Scilab Textbook Companion for
Fundamentals Of Internal Combustion Engines
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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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List of Scilab Codes

Chapter 2

Air Standard Cycles and Their Analysis

Scilab code Exa 2.1 The Ideal power develped

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

//Calculations
```

```
Vs=(pi/4)*d^2*L;//Swept volume in cm^3
V1=Vs+Vc;//According to pv diagram Total volume i.e sum of swept and clearance volume in cm^3
V2=Vc;//Volume according to pv diagram in cm^3
r=V1/V2;//Compression ratio
T2=T1*r^(g-1);//In isentropic process, Temperature at point 2 in degree centigrade
P2=P1*r^g;//In isentropic process, Pressure at point 2 in bar
P3=P2*(T3/T2);//In constant volume, process Pressure at point 3 in bar
T4=T3*(1/r)^(g-1);//In isentropic process, Temperature at point 4 in degree centigrade
P4=P3*(1/r)^(g);//In isentropic process, Pressure at point 4 in bar
no=(1-(1/r)^(g-1))*100;//Air standard efficiency of otto cycle
Q1=Cv*(T3-T2);//Heat supplied in kJ/kg
Q2=Cv*(T4-T1);//Heat rejected in kJ/kg
W=Q1-Q2;//Work done per unit mass in kJ/kg
m=[(P1*10^5*V1*10^-6)/(R*T1)]/1000;//The amount of mass in kg
W1=W*m;//Work done in kJ
pm=[(W1*10^3)/(Vs*10^-6)]/10^5;//Mean effective pressure in N/m^2
P=W1*(c/60);//Power developed in kW

//Output
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 = %3.3f 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

```
clc
clear
//Input data
CV=42000;//The calorific value of the fuel in kJ/kg
pa=5//Percentage of compression
Pa=1.2;//Pressure in the cylinder at 5% compression stroke
pb=75//Percentage of compression
Pb=4.8;//Pressure in the cylinder at 75% compression stroke
g=1.3;//polytropic index
g1=1.4//Isentropic index
n=0.6;//Air standard efficiency


//Calculations
V=(Pb/Pa)^(1/1.3);//Ratio of volumes
r=(V*(pb/100)-(pa/100))/((1-(pa/100))-(V*(1-(pb/100))))//Compression ratio
n1=((1-(1/r)^(g1-1)))*100//Relative efficiency
nthj=n*(n1/100)//Indicated thermal efficiency
x=(1/(CV*nthj))*3600//Specific fuel consumption in kg/kW.h

//Output
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

```
clc
clear
//Input data
d=0.2;//The diameter of the cylinder bore in m
L=0.3;//The length of the stroke in m
P1=1;//The pressure at the beginning of the compression in bar
T1=300;//The temperature at the beginning of the compression in K
r=16;//Compression ratio
V=0.08;//Cutt off takes place at 8& of the stroke
pi=3.141;//Mathematical constant value of pi
R=0.287;//Real gas constant in kJ/kgK
g=1.4;//Isentropic index
Cp=1.005;//Specific heat at constant prassure in kJ/kgK
Cv=0.718;//specific heat at constant volume for air in kJ/kgK

//Calculations
Vs=(pi/4)*d^2*L;//Swept volume in m^3
Vc=Vs/(r-1);//Clearance volume in m^3
V2=Vc;//Volume at point 2 in m^3
V1=Vs+Vc;//Volume at point 1 in m^3
m=(P1*10^5*V1)/(R*T1);//The amount of mass in kg
P2=P1*(r^g);//Pressure at point 2 in bar
P3=P2;//Pressure at point 3 in bar
T2=T1*r^(g-1);//Temperature at point 2 in K
V3=(V*Vs)+V2;//Volume at point 3 in m^3
C=V3/V2;//Cut off ratio
T3=C*T2;//Temperature at point 3 in K
P4=P3*(C/r)^g;//Pressure at the point 4 in bar
T4=T3*(C/r)^(g-1);//Temperature at point 4 in K
V4=V1;//Volume at point 4 in m^3
Q1=[m*Cp*(T3-T2)]/1000;//Heat supplied in kJ
Q2=[m*Cv*(T4-T1)]/1000;//Heat rejected in kJ
W=[Q1-Q2];//Work done per cycle in kJ
na=(W/Q1)*100;//Air standard efficiency
```

```
Pm=[W*1000/Vs]/10^5;//Mean effective pressure in bar

//Output
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

```
clc
clear
//Input data
Pm=7;//The mean effective pressure of a diesel cycle in bar
r=12;//The compression ratio
P1=1;//Initial pressure in bar
g=1.4;//Isentropic index

//Calculations
function[f] = F(x);//function definition
    f = 45.4*x- 12*x^1.4 -64.2;
endfunction
x = 1;//Initial guss
function[z] = D(x)//Derivative
    z= 3*x^2 - 3;
endfunction
y = fsolve(x,F, D);
C=y;//The cut off ratio
```

```
na=[1-(1/(r^(g-1)))*[((C^g)-1)/(g*(C-1))]]*100;//Air standard efficiency

//Output
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

```
clc
clear
//Input data
m=30;//The air fuel ratio by mass
T1=300;//The temperature of air at the beginning of the compression in K
r=16;//The compression ratio
CV=42000;//The calorific value of the fuel in kJ/kg
g=1.4;//Isentropic index
Cp=1.005;//Specific heat at constant prassure in kJ/kgK

//Calculations
T2=T1*(r^(g-1));//Temperature at point 2 in K
T3=[(1/m)*(CV/Cp)]+T2;//Temperature at point 3 in K
C=T3/T2;//The cut off ratio
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

//Output
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

```
clc
clear
//Input data
p1=1//Inlet pressure in bar
p2=32.425//Pressure at the end of isentropic
   compression in bar
r=6//Ratio of expansion
r1=1.4//Isentropic index

//Calculations
rc=(p2/p1)^(1/r1)//Compression ratio
b=(rc/r)//cut-off ratio
n=(1-((b^r1-1)/(rc^(r1-1)*r1*(b-1))))*100//Air-
   standard efficiency
pm=((p1*rc^r1*n/100*r1*(b-1))/((r1-1)*(rc-1)))//Mean
    effective pressure in bar

//Output
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

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

```
Cv=0.718;//specific heat at constant volume for air in kJ/kgK
Cp=1.005;//specific heat at constant pressure for air in kJ/kgK
R=0.287;//Real gas constant in kJ/kgK

//Calculations
T2=(T1*rc^(g-1))//Temperature in K
p2=(p1*rc^g)//Pressure in bar
T3=(T2*(pm/p2))//Temperature in K
T4=(Cv*(T3-T2))/(2*Cp)+T3//Temperature in K
b=(T4/T3)//Cut-off ratio
T5=(T4*(b/rc)^(g-1))//Temperature in K
p5=(p1*(T5/T1))//Pressure in bar
Q1=(Cv*(T3-T2))+(Cp*(T4-T3))//Heat supplied per unit mass in kJ/kg
Q2=Cv*(T5-T1)//Heat rejected per unit mass in kJ/kg
W=(Q1-Q2)//Workdone in kJ/kg
n=(W/Q1)*100//Air standard efficiency
Vs=((1*R*1000*T1)/(p1*10^5))*(1-1/rc)//Swept volume in m^3/kg
pmean=((W*1000)/Vs)/10^5//Mean-effective pressure in bar

//Output
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

```
clc
clear
//Input data
r=12;//Compression ratio
B=1.615;//Cut off ratio
p3=52.17;//Maximum pressure in bar
p4=p3;//Maximum pressure in bar
p1=1;//Initial pressure in bar
T1=(62+273);//Initial temperature in K
n=1.35;//Indices of compression and expansion
g=1.4;//Adiabatic exponent
mR=0.287;//Real gas constant in kJ/kgK
Cv=0.718;//specific heat at constant volume for air in kJ/kgK
Cp=1.005;//specific heat at constant pressure for air in kJ/kgK

//Calculations
T2=T1*r^(n-1);//The temperature at point 2 in K
p2=p1*(r)^n;//The pressure at point 2 in bar
T3=T2*(p3/p2);//The temperature at point 3 in K
T4=T3*B;//The temperature at point 4 in K
T5=T4*(B/r)^(n-1);//The temperature at point 5 in K
Q12=[(g-n)/(g-1)]*mR*[(T1-T2)/(n-1)];//Heat transfer during the process 1-2 for unit mass in kJ/kg
Q23=Cv*(T3-T2);//Heat transfer during the process 2-3 for unit mass in kJ/kg
Q34=Cp*(T4-T3);//Heat transfer during the process 3-4 for unit mass in kJ/kg
Q45=((g-n)/(g-1))*mR*((T4-T5)/(n-1));//Heat transfer during the process 4-5 for unit mass in kJ/kg
Q51=Cv*(T1-T5);//Heat transfer during the process 5-1 for unit mass in kJ/kg
Q1=Q23+Q34+Q45;//Heat supplied in kJ/kg
Q2=-Q12+(-Q51);//Heat rejected in kJ/kg
W=Q1-Q2;//Work done in kJ/kg
E=[W/Q1]*100;//Efficiency in percentage
Vs=[(mR*T1)/p1]*(r-1)/r;//Swept volume for unit mass
```

```
in m^3/kg
pm=[W*1000/Vs]/10^3;//Mean effective pressure in bar

//Output
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

```
clc
clear
//Input data
p1=1//Inlet pressure in bar
T1=27+273//Temperature in K
p2=4//pressure at point 2 in bar
p3=16//Maximum pressure in bar
Cv=0.573//specific heat at constant volume for gas in kJ/kgK
Cp=0.761//specific heat at constant pressure for gas in kJ/kgK

//Calculations
g=(Cp/Cv)//Adiabatic index
T2=(T1*(p2/p1)^((g-1)/g))//Temperature in K
T3=(p3/p2)*T2//Temperature in K
T4=T3*(p1/p3)^((g-1)/g)//Temperature in K
Q1=Cv*(T3-T2)//Heat supplied in kJ/kg
Q2=Cp*(T4-T1)//Heat rejected in kJ/kg
W=Q1-Q2//Workdone in kJ/kg
n=(W/Q1)*100//Efficiency of cycle
r=(p2/p1)^(1/g)//Compression ratio
```

```
R=(Cp-Cv)//Universal gas constant in kJ/kg.K
Vs=(R*1000*T1*(r-1))/(p1*10^5*r)//Swept volume in m^3/kg
pm=(W/(Vs*100))//Mean effective pressure in bar

//Output
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

```
clc
clear
//Input data
E=20;//Methanol burned with excess air in percentage
p=1;//Pressure of air in bar
t=27;//Temperature of air in degree centigrade
O=32;//The molecular weight of oxygen
N=28;//The molecular weight of nitrogen
R=8314;//Universal gas constant in Nm/kmolK
C=32;//Molecular weight of methanol
CO=44;//Molecular weight of the carbondioxide
H=18;//Molecular weight of the water

//Calculations
S=[(1.8*O)+(6.768*N)]/C;//Stoichiometric air/fuel ratio
A=[(1.8*O)+(6.768*N)]/C;//Actual air/fuel ratio
M=1.8+6.768;//1 kmole of fuel reacts with air in kmole
V=(M*R*(t+273))/(p*10^5);//Volume of air in m^3/kmole fuel
```

```
T=(1+1.8+6.768);//The total number of moles in the reactants when excess air is supplied in moles
Cm=(1/T);//Mole fraction of the methanol
Om=(1.8/T);//Mole fraction of the oxygen
Nm=(6.768/T);//Mole fraction of the nitrogen
Mr=(Cm*C)+(Om*O)+(Nm*N);//Molecular weight of reactants
Tp=(1+2+6.768+0.3);//Total number of moles in the products in moles
COm=(1/Tp);//Mole fraction of the carbondioxide
Hp=(2/Tp);//Mole fraction of the water
Np=(6.768/Tp);//Mole fraction of the nitrogen
Op=(0.3/Tp);//Mole fraction of the oxygen
Mp=(COm*CO)+(Hp*H)+(Np*N)+(Op*O);//Molecular weight of products
Pp=(Hp*p);//Partial pressure of water vapour in bar
D=60;//The dew point is the saturation temp corresponding to partial pressure in degree centigrade

//Output
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

```
clc
clear
//Input data
C1=40;//The content of C7H16 in the fuel in percentage
```

```
C2=60;//The content of C8H18 in the fuel in percentage
d=0.12;//The diameter of the bore in m
l=0.145;//The length of the bore in m
r=8.5;//Compression ratio
p=1.1;//Pressure at exhaust stroke in bar
T=720;//The temperature at the exhaust stroke in K
pi=3.141;//Mathematical constant pi
O=32;//The molecular weight of oxygen
N=28;//The molecular weight of nitrogen
C3=100;//Molecular weight of C7H16
C4=114;//The molecular weight of C8H18
R=8314;//Universal gas constant in Nm/kmolK
CO2=44;//Molecular weight of the carbondioxide
C5=28;//Molecular weight of the carbonmonoxide
H=18;//Molecular weight of the water

//Calculations
N2=100-(12+1.5+2.5);//Percentage of nitrogen in the dry products of combustion
Y=84/3.76;//The number of moles oxygen is supplied
X=13.5/7.6;//Moles of carbon
Z=(22.34-15.25)*2;//The number of moles of hydrogen
Hl=(6.4+10.8)/2;//Number of moles of hydrogen on L.H.S
Hr=7.98;//Number of moles of hydrogen on R.H.S
Hd=Hl-Hr;//Difference of hydrogen moles
A=[[12.58*(O+(3.76*N))]/[((C1/100)*C3)+((C2/100)*C4)]];//The Air/fuel ratio
Vs=(pi/4)*d^2*l;//Swept volume of the cylinder in m^3
Vc=Vs/(r-1);//Clearance volume in m^3
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
R1=R/M;//Gas constant in J/kgK
m=[(p*10^5)*Vc]/[R1*T];//Mass of the exhaust gases in the clearance space in kg
```

