
10 p=1.013; //The ambient pressure in bar
11 T=298; //The ambient temperature in K
12 ar=15; //The air fuel ratio
13 Z=0.005; //The top of the jet above the petrol level
    in the float chamber in m
14 Cdf=0.7; //The coefficient of discharge for fuel flow
15 df=750; //The specific gravity of the fuel in kg/m^3
16 R=287; //Real gas constant in J/kgK
17 pi=3.141; //The mathematical constant of pi
18 g=9.81; //The gravitational constant in m/s^2
19 n=4; //Number of cylinders
20
21 //Calculations
22 V=(pi/4)*d^2*L*(nv/100)*(N/(2*60))*n; //Volume of air
    inducted per second in m^3/s
23 da=(p*10^5)/(R*T); //The density of air in kg/m^3
24 ma=V*da; //The mass flow rate of air in kg/s
25 A2=(pi/4)*d2^2; //The area of the throat in m^2
26 P=[ma^2/(Cda^2*A2^2*2*da)]/10^5; //The change in
    pressure in bar
27 mf=ma/ar; //The mass flow rate of fuel in kg/s
28 Aj=[mf/(Cdf*(2*df*((P*10^5)-(g*Z*df)))^(1/2))]*10^6;
    //The area of the fuel jet in mm^2
29 dj=(Aj*4/pi)^(1/2); //The diameter of the fuel jet of
    a simple carburetor in mm
30
31 //Output
32 printf('The depression of the throat = %3.5f bar \n
    The diameter of the fuel jet of a simple
    carburettor = %3.2f mm ',P,dj)

```

Scilab code Exa 9.5 The critical air velocity

```

1  clc
2  clear
3  //Input data
4  mf=(6/3600); //The mass flow rate of fuel in kg/s
5  df=750; //The density of fuel in kg/m^3
6  Z=0.003; //The level in the float chamber below the
   top of the jet in m
7  p=1.013; //The ambient pressure in bar
8  T=294; //The ambient temperature in K
9  dj=0.0012; //The jet diameter in m
10 Cdf=0.65; //The discharge coefficient of the jet
11 Cda=0.8; //The discharge coefficient of air
12 A=15.3; //The air fuel ratio
13 pi=3.141; //The mathematical constant of pi
14 g=9.81; //The gravitational constant in m/s^2
15 R=287; //Real gas constant in J/kgK
16 dh=1000; //The density of water in kg/m^2
17
18 //Calculations
19 da=(p*10^5)/(R*T); //The density of air in kg/m^3
20 Ca2=Cda*((2*g*Z*df)/da)^(1/2); //The critical air
   velocity at the throat
21 Aj=(pi/4)*dj^2; //The area of the jet in m^2
22 P=[(mf^2/(Cdf^2*Aj^2*2*df))+(g*Z*df)]/10^5; //The
   depression at the throat in bar
23 h=(P*10^5)/(dh*g); //In meter of water
24 h1=(P*10^5)/g; //In mm of water
25 ma=mf*A; //The mass flow rate of air in kg/s
26 A2=[ma/((Cda*(2*da*(P*10^5))^(1/2)))]*10^4; //The
   area of the throat in cm^2
27 d2=[(A2*4/pi)^(1/2)]*10; //The effective throat
   diameter in mm
28
29 //Output
30 printf('The critical air velocity = %3.3f m/s \n The
   depression at the throat in mm of H2O = %3.2f mm
   of H2O \n The effective throat diameter %3.2f
   mm ',Ca2,h1,d2)

```

Scilab code Exa 9.6 A simple carburettor

```
1  clc
2  clear
3  //Input data
4  d2=22; //The venturi throat diameter of a simple
      carburettor in mm
5  Cda=0.82; //The coefficient of air flow
6  dj=1.2; //The fuel orifice diameter in mm
7  Cdf=0.7; //The coefficient of fuel flow
8  Z=0.004; //The petrol surface below the throat in m
9  g=9.81; //The gravitational constant in m/s^2
10 da=1.2; //The density of air in kg/m^3
11 df=750; //The density of fuel in kg/m^3
12 P=0.075; //The pressure drop in bar
13
14 //Calculations
15 A=(Cda/Cdf)*(d2^2/dj^2)*(da/df)^(1/2); //The air fuel
      ratio
16 A1=(Cda/Cdf)*(d2^2/dj^2)*((da*P)/(df*(P-(g*Z*df)
      /10^5)))^(1/2); //Air fuel ratio when the nozzle
      lip Z is considered
17 Ca2=(2*g*Z*df/da)^(1/2); //Critical velocity at the
      throat in m/s
18
19 //Output
20 printf(' (a) The air fuel ratio when the nozzle lip
      is neglected = %3.2f \n (b)The air fuel ratio
      when the nozzle lip is considered = %3.2f \n (c)
      The critical air velocity or minimum velocity
      required to start the fuel flow = %3.0f m/s ',A,
      A1,Ca2)
```

Scilab code Exa 9.7 Air fuel ratio

```
1  clc
2  clear
3  //Input data
4  h=4000; //The altitude of the airplane engine
      carburettor in m
5  A=14.7; //The air fuel ratio at sea level
6  ts=22; //The temperature at sea level in degree
      centigrade
7  R=287; //Real gas constant in J/kgK
8
9  //Calculations
10 ta=ts-(0.0065*h); //The temperature at the altitude
      in degree centigrade
11 p=1.013/10^0.2083; //The pressure at the altitude in
      bar
12 da=(p*10^5)/(R*(ta+273)); //The density at altitude
      in kg/m^3
13 ds=(1.013*10^5)/(R*(ts+273)); //The density at sea
      level in kg/m^3
14 Aa=A*(da/ds)^(1/2); //The air fuel ratio at altitude
15
16 //Output
17 printf('The air fuel ratio at altitude = %3.2f ',Aa)
```

Scilab code Exa 9.8 Throat pressure

```
1  clc
2  clear
3  //Input data
4  A=14.5; //The air fuel ratio
```



```

5 p2=0.825; //The pressure at the venturi throat in bar
6 p1=1.013; //The atmospheric pressure in bar
7 pd=37.5; //The pressure drop to the air cleaner in mm
  of Hg
8 ma=260; //The mass flow rate of air in kg/h
9
10 // Calculations
11 pa=p1-p2; //Without air cleaner the depression at the
  throat in bar
12 p21=p1-(pd/750)-pa; //The throat pressure when the
  air cleaner is fitted in bar
13 pf=pa; //Pressure of fuel without air cleaner in bar
14 pf1=p1-p21; //Pressure of the fuel with air cleaner
  in bar
15 Af=A*(pf/pf1)^(1/2); //Air fuel ratio with air
  cleaner
16
17 //Output
18 printf(' (a) The throat pressure when the air
  cleaner is fitted = %3.3f bar \n (b) The air fuel
  ratio with the air cleaner fitted = %3.2f ',p21,
  Af)

```

Scilab code Exa 9.9 The venturi throat diameter

```

1 clc
2 clear
3 //Input data
4 bp=8; //The brake power of the petrol engine in kW
5 nb=30; //The brake thermal efficiency in percent
6 CV=44000; //The calorific value of the fuel in kJ/kg
7 p1=1.013; //The suction condition of engine pressure
  in bar
8 T1=300; //The temperature at suction condition in K
9 Aj=2.5*10^-6; //The area of jet in m^2

```

```

10 Z=0.008; //The nozzle lip in m
11 g=9.81; //The gravitational force constant in m/s^2
12 A=15; //The air fuel ratio
13 Cda=0.9; //The coefficient of air flow
14 Cdf=0.7; //The coefficient of fuel flow
15 df=750; //The density of fuel in kg/m^3
16 pi=3.141; //The mathematical constant of pi
17 va=0.8; //The specific volume of air in m^3/kg
18
19 // Calculations
20 va1=va*T1/273; // Specific volume of air at
    atmospheric pressure and 300K in m^3/kg
21 da=1/va; //The density of air at inlet condition in
    kg/m^3
22 mf=bp/[(nb/100)*CV]; //Mass flow rate of fuel in kg/s
23 Cf=mf/(Cdf*df*Aj); //Velocity of fuel in m/s
24 P=[(Cf^2*df)/2]+(df*g*Z); //The pressure drop in N/m
    ^2
25 Ca=(2*P/da)^(1/2); //Velocity of air at the throat in
    m/s
26 ma=mf*A; //The mass flow rate of air in kg/s
27 A2=[ma/(Cda*da*Ca)]*10^4; //The area of the venturi
    in cm^2
28 d2=(A2*4/pi)^(1/2); //The diameter of venturi in cm
29
30 //Output
31 printf('The venturi throat diameter of the
    carburator = %3.2f cm ',d2)

```

Chapter 10

CI Engines Fuel Injection System

Scilab code Exa 10.1 The diameter of the orifice

```
1  clc
2  clear
3  //Input data
4  bsfc=0.3; //The brake specific fuel consumption in kg
      /kWh
5  bp=250; //The brake power in kW
6  N=1500; //Number of cycles per min in rpm
7  CA=15; //Crank angle in degrees
8  pi1=30; //The pressure of air in the cylinder at the
      beginning of the injection in bar
9  pi2=60; //The pressure of air in the cylinder at the
      end of the injection in bar
10 pf1=220; //The fuel injection pressure at the
      beginning in bar
11 pf2=550; //The fuel injection pressure at the end in
      bar
12 Cd=0.65; //The coefficient of discharge for the
      injector
13 df=850; //The density of the fuel in kg/m^3
```

