Scilab Textbook Companion for Internal Combustion Engines by H. B. Keswani[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

INTRODUCTION

Scilab code Exa 1.1 MECHANICAL EFFICIENCY

```
clc
clear
//Input data
BHP=51//Brake horse power in h.p
N=1000//Speed in r.p.m
FHP=17//Friction horse power in h.p

//Calculations
IHP=(BHP+FHP)//Indicated Horse power in h.p
mn=(BHP/IHP)*100//Mechanical efficiency in percent

//Output
printf('Mechanical efficiency of the engine is %i
   percent',mn)
```

Scilab code Exa 1.2 MECHANICAL EFFICIENCY

```
clc
```

```
clear
//Data taken from Ex.No.1
BHP=51//Brake horse power in h.p
N=1000//Speed in r.p.m
FHP=17//Friction horse power in h.p
//Input data
O1=BHP/2//Half of b.h.p output in h.p
O2=10//Brake horse power in h.p

//Calculations
//Case(i)
IHP1=(O1+FHP)//Indicated Horse power in h.p
mn1=(O1/IHP1)*100//Mechanical efficiency in percent

//Case(ii)
IHP2=(O2+FHP)//Indicated Horse power in h.p
mn2=(O2/IHP2)*100//Mechanical efficiency in percent


//Output
printf('Mechanical efficiency of the engine when it
    delivers \n (a) Half the b.h.p output is %3.0f
    percent \n (b) 10 b.h.p is %3.0f percent',mn1,mn2
    )
```

Scilab code Exa 1.3 BRAKE THERMAL EFFICIENCY

```
clc
clear
//Input data
Fc=220//Fuel consumption in gm/(b.h.p*hr)
CV=10600//Calorific value in kcal/kg

//Calculations
hf=(Fc/1000)*CV//Heat supplied in kcal/hr
```

```
O=632//Output in terms of kcal/hr
bn=(O/hf)*100//Brake thermal efficiency in percent

//Output
printf('Brake thermal efficiency is %3.1f percent',
    bn)
```

Scilab code Exa 1.4 THERMAL EFFICIENCY

```
clc
clear
//Input data
IHP=45//Indicated horse power in h.p
Fc=13//Fuel consumption in litres/hr
g=0.8//Specific gravity of oil
nm=80//Mechanical efficiency in percent
CV=10000//Calorific value of fuel in kcal/kg

//Calculations
BHP=(IHP*nm)/100//Brake horse power in h.p
hi=(Fc*g*CV)//Heat supplied in kcal/hour
In=((IHP*4500*60)/(427*hi))*100//Indicated thermal
    efficiency in percent
Bn=(In*(nm/100))//Brake thermal efficiency in
    percent

//Output
printf('Indicated thermal efficiency is %3.2f
    percent \n Brake thermal efficiency is %3.2f
    percent',In,Bn)
```

Scilab code Exa 1.5 FUEL CONSUMPTION

```
clc
clear
//Input data
BHP=15//Brake horse power in h.p
In=28//Indicated thermal efficiency in percent
mn=75//Mechanical efficiency in percent
CV=10000//Calorific value of fuel in kcal/kg

//Calculations
Bn=((In/100)*(mn/100))*100//Brake thermal efficiency
    in percent
I=(BHP/(Bn/100))*((4500*60)/427)//Input in kcal/hr
Fc=(I/CV)//Fuel consumption in kg/hr

//Output
printf('Fuel consumption of the engine is %3.2f kg/
   hr',Fc)
```

Chapter 3

AIR STANDARD CYCLES

Scilab code Exa 3.1 AUR STANDARD EFFICIENCY

```
clc
clear
//Input data
p=[1,8]//Pressure at the beginning and end of compression in kg/m^3
g=1.4//Ratio of specific heats

//Calculations
r=(p(2)/p(1))^(1/g)//Compression ratio
n=(1-(1/r)^(g-1))*100//Air standard efficiency in percent

//Output
printf('Air standard efficiency of an engine working on the Otto cycle is %3.1f percent',n)
```