```

//Output
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

```
clc
clear
//Input data
C=0.86;//The amount of carbon content in the 1kg of
    fuel by weight in kg
H=0.05;//The amount of hydrogen content in the 1kg
    of fuel by weight in kg
O=0.02;//The amount of oxygen content in the 1kg of
    fuel by weight in kg
S=0.005;//The amount of sulphur content in the 1kg
    of fuel by weight in kg
N=0.065;//The amount of nitrogen content in the 1kg
    of fuel by weight in kg
E=25;//The amount of excess air supplied in
    percentage
o=32;//Molecular weight of the oxygen
co=44;//Molecular weight of the carbondioxide
c=12;//Molecular weight of the carbon
s=32;//Molecular weight of the sulphur
so=64;//Molecular weight of sulphur dioxide
n=28;//Molecular weight of the nitrogen

//Calculations
o1=(o/c)*C;//The amount of oxygen required for 0.86
    kg of carbon in kg
coa=(co/c)*C;//The amount of carbondioxide produced
    for 0.86 kg of carbon in kg
```

```
o2=(o/4)*H;//The amount of oxygen required for 0.05 kg of hydrogen in kg
h2=(36/4)*H;//The amount of water produced for 0.05 kg of hydrogen in kg
o3=(o/s)*S;//The amount of oxygen required for 0.005 kg of sulphur in kg
s1=(so/s)*S;//The amount of sulphur dioxide produced for 0.005 kg of sulphur in kg
To=o1+o2+o3;//Total oxygen required for the complete combustion of fuel in kg
Tt=To-O;//The amount of oxygen required per kg of fuel for complete combustion theoretically in kg
As=(Tt*100)/23;//Stoichiometric air/fuel ratio
as=As*(1+(E/100));//The actual quantity of air supplied per kg of fuel in kg
o2a=0.23*(E/100)*As;//The oxygen in the excess air in kg
n2a=0.77*(1+(E/100))*As;//The nitrogen in the air in kg
n2e=n2a+N;//Total nitrogen in the exhaust in kg
Tw=coa+n2e+o2a;//Total weight in kg
pco=(coa/Tw)*100;//Percentage composition of carbondioxide
pn=(n2e/Tw)*100;//Percentage composition of nitrogen
po=(o2a/Tw)*100;//Percentage composition of oxygen
mco=(coa/co);//Moles of carbondioxide
mn=(n2e/n);//Moles of nitrogen
mo=(o2a/o);//Moles of oxygen
Tm=mco+mn+mo;//Total moles
vco=(mco/Tm)*100;//Volumetric analysis of carbondioxide in percentage
vn=(mn/Tm)*100;//Volumetric analysis of nitrogen in percentage
vo=(mo/Tm)*100;//Volumetric analysis of oxygen in percentage

//Output
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

```
clc
clear
//Input data
CO=12;//The composition of carbondioxide of combustion by volume in percentage
C=0.5;//The composition of carbonmoxide of combustion by volume in percentage
O=4;//The composition of oxygen of combustion by volume in percentage
N=83.5;//The composition of nitrogen of combustion by volume in percentage
o=32;//Molecular weight of the oxygen
co=44;//Molecular weight of the carbondioxide
c=12;//Molecular weight of the carbon
s=32;//Molecular weight of the sulphur
so=64;//Molecular weight of sulphur dioxide
n1=28;//Molecular weight of the nitrogen
h=2;//Molecular weight of the hydrogen

//Calculations
m=12+0.5;//Balancing carbon
x=N/3.76;//Balancing nitrogen
z=[x-(CO+(C/2)+O)]*2;//Balancing oxygen
n=z*h;//Balancing hydrogen
Af=[(x*o)+(N*n1)]/[(m*c)+(n)];//Air/fuel ratio
```

```
As=[(18.46*o)+(69.41*n1)]/173.84;//Stoichiometric air/fuel ratio
Ta=(Af/As)*100;//Percent theoretical air
mc=[(m*c)/173.84]*100;//Composition of carbon on mass basis in percent
mh=(n/173.84)*100;//Composition of hydrogen on mass basis in percent

//Output
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

```
clc
clear
//Input data
C=86;//The composition of carbon in the fuel by weight in percentage
H=14;//The composition of hydrogen in the fuel by weight in percentage
e=1.25;//Equivalent ratio
o=32;//Molecular weight of the oxygen
co=44;//Molecular weight of the carbondioxide
c=12;//Molecular weight of the carbon
s=32;//Molecular weight of the sulphur
so=64;//Molecular weight of sulphur dioxide
n=28;//Molecular weight of the nitrogen
h2=2;//Molecular weight of the hydrogen
Fc=0.86;//Fraction of C

//Calculations
```

```
Ra=1/Fc;//Relative air/fuel ratio
x=2*[1+(0.9765/2)-(1.488*0.8)];//By oxygen balance
Tm=0.5957+0.4043+4.476;//Total number of moles of dry exhaust gas
vc=(0.5957/Tm)*100;//Volumetric analysis of carbonmonoxide of combustion in percentage
vco=(0.4043/Tm)*100;//Volumetric analysis of carbondioxide of combustion in percentage
vn=(4.476/Tm)*100;//Volumetric analysis of nitrogen of combustion in percentage

//Calculations
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

```
clc
clear
//Input data
t=25;//The temperature of both reactants and products in degree centigrade
p=1;//The pressure of both reactants and products in bar

//Calculations
h=0;//Enthalpy of all elements at given temp and pressure
hf1=-103.85;//The enthalpy of the compound C3H8 in the reactants side at given temp and pressure in MJ/kmol
hf2=-393.52;//The enthalpy of carbondioxide for the given temp and pressure in MJ/kmol
```

```
hf3=-285.8;//The enthalpy of the water for the given temp and pressure in MJ/kmol
hf4=[3*hf2]+[4*hf3];//Total enthalpy in the products side in MJ/kmol
Q=hf4-hf1;//The heat transfer per mole of fuel in MJ/kmol fuel

//Output
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

```
clc
clear
//Input data
t=25;//The temperature of the air entering the diesel engine in degree centigrade
T=600;//The temperature at which the products are released in K
Ta=200;//Theoretical air used in percentage
Q=-93;//Heat loss from the engine in MJ/kmol fuel
f=1;//The fuel rate in kmol/h

//Calculations
hfr=-290.97;//The enthalpy of C12H26 for the given conditions in the reactants side in MJ/kmol
h1=-393.52;//Enthalpy of carbondioxide at formation state in MJ/kmol
h11=12.916;//The change in enthalpy for the given temp of CO2 in MJ/kmol
hfc=h1+h11;//The enthalpy of the carbondioxide in MJ/kmol
h2=-241.82;//The enthalpy of water at formation state in MJ/kmol
```

```
h22=10.498;//The change in enthalpy for the given
    temp of water in MJ/kmol
hfh=h2+h22;//The enthalpy of the water in MJ/kmol
h3=0;//Enthalpy of the oxygen gas
h33=9.247;//The change in enthalpy for the given
    temp of oxygen in MJ/kmol
hfo=h3+h33;//The enthalpy of oxygen in MJ/kmol
h4=0;//The enthalpy of the nitrogen gas
h44=8.891;//The change in enthalpy of the nitrogen
    for the given temp in MJ/kmol
hfn=h4+h44;//The enthalpy of nitrogen in MJ/kmol
hfp=(12*hfc)+(13*hfh)+(18.5*hfo)+(139.12*hfn);//The
    total enthalpy on the products side in MJ/kmol
W=Q+hfr-hfp;//The work in MJ/kmol fuel
W1=(f*W*10^3)/3600;//The work in kW

//Output
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

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

```

//Calculations
hfc=-259.28;//The enthalpy of the compound C8H18 for the given conditions in MJ/kmol fuel
hfo1=3.029;//The enthalpy of the oxygen gas in MJ/kmol fuel
hfn1=2.971;//The enthalpy of the nitrogen gas in MJ/kmol fuel
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
hfco=-393.52;//The enthalpy of carbondioxide for formation state in MJ/kmol fuel
hfco1=17.761;//The change in enthalpy of the carbondioxide for temp difference in MJ/kmol fuel
hfh=-241.82;//The enthalpy of water for formation state in MJ/kmol fuel
hfh1=14.184;//The change in the enthalpy of the water for temp difference in MJ/kmol fuel
hfo2=12.502;//The enthalpy of the oxygen gas in MJ/kmol fuel
hfn2=11.937;//The enthalpy of the nitrogen gas in MJ/kmol fuel
HP=(8*(hfco+hfco1))+(9*(hfh+hfh1))+(6.25*hfo2)+(70.5*hfn2);//The total enthalpy on the products side in MJ/kmol fuel
H=HP-HR;//The total change in enthalpy of reactants and products in MJ/kmol fuel
nf=([Q-P]*3600)/[H*10^3];//The fuel rate in kmol/s
M=(8*C)+(18*h);//Molecular weight of fuel
mf=nf*M;//The fuel consumption in kg/h

//Output
printf(' The fuel consumption for complete combustion is %3.2f kg/h',mf)
```

Scilab code Exa 3.9 The heat transfer

```
clc
clear
//Input data
t=25;//Temperature at which fuel is used for combustion in degree centigrade
p=1;//The pressure at which fuel is used in bar
T=400;//The temperature of the products of combustion in K
R=8.314*10^-3;//Universal gas constant

//Calculations
hfc=-103.85;//Enthalpy of the compound C3H8 in MJ/kmol fuel
HR=[1*(hfc-(R*(t+273)))]+[5*(-R*(t+273))];//The total enthalpy of the reactants in MJ/kmol fuel
hfco=-393.52;//The enthalpy of the carbondioxide in MJ/kmol fuel
hfco1=4.008;//The change in enthalpy of the carbondioxide for the given conditions in MJ/kmol fuel
hfh=-241.82;//The enthalpy of the water in MJ/kmol fuel
hfh1=3.452;//The change in enthalpy of the water for the given conditions in MJ/kmol fuel
HP=[3*(hfco+hfco1-(R*T))]+[4*(hfh+hfh1-(R*T))];//The total enthalpy of the products in MJ/kmol fuel
Q=HP-HR;//The total change in the enthalpy of reactans and products in MJ/kmol fuel
Q1=-Q;//Heat liberated in kJ/mol propane

//Output
printf('The heat transfer per mole of propane = %3.1
```

```
   f kJ/mol propane',Q1)
```

Scilab code Exa 3.10 The enthalpy of reaction

```
clc
clear
//Input data
T=1500;//The given temperature in K

//Calculations
hfco=-393.52;//The enthalpy of formation for
   carbondioxide in MJ/kmol
hf1=61.714;//The change in enthalpy for actual state
    and reference state in MJ/kmol
HP=hfco+hf1;//The total enthalpy in the products
   side in MJ/kmol
hfc=-110.52;//The enthalpy of formation for
   carbonmonoxide in MJ/kmol
hf2=38.848;//The change in enthalpy of CO for actual
    and reference state in MJ/kmol
hfo=0;//The enthalpy of formation for oxygen gas
hf3=40.61;//The change in enthalpy of oxygen for
   different states in MJ/kmol
HR=[hfc+hf2]+[0.5*(hfo+hf3)];//The total enthalpy in
    the reactants side in MJ/kmol
H=HP-HR;//The enthalpy of combustion in MJ/kmol

//Output
printf(' The enthalpy of combustion is  %3.3f MJ/
   kmol CO ',H)
```

Scilab code Exa 3.11 The heat transfer

```
clc
clear
//Input data
E=30;//The amount of excess air in percentage
tp=400;//The temperature at which propane enters in K
ta=300;//The temperature at which air enters in K
T=900;//The temperature at which products leave in K
m=83.7;//The average molar specific heat of propane at constant pressure in kJ/kmolK
Mp=44;//The molecular weight of propane

//Calculations
hfc=-393.52;//The enthalpy of formation for carbondioxide in MJ/kmol
hf1=28.041;//The change in enthalpy of CO2 for actual and reference state in MJ/kmol
hfh=-241.82;//The enthalpy of formation for water in MJ/kmol
hf2=21.924;//The change in enthalpy of water for actual and reference state in MJ/kmol
hfn=0;//The enthalpy of nitrogen gas
hf3=18.221;//The change in enthalpy of nitrgen for actual and reference state in MJ/kmol
hfo=0;//The enthalpy of oxygen gas
hf4=19.246;//The change in enthalpy of oxygen for actual and reference state in MJ/kmol
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
hfp=-103.85;//The enthalpy of formation for propane in MJ/kmol
R=0.0837;//Universal gas constant
hfo1=0;//The enthalpy of oxygen gas
hf11=0.054;//The change in enthalpy of oxygen gas for actual and reference state in MJ/kmol
hfn1=0;//The enthalpy of nitrogen gas
hfn22=0.054;//The change in enthalpy of nitrogen for
```

```
actual and reference state in MJ/kmol
HR=[1*(hfp+(R*(tp-ta)))]+[6.5*(hfo1+hf11)]+[24.44*(hfn1+hfn22)];//The total enthalpy on the reactants side in MJ/kmol
Q=HP-HR;//The amount of heat liberated in MJ/kmol
Q1=[-Q/Mp];//The amount of heat liberated in MJ/kg

//Output
printf(' The amount of heat transfer per kg of fuel is  %3.0f MJ/kg',Q1)
```

Scilab code Exa 3.12 The standard enthalpy

```
clc
clear
//Input data
Ta=150;//The presence of Theoretical air

//Calculations
hfc=-393.52;//The enthalpy of formation for carbondioxide in MJ/kmol
hfh=-285.8;//The enthalpy of formation for water in MJ/kmol
hfon=0;//The enthalpy of formation for oxygen and nitrogen gas
hfch=-74.87;//The enthalpy of formation for methane in MJ/kmol
HP=[hfc]+[2*hfh];//The total enthalpy on the products side in MJ/kmol
HR=1*hfch;//The total enthalpy on the reactants side in MJ/kmol
H=HP-HR;//The total change in enthalpy of reactants and products in MJ/kmol
np=2;//Number of moles of product
nr=4;//Number of moles of reactant
```

```
n=np-nr;//The difference in moles
R=8.314*10^-3;//Universal gas constant
t=298;//The temperature in K
U1=H-[n*R*t];//The standard internal energy in MJ/kmol
hfh1=-241.82;//The enthalpy of formation for water in MJ/kmol
HP1=[1*hfc]+[2*hfh1];//The total enthalpy on the products side in MJ/kmol
H1=HP1-HR;//The change in enthalpy for reactants and products in MJ/kmol
np1=4;//Number of moles of product
nr1=4;//Number of moles of reactant
n1=np1-nr1;//The difference in moles
U2=H1-[n1*R*t];//The standard internal energy in MJ/kmol

//Output
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

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

```
H=16;//The hydrogen content present in the fuel in
    percentage
t=25;//The temperature in degree centigrade
hfg=2442;//The enthalpy of vaporization for water in
     kJ/kg
c=12;//Molecular weight of carbon
h=2;//Molecular weight of hydrogen
co2=44;//Molecular weight of carbondioxide
h2o=18;//Molecular weight of water
o2=32;//Molecular weight of oxygen
R=8.314;//Universal gas constant in J/molK

//Calculations
CO2=[0.84*(co2/c)];//The amount of carbondioxide
    present per kg of fuel in kg
H2O=[0.16*(h2o/h)];//The amount of water present per
     kg of fuel in kg
cvd=H2O*hfg;//The difference in the higher and lower
     calorific value in kJ/kg fuel
HHV=cv+cvd;//The higher calorific value of the
    liquid fuel in kJ/kg fuel
np=3.08/co2;//number of moles of product in kmol/kg
    fuel
nr=3.52/o2;//The number of moles of reactant in kmol
    /kg fuel
n=np-nr;//The difference in the moles
HHVv=HHV+[n*R*(t+273)];//The higher calorific value
    at constant volume in kJ/kg fuel
LHVv=cv+[n*R*(t+273)];//The lower calorific value at
     constant volume in kJ/kg fuel

//Output
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