```

14 p1=1.013; //The atmospheric pressure in bar
15 n=4; //The number of orifices used in the nozzle
16 x=6; //Number of cylinders
17 pi=3.141; //The mathematical constant of pi
18
19 //Calculations
20 mf=bsfc*bp/60; //The mass flow rate of fuel in kg/min
21 F=(mf/(N/2))*(1/x); //Fuel injected per cycle per
    cylinder in kg
22 s=(CA/360)/(N/60); //Duration of injection in s
23 mf1=F/s; //Mass of fuel injected per second
24 p1=pf1-pi1; //Pressure difference at the beginning in
    bar
25 p2=pf2-pi2; //Pressure difference at the end in bar
26 pa=(p1+p2)/2; //Average pressure difference in bar
27 Af=[mf1/(Cd*(2*df*pa*10^5)^(1/2))]*10^6; //Area of
    cross section of the nozzle in mm^2
28 do=[(Af/n)*(4/pi)]^(1/2); //The diameter of the
    orifice in mm
29
30 //Output
31 printf('The nozzle area required per injection = %3
    .3f mm^2 \n The diameter of the orifice = %3.2f
    mm ', Af, do)

```

Scilab code Exa 10.2 Velocity of injection

```

1 clc
2 clear
3 //Input data
4 bp=30; //The brake power of the engine in kW
5 N=3000; //The engine speed in rpm
6 bsfc=0.28; //The brake specific fuel consumption in
    kg/kWh
7 API=35; //The API

```

```

8 p2=160; //The pressure at which fuel is injected in
   bar
9 CA=28; //The crank angle in degrees
10 p1=35; //The pressure in the combustion chamber in
   bar
11 Cv=0.92; //The coefficient of velocity
12 pi=3.141; //The mathematical constant of pi
13
14 // Calculations
15 S=141.5/(131.5+API); // Specific gravity
16 df=S*1000; //The density of the fuel in kg/m^3
17 D=(CA/360)/(N/60); //Duration of injection in s
18 F=(bsfc*bp)/((N/2)*60); //Fuel consumption per cycle
   in kg
19 mf=F/D; //Mass flow rate of fuel in kg/s
20 Cf=Cv*((2*(p2-p1)*10^5)/df)^(1/2); //Velocity of
   injection of the fuel in m/s
21 Af=[mf/(df*Cf)]*10^6; //Area of the fuel orifice in
   mm^2
22 d=(4*Af/pi)^(1/2); //The diameter of the orifice in
   mm
23
24 //Output
25 printf('The velocity of injection of the fuel = %3.1
   f m/s \n The diameter of the fuel orifice = %3.3f
   mm ',Cf,d)

```

Scilab code Exa 10.3 The discharge of fuel

```

1 clc
2 clear
3 //Input data
4 d=0.8*10^-3; //The diameter of an orifice in m
5 A=1.65*10^-6; //The cross sectional area in m^2
6 Cd=0.9; //The discharge coefficient of the orifice

```

```

7 Cp=0.85; //The coefficient of the passage
8 p1=170; //The injection pressure in bar
9 p2=25; //The compression pressure of the discharge in
    bar
10 df=850; //The density of the fuel in kg/m^3
11
12 // Calculations
13 Q=[(145/(22.931*10^9))^(1/2)]*10^6; //Adding two
    equations and solving then the discharge in cm^3/
    s
14 p=170-(2.161*10^9*(Q/10^6)^2); //Pressure immediately
    formed before the orifice in bar
15 Cf=Cd*((2*(p-p2)*10^5)/df)^(1/2); //The velocity of
    fuel flow through the orifice in m/s
16
17 //Output
18 printf('The discharge of fuel through the injector =
    %3.1f cm^2/s \n The jet velocity through the
    orifice = %3.1f m/s ',Q,Cf)

```

Scilab code Exa 10.4 The time

```

1 clc
2 clear
3 //Input data
4 s=20; //Spray penetration in cm
5 t1=15.7; //The spray penetration of 20 cm in ms
6 pi1=150; //The injection pressure in bar
7 pi2=450; //The injection pressure to be used in bar
8 p2=15; //The combustion chamber pressure in bar
9 d1=0.34; //The diameter of the orifice in mm
10 s1=20; //The penetration for an orifice in cm
11 d2=0.17; //If the diameter of the orifice in cm
12 t11=12; //The spray penetration in ms
13

```

```

14 //Calculations
15 t2=(t1*(pi1-p2)^(1/2))/(pi2-p2)^(1/2);//The time
    required for the spray to penetrate in ms
16 s2=d2*(s1/d1);//The penetration of the orifice in cm
17 t21=t11*(d2/d1);//The time required for the spray to
    penetrate in ms
18
19 //Output
20 printf('(a) The time required for the spray to
    penetrate = %3.2f ms \n (b) The spray penetration
    of the orifice = %3.0f cm \n The time required
    for the spray to penetrate = %3.0f ms ',t2,s2,t21
    )

```

Scilab code Exa 10.5 The pump displacement

```

1 clc
2 clear
3 //Input data
4 v=6.5;//The volume of fuel in the barrel in cc
5 d=0.3;//The diameter of fuel pipe line in cm
6 l=65;//The length of the fuel pipe line in cm
7 vi=2.5;//The volume of fuel in the injection valve
    in cc
8 K=78.5*10^-6;//The coefficient of compressibility of
    the oil per bar
9 p1=1;//The atmospheric pressure in bar
10 p2=180;//The pressure due to pump in bar
11 v3=0.1;//The pump displacement necessary for the
    fuel in cc
12 e=0.75;//The effective stroke of the plunger in cm
13 pi=3.141;//Mathematical constant of pi
14
15 //Calculations
16 V1=v+((pi*d^2)/4)*l+vi;//The total initial volume in

```

```

    cc
17 V=K*V1*(p2-p1); //Change in volume due to compression
    in cc
18 T=(V)+v3; //Total displacement of the plunger in cc
19 L=T*(4/pi)*(1/(e^2)); //Effective stroke of the
    plunger in cm
20
21 //Output
22 printf('(a) The total displacement of the plunger =
    %3.3f cc \n (b) The effective stroke of the
    plunger = %3.3f cm',T,L)

```

Scilab code Exa 10.6 The displacement volume

```

1  clc
2  clear
3  //Input data
4  n=4; //Number of cylinders
5  N=2500; //The engine speed in rpm
6  P=90; //The power produced by the engine in kW
7  bsfc=0.28; //The brake specific fuel consumption in
    kg/kWh
8  v=3.5; //The volume of fuel in the barrel in cc
9  vp=2.5; //Volume of fuel in the pipe line in cc
10 vi=2; //The fuel inside the injector in cc
11 p1=280; //The average injection pressure in bar
12 p2=30; //The compression pressure of air during
    injection in bar
13 df=850; //The density of the fuel in kg/m^3
14 K=80*10^-6; //The coefficient of compressibility of
    fuel per bar
15 pi=1; //The pressure with which fuel enter into the
    barrel in bar
16
17 //Calculations

```



```

18 F=(bsfc*P)/((N/2)*60); //Fuel consumption per cycle
    in kg
19 F1=F/n; //Fuel consumption per cylinder in kg/cycle
20 Vf=[F1/df]*10^6; //Volume of fuel injected per
    cylinder per cycle in cm^3
21 V1=v+vp+vi; //Total initial volume in cc
22 V=K*V1*(p1-pi); //Change in volume due to compression
    in cc
23 Vp=Vf+V; //Volume displaced by plunger in cc
24 W=[(1/2)*(p1-pi)*10^5*V*10^-6]+[(p1-p2)*10^5*Vf
    *10^-6]; //Pump work per cycle in J
25 P1=(W*N)/(2*60*1000); //Power lost per cylinder in kW
26 P2=P1*4; //Total power lost for pumping the fuel in
    kW
27
28 //Output
29 printf('The displacement volume of one plunger per
    cycle = %3.4f cc \n Total power lost for pumping
    the fuel = %3.3f kW',Vp,P2)

```

Scilab code Exa 10.7 The Velocity

```

1 clc
2 clear
3 //Input data
4 v1=0.3; //Velocity of the pump plunger in m/s
5 l=0.575; //The length of the fuel pipe in m
6 A=1/20; //The cross sectional area of pipe to the
    plunger cylinder
7 a=1/40; //The area of nozzle hole to the pipe
8 p1=27.6; //Initial pressure in the line in bar
9 p2=27.6; //The compression pressure of the engine
10 K=17830*10^5; //The bulk modulus of fuel in N/m^2
11 df=860; //The density of the fuel in kg/m^3
12 pi=3.141; //Mathematical constant of pi

```

```

13
14 // Calculations
15 Vs=(K/df)^(1/2); //The velocity of pressure
    disturbances in m/s
16 t=1/Vs; //Time taken by the disturbance to travel
    through pipe line in s
17 Vp=(1/A)*v1; //The velocity of the fuel at the inlet
    of the pipe line in m/s
18 p=[(K/Vs)*Vp]/10^5; //The change in pressure in bar
19 pi=p+p1; //The pressure according to change in
    velocity in bar
20 po=p1+p; //The change in total to the disturbance
    pressure in bar
21 vc=Vp-(a*((2*(po-p2))/df)^(1/2)); //Change in the
    velocity in m/s
22 pr=26.8; //By trail method the first reflected
    pressure wave from velocity in bar
23 Vc=pr*(Vs/(K/10^5)); //The change in velocity in m/s
24 po1=p1+p+pr; //The pressure at the orifice end of the
    pipe in bar
25 vo=a*((2*(po1-p2)*10^5)/df)^(1/2); //The velocity at
    the orifice end of the pipe in m/s
26
27 //Output
28 printf('(a)The velocity of the pressure disturbance
    = %3.0f m/s \n (b) The time taken by the
    disturbance to travel through the pipe line = %3
    .4f s \n (c) The velocity at the pump end of the
    pipe line as the plunger moves = %3.0f m/s \n The
    pressure at the pump end of the pipe line as the
    plunger moves = %3.1f bar \n (d) The magnitude
    of the first reflected pressure = %3.2f bar \n
    The magnitude of the first reflected velocity
    wave = %3.2f m/s \n (e)The pressure at the
    orifice end of the pipe line after the first
    reflection = %3.1f bar \n The velocity at the
    orifice end of the pipe line after the first
    reflection = %3.2f m/s ',Vs,t,Vp,pi,pr,Vc,po1,vo)

```


Chapter 11

Two Stroke Engines

Scilab code Exa 11.1 Scavenging ratio