Scilab code Exa 3.2 THERMAL EFFICIENCY

```
clc
clear
//Input data
D=0.25//Bore in m
L=0.45//Stroke in m
Cv=5//Clearance volume in litres
g=1.4//Ratio of specific heats
IHP=32//Indicated Horse power in h.p
m=14//Gas consumption in m^3/hr
CV=4000//Calorific value of gas in kcal/m^3

//Calculations
Vs=(3.14/4)*D^2*L//Stroke volume in m^3
Vc=Cv/1000//Clearance volume in m^3
r=(Vs+Vc)/Vc//Compression ratio
na=(1-(1/r)^(g-1))*100//Air standard efficiency in percent
q=(m*CV)/60//Heat supplied in kcal/min
aI=(IHP*4500)/427//Heat equivalent of I.H.P in kcal/min
itn=(aI/q)*100//Indicated thermal efficiency in percent
rn=(itn/na)*100//Relative efficiency in percent

//Output
printf('The air standard efficiency is %3.1f percent\n Indicated thermal efficiency is %3.1f percent\n Relative efficiency is %3.1f percent',na,itn,rn)
```

Scilab code Exa 3.3 FUEL CONSUMPTION

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

```
r=6//Compression ratio
It=0.6//Indicated thermal efficiency ratio
CV=10000//Calorific value in kcal/kg
g=1.4//Ratio of specific heats

//Calculations
an=(1-(1/r)^(g-1))*100//Air standard efficiency in
    percent
In=(It*(an/100))//Indicated thermal efficiency
SFC=((4500*60)/(427*CV*In))//Specific fuel
    consumption in kg/I.H.P.hr

//Output
printf('Specific fuel consumption is %3.3f kg/I.H.P.
    hr',SFC)
```

Scilab code Exa 3.4 RATIO

```
clc
clear
//Input data
T=[100+273,473+273]//Temperatures at the beginning
    and at the end of adiabatic compression in K
g=1.4//Ratio of specific heats

//Calculations
an=(1-(T(1)/T(2)))*100//Air standard efficiency in
    percent
r=(T(2)/T(1))^(1/(g-1))//Compression ratio

//Output
printf('The compression ratio is %3.2f \n Air
    standard efficiency is %i percent',r,an)
```

Scilab code Exa 3.5 AIR STANDARD EFFICIENCY

```
clc
clear
//Input data
T1=45+273//Temperature at the beginning of compression in K
p1=1//Pressure at the beginning of compression in kg/cm^2
T2=325+273//Temperature at the end of compression in K
T3=1500+273//Temperature at the end of constant volume heat addition in K
g=1.4//Ratio of specific heats

//Calculations
r=(T2/T1)^(1/(g-1))//Compression ratio
an=(1-(1/r)^(g-1))*100//Air standard efficiency in percent
p2=(p1*r^g)//Pressure at the end of compression in kg/cm^2
p3=(p2*(T3/T2))//Pressure at the end of constant volume heat addition in kg/cm^2
p4=p3/p2//Pressure at the end of adiabatic expansion in kg/cm^2
T4=T3/r^(g-1)//Temperature at the end of adiabatic expansion in K
t4=T4-273//Temperature at the end of adiabatic expansion in degree C

//Output
printf('The air standard efficiency is %3.1f percent \n Temperature at the end of adiabatic expansion is %i degree C \n Pressure at the end of
```

```
   adiabatic expansion is %3.0f kg/cm^2',an,t4,p4)
```

Scilab code Exa 3.6 HEAT AND WORK

```
clc
clear
//Input data
T1=40+273//Temperature at the beginning of
   compression in K
p1=1//Pressure at the beginning of compression in kg
   /cm^2
p2=15//Pressure at the end of adabatic compression
   in kg/cm^2
T3=2000+273//Maximum temperature during the cycle in
    K
Cv=0.17//Specific heat at constant volume in kJ/kg.K
g=1.4//Ratio of specific heats

//Calculations
T2=T1*(p2/p1)^((g-1)/g)//Temperature at the end of
   adabatic compression in K
na=(1-(T1/T2))*100//Air standard efficiency in
   percent
q=(Cv*(T3-T2))//Heat added in kcal/kg of air
W=((na/100)*q)//Workdone per kg of air in kcal
W1=(4.28*W)//Workdone per kg of air in kg.m
p3=(p2*(T3/T2))//Pressure at the end of constant
   volume heat addition in kg/cm^2
p4=(p3*p1)/p2//Pressure at the end of adiabatic
   expansion in kg/cm^2

//Output
printf('(a) The heat supplied is %3.0f kcal/kg of
   air \n (b) The workdone is %i kcal/kg of air \n (
   c) The pressure at the end of adiabatic expansion
```

```
is %3.2f kg/cm^2',q,W,p4)
```