```
clc
clear
//Input data
E=100;//The amount of excess air in percent
T=298;//The temperature of reactants in K
nc=1;//Number of moles of propane

//Calculations
hfch=-103.85;//Enthalpy of formation for propane in MJ/kmol fuel
HR=nc*hfch;//Total enthalpy on the reactants side in MJ/kmol fuel
hfc=-393.52;//Enthalpy of formation for carbondioxide in MJ/kmol fuel
hfh=-241.82;//Enthalpy of formation for water in MJ/kmol fuel
hfon=0;//Enthalpy of formation for both oxygen and nitrogen gas
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
hfn=x/37.6;//trail to get the change in enthalpy of nitrogen in MJ/kmol
T1=1500;//Assuming the products temperature for fist trail in K
hfc1=61.714;//The change in enthalpy for corbondioxide for trail temp in MJ/kmol fuel
hfh1=48.095;//The change in enthalpy for water for trail temp in MJ/kmol fuel
hfo1=40.61;//The change in enthalpy for oxygen for trail temp in MJ/kmol fuel
hfn1=38.405;//The change in enthalpy for nitrogen
```

```
for trail temp in MJ/kmol fuel
HP1=(HR-x)+(3*hfc1)+(4*hfh1)+(5*hfo1)+(37.6*hfn1);//Total enthalpy of products for first trail in MJ/kmol fuel
T2=1600;//Assuming the products temperature for second trail in K
hfc2=67.58;//The change in enthalpy for corbondioxide for trail temp in MJ/kmol fuel
hfh2=52.844;//The change in enthalpy for water for trail temp in MJ/kmol fuel
hfo2=44.279;//The change in enthalpy for oxygen for trail temp in MJ/kmol fuel
hfn2=41.903;//The change in enthalpy for nitrogen for trail temp in MJ/kmol fuel
HP2=(HR-x)+(3*hfc2)+(4*hfh2)+(5*hfo2)+(37.6*hfn2);//Total enthalpy of products for second trail in MJ/kmol fuel
Te=[[(HR-HP1)/(HP2-HP1)]*(T2-T1)]+T1;//The eatimated adiabatic flame temperature in K

//Output
printf(' The adiabatic flame temperature for steady-flow process is  %3.1f K',Te)
```

Scilab code Exa 3.15 The adiabatic flame temperature

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

```
c=37.38*10^-6;//Given Constant
d=-36.49*10^-9;//Given Constant
e=12.22*10^-12;//Given Constant

//Calculations
hfc=-393.52;//Enthalpy of formation for carbondioxide in MJ/kmol fuel
hfh=-241.82;//Enthalpy of formation for water in MJ/kmol fuel
hfn=0;//Enthalpy of formation for nitrogen gas
HP=[1*hfc]+[2*hfh]+[7.52*hfn];//The enthalpy on the products side in MJ/kmol fuel
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
hfc1=-74.87;//The enthalpy of formation for methane in MJ/kmol fuel
hfh1=9.247;//The change in enthalpy of the water in MJ/kmol
hfn1=8.891;//The change in enthalpy of nitrogen in MJ/kmol
HR=[(hfc1+hch)+(2*hfh1)+(7.52*hfn1)];//The enthalpy on the reactants side in MJ/kmol
x=HR-HP;//The enthalpy for the remaining gases in the product side in MJ/kmol
hfn2=x/7.52;//The guess enthalpy for the nitrogen gas in MJ/kmol
Tc=3700;//The corresponding temperature for the enthalpy of guess nitrogen in K
T1=2800;//The temperature assumed for the first trail in K
hco1=140.444;//The change in enthalpy for the assume temp for carbondioxide in MJ/kmol
hh1=115.294;//The change in enthalpy for the assume temp for water in MJ/kmol
hn1=85.345;//The change in enthalpy for the assume temp for nitrogen in MJ/kmol
```

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

```
Tc2=3200;//Assume temperature for the second trail in K
hcoa2=165.331;//;//The change in enthalpy for the assume temp for carbondioxide in MJ/kmol
hha2=137.553;//The change in enthalpy for the assume temp for water in MJ/kmol
hna2=100.161;//The change in enthalpy for the assume temp for nitrogen in MJ/kmol
UP2=hcoa2+(2*hha2)+(7.52*hna2)+(HR-x)-(0.08746*Tc2);//The internal energy of products in MJ/kmol fuel
Tu=[[(UR1-UP1)/(UP2-UP1)]*(Tc2-Tc1)]+Tc1;//The adiabatic flame temperature at constant pressure process in K

//Output
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

```
clc
clear
//Input data
T=600;//Temperature at constant pressure process in K
p=1;//The pressure in atm
E=50;//The amount of excess air in percent
L=20;//The amount of less air in percent
cp=52.234;//Specific constant for methane in kJ/kmolK
T1=298;//Assume the normal temperature in K

//Calculations
hfch=-74.87;//The enthalpy of formation for
```

```
carbondioxide in MJ
hch=cp*(T-T1)*10^-3;//The change in enthalpy of carbondioxide in MJ
ho=9.247;//The change in enthalpy of oxygen in MJ
hn=8.891;//The change in enthalpy of nitrogen in MJ
HR=hfch+hch+(3*ho)+(11.28*hn);//The total enthalpy on the reactants side in MJ
hfc1=-393.52;//The enthalpy of formation of carbondioxide in MJ
hfh1=-241.82;//The enthalpy of formation of water in MJ
HP=hfc1+(2*hfh1);//The enthalpy of products side in MJ
x=HR-HP;//The change in enthalpy for the remaining in MJ
hn2=x/11.28;//The enthalpy of nitrogen assumed to be in MJ/kmol
Tc=2800;//The corresponding temperature in K
T1=2000;//The temperature for first trail in K
hfc11=91.45;//The enthalpy for the assume temp for carbondioxide in MJ
hfh11=72.689;//The change in enthalpy for the assume temp for water in MJ
hfn11=56.141;//The change in enthalpy for the assume temp for nitrogen in MJ
hfo11=59.199;//;//The change in enthalpy for the assume temp for oxygen in MJ
HP1=hfc11+(2*hfh11)+(11.28*hfn11)+(hfo11)+(HR-x);//The total enthalpy on the products side for first trail in MJ
T2=2100;//The temperature for second trail in K
hfc22=97.5;//The enthalpy for the assume temp for carbondioxide in MJ
hfh22=77.831;//The change in enthalpy for the assume temp for water in MJ
hfn22=59.748;//The change in enthalpy for the assume temp for nitrogen in MJ
hfo22=62.986;//;//The change in enthalpy for the
```

```
assume temp for oxygen in MJ
HP2=hfc22+(2*hfh22)+(11.28*hfn22)+(hfo22)+(HR-x);//The total enthalpy on the products side for second trail in MJ
Ta1=[[(HR-HP1)/(HP2-HP1)]*(T2-T1)]+T1;//The adiabatic temperature for constant pressure process in K
X=2*[2-1.6];//By balance oxygen
hfchr=-74.87;//The enthalpy of formation for methane in MJ
hor=9.247;//The change in enthalpy for oxygen in MJ
hnr=8.891;//The change in enthalpy for nitrogen in MJ
HRr=hfchr+hch+(1.6*hor)+(6.01*hnr);//The total enthalpy on reactants side in MJ
hfcop=-110.52;//The formation of enthalpy for carbonmoxide in MJ
hfcp=-393.52;//The formation of enthalpy for carbondioxide in MJ
hfhp=-241.82;//The formation of enthalpy for water in MJ
HPp=(0.8*hfcop)+(0.2*hfcp)+(2*hfhp);//The enthalpy on product side in MJ
Tp1=2000;//The temperature for first trail in K
hco11=56.739;//The change in enthalpy for CO in MJ
hco211=91.45;//The change in enthalpy for CO2 in MJ
hh11=72.689;//The change in enthalpy for water in MJ
hn11=56.141;//The change in enthalpy for nitrogen in MJ
HPp1=(0.8*hco11)+(0.2*hco211)+(2*hh11)+(6.016*hn11)-HPp;///The enthalpy on the products side for trail temp in MJ
Tp2=2400;//The temperature for second trail in K
hco22=71.34;//The change in enthalpy for CO in MJ
hco222=115.788;//The change in enthalpy for CO2 in MJ
hh22=93.604;//The change in enthalpy for water in MJ
hn22=70.651;//The change in enthalpy for nitrogen in
```

```
MJ
HPp2=(0.8*hco22)+(0.2*hco222)+(2*hh22)+(6.016*hn22)+HPp;///The enthalpy on the products side for trail temp in MJ
Tp3=2300;//The temperature for first trail in K
hco33=67.676;//The change in enthalpy for CO in MJ
hco233=109.671;//The change in enthalpy for CO2 in MJ
hh33=88.295;//The change in enthalpy for water in MJ
hn33=67.007;//The change in enthalpy for nitrogen in MJ
HPp3=(0.8*hco33)+(0.2*hco233)+(2*hh33)+(6.016*hn33)+HPp;///The enthalpy on the products side for trail temp in MJ
Ta2=[[(HRr-HPp3)/(HPp2-HPp3)]*(Tp2-Tp3)]+Tp3;//The adiabatic temperature for constant pressure process in K
hccc=-283.022;//The only combustible substance is CO in MJ/kmol
Q=-0.8*hccc;//The thermal energy loss in MJ/kmol fuel

//Output
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

```
clc
clear
//Input data
T1=3000;//Given temperature in K
```

```
T2=4000;//Given temperature in K
p=1;//The pressure in atm
KP1=1.117;//Natural logarithm of equilibrium constant at 3000 K
KP2=-1.593;//Natural logarithm of equilibrium constant at 4000 K

//Calculations
Kp1=exp(KP1);//The value of equilibrium constant at 3000 K
Kp2=exp(KP2);//The value of equilibrium constant at 4000 K
a1=0.4;//The dissociation of 1 mole of CO2 for the first trail
a2=0.5;//The dissociation of 1 mole of CO2 for the second trail
K1=3.674;//The value of equilibrium constant for the first trail
K2=2.236;//The value of equilibrium constant for the second trail
a12=[[(K1-Kp1)/(K1-K2)]*(a2-a1)]+a1;//The approximate dissociation of 1 mole of CO2
A12=a12*100;//The amount of CO2 will dissociate in percent
a3=0.9;//The dissociation of 1 mole of CO2 for the first trail
a4=0.89;//The dissociation of 1 mole of CO2 for the second trail
K3=0.1995;//The value of equilibrium constant for the first trail
K4=0.2227;//The value of equilibrium constant for the second trail
a23=[[(Kp2-K4)/(K3-K4)]*(a3-a4)]+a4;//The approximate dissociation of 1 mole of CO2
A23=a23*100;//The amount of CO2 will dissociate in percent

//output
```

```
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

```
clc
clear
//Input data
p=1;//Initial pressure in atm
T=300;//Initial temperature in K
Tc=2400;//To calculate the molefraction of the products at this temperature in K
KP1=3.866;//Natural logarithm of equilibrium constant at 2400 K for the equation

//Calculations
K1=exp(KP1);//The value of equilibrium constant at 2400 K
nr=1+0.5;//The number of moles of reactants
Pp=(p*Tc)/(nr*T);//Pressure exercted on the products side per mole in atm/mole
a=0.098;//The dissociation of 1 mole of CO2
np=(a+2)/2;//The number of moles of products
xco=[2*(1-a)]/(2+a);//Mole fraction of CO2
xc=[2*a]/(2+a);//Mole fraction of CO
xo=a/(2+a);//Mole fraction of O2
PP=5.333*np;//Pressure of the product in bar

//output
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 %3.3f bar',xco,xc,xo,PP)
```

Scilab code Exa 3.20 The adiabatic flame temperature

```
clc
clear
//Input data
t=25;//The temperature of air in degree centigrade
p=1;//The pressure of air in atm
T1=2200;//Given first temperature in K
T2=2400;//Given second temperature in K
h1=59.86;//The change in enthalpy of hydrogen at
    2200 K in MJ/kmol
h2=66.915;//The change in enthalpy of hydrogen at
    2400 K in MJ/kmol
T=298;//The temperature of air in K

//Calculations
HR=0;//The total enthalpy on the reactants side
    since all the reactants are elements
Kp1=-6.774;//Natural logarithm of equilibrium
    constant at 2200 K for the equation
K1=exp(Kp1);//The value of equilibrium constant at
    2200 K
a1=0.02;//By trail and error method the degree of
    dissociation of H2O
hfh=-241.82;//The enthalpy of formation of water at
    both 2200 and 2400 K in MJ/kmol
hfh1=83.036;//The change in enthalpy of water at
    2200 K in MJ/kmol
hfd1=59.86;//The change in enthalpy of hydrogen at
    2200 K in MJ/kmol
hfo1=66.802;//The change in enthalpy of oxygen at
    2200 K in MJ/kmol
hfn1=63.371;//The change in enthalpy of nitrogen at
```

```
   2200 K in MJ/kmol
HP1=(0.98*(hfh+hfh1))+(0.02*hfd1)+(0.01*hfo1)+(1.88*
   hfn1);//The enthalpy on the products side in MJ/
   kmol
a2=0.04;//By trail and error method the degree of
   dissociation of H2O at 2400 K
hfh2=93.604;//The change in enthalpy of water at
   2400 K in MJ/kmol
hfd2=66.915;//The change in enthalpy of hydrogen at
   2400 K in MJ/kmol
hfo2=74.492;//The change in enthalpy of oxygen at
   2400 K in MJ/kmol
hfn2=70.651;//The change in enthalpy of nitrogen at
   2400 K in MJ/kmol
HP2=(0.96*(hfh+hfh2))+(0.04*hfd2)+(0.02*hfo2)+(1.88*
   hfn2);//The enthalpy on the products side in MJ/
   kmol
H1=HP1-HR;//The total change in enthalpy at 2200 K
   in MJ/kmol
H2=HP2-HR;//The total change in enthalpy at 2400 K
   in MJ/kmol
Tl=[[[T2-T1]/[HP2-HP1]]*[HR-HP1]]+T1;//The required
   temperature in K

//Output
printf('The adiabatic flame temperature taking
   dissociation into account is %3.0f K',Tl)
```