```
1  clc
2  clear
3  //Input data
4  nsc=75; //The scavenging efficiency of the two stroke
        engine in percent
5  ns=20; //The scavenging efficiency is increased by in
        percent
6
7  //Calculations
8  Rsc=log(1/(1-(nsc/100))); //The scavenging ratio for
        normal efficiency
9  nsc1=(nsc/100)+((nsc/100)*(ns/100)); //For 20%
        increase in scavenging efficiency
10 Rsc1=log(1/(1-(nsc1))); //The scavenging ratio for 20
        % more efficiency
11 Rscr=[(Rsc1-Rsc)/Rsc]*100; //Percentage increase in
        scavenging ratio in percent
12
13 //Output
14 printf('The percentage change in the scavenging
        ratio = %3.1f percent ',Rscr)
```

Scilab code Exa 11.2 Scavenging ratio

```
1  clc
2  clear
3  //Input data
4  d=0.12; //The bore diameter of the engine in m
5  l=0.15; //The stroke length of the engine in m
6  r=16; //The compression ratio
7  N=2000; //The speed of the engine in rpm
8  mf=(240/60); //Actual air flow per min in kg/min
9  T=300; //Air inlet temperature in K
10 p=1.025; //Exhaust pressure in bar
11 pi=3.141; //Mathematical constant of pi
12 R=287; //Real gas constant in J/kg
13
14 //Calculations
15 da=(p*10^5)/(R*T); //The density of air in kg/m^3
16 Vs=[(pi)*(d^2)*l]/4; //Swept volume in m^3
17 V=(r/(r-1))*Vs; //Total cylinder volume in m^3
18 m=da*V; //Ideal mass in total cylinder volume in kg
    per cycle
19 m1=m*N; //Ideal mass per unit time in kg/min
20 Rsc=mf/m1; //Scavenging ratio
21 nsc=[(1-exp(-Rsc))*100]; //Scavenging efficiency in
    percent
22 ntr=[(nsc/100)/Rsc]*100; //Trapping efficiency in
    percent
23
24 //Output
25 printf('(a) The scavenging ratio = %3.3f \n (b) The
    scavenging efficiency = %3.1f percent \n (c) The
    trapping efficiency = %3.1f percent ',Rsc,nsc,ntr
    )
```

Scilab code Exa 11.3 The bore

```
1  clc
2  clear
3  //Input data
4  mf=6.5; //Mass flow rate of fuel in kg/h
5  N=3000; //The speed of the engine in rpm
6  a=15; //The air fuel ratio
7  CV=44000; //The calorific value of the fuel in kJ/kg
8  pm=9; //The mean piston speed in m/s
9  pmi=4.8; //The mean pressure in bar
10 nsc=85; //The scavenging efficiency in percent
11 nm=80; //The mechanical efficiency in percent
12 R=290; //Real gas constant in J/kgK
13 p=1.03; //The pressure of the mixture in bar
14 T=288; //The temperature of the mixture in K
15 pi=3.141; //Mathematical constant
16
17 //Calculations
18 ma=a*mf; //Mass flow rate of air in kg/h
19 L=[(pm*60)/(2*N)]*100; //The length of the stroke in
    cm
20 mac=mf+ma; //Actual mass flow rate in kg/h
21 mi=(mac)/(nsc/100); //Ideal mass flow rate in kg/h
22 da=(p*10^5)/(R*T); //The density of the mixture in kg
    /m^3
23 d=[[(mi/da)*(4/pi)*(1/(L/100))*(1/(60*N))]^(1/2)
    ]*100; //The diameter of the bore in cm
24 ip=(pmi*10^5*(L/100)*((pi/4)*(d/100)^2)*N)/(60*1000)
    ; //Power obtained in kW
25 bp=ip*(nm/100); //Brake power in kW
26 nth=(bp/((mf/3600)*CV))*100; //Thermal efficiency of
    the engine in percent
27
```

```

28 //Output
29 printf(' The diameter of the bore = %3.2f cm \n The
    length of the stroke = %3.0f cm \n The brake
    power = %3.2f kW \n The brake thermal efficiency
    = %3.1f percent ',d,L,bp,nth)

```

Scilab code Exa 11.4 The scavenging ratio

```

1  clc
2  clear
3  //Input data
4  d=0.08; //The diameter of the bore in m
5  L=0.1; //The length of the stroke in m
6  r=8; //The compression ratio
7  o=60; //The exhaust port open before BDC in degrees
8  v=60; //The exhaust port closes after BDC in degrees
9  a=15; //Air fuel ratio
10 T=300; //The temperature of the mixture entering into
    the engine in K
11 p=1.05; //The pressure in the cylinder at the time of
    closing
12 R=290; //Real gas constant in J/kgK
13 ma=150; //Mass flow rate of air in kg/h
14 N=4000; //The speed of the engine in rpm
15 pi=3.1414; //Mathematical constant of pi
16
17 //Calculations
18 mf=ma/a; //Mass flow rate of fuel in kg/h
19 mac=ma+mf; //Actual mass flow rate in kg/h
20 r=(L*100)/2; //Half the length of the stroke in cm
21 Le=(r+(r*sin (pi/6)))/100; //Effective stroke length
    in m
22 Vse=(pi*d^2*Le)/4; //Swept volume corresponding to Le
    in m^3
23 V=(r/(r-1))*Vse; //Total volume corresponding to m^3

```

```

24 da=(p*10^5)/(R*T); //The density in kg/m^3
25 m=V*da; //Mass of mixture per cycle in kg/cycle
26 mi=m*60*N; //Ideal rate of mass flow in kg/h
27 Rsc=mac/mi; //Scavenging ratio
28 nsc=(1-(exp(-Rsc)))*100; //Scavenging efficiency in
    percent
29 ntr=nsc/Rsc; //Trapping efficiency in percent
30
31 //Output
32 printf(' The scavenging ratio = %3.3f \n The
    scavenging efficiency = %3.2f percent \n The
    trapping efficiency = %3.2f percent ',Rsc,nsc,ntr
    )

```

Scilab code Exa 11.5 The scavenging efficiency

```

1  clc
2  clear
3  //Input data
4  d=8.25; //The diameter of the bore in cm
5  L=11.25; //The length of the stroke in cm
6  r=8; //The compression ratio
7  N=2500; //The speed of the engine in rpm
8  ip=17; //Indicated power in kW
9  a=0.08; //Fuel air ratio
10 T=345; //Inlet temperature mixture in K
11 p=1.02; //Exhaust pressure in bar
12 CV=44000; //The calorific value of the fuel in kJ/kg
13 nth=0.29; //Indicated thermal efficiency
14 M=114; //Molar mass of fuel
15 pi=3.141; //Mathematical constant
16 R=8314; //Universal Gas constant in J/kgK
17
18 //Calculations
19 Vs=(pi*d^2*L)/4; //Displacement volume in cm^3

```



```

20 V=(r/(r-1))*Vs; //Total cylinder volume in m^3
21 ps=[(29*p*10^5)/(R*T)]*(1/(1+a*(29/M))); //The
    density of dry air in kg/m^3
22 nsc=[(ip*1000)/((N/60)*V*10^-6*ps*a*CV*1000*ntn)
    ]*100; //The scavenging efficiency in percent
23
24 //Output
25 printf('The scavenging efficiency = %3.1f percent ',
    nsc)

```

Scilab code Exa 11.6 The flow coefficient

```

1  clc
2  clear
3  //Input data
4  S=15; //The speed of the piston in m/s
5  ps=0.35; //The scavenging pressure in bar
6  pa=1.03; //Atmospheric pressure in bar
7  r=18; //The compression ratio
8  t=35; //The inlet temperature in degree centigrade
9  Rsc=0.9; //The scavenging ratio
10 ta=15; //The atmospheric temperature in degree
    centigrade
11 nc=0.75; //Compressor efficiency
12 g=1.4; //Adiabatic index
13 R=287; //Real gas constant in J/kgK
14 Cp=1005; //Specific heat of gas in J/kgK
15
16 //Calculations
17 pi=ps+pa; //The scavenging pressure in bar
18 Ti=(273+ta)+t; //The inlet temperature in K
19 pr=pa/pi; //The ratio of the pressure for
    calculations
20 di=(pi*10^5)/(R*Ti); //The density in kg/m^3
21 ai=(g*R*Ti)^(1/2); //The sonic velocity in m/s

```

```

22 C=(Rsc)/[2*((r-1)/r)*(ai/S)*(pi/pa)*[(2/(g-1))*[(pr
    )^(2/g)]-[(pr)^((g+1)/g)]]^(1/2)];//The flow
    coefficient
23 ds=(pa*10^5)/(R*Ti);//The density in kg/m^3
24 mep=(ds*Rsc*Cp*Ti*[(pi/pa)^((g-1)/g)]-1)/[(nc*((r
    -1)/r))*10^5];//Mean effective pressure in bar
25
26 //Output
27 printf(' The flow coefficient = %3.4f \n The
    compressor mean effective pressure = %3.1f bar ',
    C,mep)

```

Chapter 13

Engine Friction and Lubrication

Scilab code Exa 13.1 The friction force