Scilab code Exa 3.7 AIR STANDARD EFFICIENCY

```
clc
clear
//Input data
r=16//Compression ratio
k=5//Cut off takes place at 5% of the stroke
g=1.4//Ratio of specific heats

//Calculations
c=(((k/100)*(r-1))+1)//Cut off ratio
na=(1-((1/r^(g-1))*((c^g-1)/(g*(c-1)))))*100//Air standard efficiency in percent

//Output
printf('The air standard efficiency is %3.1f percent ',na)
```

Scilab code Exa 3.8 THERMAL EFFICIENCY

```
clc
clear
//Input data
p1=1.05//Inlet pressure in kg/cm^2
T1=15+273//Inlet temperature in K
p2=33.4//Pressure at the end of adiabatic compression in kg/cm^2
r=5//The ratio of expansion
Cp=0.238//Specific heat at constant pressure in kJ/kg.K
Cv=0.17//Specific heat at constant volume in kJ/kg.K
```

```
g=1.4//Ratio of specific heats

//Calculations
r1=(p2/p1)^(1/g)//Compression ratio
k=r1/r//Cutoff ratio
T2=(p2/p1)^((g-1)/g)*T1//Temperature at the end of
    adiabatic compression in K
T3=T2*k//Temperature at the end of constant pressure
     heat addition in K
T4=T3*(1/r)^(g-1)//Temperature at the end of
    adiabatic expansion in K
qa=(Cp*(T3-T2))//Heat added in kcal/kg of air
qre=(Cv*(T4-T1))//Heat rejected in kcal/kg of air
nt=((qa-qre)/qa)*100//Ideal thermal efficiency in
    percent

//Output
printf('The ideal thermal efficiency is %3.1f
    percent',nt)
```

Scilab code Exa 3.9 TEMPERATURE AND EFFICIENCY

```
clc
clear
//Input data
p1=1//Pressure at the end of suction stroke in kg/cm
    ^2
T1=30+273//Temperature at the end of suction stroke
    in kg/cm^2
T3=1500+273//Maximum temperature during the cycle in
     K
r=16//Compression ratio
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K
Cv=0.17//Specific heat at constant volume in kJ/kg.K
```

```
g=1.41//Ratio of specific heats

//Calculations
T2=T1*r^(g-1)//Temperature at the end of adiabatic
    compression in K
s=(((T3/T2)-1)/(r-1))*100//Percentage of the stroke
    at which cut off occurs
r1=(r/(T3/T2))//Expansion ratio
T4=T3/(r1)^(g-1)//Temperature at the end of
    adiabatic expansion in K
qa=(Cp*(T3-T2))//Heat added in kcal/kg of air
qre=(Cv*(T4-T1))//Heat rejected in kcal/kg of air
nt=((qa-qre)/qa)*100//Air standard efficiency in
    percent

//Output
printf('(a) The percentage of stroke at which cut
    off takes place is %3.2f percent \n (b) The
    temperature at the end of expansion stroke is %3
    .0f K \n (c) The theoretical efficiency is %3.0f
    percent',s,T4,nt)
```

Scilab code Exa 3.10 PRESSURE AND HEAT

```
clc
clear
//Input data
p1=1//Pressure at the beginning of compression in kg
    /cm^2
T1=80+273//Temperature at the beginning of
    compression in K
r=14//Compression ratio
p4=2.7//Pressure at the end of expansion in kg/cm^2
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K
```

```
g=1.4//Ratio of specific heats

//Calculations
p2=p1*r^g//Pressure at the end of compression in kg/cm^2
s=(((r*(p4/p2)^(1/g))-1)/(r-1))*100//Percentage of stroke when the fuel is cut off in percent
T2=(T1*(p2/p1))/r//Temperature at the end of compression in K
T3=(T2*r*(p4/p2)^(1/g))//Temperature at the end of adiabatic expansion in K
q=(Cp*(T3-T2))//Heat supplied in kcal/kg

//Output
printf('(a) The maximum pressure attained during the cycle is %3.1f kg/cm^2 \n (b) The percentage of working stroke at which the heat supply to the working fluid ceases is %3.2f percent \n (c) The heat received per kg of woring substance during the cycle is %3.0f kcal/kg',p2,s,q)
```