Chapter 4

Fuel Air Cycles and Their Analysis

Scilab code Exa 4.1 Efficiency

```
clc
clear
//Input data
r=8.5;//The compression ratio
sv=1.4;//The specific heat at constant volume in
   percent

//Calculations
n=1-(1/r)^(sv-1);//The efficiency of the otto cycle
ef=[((1-n)/n)*(sv-1)*(log(r))*(sv/100)]*100;//The
   percentage change in efficiency of an otto cycle
   and is negative

//Output
printf('The efficiency decreases by %3.3f percent ',
   ef)
```

Scilab code Exa 4.2 Efficiency

```
clc
clear
//Input data
r=18;//The compression ratio
l=6;//The cut off taking place corresponding of the stroke in percent
sc=2;//The specific heat at constant volume increases in percent
cv=0.717;//The specific heat at constant volume in kJ/kgK
R=0.287;//Gas constant in kJ/kgK

//Calculations
Vs=(r-1);//The ratio of swept volume and volume 2
B=((l/100)*Vs)+1;//The cut off ratio
cp=cv+R;//The specific heat at constant pressure in kJ/kgK
R1=cp/cv;//The ratio of specific heats
n=1-[[[[(1/r)^(R1-1)]*(B^R1-1)]/(R1*(B-1))]];//The efficiency of the diesel cycle
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

//Output
printf('The efficiency decreases by %3.3f percent ',dn)
```

Scilab code Exa 4.3 Temperature

```
clc
clear
//Input data
```

```
r=8;//The compression ratio
af=15;//Air/fuel ratio
p1=1;//The pressure at the beginning of a compression stroke in bar
t=60;//The temperature at the beginning of a compression stroke in degree centigrade
cv=44000;//The calorific value of the fuel in kJ/kg
n=1.32;//The index of the compression
Cv=0.717;//specific heat at constant volume in kJ/kgK

//Calculations
T1=t+273;//The temperature at the beginning of a compression stroke in K
p2=p1*(r)^n;//The pressure at the end of a compression stroke in bar
T2=T1*r^(n-1);//The temperature at the end of a compression stroke in K
f=(1/(af+1));//The amount of fuel present in 1 kg of mixture in kg
a=(af/(af+1));//The amount of air present in 1 kg of mixture in kg
q23=cv/(af+1);//The heat transfer during process 2-3 per kg of mixture in kJ/kg
T3=[[-10430+[(10430)^2+(4*494.8*10^5)]^(1/2)]/2];//The temperature at point 3 in K
p3=(T3/T1)*(r)*p1;//The pressure at point 3 in bar
T31=(q23/Cv)+T2;//The pressure at point 3 in K
p31=(T31/T1)*r*p1;//The pressure at point 3 in bar

//Output
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

```

clc
clear
//Input data
r=21;//The compression ratio
af=29;//Air/fuel ratio
T=1000;//The temperature at the end of compression in K
cv=42000;//The calorific value of the in kJ/kg
R=0.287;//Gas constant in kJ/kgK

//Calculations
q23=cv/(af+1);//Heat transfer during the process 2-3 per kg of mixture in kJ
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
function y=f1(x),y=(0.997+(28*10^-6)*x),endfunction
I=intg(T,T3,list(f1));//Integrating the above function
abs(I)
V3=(T3/T);//The ratio of volumes at 2 and 3 points
Vs=(r-1);//Swept volume in terms of V2
V=V3-1;//The difference in the volume at 2 and 3 points
pc=(V/Vs)*100;//The percentage stroke during which the combustion is completed in percent

//Output
printf('The percentage of stroke at which combustion is complete = %3.3f percent ',pc)
```

Scilab code Exa 4.5 The pressure

```

clc
clear
//Input data
r=16;//The compression ratio
l=6;//The cut-off of the stroke in percent
p3=70;//The maximum pressure obtained in bar
p1=1;//The pressure at the beginning of compression in bar
T1=(100+273);//The temperature at the beginning of compression in K
R=0.287;//Gas constant in kJ/kgK
g=1.4;//Assume the isentropic index

//Calculations
T2=T1*(r)^(g-1);//The temperature at point 2 in K
function y=f1(x),y=(0.716+(125*10^-6)*x),endfunction
I=intg(373,1131,list(f1));//Integrating the above function
abs(I)
Cv=(1/(1131-373))*I;//The specific heat at constant volume for the temp range T2 and T3 in kJ/kgK
Cp=Cv+R;//The specific heat at constant pressure in kJ/kgK
g1=Cp/Cv;//The ratio of specific heats
T21=T1*(r)^(g1-1);//The temperature at point 2 in K
function y=f1(x),y=(0.716+(125*10^-6)*x),endfunction
I1=intg(373,995,list(f1));//Integrating the above function
abs(I1)
Cv1=(1/(995-373))*I1;//The specific heat at constant volume for the temp range T2 and T3 in kJ/kgK
```

```
Cp1=Cv1+R;//The specific heat at constant pressure in kJ/kgK
g2=Cp1/Cv1;//The ratio of specific heats
T22=T1*(r)^(g2-1);//The temperature at point 2 in K
p2=(T22/T1)*r*p1;//The pressure at point 2 in bar
T3=(p3/p2)*T22;//The temperature at point 3 in K
V=[(l/100)*(r-1)]+1;//The ratio of volumes at 3-4 points
T4=(V)*T3;//The temperature at point 4 in K
p4=p3;//The pressure at point 4 in bar
g3=1.3;//Assume isentropic index
V5=r/V;//The ratio of volumes at 4-5 process
T5=T4*(1/V5)^(g3-1);//The temperature at point 5 in K
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
Cp2=Cv2+R;//The specific heat at constant pressure in kJ/kgK
g4=Cp2/Cv2;//The ratio of specific heats
T51=T4*(1/V5)^(g4-1);//The temperature at point 5 in K
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
Cp3=Cv3+R;//The specific heat at constant pressure in kJ/kgK
g5=Cp3/Cv3;//The isentropic index
T52=T4*(1/V5)^(g5-1);//The temperature at point 5 in K
p5=(T52/T1)*p1;//The pressure at point 5 in bar

//Output
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  P4 = %3.0f  bar \n at  point  5  ,
  Temperature  T5 = %3.0f  K     and  Pressure  P5 = %3
  .2f  bar  ',T22,p2,T3,p3,T4,p4,T52,p5)
```

Scilab code Exa 4.6 Molecular expansion

```
clc
clear
//Input data
r=8;//Compression ratio
lcv=44000;//The lower heating value of the fuel in
   kJ/kg
af=15;//The air/fuel ratio
Cv=0.71;//The specific heat at constant volume in kJ
   /kgK
p=1;//The pressure at the beginning of the
   compression in bar
t=60;//The temperature at the beginning of the
   compression in degree centigrade
Mo=32;//Molecular weight of oxygen
Mn=28.161;//Molecular weight of nitrogen
Mh=18;//Molecular weight of water
n=1.3;//Polytropic index

//Calculations
T1=(t+273);//The temperature at the beginning of the
    compression in K
sa=[12.5*[Mo+(3.76*Mn)]]/[(12*8)+(1*Mh)];//The
   stoichiometric air fuel ratio
Y=af*[[(12*8)+(1*Mh)]/(Mo+(3.76*Mn))];//To balance
   the oxygen and nitrogen
x=(12.5-Y)*2;//By oxygen balance
nb=1+Y+(Y*3.76);//Number of moles before combustion
na=x+7.8+9+46.624;//Number of moles after combustion
Me=[(na-nb)/nb]*100;//The percentage molecular
```

```
expansion in percent
T2=T1*(r)^(n-1);//The temperature at point 2 in K
T3=[lcv/(af+1)]*(1/Cv)+(T2);//The temperature at point 3 in K
p3=r*(T3/T1)*p;//The pressure at point 3 in bar
p31=p3*(na/nb);//The pressure at point 3 with molar expansion in bar

//Output
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

```
clc
clear
//Input data
f=0.03;//The residual fraction of an engine
e=1.2;//The equivalence ratio

//Calculations
F=0.0795;//Fuel/air ratio for corresponding equivalence ratio
T=1+F;//Total mass in kg
fa=1-f;//Fresh air in kg
ff=F*(fa);//Fresh fuel in kg
ra=f;//Air in residual in kg
rf=ra*F;//Fuel in residual in kg

//Output
```

```
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

```
clc
clear
//Input data
T=800;//The given temperature in K
e=1;//The equivalence ratio

//Calculations
hi=154.723;//Sensible Enthalpy for isooctane at 800
   K in MJ/kmol
ho=15.841;//Sensible Enthalpy for oxygen at 800 K in
    MJ/kmol
hn=15.046;//Sensible Enthalpy for nitrogen at 800 K
   in MJ/kmol
nc=0.00058;//Number of kmoles of C8H18 for
   equivalence ratio for 1 kg of air
no=0.00725;//Number of kmoles of oxygen for
   equivalence ratio for 1 kg of air
nn=0.0273;//Number of kmoles of nitrogen for
   equivalence ratio for 1 kg of air
Hs=(nc*hi)+(no*ho)+(nn*hn);//Total sensible enthalpy
    of reactants in MJ per kg of air
Hs1=Hs*1000;//Total sensible enthalpy of reactants
   in kJ per kg of air
R=8.314;//Gas constant in kJ/kgK
n=nc+no+nn;//Total number of kmoles for 1 kg of air
Us=Hs-(n*R*10^-3*(T-298));//sensible internal energy
    of reactants in MJ per kg of air
Us1=Us*1000;//sensible internal energy of reactants
   in kJ per kg of air
```

```

//Output
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

```
clc
clear
//Input data
T=500;//The given temperature in K
e=1;//Equivalence ratio

//Calculations
Ai=0.0662;//The amount of isooctane for 1 kg of air in kg
Ta=298;//Consider the ambient temperature in K
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
R=8.314;//Gas constant in kJ/kgK
Ri=R/114;//Gas constant for isooctane in kJ/kgK
W=[0.5874-(0.662*Ri*log(T/Ta))-(0.287*log(T/Ta))]*1000;//Gas constant for isooctane in kJ/kgK

//Output
printf('The isentropic compression functions at 500 K for the unburned, \n isooctsne-air mixture are %3.1f J/kg air and %3.1f J/kg air ',E,W)
```

Scilab code Exa 4.10 Work input

```
clc
clear
//Input data
r=7.8;//Compression ratio
p=1;//The pressure at the start of compression in
   atm
T1=335;//The temperature at the start of compression
    in K

//Calculations
W1=100;//Isentropic compression function for T1 in J
   /kg air K
W2=W1-(292*log(1/r));//Isentropic compression
   function in J/kg air K
T2=645;//The temperature corresponding to isentropic
    compression function in J/kg air K
V1=(292*T1)/(p*10^5);//Volume at initial in m^3/kg
   air
p2=p*(T2/T1)*r;//The pressure at the end of
   compression stroke in atm
V2=V1/r;//The volume per unit mass of air at the end
    of the compression stroke in m^3/kg air
U1=35;//Internal energy corresponding to temp T1 in
   kJ/kg air
U2=310;//Internal energy corresponding to temp T2 in
    kJ/kg air
W=U2-U1;//Work input during compression in kJ/kg air
E1=120;//Isentropic compression function at T1
E2=910;//Isentropic compression function at T2
p21=[exp((E2-E1)/292)];//The pressure at the end of
   compression stroke in atm

//Output
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

```
clc
clear
//Input data
p=65;//The pressure in the cylinder in bar
r=10;//The compression ratio
V3=0.1;//The volume per unit mass of air at the start of expansion in m^3/kg air
p3=p*100;//The pressure in the cylinder after the completion of combustion in kN/m^2

//Calculations
T3=2240;//The temperature from the chart corresponding to p3,V3 in K
u3=-1040;//The energy from the chart in kJ/kg air
s3=8.87;//The entropy from the chart in kJ/kg air K
s4=s3;//Since the process is isentropic
V4=r*V3;//The volume per unit mass of air at the end of expansion stroke in m^3/kg air
T4=1280;//The temperature from the chart corresponding to p4,V4 in K
u4=-2220;//The energy from the chart in kJ/kg air
p4=4.25;//The pressure from the chart in bar
W=-(u4-u3);//Work of expansion in kJ/kg air

//Output
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

```
clc
clear
//Input data
Tu=645;//The temperature at the end of compression
   process in K
usu=310;//The internal energy at the end of
   compression process in kJ/kg air
pu=(15.4*1.013);//The pressure at the end of the
   compression process in bar
Vu=0.124;//The volume at the end of the compression
   process in m^3/kg air
e=1;//Equivalence ratio
f=0.065;//Burned gas fraction

//Calculations
ufu=-118.5-(2963*f);//Internal energy of formation
   in kJ/kg air
ub=usu-ufu;//The internal energy for constant volume
    adiabatic combustion in kJ/kg air
Vb=Vu;//The volume for constant volume adiabatic
   combustion in kJ/kg air
Tb=2820;//The temperature for constant volume
   adiabatic combustion corresponding to ub,Vb on
   the burnt gas chart in K
pb=6500;//The pressure for constant volume adiabatic
    combustion corresponding to ub,Vb on the burnt
   gas chart in kN/m^2
hfu=-129.9-(2958*f);//The enthalpy of formation in
   kJ/kg air
hsu=440;//The enthalpy from chart corresponding to
   temp Tu in kJ/kg air
hb=hsu+hfu;//The enthalpy for constant pressure
```

```
   adiabatic combustion in kJ/kg air
pb1=1560;//The pressure for constant pressure
   adiabatic combustion in kN/m^2
ub1=-700;//Trail and error along the pb internal
   energy in kJ/kg air
vb1=(118-ub1)/pb;//The volume in m^3/kg air
Tb1=2420;//The temperature for constant pressure
   adiabatic combustion corresponding to ub,Vb on
   the burnt gas chart in K

//Output
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

```
clc
clear
//Input data
r=8;//The compression ratio
T1=350;//The given temperature at the start of
   compression in K
p=1;//The given pressure at the start of compression
    in bar
f=0.08;//The exhaust residual fraction
cv=44000;//The calorific value in kJ/kg

//Calculations
W1=150;//Isentropic compression functions for
   corresponding temp T1 in J/kg air K
W2=W1-(292*log(1/r));//Isentropic compression
```