```
1  clc
2  clear
3  //Input data
4  d=0.08; //The diameter of bore in m
5  L=0.075; //The length of the stroke in m
6  l=0.152; //The connecting rod length in m
7  h=0.062; //Skirt length of the piston in m
8  Fr=8000; //Compressive force in the connecting rod in
      N
9  p=3000; //The pressure in the cylinder kPa
10 y=0.004*10^-3; //The clearance between piston and
      cylinder wall in m
11 U=0.006; //The dynamic viscosity of the lubricating
      oil in pa.s
12 u=8.2; //The piston speed in m/s
13 pi=3.141; //Mathematical constant of pi
14
15 //Calculations
16 ts=(U*u)/y; //The shear stress in N/m^2
17 A=pi*d*h; //Contact area between the piston and the
      cylinder in m^2
```

```

18 Ff=ts*A;//Friction force on the piston inN
19 r=L/2;//Crank length in m
20 A=atan(r/l);//The angle made by the crank in radians
21 Ft=Fr*sin(A);//The side thrust in N
22 //Output
23 printf(' The friction force on the piston = %3.0f N
    \n The thrust force on the cylinder wall = %3.0f
    N',Ff,Ft)

```

Scilab code Exa 13.2 A four cylinder IC engine

```

1  clc
2  clear
3  //Input data
4  d=0.065;//The cylinder bore diameter in m
5  L=6;//The length of the stroke in cm
6  l=12;//The length of the connecting rod in cm
7  p=50;//The pressure in the cylinder in bar
8  q=90;//The crank position in power stroke of the
    cycle for one cylinder in degrees
9  Ff=900;//Friction force in N
10 pi=3.141;//Mathematical constant valu of pi
11 o=0.2;//Wrist pin off set in cm
12
13 //Calculations
14 r=L/2;//The crank length in cm
15 sineA=r/l;//The value of sine
16 cosA=(1-(sineA)^2)^(1/2);//The value of cosine
17 Fr=[[(p*10^5*(pi/4)*d^2)-Ff]/cosA]/1000;//The force
    in the connecting rod in kN
18 Ft=Fr*sineA;//The side thrust on the piston in kN
19 sineA1=(r-o)/l;//The value of sine
20 cosA1=(1-(sineA1)^2)^(1/2);//The value of cosine
21 Fr1=[[(p*10^5*(pi/4)*d^2)-Ff]/cosA1]/1000;//The
    force in the connecting rod in kN

```

```
22 Ft1=Fr1*sineA1;//The side thrust in kN
23
24 //Output
25 printf('(a) The force in the connecting rod = %3.3f
    kN \n The side thrust on the piston = %3.3f kN \n
    (b) The side thrust on the piston = %3.3f kN ',
    Fr,Ft,Ft1)
```

Chapter 15

Air Capacity and Supercharging

Scilab code Exa 15.1 The efficiencies

```
1  clc
2  clear
3  //Input data
4  Vs=0.0028; //Swept volume in m^3
5  N=3000; //Speed of the engine in rpm
6  ip=12.5; //The average indicated power developed in
   kW/m^3
7  nv=85; //Volumetric efficiency in percent
8  p1=1.013; //The atmospheric pressure in bar
9  T1=288; //The atmospheric temperature in K
10 ni=74; //Isentropic efficiency in percent
11 pr=1.6; //The pressure ratio
12 nm=78; //All mechanical efficiencies in percent
13 g=1.4; //Adiabatic index
14 R=287; //Real gas constant in J/kgK
15 Cp=1.005; //The specific heat of gas in kJ/kgK
16
17 //Calculations
18 Vs1=(Vs*(N/2)); //Volume swept by the piston per
```

```

    minute in m3/min
19 Vi=(nv/100)*Vs1;//Unsupercharged induced volume in m
    ^3/min
20 p2=pr*p1;//Blower delivery pressure in bar
21 T21=T1*(p2/p1)^((g-1)/g);//Temperature after
    isentropic compression in K
22 T2=T1+((T21-T1)/((ni/100)));//Blower delivery
    temperature in K
23 Ve=(Vs1*p2*T1)/(T2*p1);//Equivalent volume at 1.013
    bar and 15 degree centigrade in m3/min
24 nv1=[Ve/Vs1]*100;//Volumetric efficiency of
    supercharged engine in percent
25 Vii=Ve-Vi;//Increase in induced volume in m3/min
26 ipa=ip*Vii;//Increase in ip from air induced in kW
27 ipi=[(p2-p1)*105*Vs1]/(60*1000);//Increase in ip
    due to increased induction pressure in kW
28 ipt=ipa+ipi;//Total increase in ip in kW
29 bp=ipt*(nm/100);//Increase in engine bp in kW
30 ma=(p2*(Vs1/60)*105)/(R*T2);//Mass of air delivered
    per second by blower in kg/s
31 P=ma*Cp*(T2-T1);//Power input to blower in kW
32 Pd=P/(nm/100);//Power required to drive the blower
    in kW
33 bpn=bp-Pd;//Net increase in bp in kW
34 bpu=ip*Vi*(80/100);//The bp of unsupercharged engine
    in kW
35 bpp=(bpn/(bpu))*100;//Percentage increase in bp in
    percent
36
37 //Output
38 printf('The volumetric efficiency of supercharged
    engine = %3.0f percent \n The increase in brake
    power by supercharging = %3.2f kW \n The
    percentage increase in brake power = %3.1f
    percent ',nv1,bpn,bpp)

```

Scilab code Exa 15.2 Engine capacity

```
1  clc
2  clear
3  //Input data
4  p=1.013; //The pressure at the sea level in bar
5  T=283; //The temperature at the sea level in K
6  bp=275; //Brake power in kW
7  N=1800; //The speed of the engine in rpm
8  a=20; //Air fuel ratio
9  R=287; //The real gas constant in J/kgK
10 bsfc=0.24; //Brake specific fuel consumption in kg/
    kWh
11 nv=80; //Volumetric efficiency in percent
12 p2=0.75; //The atmospheric pressure at altitude in
    bar
13 P=9; //The power consumed by supercharger of the
    total power produced by the engine in percent
14 T2=303; //The temperature of air leaving the
    supercharger in K
15
16 //Calculations
17 mf=[bsfc*bp]/60; //Mass of fuel consumed in kg/min
18 ma1=mf*(a); //Mass of air used in kg/min
19 ma=(2/N)*ma1; //Actual mass of air taken in per cycle
    in kg/cycle
20 dai=(p*10^5)/(R*T); //The density of air in kg/m^3
21 Vd=(ma/(dai*(nv/100))); //Volume displaced by the
    piston in m^3
22 pmb=(bp*2*60*1000)/(Vd*N*10^5); //Brake mean
    effective pressure in bar
23 GP=bp/(1-0.09); //Gross power in kW
24 ma2=(ma1/bp)*GP; //The mass flow rate of air for
    gross power in kg/min
```



```

25 ma1=(ma2*2)/N; //Mass of air required for gross power
    per cycle in kg/cycle
26 p21=[(R*T2*ma1)/((nv/100)*Vd)]/10^5; //The pressure
    at the outlet condition of the supercharger in
    bar
27 pi=p21-p2; //Increase in air pressure required in the
    supercharger in bar
28
29 //Output
30 printf('(a) The engine capacity Vd = %3.4f m^3 \n
    The bmep of the unsupercharged engine = %3.3f bar
    \n (b) Increase in air pressure required in the
    supercharged = %3.3f bar ',Vd,pmb,pi)

```

Scilab code Exa 15.3 Four stroke SI engine

```

1  clc
2  clear
3  //Input data
4  Vs=0.003; //Swept volume in m^3
5  bmep=9; //Brake mean effective pressure in bar
6  N=4000; //The speed of the engine in rpm
7  ni=30; //Indicated thermal efficiency in percent
8  nm=90; //Mechanical efficiency in percent
9  bmep1=12; //The brake mean effective pressure of
    other engine in bar
10 N1=4000; //The speed of other engine in rpm
11 ni1=25; //The indicated thermal efficiency of other
    engine in percent
12 nm1=91; //The mechanical efficiency of other engine
    in percent
13 m=200; //The mass of naturally aspirated engine in kg
14 m1=220; //The mass of supercharged engine in kg
15 CV=44000; //The calorific value of the fuel in kJ/kg
16

```

```

17 // Calculations
18 bp=(bmep*10^5*Vs*N)/(2*60*1000); //The brake power in
    kW
19 ip=bp/(nm/100); //The indicated power in kW
20 mf=(ip)/((ni/100)*CV); //Mass flow rate of fuel in kg
    /s
21 bp1=(bmep1*10^5*Vs*N1)/(2*60*1000); //The brake power
    for supercharged engine in kW
22 ip1=bp1/(nm1/100); //The indicated power for
    supercharged engine in kW
23 mf1=ip1/((ni1/100)*CV); //Mass flow rate of fuel for
    supercharged engine in kg/s
24 mf2=mf*3600; //Mass flow rate of fuel per hour in kg/
    h
25 mf3=mf1*3600; //Mass flow rate of fuel per hour in
    supercharged engine in kg/h
26 x=[(200/90)-(220/120)]/[(43.2/120)-(27.27/90)]; //
    Maximum hours of fuel supply foe test in hrs
27
28 //Output
29 printf (' The maximum hours required for supply of
    sufficient fuel = %3.3f hr ',x)

```

Scilab code Exa 15.4 Centrifugal compressor

```

1 clc
2 clear
3 //Input data
4 d=0.1; //The diameter of the bore in m
5 L=0.12; //The length of the stroke in m
6 N=3000; //The speed of the engine in rpm
7 n=4; //Number of cylinders
8 pi=3.141; //Mathematical constant of pi
9 R=287; //Real gas constant in J/kgK
10 t=120; //Output Torque in Nm

```