Scilab code Exa 3.11 AIR STANDARD EFFICIENCY

```
clc
clear
d=0.25//Diameter of the cylinder in m
L=0.35//Stroke in m
Cv=1500//Clearance volume in c.c
s=5//cut off ratio takes place at 5 percent of stroke
a=1.4//Explosion ratio
g=1.4//Ratio of specific heats for air

//Calculations
Vs=(3.14/4)*d^2*L//Stroke volume in m^3
```

```
r=(Vs*10^6+Cv)/Cv//Compression ratio
k=(Cv+((s/100)*Vs*10^6))/Cv//Cut off ratio
na=(1-((1/(r^(g-1)))*((a*k^g-1)/((a-1)+a*g*(k-1)))))
    *100//Air standard efficiency in percent

//Output
printf('The air standard efficiency of the engine is
     %3.1f percent',na)
```

Scilab code Exa 3.12 AIR STANDARD EFFICIENCY

```
clc
clear
//Input data
d=0.2//Diameter of the cylinder in m
L=0.4//Stroke in m
r=13.5//Compression ratio
a=1.42//Explosion ratio
s=5.1//Cut off occurs at 5.1 percent of the stroke
g=1.4//Ratio of specific heats for air

//Calculations
Vs=(3.14/4)*d^2*L*10^-6//Stroke volume in c.c
Vc=Vs/r//Clearance volume in c.c
k=(((s/100)*Vs)+Vc)/Vc//Cut off ratio
ASE=(1-((1/(r^(g-1)))*((a*k^g-1)/((a-1)+a*g*(k-1))))
    )*100//Air standard efficiency in percent

//Output
printf('The air standard efficiency of the engine is
     %3.1f percent',ASE)
```

Scilab code Exa 3.13 TEMPERATURE AND EFFICIENCY

```
clc
clear
//Input data
x=[2/3,1/3]//The dual cycle atkes two−thirds of its total heat supply at constant volume and one−third at constant pressure
r=13//Compression ratio
p3=43//Maximum pressure of the cycle in kg/cm^2
p1=1//Pressure at intake in kg/cm^2
T1=15+273//Intake temperature in K
Cp=0.24//Specific heat at constant pressure in kJ/kg.K
Cv=0.17//Specific heat at constant volume in kJ/kg.K
g=1.41//Ratio of specific heats

//Calculations
T2=T1*r^(g-1)//Temperature at the end of compression in K
p2=(p1*r^g)//Pressure at the end of compression in kg/cm^2
T3=T2*p3/p2//Temperature at the end of constant volume heat addition in K
q23=Cv*(T3-T2)//Heat added at constant volume in kcal/kg
q34=(1/2)*q23//Heat added at constant pressure in kcal/kg
T4=(q34/Cp)+T3//Temperature at the end of constant pressure heat supply in K
T5=(T4*((p1*(T4/T3))/r)^(g-1))//Temperature at the end of expansion in K
na=(1-((Cv*(T5-T1))/((Cv*(T3-T2))+(Cp*(T4-T3)))))*100//Efficiency in percent
T=[T1-273,T2-273,T3-273,T4-273,T5-273]//Temperature at the five cardinal points in degree C

//Output
printf('(a) The temperature at the five cardinal points of the cycle are : \n point 1 is %3.0f
```

```
degree C \n point 2 is %3.0f degree C \n point 3 is %3.0f degree C \n point 4 is %3.1f degree C \n point 5 is %3.0f degree C \n\n (b) The ideal thermal efficiency of the cycle is %3.1f percent',T(1),T(2),T(3),T(4),T(5),na)
```

Scilab code Exa 3.14 AIR STANDARD EFFICIENCY

```
clc
clear
//Input data
p1=1//Pressure at intake in kg/cm^2
T1=100+273//Intake temperature in K
r=10//Compression ratio
p3=70//Maximum pressure of the cycle in kg/cm^2
q=400//Amount of heat added in kcal/kg of air
Cp=0.24//Specific heat at constant pressure in kJ/kg.K
Cv=0.17//Specific heat at constant volume in kJ/kg.K
g=1.41//Ratio of specific heats

//Calculations
T2=(T1*r^(g-1))//Temperature at the end of compression in K
p2=(p1*r^g)//Pressure at the end of compression in kg/cm^2
T3=T2*(p3/p2)//Temperature at the end of constant volume heat addition in K
qv=(Cv*(T3-T2))//Heat added at constant volume in kcal/kg
qp=(q-qv)//Heat added at constant pressure in kcal/kg
T4=(qp/Cp)+T3//Temperature at the end of constant pressure heat supply in K
k=(T4/T3)//Cut off ratio
```

```
T5=T4/(r/k)^(g-1)//Temperature at the end of expansion in K
qv2=Cv*(T5-T1)//Heat added at constant volume in kcal/kg
W=q-qv2//Workdone in kcal/kg of air
na=(W/q)*100//Air standard efficiency in percent

//Output
printf('The temperature at the five cardinal points of the cycle are : \n point 1 is %3.0f K \n point 2 is %3.0f K \n point 3 is %3.0f K \n point 4 is %3.0f K \n point 5 is %3.0f K \n\n The air standard efficiency of the engine is %3.1f percent',T1,T2,T3,T4,T5,na)
```