```
function in J/kg air K
T2=682;//The temperature corresponding to isentropic compression function in K
V1=(292*T1)/(p*10^5);//The initial volume in m^3/kg air
p2=p*(T2/T1)*r;//The pressure at point 2 in atm
V2=V1/r;//The volume at point 2 in m^3/kg air
us2=350;//The internal energy corresponding to temp T2 in K
us1=40;//The internal energy corresponding to temp T1 in K
Wc=us2-us1;//Adiabatic compression work in kJ/kg air
ufu=-118.5-(2963*f);//The internal energy of formation in kJ/kg air
u3=us2+ufu;//The internal energy at point 3 in kJ/kg air
V3=V2;//The volume at point 3 in m^3/kg air
T3=2825;//The temperature at point 3 corresponding to u3,V3 on the burned gas chart in K
p3=7100;//The pressure at point 3 in kN/m^2
s3=9.33;//Entropy at point 3 in kJ/kg air K
s4=s3;//Entropy is same in kJ/kg air K
V4=V1;//The volume at point 4 in m^3/kg air
u4=-1540;//The internal energy at point 4 corresponding to V4,s4 in kJ/kg air
p4=570;//The pressure at point 4 in kN/m^2
T4=1840;//The temperature at point 4 in K
We=u3-u4;//The expansion work in kJ/kg air
Wn=We-Wc;//The net work output in kJ/kg air
nth=[(Wn)/((1-f)*0.0662*cv)]*100;//The indicated thermal efficiency in percent
imep=((Wn*1000)/(V1-V2))/10^5;//The indicated mean effective pressure in bar
nv=[((1-f)*287*298)/(1.013*10^5*(1-0.125))]*100;//The volumetric efficiency in percent

//Output
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

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

```
pi=3.141;//The mathematical constant of pi

//Calculations
p2=p1*[1-(C2^2/(Cva^2*2*Cp*(t1+273)))]^(g/(g-1));//Throat pressure in bar
da1=((p1*10^5)/(R*(t1+273)));//The density of air at inlet in kg/m^3
da2=[(da1)*(p2/p1)^(1/g)];//The density of air at the throat in kg/m^3
A2=[(ma/60)/(da2*C2)]*10^4;//The throat area in cm^2
d2=(4*A2/pi)^(1/2);//The throat diameter of the choke in cm
pv=p1-p2;//Pressure drop at venturi in bar
pj=Cpd*pv;//Pressure drop at jet in bar
Aj=[(mf/60)/(Cdf*(2*df*pj*10^5)^(1/2))]*10^6;//The area of the jet in mm^2
dj=(4*Aj/pi)^(1/2);//The oriface diameter in mm

//Output
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

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

```
Cp=1005;//The specific heat of gas in J/kgK
g=1.4;//Adiabatic index
C2=100;//The air flow velocity at choke in m/s
Cda=0.85;//The velocity coefficient for the venturi
Cdf=0.66;//The coefficient of discharge of the main fuel jet
sf=0.75;//The specific gravity of fuel
d=0.4;//The ratio of the diameter to choke diameter
af=14;//The air fuel ratio
gf=9.81;//The gravitational force constant in m/s^2
Z=0.006;//The petrol surface below the choke in m
df=750;//The density of the fuel in kg/m^3

//Calculations
Va=((nv/100)*Vs*N)/(2*60);//The volume of air induced in m^3/s
V1=Va/2;//The carburator delivers an air flow in m^3/s
ma=(p1*10^5*V1)/(R*(t1+273));//The mass flow rate of air in kg/s
p2=p1*[1-(C2^2/(2*Cp*(t1+273)))]^(g/(g-1));//The pressure at throat in bar
da1=[(p1*10^5)/(R*(t1+273))];//The density of air in kg/m^3
da2=da1*(p2/p1)^(1/g);//Density of air at throat in kg/m^3
A2=[ma/(da2*C2*Cda)]*10^6;//The throat area in mm^2
D=[(A2*4)/(pi*0.84)]^(1/2);//The choke diameter in mm
mf=ma/af;//The mass flow rate of fuel in kg/s
pm=[p1-p2-(gf*Z*df/10^5)]*10^5;//The pressure difference across the main jet in N/m^2
Aj=(mf/(Cdf*(2*df*pm)^(1/2)))*10^6;//The area of the jet in mm^2
dj=(4*Aj/pi)^(1/2);//The diameter of the jet in mm

//Output
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

```
clc
clear
//Input data
d=0.08;//The diameter of the bore in m
L=0.09;//The length of the stroke in m
N=4000;//The engine rpm
C=84;//The carbon content in the fuel by mass in
   percent
H=16;//The hydrogen content in the fuel by mass in
   percent
nv=80;//The volumetric efficiency of the engine in
   percent
p1=1;//The pressure at ambient condition in bar
t1=25;//The temperature at ambient condition in
   degree centigrade
p=0.06;//The depression at venturi throat in bar
ma=0.95;//The actuat quantity of air supplied
Ra=287;//Real gas constant in J/kgK
Rf=98;//Real gas constant in J/kgK
pi=3.141;//The mathematical constant of pi
n=4;//Number of cylinders
Cp=1005;//The specific heat of gas in J/kgK
g=1.4;//Adiabatic index

//Calculations
V=(pi/4)*d^2*L*(nv/100)*(N/(2*60))*n;//The volume of
    mixture supplied to the engine in m^3/s
Af=(100/23)*((C*(32/12))+(H*8))/100;//Stoichiometric
    air/fuel ratio
mfa=Af*ma;//The actual mass of air supplied per kg
   of fuel in kg/kg fuel
```

```
Aaf=mfa;//Actual air fuel ratio
da=(p1*10^5)/(Ra*(t1+273));//The density of air at one bar in kg/m^3
dv=(p1*10^5)/(Rf*(t1+273));//The density of fuel vapour in kg/m^3
ma1=V/((1/da)+(1/(mfa*dv)));//Mass flow rate of air in kg/s
mf1=ma1/mfa;//Mass flow rate of fuel in kg/s
p2=p1-p;//The pressure at the outlet in bar
C2=[2*Cp*(t1+273)*(1-(p2/p1)^((g-1)/g))]^(1/2);//Velocity of air at the throat in m/s
T2=(t1+273)*(p2/p1)^((g-1)/g);//The temperature at throat in K
d2=(p2*10^5)/(Ra*T2);//The density of the air at throat in kg/m^3
A2=[ma1/(d2*C2)]*10^4;//The cross sectional area of the venturi throat in cm^2
d2=(A2*4/pi)^(1/2);//The diameter of the venturi throat in cm

//Output
printf('The fuel flow rate = %3.6f kg/s \n The velocity of air at throat = %3.1f m/s \n The throat diameter = %3.2f cm ',mf1,C2,d2)
```

Scilab code Exa 9.4 The depression at the throat

```
clc
clear
//Input data
d=0.1;//The diameter of the bore in m
L=0.12;//The length of the stroke in m
N=3000;//The engine rpm
d2=0.035;//The throat diameter of carburettor venturi in m
```

```
nv=80;//The volumetric efficiency of the engine in
    percent
Cda=0.82;//The coefficient of discharge of air flow
p=1.013;//The ambient pressure in bar
T=298;//The ambient temperature in K
ar=15;//The air fuel ratio
Z=0.005;//The top of the jet above the petrol level
    in the float chamber in m
Cdf=0.7;//The coefficient of discharge for fuel flow
df=750;//The specific gravity of the fuel in kg/m^3
R=287;//Real gas constant in J/kgK
pi=3.141;//The mathematical constant of pi
g=9.81;//The gravitational constant in m/s^2
n=4;//Number of cylinders

//Calculations
V=(pi/4)*d^2*L*(nv/100)*(N/(2*60))*n;//Volume of air
     inducted per second in m^3/s
da=(p*10^5)/(R*T);//The density of air in kg/m^3
ma=V*da;//The mass flow rate of air in kg/s
A2=(pi/4)*d2^2;//The area of the throat in m^2
P=[ma^2/(Cda^2*A2^2*2*da)]/10^5;//The change in
    pressure in bar
mf=ma/ar;//The mass flow rate of fuel in kg/s
Aj=[mf/(Cdf*(2*df*((P*10^5)-(g*Z*df)))^(1/2))]*10^6;
    //The area of the fuel jet in mm^2
dj=(Aj*4/pi)^(1/2);//The diameter of the fuel jet of
     a simple carburator in mm

//Output
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

```
clc
clear
//Input data
mf=(6/3600);//The mass flow rate of fuel in kg/s
df=750;//The density of fuel in kg/m^3
Z=0.003;//The level in the float chamber below the top of the jet in m
p=1.013;//The ambient pressure in bar
T=294;//The ambient temperature in K
dj=0.0012;//The jet diameter in m
Cdf=0.65;//The discharge coefficient of the jet
Cda=0.8;//The discharge coefficient of air
A=15.3;//The air fuel ratio
pi=3.141;//The mathematical constant of pi
g=9.81;//The gravitational constant in m/s^2
R=287;//Real gas constant in J/kgK
dh=1000;//The density of water in kg/m^2

//Calculations
da=(p*10^5)/(R*T);//The density of air in kg/m^3
Ca2=Cda*((2*g*Z*df)/da)^(1/2);//The critical air velocity at the throat
Aj=(pi/4)*dj^2;//The area of the jet in m^2
P=[(mf^2/(Cdf^2*Aj^2*2*df))+(g*Z*df)]/10^5;//The dipression at the throat in bar
h=(P*10^5)/(dh*g);//In meter of water
h1=(P*10^5)/g;//In mm of water
ma=mf*A;//The mass flow rate of air in kg/s
A2=[ma/((Cda*(2*da*(P*10^5))^(1/2)))]*10^4;//The area of the throat in cm^2
d2=[(A2*4/pi)^(1/2)]*10;//The effective throat diameter in mm

//Output
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

```
clc
clear
//Input data
d2=22;//The venturi throat diameter of a simple carburettor in mm
Cda=0.82;//The coefficient of air flow
dj=1.2;//The fuel orifice diameter in mm
Cdf=0.7;//The coefficient of fuel flow
Z=0.004;//The petrol surface below the throat in m
g=9.81;//The gravitational constant in m/s^2
da=1.2;//The density of air in kg/m^3
df=750;//The density of fuel in kg/m^3
P=0.075;//The pressure drop in bar

//Calculations
A=(Cda/Cdf)*(d2^2/dj^2)*(da/df)^(1/2);//The air fuel ratio
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
Ca2=(2*g*Z*df/da)^(1/2);//Critical velocity at the throat in m/s

//Output
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

```
clc
clear
//Input data
h=4000;//The altitude of the airplane engine carburettor in m
A=14.7;//The air fuel ratio at sea level
ts=22;//The temperature at sea level in degree centigrade
R=287;//Real gas constant in J/kgK

//Calculations
ta=ts-(0.0065*h);//The temperature at the altitude in degree centigrade
p=1.013/10^0.2083;//The pressure at the altitude in bar
da=(p*10^5)/(R*(ta+273));//The density at altitude in kg/m^3
ds=(1.013*10^5)/(R*(ts+273));//The density at sea level in kg/m^3
Aa=A*(da/ds)^(1/2);//The air fuel ratio at altitude

//Output
printf('The air fuel ratio at altitude = %3.2f ',Aa)
```

Scilab code Exa 9.8 Throat pressure

```
clc
clear
//Input data
A=14.5;//The air fuel ratio
```

```
p2=0.825;//The pressure at the venturi throat in bar
p1=1.013;//The atmospheric pressure in bar
pd=37.5;//The pressure drop to the air cleaner in mm
    of Hg
ma=260;//The mass flow rate of air in kg/h

//Calculations
pa=p1-p2;//Without air cleaner the depression at the
    throat in bar
p21=p1-(pd/750)-pa;//The throat pressure when the
   air cleaner is fitted in bar
pf=pa;//Pressure of fuel without air clesner in bar
pf1=p1-p21;//Pressure of the fuel with air cleaner
   in bar
Af=A*(pf/pf1)^(1/2);//Air fuel ratio with air
   cleaner

//Output
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

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

```
Z=0.008;//The nozzle lip in m
g=9.81;//The gravitational force constant in m/s^2
A=15;//The air fuel ratio
Cda=0.9;//The coefficient of air flow
Cdf=0.7;//The coefficient of fuel flow
df=750;//The density of fuel in kg/m^3
pi=3.141;//The mathematical constant of pi
va=0.8;//The specific volume of air in m^3/kg

//Calculations
va1=va*T1/273;//Specific volume of air at atmospheric pressure and 300K in m^3/kg
da=1/va;//The density of air at inlet condition in kg/m^3
mf=bp/[(nb/100)*CV];//Mass flow rate of fuel in kg/s
Cf=mf/(Cdf*df*Aj);//Velocity of fuel in m/s
P=[(Cf^2*df)/2]+(df*g*Z);//The pressure drop in N/m^2
Ca=(2*P/da)^(1/2);//Velocity of air at the throat in m/s
ma=mf*A;//The mass flow rate of air in kg/s
A2=[ma/(Cda*da*Ca)]*10^4;//The area of the venturi in cm^2
d2=(A2*4/pi)^(1/2);//The diameter of venturi in cm

//Output
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

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

```
p1=1.013;//The atmospheric pressure in bar
n=4;//The number of orifices used in the nozzle
x=6;//Number of cylinders
pi=3.141;//The mathematical constant of pi

//Calculations
mf=bsfc*bp/60;//The mass flow rate of fuel in kg/min
F=(mf/(N/2))*(1/x);//Fuel injected per cycle per cylinder in kg
s=(CA/360)/(N/60);//Duration of injection in s
mf1=F/s;//Mass of fuel injected per second
p1=pf1-pi1;//Pressure difference at the beginning in bar
p2=pf2-pi2;//Pressure difference at the end in bar
pa=(p1+p2)/2;//Average pressure difference in bar
Af=[mf1/(Cd*(2*df*pa*10^5)^(1/2))]*10^6;//Area of cross section of the nozzle in mm^2
do=[(Af/n)*(4/pi)]^(1/2);//The diameter of the orifice in mm

//Output
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

```
clc
clear
//Input data
bp=30;//The brake power of the engine in kW
N=3000;//The engine speed in rpm
bsfc=0.28;//The brake specific fuel consumption in kg/kWh
API=35;//The API
```

```
p2=160;//The pressure at which fuel is injected in bar
CA=28;//The crank angle in degrees
p1=35;//The pressure in the combustion chamber in bar
Cv=0.92;//The coefficient of velocity
pi=3.141;//The mathematical constant of pi

//Calculations
S=141.5/(131.5+API);//Specific gravity
df=S*1000;//The density of the fuel in kg/m^3
D=(CA/360)/(N/60);//Duration of injection in s
F=(bsfc*bp)/((N/2)*60);//Fuel consumption per cycle in kg
mf=F/D;//Mass flow rate of fuel in kg/s
Cf=Cv*((2*(p2-p1)*10^5)/df)^(1/2);//Velocity of injection of the fuel in m/s
Af=[mf/(df*Cf)]*10^6;//Area of the fuel orifice in mm^2
d=(4*Af/pi)^(1/2);//The diameter of the orifice in mm

//Output
printf('The velocity of injection of the fuel = %3.1f m/s \n The diameter of the fuel orifice = %3.3f mm ',Cf,d)
```