```

11 nm=85; //The mechanical efficiency of the engine in
    percent
12 T1=288; //The inlet temperature of air into
    compressor in K
13 p1=1; //The inlet pressure of air into compressor in
    bar
14 Q=1200; //Heat rejected rate in kJ/min
15 T=328; //The outlet temperature of air in K
16 p=1.7; //The outlet pressure of air in bar
17 nv=90; //Volumetric efficiency in percent
18 Cp=1.005; //Specific heat of gas in kJ/kg
19
20 //Calculations
21 bp=(2*pi*N*t)/(60*1000); //The brake power in kW
22 ip=bp/(nm/100); //The indicated power in kW
23 pmi=[(ip*2*60*1000*4)/[L*(pi*d^2)*N*n]]/10^5; //The
    mean effective pressure in bar
24 Vs=(pi/4)*d^2*L; //Swept volume in m^3
25 Vs1=Vs*(N/2)*n; //Volume swept by the piston per min
26 V1=(nv/100)*Vs1; //Rate of volume flow of air into
    the engine in m^3/min
27 me=[(p*10^5*V1)/(R*T)]*60; //Rate of mass flow of air
    into the engine in kg/h
28 E=Q/60; //Energy balance in the after cooling in kJ/s
29 T2=[(bp/E)*T-T1]/((bp/E)-1); //The outlet temperature
    of air in K
30 mc=[(bp)/(Cp*(T2-T1))]*3600; //Mass flow rate in kg/h
31 maf=mc-me; //Rate of air flow available to the
    consumer in kg/h
32
33 //Output
34 printf('(a) The imep of the supercharged engine = %3
    .3f bar \n (b) The rate of air consumed by the
    engine = %3.1f kg/h \n (c) The rate of air flow
    available to the consumer = %3.1f kg/h ', pmi, me,
    maf)

```

Scilab code Exa 15.5 Six cylinder engine

```
1  clc
2  clear
3  //Input data
4  Vs=0.0045; //Swept volume in m^3
5  N=4000; //The speed of the engine in rpm
6  nv=150; //Overall volumetric efficiency in percent
7  ni=90; //Isentropic efficiency of the compressor in
    percent
8  nm=85; //Mechanical efficiency in percent
9  T=330; //The temperature of compressed air after
    cooler in K
10 p2=1.8; //The pressure of the compressed air in bar
11 T1=290; //The ambient temperature of air in K
12 p1=1; //The pressure of the ambient condition in bar
13 R=287; //The real gas constant in J/kgK
14 g=1.4; //Adiabatic index
15 Cp=1.005; //The specific heat of gas in kJ/kgK
16
17 //Calculations
18 T21=T1*(p2/p1)^((g-1)/g); //The temperature at 2' in
    K
19 T2=T1+[(T21-T1)/(ni/100)]; //The temperature of air
    after compressor in K
20 Vs1=Vs*(N/(2*60)); //Rate of swept volume in m^3/s
21 Va=(nv/100)*Vs1; //Volume of air induced in m^3/s
22 d=(p1*10^5)/(R*T1); //The density of air at ambient
    condition in kg/m^3
23 ma=d*Va; //Mass of air induced in kg/s
24 Q=ma*Cp*(T2-T); //Heat rejected from after cooler in
    kJ/s
25 P=ma*Cp*(T2-T1); //Power needed to run the compressor
    in kW
```

```

26 Pa=P/(nm/100); //Power absorbed from the engine in kW
27
28 //Output
29 printf( '(a) The rate of heat rejected from the
    after cooler = %3.3f kJ/s \n (b) The power
    absorbed by the supercharger from the engine = %3
    .2f kW ',Q,Pa)

```

Scilab code Exa 15.6 Turbocharger

```

1  clc
2  clear
3  //Input data
4  p1=0.98; //The inlet pressure of air in bar
5  T1=290; //The inlet temperature of air in K
6  p2=1.8; //The pressure of air delivered to the engine
    in bar
7  a=20; //The air fuel ratio
8  T3=850; //The temperature of the exhaust gases
    leaving the engine in K
9  p3=1.6; //The pressure of the exhaust gases leaving
    the engine in bar
10 p4=1.03; //The turbine exhaust pressure in bar
11 nc=80; //The isentropic efficiency of compressor in
    percent
12 nt=85; //The isentropic efficiency of turbine in
    percent
13 Cpa=1.005; //The specific heat of air in kJ/kgK
14 Cpg=1.15; //The specific heat of gas in kJ/kgK
15 g=1.33; //isentropic index
16 h=1.4; //Adiabatic index
17
18 //Calculations
19 T21=T1*(p2/p1)^((h-1)/h); //The temperature at point
    2' for compressor in K

```

```

20 T2=T1+((T21-T1)/(nc/100));//The temperature of air
    leaving the compressor in K
21 T22=T2-273;//The temperature of air leaving the
    compressor in degree centigrade
22 T41=T3*(p4/p3)^((g-1)/g);//The temperature at point
    4' for turbine in K
23 T4=T3-((nt/100)*(T3-T41));//The temperature of gas
    leaving the turbine in K
24 T44=T4-273;//The temperature of gas leaving the
    turbine in degree centigrade
25 mf=1;//Assume mass flow rate of fuel in kg/s
26 ma=mf*a;//Then the mass flow rate of air in kg/s
27 Wc=ma*Cpa*(T2-T1);//Power required by the compressor
    in kW
28 mg=ma+mf;//Mass flow rate of gas in kg/s
29 Wt=mg*Cpg*(T3-T4);//Power developed by the turbine
    in kW
30 Pt=(Wc/Wt)*100;//Percentage of turbine power used to
    run the compressor in percent
31
32 //Output
33 printf('(a) The temperature of the air leaving the
    compressor = %3.0f degree centigrade \n (b) The
    temperature of gases leaving the turbine = %3.0f
    degree centigrade \n (c) The mechanical power
    used to run the turbocharger , when expressed as a
    percentage of power generated in the turbine =
    %3.1f percent ',T22,T44,Pt)

```

Scilab code Exa 15.7 The power

```

1
2
3 clc
4 clear

```

```

5 //Input data
6 a=14;//Air fuel ratio
7 T1=288;//The ambient temperature of air in K
8 T2=(288-23);//The evaporation of fuel cause 23
    degree C drop in mixture temperature in K
9 p=1.3;//Pressure ratio
10 nc=75;//The isentropic efficiency of the compressor
    in percent
11 Cpm=1.05;//The specific heat of the mixture in kJ/
    kgK
12 Cpa=1;//The specific heat of air in kJ/kgK
13 g=1.33;//Adiabatic index
14 h=1.4;//Isentropic index
15 ma=1;//Mass flow rate of air in kg/s
16
17 //Calculations
18 T31=T2*p^((g-1)/g);//Temperature at point 3' in K
19 T3=T2+((T31-T2)/(nc/100));//Temperature of the gas
    after compressor in K
20 mm=1+(1/a);//Mass flow rate of mixture in kg/s
21 Wc1=mm*Cpm*(T3-T2);//Power required by the
    compressor in kW/kg of air per second
22 T21=T1*p^((h-1)/h);//Temperature at point 2' in K
23 T4=T1+((T21-T1)/(nc/100));//The temperature after
    leaving the compressor in K
24 Wc2=ma*Cpa*(T4-T1);//Power required by the
    compressor in kW/kg of air per second
25 T5=T4-23;//Temperature of the gas after carburettor
    in K
26 Ps=[(Wc2-Wc1)*100]/Wc2;//Saving of power in the
    first case in percent
27
28 //Output
29 printf('(a) The power required by the compressor for
    carburettor placed before the supercharger = %3
    .2f kW/kg of air per second \n (b) The power
    required by the compressor for carburettor placed
    after the supercharger = %3.2f kW/kg of air per

```

```
second \n Percentage of turbine power used to run
the compressor = %3.1f percent ',Wc1,Wc2,Ps)
30
31 //Error .The reason for variation in the result
compared to the textbook is that , in the
textbook Wc1 value is rounded of to the nearest
integer and Wc2 value has small decimal error so
the final result is slightly higher
```

Chapter 16

Engine Testing and Performance

Scilab code Exa 16.1 Three litre spark ignition

```
1  clc
2  clear
3  //Input data
4  N=3000; //The speed of the engine in rpm
5  r=9; //Compression ratio
6  l=17.2; //The length of the connecting rod in cm
7  t=20; //The combustion ends at a TDC in degrees
8  pi=3.141; //Mathematical constant of pi
9  k=3; //Three litre spark engine
10 n=6; //V-6 Engine
11
12 //Calculations
13 Vs=(k/n)*10^-3; //Swept volume per cylinder in m^3
14 d=[[(Vs*4)/pi]^(1/3)]; //The diameter of the bore in
    m
15 L=d*100; //The length of the stroke in cm
16 up=2*d*N/60; //Average piston speed in m/s
17 Vc=[Vs/(r-1)]*10^6; //Clearence volume in cm^3
18 cr=(L)/2; //Crank radius in cm
```