Scilab code Exa 3.15 WORK DONE AND EFFICIENCY

```
clc
clear
//Input data
r=12//Compression ratio
p1=0.955//Pressure at the start of compression in kg/cm^2
T1=85+273//Temperature at the start of compression in K
p3=55//Maximum pressure of the cycle in kg/cm^2
x=(1/30)//Constant pressure heat reception contnues for 1/30 of the stroke
Cp=0.238//Specific heat at constant pressure in kJ/kg.K
Cv=0.17//Specific heat at constant volume in kJ/kg.K
g=1.4//Ratio of specific heats

//Calculations
T2=T1*r^(g-1)//Temperature at the end of compression
```

```
in K
p2=(p1*r^g)//Pressure at the end of compression in kg/cm^2
T3=T2*(p3/p2)//Temperature at the end of constant volume heat addition in K
T4=(T3*((p1+x*(r-1))/p1))//Temperature at the end of constant pressure heat supply in K
T5=T4*((p1+x*(r-1))/r)^(g-1)//Temperature at the end of expansion in K
qs=(Cv*(T3-T2))+(Cp*(T4-T3))//Heat supplied in kcal/kg of air
qre=(Cv*(T5-T1))//Heat rejected in kcal/kg of air
W=(qs-qre)//Workdone in kcal/kg of air
an=((qs-qre)/qs)*100//Air standard efficiency in percent

//Ouptut
printf('The wordone per kg of air is %3.2f kcal \n The ideal thermal efficiency is %3.1f percent',W,an)
```

Scilab code Exa 3.16 TEMPERATURE AND EFFICIENCY

```
clc
clear
//Input data
p1=1//Pressure of air intake in kg/cm^2
T1=50+273//Temperature of air intake in K
v=(1/14)//Volume compresses by it adiabatically of its original volume
x=2//During the first stage, the pressure increases at constant volume to twice the pressure of the adiabatc compression, and during the second stage the volume is increased twice the clearance volume at constant pressure
```

```
r=(1/v)//Compression ratio
Cp=0.237//Specific heat at constant pressure in kJ/kg.K
Cv=0.169//Specific heat at constant volume in kJ/kg.K
g=1.4//Ratio of specific heats for air

//Calculations
T2=T1*r^(g-1)//Temperature at the end of compression in K
p2=(p1*r^g)//Pressure at the end of compression in kg/cm^2
p3=x*p2//Pressure at the end of the heat addition at constant volume in kg/cm^2
T3=T2*(p3/p2)//Temperature at the end of constant volume heat addition in K
T4=(T3*x)//Temperature at the end of constant pressure heat supply in K
T5=T4/(r/x)^(g-1)//Temperature at the end of expansion in K
qs=(Cv*(T3-T2))+(Cp*(T4-T3))//Heat supplied in kcal/kg of air
qre=(Cv*(T5-T1))//Heat rejected in kcal/kg of air
na=((qs-qre)/qs)*100//Air standard efficiency in percent
T=[T1-273,T2-273,T3-273,T4-273,T5-273]//Temperature at the five key points in degree C

//Output
printf('(a) The temperature at the five key points of the cycle are : \n point 1 is %3.0f K = %3.0f degree C \n point 2 is %3.0f K = %3.0f degree C \n point 3 is %3.0f K = %3.0f degree C \n point 4 is %3.0f K = %3.0f degree C \n point 5 is %3.0f K = %3.0f degree C \n\n (b) The ideal thermal efficiency of the cycle is %3.2f percent',T1,T(1),T2,T(2),T3,T(3),T4,T(4),T5,T(5),na)
```