Scilab code Exa 10.3 The discharge of fuel

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

```
Cp=0.85;//The coefficient of the passage
p1=170;//The injection pressure in bar
p2=25;//The compression pressure of the discharge in bar
df=850;//The density of the fuel in kg/m^3

//Calculations
Q=[(145/(22.931*10^9))^(1/2)]*10^6;//Adding two equations and solving then the discharge in cm^3/s
p=170-(2.161*10^9*(Q/10^6)^2);//Pressure immediately formed before the orifice in bar
Cf=Cd*((2*(p-p2)*10^5)/df)^(1/2);//The velocity of fuel flow through the orifice in m/s

//Output
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

```
clc
clear
//Input data
s=20;//Spray penetration in cm
t1=15.7;//The spray penetration of 20 cm in ms
pi1=150;//The injection pressure in bar
pi2=450;//The injection pressure to be used in bar
p2=15;//The combustion chamber pressure in bar
d1=0.34;//The diameter of the orifice in mm
s1=20;//The penetration for an orifice in cm
d2=0.17;//If the diameter of the orifice in cm
t11=12;//The spray penetration in ms

```

```
//Calculations
t2=(t1*(pi1-p2)^(1/2))/(pi2-p2)^(1/2);//The time required for the spray to penetrate in ms
s2=d2*(s1/d1);//The penetration of the orifice in cm
t21=t11*(d2/d1);//The time required for the spray to penetrate in ms

//Output
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

```
clc
clear
//Input data
v=6.5;//The volume of fuel in the barrel in cc
d=0.3;//The dimeter of fuel pipe line in cm
l=65;//The length of the fuel pipe line in cm
vi=2.5;//The volume of fuel in the injection valve in cc
K=78.5*10^-6;//The coefficient of compressibility of the oil per bar
p1=1;//The atmospheric pressure in bar
p2=180;//The pressure due to pump in bar
v3=0.1;//The pump displacement necessary for the fuel in cc
e=0.75;//The effective stroke of the plunger in cm
pi=3.141;//Mathematical constant of pi

//Calculations
V1=v+((pi*d^2)/4)*l+vi;//The total initial volume in
```

```
cc
V=K*V1*(p2-p1);//Change in volume due to compression in cc
T=(V)+v3;//Total displacement of the plunger in cc
L=T*(4/pi)*(1/(e^2));//Effective stroke of the plunger in cm

//Output
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

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

//Calculations
```

```
F=(bsfc*P)/((N/2)*60);//Fuel consumption per cycle
   in kg
F1=F/n;//Fuel consumption per cylinder in kg/cycle
Vf=[F1/df]*10^6;//Volume of fuel injected per
   cylinder per cycle in cm^3
V1=v+vp+vi;//Total initial volume in cc
V=K*V1*(p1-pi);//Change in volume due to compression
    in cc
Vp=Vf+V;//Volume displaced by plunger in cc
W=[(1/2)*(p1-pi)*10^5*V*10^-6]+[(p1-p2)*10^5*Vf
   *10^-6];//Pump work per cycle in J
P1=(W*N)/(2*60*1000);//Power lost per cylinder in kW
P2=P1*4;//Total power lost for pumping the fuel in
   kW

//Output
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

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

```

//Calculations
Vs=(K/df)^(1/2);//The velocity of pressure disturbances in m/s
t=l/Vs;//Time taken by the disturbance to travel through pipe line in s
Vp=(1/A)*v1;//The velocity of the fuel at the inlet of the pipe line in m/s
p=[(K/Vs)*Vp]/10^5;//The change in pressure in bar
pi=p+p1;//The pressure according to change in velocity in bar
po=p1+p;//The change in total to the disturbance pressure in bar
vc=Vp-(a*((2*(po-p2))/df)^(1/2));//Change in the velocity in m/s
pr=26.8;//By trail method the first reflected pressure wave from velocity in bar
Vc=pr*(Vs/(K/10^5));//The change in velocity in m/s
po1=p1+p+pr;//The pressure at the orifice end of the pipe in bar
vo=a*((2*(po1-p2)*10^5)/df)^(1/2);//The velocity at the oriface end of the pipe in m/s

//Output
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 oriface end of the pipe line after the first reflection = %3.1f bar \n The velocity at the oriface 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

```
clc
clear
//Input data
nsc=75;//The scavenging efficiency of the two stroke
    engine in percent
ns=20;//The scavenging efficiency is increased by in
    percent

//Calculations
Rsc=log(1/(1-(nsc/100)));//The scavenging ratio for
   normal efficiency
nsc1=(nsc/100)+((nsc/100)*(ns/100));//For 20%
   increase in scavenging efficiency
Rsc1=log(1/(1-(nsc1)));//The scavenging ratio for 20
   % more efficiency
Rscr=[(Rsc1-Rsc)/Rsc]*100;//Percentage increase in
   scavenging ratio in persent

//Output
printf('The percentage change in the scavenging
   ratio = %3.1f percent ',Rscr)
```

Scilab code Exa 11.2 Scavenging ratio

```
clc
clear
//Input data
d=0.12;//The bore diameter of the engine in m
l=0.15;//The stroke length of the engine in m
r=16;//The compression ratio
N=2000;//The speed of the engine in rpm
mf=(240/60);//Actual air flow per min in kg/min
T=300;//Air inlet temperature in K
p=1.025;//Exhaust pressure in bar
pi=3.141;//Mathematical constant of pi
R=287;//Real gas constant in J/kg

//Calculations
da=(p*10^5)/(R*T);//The density of air in kg/m^3
Vs=[(pi)*(d^2)*l]/4;//Swept volume in m^3
V=(r/(r-1))*Vs;//Total cylinder volume in m^3
m=da*V;//Ideal mass in total cylinder volume in kg per cycle
m1=m*N;//Ideal mass per unit time in kg/min
Rsc=mf/m1;//Scavenging ratio
nsc=[(1-exp(-Rsc))*100];//Scavenging efficiency in percent
ntr=[(nsc/100)/Rsc]*100;//Trapping efficiency in percent

//Output
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

```
clc
clear
//Input data
mf=6.5;//Mass flow rate of fuel in kg/h
N=3000;//The speed of the engine in rpm
a=15;//The air fuel ratio
CV=44000;//The calorific value of the fuel in kJ/kg
pm=9;//The mean piston speed in m/s
pmi=4.8;//The mean pressure in bar
nsc=85;//The scavenging efficiency in percent
nm=80;//The mechanical efficiency in percent
R=290;//Real gas constant in J/kgK
p=1.03;//The pressure of the mixture in bar
T=288;//The temperature of the mixture in K
pi=3.141;//Mathematical constant

//Calculations
ma=a*mf;//Mass flow rate of air in kg/h
L=[(pm*60)/(2*N)]*100;//The length of the stroke in
   cm
mac=mf+ma;//Actual mass flow rate in kg/h
mi=(mac)/(nsc/100);//Ideal mass flow rate in kg/h
da=(p*10^5)/(R*T);//The density of the mixture in kg
   /m^3
d=[[(mi/da)*(4/pi)*(1/(L/100))*(1/(60*N))]^(1/2)
   ]*100;//The diameter of the bore in cm
ip=(pmi*10^5*(L/100)*((pi/4)*(d/100)^2)*N)/(60*1000)
   ;//Power obtained in kW
bp=ip*(nm/100);//Brake power in kW
nth=(bp/((mf/3600)*CV))*100;//Thermal efficiency of
   the engine in percent

```

```
//Output
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

```
clc
clear
//Input data
d=0.08;//The diameter of the bore in m
L=0.1;//The length of the stroke in m
r=8;//The compression ratio
o=60;//The exhaust port open before BDC in degrees
v=60;//The exhaust port closes after BDC in degrees
a=15;//Air fuel ratio
T=300;//The temperature of the mixture entering into
    the engine in K
p=1.05;//The pressure in the cylinder at the time of
    closing
R=290;//Real gas constant in J/kgK
ma=150;//Mass flow rate of air in kg/h
N=4000;//The speed of the engine in rpm
pi=3.1414;//Mathematical constant of pi

//Calculations
mf=ma/a;//Mass flow rate of fuel in kg/h
mac=ma+mf;//Actual mass flow rate in kg/h
r=(L*100)/2;//Half the length of the stroke in cm
Le=(r+(r*sin (pi/6)))/100;//Effective stroke length
   in m
Vse=(pi*d^2*Le)/4;//Swept volume corresponding to Le
    in m^3
V=(r/(r-1))*Vse;//Total volume corresponding to m^3
```

```
da=(p*10^5)/(R*T);//The density in kg/m^3
m=V*da;//Mass of mixture per cycle in kg/cycle
mi=m*60*N;//Ideal rate of mass flow in kg/h
Rsc=mac/mi;//Scavenging ratio
nsc=(1-(exp(-Rsc)))*100;//Scavenging efficiency in percent
ntr=nsc/Rsc;//Trapping efficiency in percent

//Output
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

```
clc
clear
//Input data
d=8.25;//The diameter of the bore in cm
L=11.25;//The length of the stroke in cm
r=8;//The compression ratio
N=2500;//The speed of the engine in rpm
ip=17;//Indicated power in kW
a=0.08;//Fuel air ratio
T=345;//Inlet temperature mixture in K
p=1.02;//Exhaust pressure in bar
CV=44000;//The calorific value of the fuel in kJ/kg
nth=0.29;//Indicated thermal efficiency
M=114;//Molar mass of fuel
pi=3.141;//Mathematical constant
R=8314;//Universal Gas constant in J/kgK

//Calculations
Vs=(pi*d^2*L)/4;//Displacement volume in cm^3
```

```
V=(r/(r-1))*Vs;//Total cylinder volume in m^3
ps=[(29*p*10^5)/(R*T)]*(1/(1+a*(29/M)));//The density of dry air in kg/m^3
nsc=[(ip*1000)/((N/60)*V*10^-6*ps*a*CV*1000*nth)]*100;//The scavenging efficiency in percent

//Output
printf('The scavenging efficiency = %3.1f percent',nsc)
```

Scilab code Exa 11.6 The flow coefficient

```
clc
clear
//Input data
S=15;//The speed of the piston in m/s
ps=0.35;//The scavenging pressure in bar
pa=1.03;//Atmospheric pressure in bar
r=18;//The compression ratio
t=35;//The inlet temperature in degree centigrade
Rsc=0.9;//The scavenging ratio
ta=15;//The atmospheric temperature in degree centigrade
nc=0.75;//Compressor efficiency
g=1.4;//Adiabatic index
R=287;//Real gas constant in J/kgK
Cp=1005;//Specific heat of gas in J/kgK

//Calculations
pi=ps+pa;//The scavenging pressure in bar
Ti=(273+ta)+t;//The inlet temperature in K
pr=pa/pi;//The ratio of the pressure for calculations
di=(pi*10^5)/(R*Ti);//The density in kg/m^3
ai=(g*R*Ti)^(1/2);//The sonic velocity in m/s
```

```
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
ds=(pa*10^5)/(R*Ti);//The density in kg/m^3
mep=(ds*Rsc*Cp*Ti*[[(pi/pa)^((g-1)/g)]-1])/[(nc*((r-1)/r))*10^5];//Mean effective pressure in bar

//Output
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

```
clc
clear
//Input data
d=0.08;//The diameter of bore in m
L=0.075;//The length of the stroke in m
l=0.152;//The connecting rod length in m
h=0.062;//Skirt length of the piston in m
Fr=8000;//Compressive force in the connecting rod in
    N
p=3000;//The pressure in the cylinder kPa
y=0.004*10^-3;//The clearence between piston and
   cylinder wall in m
U=0.006;//The dynamic viscosity of the lubricating
   oil in pa.s
u=8.2;//The piston speed in m/s
pi=3.141;//Mathematical constant of pi

//Calculations
ts=(U*u)/y;//The shear stress in N/m^2
A=pi*d*h;//Contact area between the piston and the
   cylinder in m^2
```

```
Ff=ts*A;//Friction force on the piston inN
r=L/2;//Crank length in m
A=atan(r/l);//The angle made by the crank in radians
Ft=Fr*sin(A);//The side thrust in N
//Output
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

```
clc
clear
//Input data
d=0.065;//The cylinder bore diameter in m
L=6;//The length of the stroke in cm
l=12;//The length of the connecting rod in cm
p=50;//The pressure in the cylinder in bar
q=90;//The crank position in power stroke of the cycle for one cylinder in degrees
Ff=900;//Friction force in N
pi=3.141;//Mathematical constant valu of pi
o=0.2;//Wrist pin off set in cm

//Calculations
r=L/2;//The crank length in cm
sineA=r/l;//The value of sine
cosA=(1-(sineA)^2)^(1/2);//The value of cosine
Fr=[[(p*10^5*(pi/4)*d^2)-Ff]/cosA]/1000;//The force in the connecting rod in kN
Ft=Fr*sineA;//The side thrust on the piston in kN
sineA1=(r-o)/l;//The value of sine
cosA1=(1-(sineA1)^2)^(1/2);//The value of cosine
Fr1=[[(p*10^5*(pi/4)*d^2)-Ff]/cosA1]/1000;//The force in the connecting rod in kN
```

```
Ft1=Fr1*sineA1;//The side thrust in kN

//Output
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

```
clc
clear
//Input data
Vs=0.0028;//Swept volume in m^3
N=3000;//Speed of the engine in rpm
ip=12.5;//The average indicated power developed in
    kW/m^3
nv=85;//Volumetric efficiency in percent
p1=1.013;//The atmospheric pressure in bar
T1=288;//The atmospheric temperature in K
ni=74;//Isentropic efficiency in percent
pr=1.6;//The pressure ratio
nm=78;//All mechanical efficiencies in percent
g=1.4;//Adiabatic index
R=287;//Real gas constant in J/kgK
Cp=1.005;//The specific heat of gas in kJ/kgK

//Calculations
Vs1=(Vs*(N/2));//Volume swept by the piston per
```

```
minute in m^3/min
Vi=(nv/100)*Vs1;//Unsupercharged induced volume in m^3/min
p2=pr*p1;//Blower delivery pressure in bar
T21=T1*(p2/p1)^((g-1)/g);//Temperature after isentropic compression in K
T2=T1+((T21-T1)/((ni/100)));//Blower delivery temperature in K
Ve=(Vs1*p2*T1)/(T2*p1);//Equivalent volume at 1.013 bar and 15 degree centigrade in m^3/min
nv1=[Ve/Vs1]*100;//Volumetric efficiency of supercharged engine in percent
Vii=Ve-Vi;//Increase in induced volume in m^3/min
ipa=ip*Vii;//Increase in ip from air induced in kW
ipi=[(p2-p1)*10^5*Vs1]/(60*1000);//Increase in ip due to increased induction pressure in kW
ipt=ipa+ipi;//Total increase in ip in kW
bp=ipt*(nm/100);//Increase in engine bp in kW
ma=(p2*(Vs1/60)*10^5)/(R*T2);//Mass of air delivered per second by blower in kg/s
P=ma*Cp*(T2-T1);//Power input to blower in kW
Pd=P/(nm/100);//Power required to drive the blower in kW
bpn=bp-Pd;//Net increase in bp in kW
bpu=ip*Vi*(80/100);//The bp of unsupercharged engine in kW
bpp=(bpn/(bpu))*100;//Percentage increase in bp in percent

//Output
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