```

19 R=1/cr;//The ratio of the connecting rod length to
    crank radius
20 up1=up*[(pi/2)*sin(pi/9)*(1+(cos(pi/9)/(R^2-(sin(pi
    /9)^2))^(1/2)))];//The piston speed at the end of
    combustion in m/s
21 s=(cr*cos(pi/9))+(1^2-(cr^2)*(sin(pi/9))^2)^(1/2);//
    Distance between crank axis and wrist pin in cm
22 x=1+cr-s;//The distance the piston travels from TDC
    at the end of combustion in cm
23 V=Vc+(pi/4)*(d*100)^2*x;//Instantaneous volume in cm
    ^3
24
25 //Output
26 printf('(a)The cylinder bore and The stroke length (
    d = L) = %3.1f cm \n (b) The average piston speed
    = %3.1f m/s \n (c) The clearance volume of one
    cylinder = %3.1f cm^3 \n (d) The piston speed at
    the end of combustion = %3.2f m/s \n (e) The
    distance the piston travels from TDC at the end
    of combustion = %3.2f cm \n (f) Instantaneous
    volume = %3.1f cm^3 ',L,up,Vc,up1,x,V)

```

Scilab code Exa 16.2 Single cylinder four stroke

```

1 clc
2 clear
3 //Input data
4 d=0.175;//The diameter of the bore in m
5 pi=3.141;//The mathematical constant of pi
6 L=0.32;//The length of the stroke in m
7 p=6.5;//Mean effective pressure in bar
8 pp=0.4;//Pumping loop mean effective pressure in bar
9 N=510;//The speed of the engine in rpm
10 pm=0.65;//Diagrams from the dead cycle give a mep in
    bar

```

```

11 n=55; //Firing strokes per minute
12
13 //Calculations
14 pmi=p-pp; //The net imep at full load in bar
15 c=((N/2)-n); //Dead cycles per minute at no load
16 ipw=pmi*10^5*L*(pi/4)*d^2*(n/60)*(1/1000); //
    Indicating power for working cycles in kW
17 Pp=pm*10^5*L*(pi/4)*d^2*(c/60)*(1/1000); //Pumping
    power of dead cycles in kW
18 fp=ipw-Pp; //Power in kW
19 fip=pmi*10^5*L*(pi/4)*d^2*(N/(2*60))*(1/1000); //Full
    load indicated power in kW
20 fbp= fip-fp; //Full load break power in kW
21 nm=(fbp/fip)*100; //Mechanical efficiency in percent
22
23 //Output
24 printf(' The full load break power = %3.2f kW \n The
    mechanical efficiency of the engine = %3.1f
    percent ', fbp, nm)

```

Scilab code Exa 16.3 The bmep

```

1  clc
2  clear
3  //Input data
4  d=0.09; //The diameter of the bore in m
5  L=0.1; //The length of the stroke in m
6  T=120; //The torque measured in Nm
7  pi=3.141; //Mathematical constant of pi
8  n=4; //Number of cylinders
9
10 //Calculations
11 pmb=[(4*pi*T)/(L*(pi/4)*d^2*n)]/10^5; //The brake
    mean effective pressure in bar
12

```

```

13 //Output
14 printf('The brake mean effective pressure = %3.2f
        bar ',pmb)

```

Scilab code Exa 16.4 Four cylinder SI engine

```

1  clc
2  clear
3  //Input data
4  d=0.06; //The diameter of the bore in m
5  L=0.085; //The length of the stroke in m
6  N=3000; //The speed of the engine in rpm
7  r=0.35; //Torque arm radius in m
8  W=160; //Weight in N
9  pi=3.141; //Mathematical constant
10 f=6.6; //Fuel consumption in l/h
11 g=0.78; //specific gravity of the fuel
12 CV=44000; //The calorific value of the fuel in kJ/kg
13 w1=114; //Brake load for cylinder 1 in N
14 w2=110; //Brake load for cylinder 2 in N
15 w3=112; //Brake load for cylinder 3 in N
16 w4=116; //Brake load for cylinder 4 in N
17 n=4; //Number of cylinders
18
19 //Calculations
20 Vf=(f*10^-3)/3600; //Volume flow rate of fuel in m^3/
    s
21 df=g*1000; //The density of the fuel in kg/m^3
22 mf=df*Vf; //Mass flow rate of fuel in kg/s
23 T=W*r; //Torque in Nm
24 bp=(2*pi*N*T)/(60*1000); //The brake power in kW
25 pmb=[(120*bp*1000)/(L*(pi/4)*d^2*N*n)]/10^5; //Brake
    mean effective pressure in bar
26 nb=[(bp)/(mf*CV)]*100; //The brake thermal efficiency
    in percent

```

```

27 bsfc=(mf*3600)/bp;//Brake specific fuel consumption
    in kg/kWh
28 bp1=[(2*pi*N*w1*r)/(60*1000)];//Brake power from
    morse test in kW
29 ip1=bp-bp1;//Indicated power in kW
30 ip2=bp-[(2*pi*N*w2*r)/(60*1000)];//Indicated power
    in kW
31 ip3=bp-[(2*pi*N*w3*r)/(60*1000)];//Indicated power
    in kW
32 ip4=bp-[(2*pi*N*w4*r)/(60*1000)];//Indicated power
    in kW
33 ip=ip1+ip2+ip3+ip4;//Total indicated power in kW
34 nm=(bp/ip)*100;//Mechanical efficiency in %
35 pmi=pmb/(nm/100);//The imep in bar
36
37 //Output
38 printf('The brake power = %3.2f kW \n The brake mean
    effective pressure = %3.2f bar \n The brake
    thermal efficiency = %3.0f percent \n The brake
    specific fuel consumption = %3.3f kg/kWh \n The
    indicated power = %3.2f kW \n The mechanical
    efficiency = %3.1f percent \n The indicated mean
    effective pressure = %3.1f bar ',bp,pmb,nb,bsfc,
    ip,nm,pmi)

```

Scilab code Exa 16.5 The efficiencies

```

1 clc
2 clear
3 //Input data
4 d=0.15;//The diameter of the bore in m
5 L=0.16;//The length of the stroke in m
6 N=500;//The speed of the engine in rpm
7 mf=0.0475;//Fuel consumption in kg/min
8 CV=42000;//The calorific value in kJ/kg

```

```

9 w=400; //The tension on either side of the pulley in
  N
10 c=2.2; //Brake circumference in m
11 l=50; //Length of the indicator diagram in mm
12 ap=475; //Area of the positive loop of indicator
  diagram in mm^2
13 an=25; //Area of the negative loop of indicator
  diagram in mm^2
14 s=0.8333; //Spring constant in bar/mm
15 pi=3.141; //Mathematical constant of pi
16
17 //Calculations
18 r=c/(2*pi); //Arm length in m
19 T=w*r; //Torque in Nm
20 bp=(2*pi*N*T)/(60*1000); //Brake power in kW
21 M=(ap-an)/l; //Mean height of indicator diagram in mm
22 imep=M*s; //Indicated mean effective pressure in bar
23 ip=(imep*10^5*L*(pi/4)*d^2*(N/(2*60))*(1/1000)); //
  Indicated power in kW
24 nm=(bp/ip)*100; //The mechanical efficiency in
  percent
25 nb=[(bp*60)/(mf*CV)]*100; //The brake thermal
  efficiency in percent
26 ni=[(nb/100)/(nm/100)]*100; //The indicated thermal
  efficiency in percent
27 bsfc=(mf*60)/bp; //Brake specific fuel consumption in
  kg/kWh
28
29 //Output
30 printf('(a) The brake power = %3.2f kW \n (b) The
  indicated power = %3.3f kW \n (c) The mechanical
  efficiency = %3.0f percent \n (d) The brake
  thermal efficiency = %3.2f percent \n (e) The
  indicated thermal efficiency = %3.1f percent \n (
  f) The brake specific fuel consumption = %3.3f kg
  /kWh ',bp,ip,nm,nb,ni,bsfc)

```

Scilab code Exa 16.6 Eight cylinder four stroke SI engine

```
1  clc
2  clear
3  //Input data
4  n=8; //Number of cylinders
5  d=0.08; //The diameter of the bore in m
6  L=0.1; //The length of the stroke in m
7  N=4500; //The speed of the engine in rpm
8  dy=0.55; //The dynamometer readings in m
9  w=40; //The weight of the dynamometer scale reading
    in kg
10 c=100; //Fuel consumption in cc
11 t=9.5; //Time taken for fuel consumption in s
12 CV=44000; //The calorific value of the fuel in kJ/kg
13 p=1; //The atmospheric air pressure in bar
14 T=300; //The atmospheric air temperature in K
15 pi=3.141; //Mathematical constant of pi
16 ma=6; //Mass flow rate of air in kg/min
17 g=0.7; //Specific gravity of the fuel
18 Vc=65; //The clearance volume of each cylinder in cc
19 R=287; //Real gas constant in J/kgK
20 g=1.4; //Isentropic index
21
22 //Calculations
23 bp=(2*pi*N*dy*w*9.81)/(60*1000); //The brake power in
    kW
24 bmep=[(bp*1000*60)/(L*(pi/4)*d^2*(N/2)*n)]/10^5; //
    The brake mean effective pressure in bar
25 mf=(c*g*3600)/(t*2*1000); //The mass flow rate of
    fuel in kg/h
26 bsfc=(mf/bp); //Brake specific fuel consumption in kg
    /kWh
27 bsac=(ma*60)/bp; //Brake specific air consumption in
```

```

kg/kWh
28 a=bsac/bsfc;//Air fuel ratio
29 nb=((bp*3600)/(mf*CV))*100;//The brake thermal
    efficiency in percent
30 Va=(ma*R*T)/(p*10^5);//The volume flow rate of air
    at intake condition in m^3/min
31 Vs=(pi/4)*d^2*L*(N/2)*n;//The swept volume per
    minute in m^3/min
32 nv=(Va/Vs)*100;//Volumetric efficiency in percent
33 Vs1=[(pi/4)*d^2*L]*10^6;//Swept volume per cylinder
    in cc
34 cr=(Vs1+Vc)/Vc;//Compression ratio
35 na=[1-(1/cr)^(g-1)]*100;//Air standard efficiency in
    percent
36 re=[(nb)/(na)]*100;//Relative efficiency in percent
37
38 //Output
39 printf( 'The brake power = %3.1f kW \n The brake
    mean effective pressure = %3.3f bar \n The brake
    specific fuel consumption = %3.3f kg/kWh \n The
    brake specific air consumption = %3.2f kg/kWh \n
    The air fuel ratio = %3.2f \n The brake thermal
    efficiency = %3.1f percent \n The volumetric
    efficiency = %3.1f percent \n The relative
    efficiency = %3.1f percent ',bp,bmep,bsfc,bsac,a,
    nb,nv,re)

```

Scilab code Exa 16.7 Six cylinder four stroke