Scilab code Exa 3.18 MEAN EFFECTIVE PRESSURE

```
clc
clear
//Input data
n=6//Six cylinder engine
r=5//Compression ratio
Vc=110//Clearance volume in c.c
a=0.66//Efficiency ratio referred to the air
   standard cycle
N=2400//Speed in r.p.m
m=9.9//Mass of petrol in kg
CV=10600//Calorific value of fuel in kcal/kg
g=1.4//Ratio of specific heats

//Calculations
Vs=(r*Vc-Vc)//Swept Volume in c.c
na=(1-(1/r)^(g-1))*100//Air standard efficiency in
   percent
nt=(na/100)*a//Thermal efficiency
IHP=(nt*CV*m*427)/(4500*60)//Indicated Horse Power
   in h.p
pm=(((IHP/n)*4500*100*2)/(Vs*N))//Average indicated
   mean effective pressure in kg/cm^2

//Output
printf('The average indicated mean effective
   pressure in each cylinder is %3.3f kg/cm^2',pm)
```

Scilab code Exa 3.19 CYLINDER SIZES

```
clc
```

```
clear
//Input data
n=4//Four cylinder engine
BHP=40//Brake horse power in h.p
N=3000//Speed in r.p.m
nm=70//Mechanical efficiency in percent
pm=13.5//Indicated mean effective pressure in kg/cm^2
//Bore is equal to stroke

//Calculations
//case(i)
d1=((BHP*100*4500*n*2)/(n*(nm/100)*pm*N*3.14))^(1/3)//Cylinder bore or stroke length in cm

//Case(ii)
d2=((BHP*100*4500*n)/(n*(nm/100)*pm*N*3.14))^(1/3)*10//Cylinder bore or stroke length in cm

//Output
printf('The cylinder sizes for a bore equal to stroke of a four cylinder in case of \n (i)Four stroke engine is %3.1f cm \n (ii)Two stroke engine is %3.0f mm',d1,d2)
```

Scilab code Exa 3.20 THERMAL EFFICIENCY

```
clc
clear
//Input data
T=[50+273,345+273]//Temperatures at the beginning and end of compression in K
g=1.4//ratio of specific heats
IHP=25//Indicated horse power in h.p
m=5.44//Mass of fuel consumed per hour in kg
```

```
CV=10300//Calorific value in kcal/kg

//Calculations
na=(1-(T(1)/T(2)))*100//Air standard efficiency in
    percent
r=(T(2)/T(1))^(1/(g-1))//Compression ratio
qIHP=(IHP*4500)/427//Heat equivalent of I.H.P in
    kcal/min
q=(m*CV)/60//Heat supplied per minute in kcal/min
Ith=(qIHP/q)*100//Indicated thermal efficiency in
    percent
nr=(Ith/na)*100//Efficiency ratio

//Output
printf('The air standard efficiency is %3.1f percent
    \n The compression ratio is %3.2f \n Indicated
    thermal efficiency is %3.1f percent \n Efficiency
    ratio is %3.1f percent',na,r,Ith,nr)
```

Scilab code Exa 3.21 COMPRESSION RATIO

```
clc
clear
//Input data
CV=10000//Calorific value of petrol in kcal/kg
pe=[30,70]//Percentage of compression strokes in
    percent
p=[1.33,2.66]//Pressures in the cylinder
    corresponding to the compression strokes in kg/cm
    ^2
n=1.33//Polytropic constant
rn=50//Relative efficiency in percent
g=1.4//ratio of specific heats

//Calculations
```

```
v=(p(2)/p(1))^(1/n)//Ratio of specific volumes
r=((pe(2)/100)*v-(pe(1)/100))/((pe(2)/100)-((pe(1)
   /100)*v))//Compression ratio
na=(1-(1/r)^(g-1))*100//Air standard efficiency in
   percent
ith=(rn*na)/100//Indicated thermal efficiency in
   percent
q=(4500*60)/(427*(ith/100))//Heat supplied in kcal/i
   .h.p.hr
Sc=(q/CV)//Specific consumption in kg/i.h.p.hr

//Output
printf('Compression ratio is %3.2f \n Specific
   consumption is %3.3f kg/i.h.p.hr',r,Sc)
```