```
clc
clear
//Input data
p=1.013;//The pressure at the sea level in bar
T=283;//The temperature at the sea level in K
bp=275;//Brake power in kW
N=1800;//The speed of the engine in rpm
a=20;//Air fuel ratio
R=287;//The real gas constant in J/kgK
bsfc=0.24;//Brake specific fuel consumption in kg/kWh
nv=80;//Volumetric efficiency in percent
p2=0.75;//The atmospheric pressure at altitude in bar
P=9;//The power consumed by supercharger of the total power produced by the engine in percent
T2=303;//The temperature of air leaving the supercharger in K

//Calculations
mf=[bsfc*bp]/60;//Mass of fuel consumed in kg/min
ma1=mf*(a);//Mass of air used in kg/min
ma=(2/N)*ma1;//Actual mass of air taken in per cycle in kg/cycle
dai=(p*10^5)/(R*T);//The density of air in kg/m^3
Vd=(ma/(dai*(nv/100)));//Volume displaced by the piston in m^3
pmb=(bp*2*60*1000)/(Vd*N*10^5);//Brake mean effective pressure in bar
GP=bp/(1-0.09);//Gross power in kW
ma2=(ma1/bp)*GP;//The mass flow rate of air for gross power in kg/min
```

```
ma1=(ma2*2)/N;//Mass of air required for gross power per cycle in kg/cycle
p21=[(R*T2*ma1)/((nv/100)*Vd)]/10^5;//The pressure at the outlet condition of the supercharger in bar
pi=p21-p2;//Increase in air pressure required in the supercharger in bar

//Output
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

```
clc
clear
//Input data
Vs=0.003;//Swept volume in m^3
bmep=9;//Brake mean effective pressure in bar
N=4000;//The speed of the engine in rpm
ni=30;//Indicated thermal efficiency in percent
nm=90;//Mechanical efficiency in percent
bmep1=12;//The brake mean effective pressure of other engine in bar
N1=4000;//The speed of other engine in rpm
ni1=25;//The indicated thermal efficiency of other engine in percent
nm1=91;//The mechanical efficiency of other engine in percent
m=200;//The mass of naturally aspired engine in kg
m1=220;//The mass of supercharged engine in kg
CV=44000;//The calorific value of the fuel in kJ/kg

```

```
//Calculations
bp=(bmep*10^5*Vs*N)/(2*60*1000);//The brake power in kW
ip=bp/(nm/100);//The indicated power in kW
mf=(ip)/((ni/100)*CV);//Mass flow rate of fuel in kg/s
bp1=(bmep1*10^5*Vs*N1)/(2*60*1000);//The brake power for supercharged engine in kW
ip1=bp1/(nm1/100);//The indicated power for supercharged engine in kW
mf1=ip1/((ni1/100)*CV);//Mass flow rate of fuel for supercharged engine in kg/s
mf2=mf*3600;//Mass flow rate of fuel per hour in kg/h
mf3=mf1*3600;//Mass flow rate of fuel per hour in supercharged engine in kg/h
x=[(200/90)-(220/120)]/[(43.2/120)-(27.27/90)];//Maximum hours of fuel supply foe test in hrs

//Output
printf(' The maximum hours required for supply of sufficient fuel = %3.3f hr ',x)
```

Scilab code Exa 15.4 Centrifugal compressor

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

```
nm=85;//The mechanical efficiency of the engine in percent
T1=288;//The inlet temperature of air into compressor in K
p1=1;//The inlet pressure of air into compressor in bar
Q=1200;//Heat rejected rate in kJ/min
T=328;//The outlet temperature of air in K
p=1.7;//The outlet pressure of air in bar
nv=90;//Volumetric efficiency in percent
Cp=1.005;//Specific heat of gas in kJ/kg

//Calculations
bp=(2*pi*N*t)/(60*1000);//The brake power in kW
ip=bp/(nm/100);//The indicated power in kW
pmi=[(ip*2*60*1000*4)/[L*(pi*d^2)*N*n]]/10^5;//The mean effective pressure in bar
Vs=(pi/4)*d^2*L;//Swept volume in m^3
Vs1=Vs*(N/2)*n;//Volume swept by the piston per min
V1=(nv/100)*Vs1;//Rate of volume flow of air into the engine in m^3/min
me=[(p*10^5*V1)/(R*T)]*60;//Rate of mass flow of air into the engine in kg/h
E=Q/60;//Energy balance in the after cooling in kJ/s
T2=[(bp/E)*T-T1]/((bp/E)-1);//The outlet temperature of air in K
mc=[(bp)/(Cp*(T2-T1))]*3600;//Mass flow rate in kg/h
maf=mc-me;//Rate of air flow available to the consumer in kg/h

//Output
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

```
clc
clear
//Input data
Vs=0.0045;//Swept volume in m^3
N=4000;//The speed of the engine in rpm
nv=150;//Overall volumetric efficiency in percent
ni=90;//Isentropic efficiency of the compressor in percent
nm=85;//Mechanical efficiency in percent
T=330;//The temperature of compressed air after cooler in K
p2=1.8;//The pressure of the compressed air in bar
T1=290;//The ambient temperature of air in K
p1=1;//The pressure of the ambient condition in bar
R=287;//The real gas constant in J/kgK
g=1.4;//Adiabatic index
Cp=1.005;//The specific heat of gas in kJ/kgK

//Calculations
T21=T1*(p2/p1)^((g-1)/g);//The temperature at 2' in K
T2=T1+[(T21-T1)/(ni/100)];//The temperature of air after compressor in K
Vs1=Vs*(N/(2*60));//Rate of swept volume in m^3/s
Va=(nv/100)*Vs1;//Volume of air induced in m^3/s
d=(p1*10^5)/(R*T1);//The density of air at ambient condition in kg/m^3
ma=d*Va;//Mass of air induced in kg/s
Q=ma*Cp*(T2-T);//Heat rejected from after cooler in kJ/s
P=ma*Cp*(T2-T1);//Power needed to run the compressor in kW
```

```
Pa=P/(nm/100);//Power absorbed from the engine in kW

//Output
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

```
clc
clear
//Input data
p1=0.98;//The inlet pressure of air in bar
T1=290;//The inlet temperature of air in K
p2=1.8;//The pressure of air delivered to the engine in bar
a=20;//The air fuel ratio
T3=850;//The temperature of the exhaust gases leaving the engine in K
p3=1.6;//The pressure of the exhaust gases leaving the engine in bar
p4=1.03;//The turbine exhaust pressure in bar
nc=80;//The isentropic efficiency of compressor in percent
nt=85;//The isentropic efficiency of turbine in percent
Cpa=1.005;//The specific heat of air in kJ/kgK
Cpg=1.15;//The specific heat of gas in kJ/kgK
g=1.33;//isentropic index
h=1.4;//Adiabatic index

//Calculations
T21=T1*(p2/p1)^((h-1)/h);//The temperature at point 2' for compressor in K
```

```
T2=T1+((T21-T1)/(nc/100));//The temperature of air leaving the compressor in K
T22=T2-273;//The temperature of air leaving the compressor in degree centigrade
T41=T3*(p4/p3)^((g-1)/g);//The temperature at point 4' for turbine in K
T4=T3-((nt/100)*(T3-T41));//The temperature of gas leaving the turbine in K
T44=T4-273;//The temperature of gas leaving the turbine in degree centigrade
mf=1;//Assume mass flow rate of fuel in kg/s
ma=mf*a;//Then the mass flow rate of air in kg/s
Wc=ma*Cpa*(T2-T1);//Power required by the compressor in kW
mg=ma+mf;//Mass flow rate of gas in kg/s
Wt=mg*Cpg*(T3-T4);//Power developed by the turbine in kW
Pt=(Wc/Wt)*100;//Percentage of turbine power used to run the compressor in percent

//Output
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

```


clc
clear
```

```
//Input data
a=14;//Air fuel ratio
T1=288;//The ambient temperature of air in K
T2=(288-23);//The evaporation of fuel cause 23 degree C drop in mixture temperature in K
p=1.3;//Pressure ratio
nc=75;//The isentropic efficiency of the compressor in percent
Cpm=1.05;//The specific heat of the mixture in kJ/kgK
Cpa=1;//The specific heat of air in kJ/kgK
g=1.33;//Adiabatic index
h=1.4;//Isentropic index
ma=1;//Mass flow rate of air in kg/s

//Calculations
T31=T2*p^((g-1)/g);//Temperature at point 3' in K
T3=T2+((T31-T2)/(nc/100));//Temperature of the gas after compressor in K
mm=1+(1/a);//Mass flow rate of mixture in kg/s
Wc1=mm*Cpm*(T3-T2);//Power required by the compressor in kW/kg of air per second
T21=T1*p^((h-1)/h);//Temperature at point 2' in K
T4=T1+((T21-T1)/(nc/100));//The temperature after leaving the compressor in K
Wc2=ma*Cpa*(T4-T1);//Power required by the compressor in kW/kg of air per second
T5=T4-23;//Temperature of the gas after carburettor in K
Ps=[(Wc2-Wc1)*100]/Wc2;//Saving of power in the first case in percent

//Output
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)

//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

```
clc
clear
//Input data
N=3000;//The speed of the engine in rpm
r=9;//Compression ratio
l=17.2;//The length of the connecting rod in cm
t=20;//The combustion ends at a TDC in degrees
pi=3.141;//Mathematical constant of pi
k=3;//Three litre spark engine
n=6;//V-6 Engine

//Calculations
Vs=(k/n)*10^-3;//Swept volume per cylinder in m^3
d=[[(Vs*4)/pi]^(1/3)];//The diameter of the bore in
   m
L=d*100;//The length of the stroke in cm
up=2*d*N/60;//Average piston speed in m/s
Vc=[Vs/(r-1)]*10^6;//Clearence volume in cm^3
cr=(L)/2;//Crank radius in cm
```

```
R=l/cr;//The ratio of the connecting rod length to
    crank radius
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
s=(cr*cos(pi/9))+(l^2-(cr^2)*(sin(pi/9))^2)^(1/2);//
    Distance between crank axis and wrist pin in cm
x=l+cr-s;//The distance the piston travels from TDC
    at the end of combustion in cm
V=Vc+(pi/4)*(d*100)^2*x;//Instantaneous volume in cm
    ^3

//Output
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 clearence 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

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

```
n=55;//Firing strokes per minute

//Calculations
pmi=p-pp;//The net imep at full load in bar
c=((N/2)-n);//Dead cycles per minute at no load
ipw=pmi*10^5*L*(pi/4)*d^2*(n/60)*(1/1000);//
   Indicating power for working cycles in kW
Pp=pm*10^5*L*(pi/4)*d^2*(c/60)*(1/1000);//Pumping
   power of dead cycles in kW
fp=ipw-Pp;//Power in kW
fip=pmi*10^5*L*(pi/4)*d^2*(N/(2*60))*(1/1000);//Full
    load indicated power in kW
fbp=fip-fp;//Full load break power in kW
nm=(fbp/fip)*100;//Mechanical efficiency in percent

//Output
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

```
clc
clear
//Input data
d=0.09;//The diameter of the bore in m
L=0.1;//The length of the stroke in m
T=120;//The torque measured in Nm
pi=3.141;//Mathematical constant of pi
n=4;//Number of cylinders

//Calculations
pmb=[(4*pi*T)/(L*(pi/4)*d^2*n)]/10^5;//The brake
   mean effective pressure in bar

```

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

Scilab code Exa 16.4 Four cylinder SI engine

```
clc
clear
//Input data
d=0.06;//The diameter of the bore in m
L=0.085;//The length of the stroke in m
N=3000;//The speed of the engine in rpm
r=0.35;//Torque arm radius in m
W=160;//Weight in N
pi=3.141;//Mathematical constant
f=6.6;//Fuel consumption in l/h
g=0.78;//specific gravity of the fuel
CV=44000;//The calorific value of the fuel in kJ/kg
w1=114;//Brake load for cylinder 1 in N
w2=110;//Brake load for cylinder 2 in N
w3=112;//Brake load for cylinder 3 in N
w4=116;//Brake load for cylinder 4 in N
n=4;//Number of cylinders

//Calculations
Vf=(f*10^-3)/3600;//Volume flow rate of fuel in m^3/s
df=g*1000;//The density of the fuel in kg/m^3
mf=df*Vf;//Mass flow rate of fuel in kg/s
T=W*r;//Torque in Nm
bp=(2*pi*N*T)/(60*1000);//The brake power in kW
pmb=[(120*bp*1000)/(L*(pi/4)*d^2*N*n)]/10^5;//Brake mean effective pressure in bar
nb=[(bp)/(mf*CV)]*100;//The brake thermal efficiency in percent
```

```
bsfc=(mf*3600)/bp;//Brake specific fuel consumption
    in kg/kWh
bp1=[(2*pi*N*w1*r)/(60*1000)];//Brake power from
    morse test in kW
ip1=bp-bp1;//Indicated power in kW
ip2=bp-[(2*pi*N*w2*r)/(60*1000)];//Indicated power
    in kW
ip3=bp-[(2*pi*N*w3*r)/(60*1000)];//Indicated power
    in kW
ip4=bp-[(2*pi*N*w4*r)/(60*1000)];//Indicated power
    in kW
ip=ip1+ip2+ip3+ip4;//Total indicated power in kW
nm=(bp/ip)*100;//Mechanical efficiency in %
pmi=pmb/(nm/100);//The imep in bar

//Output
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

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

```
w=400;//The tension on either side of the pulley in
   N
c=2.2;//Brake circumference in m
l=50;//Length of the indicator diagram in mm
ap=475;//Area of the positive loop of indicator
   diagram in mm^2
an=25;//Area of the negative loop of indicator
   diagram in mm^2
s=0.8333;//Spring constant in bar/mm
pi=3.141;//Mathematical constant of pi

//Calculations
r=c/(2*pi);//Arm length in m
T=w*r;//Torque in Nm
bp=(2*pi*N*T)/(60*1000);//Brake power in kW
M=(ap-an)/l;//Mean height of indicator diagram in mm
imep=M*s;//Indicated mean effective pressure in bar
ip=(imep*10^5*L*(pi/4)*d^2*(N/(2*60))*(1/1000));//
   Indicated power in kW
nm=(bp/ip)*100;//The mechanical efficiency in
   percent
nb=[(bp*60)/(mf*CV)]*100;//The brake thermal
   efficiency in percent
ni=[(nb/100)/(nm/100)]*100;//The indicated thermal
   efficiency in percent
bsfc=(mf*60)/bp;//Brake specific fuel consumption in
    kg/kWh