```

1 clc
2 clear
3 //Input data
4 n=6;//Number of cylinders
5 Do=0.03;//Orifice diameter in m
6 Cd=0.6;//Coefficient of discharge

```



```

7 H=0.14; //Pressure drop across the orifice
8 d=0.1; //The diameter of the bore in m
9 L=0.11; //The length of the stroke in m
10 W=540; //Brake load in N
11 N=2500; //Engine speed in rpm
12 ch=83/17; //C/H ratio by mass
13 p=1; //Ambient pressure in bar
14 t=18; //Time taken for fuel consumption in s
15 f=100; //The amount of fuel consumption in cc
16 T=300; //Ambient air temperature in K
17 df=780; //The density of the fuel in kg/m^3
18 R=287; //Real gas constant in J/kgK
19 g=9.81; //Gravitational force constant in m/s^2
20 pi=3.141; //Mathematical constant
21 dhg=13600; //Density of Hg in kg/m^3
22
23 //Calculations
24 da=(p*10^5)/(R*T); //The density of air in kg/m^3
25 Va=(Cd*(pi/4)*Do^2*[2*g*H*(dhg/da)]^(1/2)); //Volume
    flow rate of air in m^3/s
26 Vs=(pi/4)*d^2*L*(N/(2*60))*n; //Swept volume per
    second in m^3/s
27 nv=(Va/Vs)*100; //Volumetric efficiency in percent
28 bp=(W*N)/(20000); //The brake power in kW
29 bmep=[(bp*1000)/(L*(pi/4)*d^2*(N/(2*60))*n)]/10^5; //
    The brake mean effective pressure in bar
30 T=(60*bp*1000)/(2*pi*N); //Torque in Nm
31 mf=(f/18)*(780/1000)*(1/1000)*3600; //Mass flow rate
    of fuel in kg/h
32 bsfc=mf/bp; //The brake specific fuel consumption in
    kg/kWh
33 so=(0.83*(32/12))+(0.17*(8/1)); //Stoichiometric
    oxygen required per kg of fuel in kg/kg fuel
34 sa=so/bsfc; //Stoichiometric air required in kg/kg
    fuel
35 maa=Va*da; //Actual mass flow rate of air in kg/s
36 af=(maa*3600)/mf; //Actual air fuel ratio
37 pea=[(af-sa)/sa]*100; //Percentage of excess air in

```

```

    percent
38
39 //Output
40 printf('The volumetric efficiency = %3.1f percent \n
    The brake mean effective pressure = %3.2f bar \n
    The brake power = %3.1f kW \n The Torque = %3.1f
    Nm \n The brake specific fuel consumption = %3.3
    f kg/kWh \n The percentage of excess air = %3.1f
    percent ',nv,bmep,bp,T,bsfc,pea)

```

Scilab code Exa 16.8 The efficiencies

```

1  clc
2  clear
3  //Input data
4  d=0.2; //The diameter of bore in m
5  L=0.3; //The length of the stroke in m
6  r=5.5; //The compression ratio of the engine
7  N=400; //The speed of the engine in rpm
8  imep=4.5; //The indicative mean effective pressure in
    bar
9  a=6; //Air to gas by volume
10 CV=12000; //The calorific value of the gas in kJ/m^3
11 T=340; //The temperature at the beginning of the
    compression stroke in K
12 p=0.97; //The pressure at the beginning of the
    compression stroke in bar
13 pi=3.141; //The mathematical constant of pi
14 g=1.4; //Adiabatic index
15
16 //Calculations
17 Vs=(pi/4)*d^2*L; //The swept volume in m^3
18 Vc=Vs/(r-1); //The clearance volume in m^3
19 V=Vs+Vc; //Total cylinder volume in m^3
20 Vg=V/7; //Volume of the gas in total cylinder volume

```

```

    in m^3
21 Vntp=((p*Vg)/T)*(273/1.013); //Volume of gas at NTP
    in m^3
22 Q=Vntp*CV*(N/(2*60)); //Heat supplied by the fuel in
    kJ/s
23 ip=(imep*10^5*L*(pi/4)*d^2*(N/(2*60))*(1/1000)); //
    Indicated power in kW
24 ni=(ip/Q)*100; //Indicated thermal efficiency in
    percent
25 na=[1-(1/r)^(g-1)]*100; //Air standard efficiency in
    percent
26 nr=(ni/na)*100; //Relative efficiency based on
    indicated thermal efficiency in percent
27
28 //Output
29 printf('The indicated power = %3.2f kW \n The
    thermal efficiency = %3.1f percent \n The
    relative efficiency = %3.1f percent ',ip,ni,nr)

```

Scilab code Exa 16.9 Six cylinder four stroke

```

1  clc
2  clear
3  //Input data
4  n=6; //Number of cylinder
5  bp=130; //Brake power in kW
6  N=1800; //The speed of the engine in rpm
7  CV=42000; //The calorific value of the fuel in kJ/kg
8  C=86; //The composition of carbon in the fuel in
    percent
9  H=13; //The composition of Hydrogen in the fuel in
    percent
10 NC=1; //The non combustibles present in the fuel in
    percent
11 na=85; //The absolute volumetric efficiency in

```

```

    percent
12 ni=38; //The indicated thermal efficiency in percent
13 nm=80; //The mechanical efficiency in percent
14 ac=110; //The excess consumption of air in percent
15 sb=1.2; //The stroke to the bore ratio
16 da=1.3; //The density of air in kg/m^3
17 pi=3.141; //Mathematical constant of pi
18
19 // Calculations
20 saf=((C/100)*(32/12))+((H/100)*(8/1))*(1/0.23); //
    The stoichiometric air fuel ratio
21 aaf=saf*(1+1.1); //The actual air fuel ratio
22 Ma=(0.23*32)+(0.77*28); //The molecular weight of air
    in kg/kmol
23 a=(C/100)/12; //For carbon balance
24 b=(H/100)/2; //For hydrogen balace
25 x=aaf/Ma; //Number of kmol of air per kg of fuel
26 c=(0.21*x)-a-(b/2); //For oxygen balance
27 d1=0.79*x; //For nitrogen balance
28 ip=bp/(nm/100); //The indicated power in kW
29 mf=ip/[(ni/100)*CV]; //The mass flow rate of fuel in
    kg/s
30 ma=mf*aaf; //The mass flow rate of air in kg/s
31 Va=ma/da; //Actual volume flow rate in m^3/s
32 Vs=Va/(na/100); //The swept volume per second in m^3/
    s
33 d=[[Vs*(4/pi)*(1/1.2)*((2*60)/N)*(1/n)]^(1/3)]*1000;
    //The diameter of the bore in mm
34 L=1.2*d; //The length of the stroke in mm
35 T=a+c+d1; //The total composition in kmol
36 CO2=(a/T)*100; //The volume of CO2 in %
37 O2=(c/T)*100; //The volume of O2 in %
38 N2=(d1/T)*100; //The volume of N2 in %
39
40 //Output
41 printf(' The volumetric composition of dry exhaust
    gas : \n    1) CO2 = %3.5f kmol    and    volume =
    %3.2f percent \n    2) O2 = %3.5f kmol    and

```

volume = %3.2f percent \n 3) N2 = %3.5f kmol
 and volume = %3.2f percent \n The bore of the
 engine = %3.0f mm \n The stroke of the engine =
 %3.1f mm ',a,CO2,c,O2,d1,N2,d,L)

Scilab code Exa 16.10 Heat balance sheet

```

1  clc
2  clear
3  //Input data
4  d=0.18; //The diameter of the cylinder in m
5  pi=3.141; //Mathematical constant of pi
6  L=0.24; //The length of the stroke in m
7  t=30; //Duration trail in min
8  N=9000; //Number of revolutions
9  Ne=4450; //Total number of explosions
10 pmi=5.35; //Gross imep in bar
11 pp=0.35; //Pumping imep in bar
12 W=40; //Net load on brake wheel in kg
13 dd=0.96; //Diameter of the brake wheel drum in m
14 dr=0.04; //Diameter of the rope in m
15 V=2.6; //Volume of gas used in m^3
16 pg=136; //pressure of gas in mmof Hg
17 dg=0.655; //The density of gas in kg/m^3
18 T=290; //The ambient temperature of air in K
19 CV=19000; //The calorific value of the fuel in kJ/m^3
20 ta=40; //Total air used in m^3
21 p=720; //Pressure of air in mm of Hg
22 Te=340; //Temperature of exhaust gas in degree
    centigrade
23 Cpg=1.1; //Specific heat of gas in kJ/kgK
24 C=80; //Cooling water circulated in kg
25 Tr=30; //Rise in temperature of cooling water in
    degree centigrade
26 R=287; //Real gas constant in J/kgK
  
```

```

27
28 // Calculations
29 ip=(pmi-pp)*10^5*L*(pi/4)*d^2*(Ne/(30*60))*(1/1000);
    //The indicated power in kW
30 bp=(pi*(N/(30*60))*W*9.81*(dd+dr)*(1/1000)); //The
    brake power in kW
31 pgs=760+(pg/13.6); //Pressure of gas supplied in mm
    of Hg
32 Vg=((pgs*V)/290)*(273/760); //The volume of gas in m
    ^3
33 Q=(Vg*CV)/30; //Heat supplied by gas used at NTP in
    kJ/min
34 Qbp=bp*60; //Heat equivalent of bp in kJ/min
35 Qc=(C/t)*4.18*Tr; //Heat lost to cooling medium in kJ
    /min
36 Va=[((p*ta)/T)*(273/760)]/30; //Volume of air used in
    kg/min
37 da=(1.013*10^5)/(R*273); //The density of air in kg/m
    ^3
38 ma=Va*da; //Mass of air used in kg/min
39 mg=(Vg/30)*dg; //Mass of gas at NTP in kg/min
40 me=ma+mg; //Total mass of exhaust gas in kg/min
41 Qe=me*Cpg*(Te-(T-273)); //Heat loss to exhaust gas in
    kJ/min
42 Qu=Q-(Qe+Qc+Qbp); //Unaccounted heat loss in kJ/min
43 nm=(bp/ip)*100; //Mechanical efficiency in percent
44 ni=((ip*60)/Q)*100; //Indicated thermal efficiency in
    percent
45 x=((Qbp/1571)*100); //percentage heat in bp
46 y=((Qc/1571)*100); //Percent heat lost to cooling
    water
47 z=((Qe/1571)*100); //Percent heat to exhaust gases
48 k=((Qu/1571)*100); //Percent heat unaccounted
49
50 //Output
51 printf('

```

n	Heatinput	kJ/min
---	-----------	--------

percent	Heat expenditure	kJ/min	
percent	\n		
\n			
Heat			
\n			
	supplied	1571	100
(a)	Heat in bp	%3.1 f	%3.1 f
%3.1 f	\n		
(b)	Heat loss to cooling water	%3.1 f	%3.1 f
\n			
(c)	Heat to exhaust gas	%3.1 f	%3.1 f
\n			
(d)	Unaccounted heat	%3.1 f	%3.1 f
\n			
\n The mechanical efficiency = %3.2 f			
percent	\n The Indicated thermal efficiency = %3		
.1 f	percent ', Qbp, x, Qc, y, Qe, z, Qu, k, nm, ni)		

Scilab code Exa 16.11 Heat balance sheet

```

1  clc
2  clear
3  //Input data
4  bp=30; //The brake power in kw
5  mf=10; //Mass flow rate of fuel in kg/h
6  CV=42000; //Calorific value of the fuel in kJ/kg
7  mw=9; //Mass flow rate of water in kg/min
8  Tr=60; //Rise in temperature of the cooling water in
    degree centigrade
9  mwe=9.5; //Mass flow rate of water through exhaust
    gas calorimeter in kg/min

```

```

10 Tc=40; //Rise in temperature when passing through
    calorimeter in degree centigrade
11 Te=80; //Temperature of exhaust gas leaving the
    calorimeter in degree centigrade
12 a=20; //Air fuel ratio
13 T=17; //Ambient temperature in degree centigrade
14 Cpw=4.18; //Specific heat of water in kJ/kgK
15 Cpg=1; //Mean specific heat of gas in kJ/kgK
16
17 //Calculations
18 Qf=(mf/60)*CV; //Heat supplied by fuel in kJ/min
19 Qbp=bp*60; //Heat equivalent to bp in kJ/min
20 Qc=mw*Cpw*Tr; //Heat carried away by the jacket
    cooling water in kJ/min
21 mg=(mf/60)+(mf/60)*a; //Mass of exhaust gas formed in
    kg/min
22 Qe=(mwe*Cpw*Tc)+(mg*Cpg*(Te-T)); //Heat carried away
    by exhaust gas in kJ/min
23 Qu=Qf-(Qbp+Qc+Qe); //Unaccounted heat in kJ/min
24 x=((Qbp/Qf))*100; //Percentage heat in bp
25 y=(Qc/Qf)*100; //Percentage loss of cooling water
26 z=(Qe/Qf)*100; //Percentage loa of heat to exhaust
    gases
27 k=(Qu/Qf)*100; //Percentage heat loss unaccounted
28
29 //Output
30 printf( '

```

n	Heat input	kJ/min	percent	
	Heat expenditure		kJ/min	
	percent	\n		
n	Heat supplied by fuel	%3.0 f	100	(a)
	Heat in bp	%3.0 f		%3
.2 f	\n			
				(b)
	Heat loss to cooling water	%3.0 f		%3
.2 f	\n			

```

Heat to exhaust gases          %3.0 f          (c)
.2 f          \n                %3

Unaccounted heat loss          %3.0 f          (d)
.2 f          \n                %3
total                          %3.0 f          100
total                          %3.0 f
100          \n

```

```

', Qf , Qbp , x , Qc , y , Qe , z , Qu , k , Qf , Qf )

```

Scilab code Exa 16.12 Heat balance sheet

```

1  clc
2  clear
3  //Input data
4  n=4; //Number of cylinders
5  d=0.085; //The diameter of the bore m
6  L=0.095; //The length of the stroke in m
7  tr=0.35; //Torque radius in m
8  N=3000; //The speed of the engine in rpm
9  w=430; //Net brake load in N
10 w1=300; //Net brake load produced at the same speed
    by three cylinders in N
11 mf=0.24; //The mass flow rate of fuel in kg/min
12 CV=44000; //The calorific value of the fuel in kJ/kg
13 mw=65; //Mass flow rate of water in kg/min
14 Tw=12; //The rise in temperature in degree centigrade
15 a=15; //The air fuel ratio
16 Te=450; //The temperature of the exhaust gas in
    degree centigrade
17 Ta=17; //Ambient temperature in degree centigrade
18 p=76; //Barometric pressure in cm of Hg
19 H=15.5; //The proportion of hydrogen by mass in the
    fuel in percent

```

```

20 Cpe=1; //The mean specific heat of dry exhaust gas in
    kJ/kgK
21 Cps=2; //The specific heat of super heated steam in
    kJ/kgK
22 Cpw=4.18; //The specific heat of water in kJ/kgK
23 Ts=100; //At 76 cm of Hg The temperature in degree
    centigrade
24 hfg=2257; //The Enthalpy in kJ/kg
25 pi=3.141; //Mathematical constant of pi
26 R=287; //Real gas constant in J/kgK
27
28 // Calculations
29 bp=(2*pi*N*w*tr)/(60*1000); //The brake power in kW
30 bp1=(2*pi*N*w1*0.35)/(60*1000); //The brake power
    when each cylinder is cut off in kW
31 ip=bp-bp1; //Indicated power per cycle in kW
32 ip1=n*ip; //Indicated power of the engine in kW
33 imep=[(ip1*60*1000)/(L*(pi/4)*d^2*(N/2)*n)]/10^5; //
    The indicated mean effective pressure in bar
34 ni=[(ip1*60)/(mf*CV)]*100; //Indicated thermal
    efficiency in percent
35 bsfc=(mf*60)/bp; //Brake specific fuel consumption in
    kg/kWh
36 Vs=(pi/4)*d^2*L*(N/2)*n; //Swept volume in m^3/min
37 ma=a*mf; //Mass flow rate of air in kg/min
38 da=(1*10^5)/(R*(Ta+273)); //The density of air in kg/
    m^3
39 Va=ma/da; //Volume of air flow in m^3/min
40 nv=[Va/Vs]*100; //Volumetric efficiency in percent
41 Qf=mf*CV; //Heat supplied by fuel in kJ/min
42 Qbp=bp*60; //The heat equivalent to bp in kJ/min
43 Qc=mw*Cpw*Tw; //Heat lost to cooling water in kJ/min
44 mv=9*(H/100)*mf; //Mass of water vapour in kg/min
45 me=ma+mf-mv; //Mass of dry exhaust gas in kg/min
46 Qe=me*Cpe*(Te-Ta); //Heat carried away by the exhaust
    gas in kJ/min
47 Qs=(mv*([Cpw*(Ts-Ta)]+hfg+(Cps*(Te-Ts)))); //Heat
    lost in steam in kJ/min

```

```

48 Qu=Qf-(Qbp+Qc+Qe+Qs); //Unaccounted heat loss in kJ/
    min
49 x=(Qbp/Qf)*100; //Percentage of heat in bp
50 y=(Qc/Qf)*100; //Percentage of heat loss in colling
    water
51 z=(Qe/Qf)*100; //Percentage heat loss in dry exhaust
    gas
52 k=(Qs/Qf)*100; //Percentage heat lost to steam
53 l=(Qu/Qf)*100; //Percentage of unaccounted heat lost
54
55 //Output
56 printf('

```

n	Heat input	kJ/min	percent
	Heat expenditure	kJ/min	
	percent		

n	Heat supplied by fuel	%3.0 f	100
	(a) Heat in bp		%3.0 f
	%3.2 f		\n
	(b) Heat lost to cooling water	%3.0 f	%3
	.2 f		\n
	(c) Heat to dry exhaust	%3.0 f	%3
	.2 f		\n
	(d) Heat lost in steam	%3.0 f	%3
	.2 f		\n
	(e) Unaccounted heat loss	%3.0 f	%3
	.2 f		\n
	total	%3.0 f	
	100	Total	
	%3.0 f	100	\n

```

n \n The indicated mean effective pressure = %3.2
f bar \n The indicated thermal efficiency = %3.1f
percent \n The brake specific fuel consumption =

```

```
%3.4f kg/kWh \n The volumetric efficiency = %3.1
f percent ', Qf, Qbp, x, Qc, y, Qe, z, Qs, k, Qu, l, Qf, Qf,
imep, ni, bsfc, nv)
```