//Output
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

```
clc
clear
//Input data
n=8;//Number of cylinders
d=0.08;//The diameter of the bore in m
L=0.1;//The length of the stroke in m
N=4500;//The speed of the engine in rpm
dy=0.55;//The dynamometer readings in m
w=40;//The weight of the dynamometer scale reading in kg
c=100;//Fuel consumption in cc
t=9.5;//Time taken for fuel consumption in s
CV=44000;//The calorific value of the fuel in kJ/kg
p=1;//The atmospheric air pressure in bar
T=300;//The atmospheric air temperature in K
pi=3.141;//Mathematical constant of pi
ma=6;//Mass flow rate of air in kg/min
g=0.7;//Specific gravity of the fuel
Vc=65;//The clearance volume of each cylinder in cc
R=287;//Real gas constant in J/kgK
g=1.4;//Isentropic index

//Calculations
bp=(2*pi*N*dy*w*9.81)/(60*1000);//The brake power in kW
bmep=[(bp*1000*60)/(L*(pi/4)*d^2*(N/2)*n)]/10^5;//The brake mean effective pressure in bar
mf=(c*g*3600)/(t*2*1000);//The mass flow rate of fuel in kg/h
bsfc=(mf/bp);//Brake specific fuel consumption in kg/kWh
bsac=(ma*60)/bp;//Brake specific air consumption in
```

```
kg/kWh
a=bsac/bsfc;//Air fuel ratio
nb=((bp*3600)/(mf*CV))*100;//The brake thermal efficiency in percent
Va=(ma*R*T)/(p*10^5);//The volume flow rate of air at intake condition in m^3/min
Vs=(pi/4)*d^2*L*(N/2)*n;//The swept volume per minute in m^3/min
nv=(Va/Vs)*100;//Volumetric efficiency in percent
Vs1=[(pi/4)*d^2*L]*10^6;//Swept volume per cylinder in cc
cr=(Vs1+Vc)/Vc;//Compression ratio
na=[1-(1/cr)^(g-1)]*100;//Air standard efficiency in percent
re=[(nb)/(na)]*100;//Relative efficiency in percent

//Output
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

```
clc
clear
//Input data
n=6;//Number of cylinders
Do=0.03;//Orifice diameter in m
Cd=0.6;//Coefficient of discharge
```

```
H=0.14;//Pressure drop across the orifice
d=0.1;//The diameter of the bore in m
L=0.11;//The length of the stroke in m
W=540;//Brake load in N
N=2500;//Engine speed in rpm
ch=83/17;//C/H ratio by mass
p=1;//Ambient pressure in bar
t=18;//Time taken for fuel consumption in s
f=100;//The amount of fuel consumption in cc
T=300;//Ambient air temperature in K
df=780;//The density of the fuel in kg/m^3
R=287;//Real gas constant in J/kgK
g=9.81;//Gravitational force constant in m/s^2
pi=3.141;//Mathematical constant
dhg=13600;//Density of Hg in kg/m^3

//Calculations
da=(p*10^5)/(R*T);//The density of air in kg/m^3
Va=(Cd*(pi/4)*Do^2*[2*g*H*(dhg/da)]^(1/2));//Volume flow rate of air in m^3/s
Vs=(pi/4)*d^2*L*(N/(2*60))*n;//Swept volume per second in m^3/s
nv=(Va/Vs)*100;//Volumetric efficiency in percent
bp=(W*N)/(20000);//The brake power in kW
bmep=[(bp*1000)/(L*(pi/4)*d^2*(N/(2*60))*n)]/10^5;//The brake mean effective pressure in bar
T=(60*bp*1000)/(2*pi*N);//Torque in Nm
mf=(f/18)*(780/1000)*(1/1000)*3600;//Mass flow rate of fuel in kg/h
bsfc=mf/bp;//The brake specific fuel consumption in kg/kWh
so=(0.83*(32/12))+(0.17*(8/1));//Stoichiometric oxygen required per kg of fuel in kg/kg fuel
sa=so/bsfc;//Stoichiometric air required in kg/kg fuel
maa=Va*da;//Actual mass flow rate of air in kg/s
af=(maa*3600)/mf;//Actual air fuel ratio
pea=[(af-sa)/sa]*100;//Percentage of excess air in
```

```
percent

//Output
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 = %3.3f kg/kWh \n The percentage of excess air = %3.1f percent ',nv,bmep,bp,T,bsfc,pea)
```

Scilab code Exa 16.8 The efficiencies

```
clc
clear
//Input data
d=0.2;//The diameter of bore in m
L=0.3;//The length of the stroke in m
r=5.5;//The compression ratio of the engine
N=400;//The speed of the engine in rpm
imep=4.5;//The indicative mean effective pressure in bar
a=6;//Air to gas by volume
CV=12000;//The calorific value of the gas in kJ/m^3
T=340;//The temperature at the beginning of the compression stroke in K
p=0.97;//The pressure at the beginning of the compression stroke in bar
pi=3.141;//The mathematical constant of pi
g=1.4;//Adiabatic index

//Calculations
Vs=(pi/4)*d^2*L;//The swept volume in m^3
Vc=Vs/(r-1);//The clearance volume in m^3
V=Vs+Vc;//Total cylinder volume in m^3
Vg=V/7;//Volume of the gas in total cylinder volume
```

```
in m^3
Vntp=((p*Vg)/T)*(273/1.013);//Volume of gas at NTP in m^3
Q=Vntp*CV*(N/(2*60));//Heat supplied by the fuel in kJ/s
ip=(imep*10^5*L*(pi/4)*d^2*(N/(2*60))*(1/1000));//Indicated power in kW
ni=(ip/Q)*100;//Indicated thermal efficincy in percent
na=[1-(1/r)^(g-1)]*100;//Air standard efficiency in percent
nr=(ni/na)*100;//Relative efficiency based on indicated thermal efficiency in percent

//Output
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

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

```
percent
ni=38;//The indicated thermal efficiency in percent
nm=80;//The mechanical efficiency in percent
ac=110;//The excess consumption of air in percent
sb=1.2;//The stroke to the bore ratio
da=1.3;//The density of air in kg/m^3
pi=3.141;//Mathematical constant of pi

//Calculations
saf=(((C/100)*(32/12))+((H/100)*(8/1)))*(1/0.23);//The stoichiometric air fuel ratio
aaf=saf*(1+1.1);//The actual air fuel ratio
Ma=(0.23*32)+(0.77*28);//The molecular weight of air in kg/kmol
a=(C/100)/12;//For carbon balance
b=(H/100)/2;//For hydrogen balace
x=aaf/Ma;//Number of kmol of air per kg of fuel
c=(0.21*x)-a-(b/2);//For oxygen balance
d1=0.79*x;//For nitrogen balance
ip=bp/(nm/100);//The indicated power in kW
mf=ip/[(ni/100)*CV];//The mass flow rate of fuel in kg/s
ma=mf*aaf;//The mass flow rate of air in kg/s
Va=ma/da;//Actual volume flow rate in m^3/s
Vs=Va/(na/100);//The swept volume per second in m^3/s
d=[[Vs*(4/pi)*(1/1.2)*((2*60)/N)*(1/n)]^(1/3)]*1000;//The diameter of the bore in mm
L=1.2*d;//The length of the stroke in mm
T=a+c+d1;//The total composition in kmol
CO2=(a/T)*100;//The volume of CO2 in %
O2=(c/T)*100;//The volume of O2 in %
N2=(d1/T)*100;//The volume of N2 in %

//Output
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

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

```

//Calculations
ip=(pmi-pp)*10^5*L*(pi/4)*d^2*(Ne/(30*60))*(1/1000);//The indicated power in kW
bp=(pi*(N/(30*60))*W*9.81*(dd+dr)*(1/1000));//The brake power in kW
pgs=760+(pg/13.6);//Pressure of gas supplied in mm of Hg
Vg=((pgs*V)/290)*(273/760);//The volume of gas in m^3
Q=(Vg*CV)/30;//Heat supplied by gas used at NTP in kJ/min
Qbp=bp*60;//Heat equivalent of bp in kJ/min
Qc=(C/t)*4.18*Tr;//Heat lost to cooling medium in kJ/min
Va=[((p*ta)/T)*(273/760)]/30;//Volume of air used in kg/min
da=(1.013*10^5)/(R*273);//The density of air in kg/m^3
ma=Va*da;//Mass of air used in kg/min
mg=(Vg/30)*dg;//Mass of gas at NTP in kg/min
me=ma+mg;//Total mass of exhaust gas in kg/min
Qe=me*Cpg*(Te-(T-273));//Heat loss to exhaust gas in kJ/min
Qu=Q-(Qe+Qc+Qbp);//Unaccounted heat loss in kJ/min
nm=(bp/ip)*100;//Mechanical efficiency in percent
ni=((ip*60)/Q)*100;//Indicated thermal efficiency in percent
x=((Qbp/1571)*100);//percentage heat in bp
y=((Qc/1571)*100);//Percent heat lost to cooling water
z=((Qe/1571)*100);//Percent heat to exhaust gases
k=((Qu/1571)*100);//Percent heat unaccounted

//Output
printf('
   ____________________________________________________________________
   n              Heatinput          kJ/min
```

```
percent      Heat expenditure            kJ/min
      percent  \n
_____________________________________________________________________
 \n                         Heat

\n                        supplied      1571         100
        (a) Heat in bp                      %3.1f
      %3.1f   \n

(b) Heat loss to cooling water  %3.1f        %3.1f
   \n

(c) Heat to exhaust gas          %3.1f        %3.1f
   \n

(d) Unaccounted heat            %3.1f      %3.1f \
n
_____________________________________________________________________
         \n The mechanical efficiency = %3.2f
percent \n The Indicated thermal efficiency = %3
.1f percent ',Qbp,x,Qc,y,Qe,z,Qu,k,nm,ni)
```

Scilab code Exa 16.11 Heat balance sheet

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

```
Tc=40;//Rise in temperature when passing through
   calorimeter in degree centigrade
Te=80;//Temperature of exhaust gas leaving the
   calorimeter in degree centigrade
a=20;//Air fuel ratio
T=17;//Ambient temperature in degree centigrade
Cpw=4.18;//Specific heat of water in kJ/kgK
Cpg=1;//Mean specific heat of gas in kJ/kgK

//Calculations
Qf=(mf/60)*CV;//Heat supplied by fuel in kJ/min
Qbp=bp*60;//Heat equvalent to bp in kJ/min
Qc=mw*Cpw*Tr;//Heat carried away by the jacket
   cooling water in kJ/min
mg=(mf/60)+(mf/60)*a;//Mass of exhaust gas formed in
    kg/min
Qe=(mwe*Cpw*Tc)+(mg*Cpg*(Te-T));//Heat carried away
   by exhaust gas in kJ/min
Qu=Qf-(Qbp+Qc+Qe);//Unaccounted heat in kJ/min
x=((Qbp/Qf))*100;//Percentage heat in bp
y=(Qc/Qf)*100;//Percentage loss of cooling water
z=(Qe/Qf)*100;//Percentage loaa of heat to exhaust
   gases
k=(Qu/Qf)*100;//Percentage heat loss unaccounted

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

```
                                                          (c)
   Heat to exhaust gases           %3.0f                   %3
   .2f        \n
                                                            (d)
   Unaccounted heat loss            %3.0f                   %3
   .2f       \n           total                   %3.0f       100
                        total                          %3.0f
              100     \n
   ----------------------------------------------------------------------
    ',Qf,Qbp,x,Qc,y,Qe,z,Qu,k,Qf,Qf)
```

Scilab code Exa 16.12 Heat balance sheet

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

```
Cpe=1;//The mean specific heat of dry exhaust gas in kJ/kgK
Cps=2;//The specific heat of super heated steam in kJ/kgK
Cpw=4.18;//The specific heat of water in kJ/kgK
Ts=100;//At 76 cm of Hg The temperature in degree centigrade
hfg=2257;//The Enthalpy in kJ/kg
pi=3.141;//Mathematical constant of pi
R=287;//Real gas constant in J/kgK

//Calculations
bp=(2*pi*N*w*tr)/(60*1000);//The brake power in kW
bp1=(2*pi*N*w1*0.35)/(60*1000);//The brake power when each cylinder is cut off in kW
ip=bp-bp1;//Indicated power per cycle in kW
ip1=n*ip;//Indicated power of the engine in kW
imep=[(ip1*60*1000)/(L*(pi/4)*d^2*(N/2)*n)]/10^5;//The indicated mean effective pressure in bar
ni=[(ip1*60)/(mf*CV)]*100;//Indicated thermal efficiency in percent
bsfc=(mf*60)/bp;//Brake specific fuel consumption in kg/kWh
Vs=(pi/4)*d^2*L*(N/2)*n;//Swept volume in m^3/min
ma=a*mf;//Mass flow rate of air in kg/min
da=(1*10^5)/(R*(Ta+273));//The density of air in kg/m^3
Va=ma/da;//Volume of air flow in m^3/min
nv=[Va/Vs]*100;//Volumetric efficiency in percent
Qf=mf*CV;//Heat supplied by fuel in kJ/min
Qbp=bp*60;//The heat equivalent to bp in kJ/min
Qc=mw*Cpw*Tw;//Heat lost to cooling water in kJ/min
mv=9*(H/100)*mf;//Mass of water vapour in kg/min
me=ma+mf-mv;//Mass of dry exhaust gas in kg/min
Qe=me*Cpe*(Te-Ta);//Heat carried away by the exhaust gas in kJ/min
Qs=(mv*([Cpw*(Ts-Ta)]+hfg+(Cps*(Te-Ts))));//Heat lost in steam in kJ/min
```

```
Qu=Qf-(Qbp+Qc+Qe+Qs);//Unaccounted heat loss in kJ/
    min
x=(Qbp/Qf)*100;//Percentage of heat in bp
y=(Qc/Qf)*100;//Percentage of heat loss in colling
    water
z=(Qe/Qf)*100;//Percentage heat loss in dry exhaust
    gas
k=(Qs/Qf)*100;//Percentage heat lost to steam
l=(Qu/Qf)*100;//Percentage  of unaccounted heat lost

//Output
printf('
   ----------------------------------------------------------------------------------------------------
    n        Heat input                 kJ/min         percent
                Heat expenditure             kJ/min
    percent    \n
   ----------------------------------------------------------------------------------------------------
    n   Heat supplied by fuel      %3.0f            100
          (a) Heat in bp                          %3.0f
              %3.2f   \n

    (b) Heat lost to cooling water     %3.0f          %3
    .2f   \n

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

    (d) Heat lost in steam             %3.0f          %3
    .2f   \n

    (e) Unaccounted heat loss          %3.0f          %3
    .2f   \n           total                %3.0f
              100                          Total
                   %3.0f            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 comsumption =
```

```
 %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)
```