Scilab code Exa 3.22 EFFICIENCY

```
clc
clear
//Input data
n=4//Four cylinder four stroke
d=7.5//Bore in cm
L=8.75//Stroke in cm
r=6//Compression ratio
n1=55//Efficiency in percent
g=1.4//ratio of specific heats
N=2400//Speed in r.p.m
pm=7//Brake mean effective pressure in kg/cm^2
m=9//Mass of fuel per hour in kg
CV=10500//Calorific Value in kcal/kg

//Calculations
an=(1-(1/r)^(g-1))*100//Air standard efficiency in
   percent
In=(an*n1)/100//Indicated thermal efficiency in
```

```
percent. In textbook, answer is wrong
BHP=(pm*(3.14/4)*d^2*(L/100)*(N/2)*n)//Brake horse power in kg.m/min
Bth=((BHP*60)/(427*CV*m))*100//Brake thermal efficiency in percent
nm=(Bth/In)*100//Mechanical efficiency in percent
Sc=((4500*60)/(427*(Bth/100)*CV))//Specific consumption in g/i.h.p.hr

//Output
printf('Indicated thermal efficiency is %3.1f percent \n Brake thermal efficiency is %3.1f percent \n Mechanical efficiency is %3.1f percent \n Specific fuel consumption is %3.3f kg/i.h.p.hr',In,Bth,nm,Sc)
```

Scilab code Exa 3.26 PERCENTAGE CHANGE IN EFFICIENCY

```
clc
clear
//Input data
r=7//Compression ratio
v=1//Specific heat at constant volume increases by 1 percent
g=1.4//Ratio of specific heats

//Calculations
e=(1-(1/r^(g-1)))//Air standard efficiency
dee=-(((1-e)*(g-1)*log(r)*(v/100))/e)*100//Change in efficiency to the original efficiency
x=-(dee)//For Output purpose

//Output
printf('Percentage change is efficiency is %3.2f percent i.e., a decrease of %3.2f percent',dee,x)
```

Scilab code Exa 3.30 MAXIMUM HORSE POWER

```
clc
clear
//Input data
N=210//Speed in r.p.m
d=0.3//Diameter of the piston in m
L=0.4//Stroke in m
v=2.5//Clearance volume is 2.5% of the swept volume.
    But in textbook it is given wrong as 25%
CO=19.7//Percentage of CO gas
H2=28.8//Percentage of H2 gas
CO2=14.4//Percentage of CO2 gas
N2=37.1//Percentage of N2 gas
x=0.875//Total mixture at N.T.P admitted per suction
    stroke is 0.875 of the total volume behind the
    piston at the end of the stroke
tn=35//Thermal efficiency in percent
CVH2=13200//Calorific value of H2 per kg in kcal
CVC=2540//Calorific value of carbon burning from CO
    to CO2 in kcal/kg
de=1.293//Density of air in kg/m^3
mC=12//Molecular weight of carbon
mO2=32//Molecular weight of O2
mH2=2//Molecular weight of H2
mCO=28//Molecular weight of CO

//Calculations
a=((100/21)*((CO2/100)+((CO/2)/100)))//Air per cu.m
    of gas in cu.m
Vm=(a+1)//Volume of mixture per cu.m of gas in cu.m
Vs=((3.14/4)*d^2*L)//Swept volume in cu.m
Vc=(Vs*v)/100//Clearance volume in cu.m
V=Vc+Vs//Total volume in cu.m
```

```
VC=V*x//Volume of charge admitted per stroke in cu.m
VM=VC*(N/2)//Charge volume per minute in cu.m
VG=(VM/Vm)//cu.m of gas per minute
vH2=(VG*(H2/100))//Volume of H2 per minute in cu.m
vCO=(VG*(CO/100))//Volume of CO per minute in cu.m
CVH2cum=(mH2*CVH2)/(vH2*1000)//Calorific value of H2
    per cu.m in kcal
CVCO=(CVC*(2*mC)/(2*mCO))//Calorific value of CO per
    kg in kcal
CVCOcum=(mCO*CVCO)/(vH2*1000)//Calorific value of CO
    per cu.m in kcal
qH2=(16.09*CVH2cum)//Heat in charge due to H2 in
   kcal
qCO=(11*CVCOcum)//Heat in charge due to CO in kcal
qt=(qH2+qCO)//Heat supplied per minute in kcal
qu=(qt*(tn/100))//Heat utilised in kcal
hp=(qu*427)/4500//H.P developed

//Output
printf('Maximum horse power that can be developed is
    %3.1f H.P',hp)
```

Scilab code Exa 3.31 AIR FUEL RATIO

```
clc
clear
//Input data
vCH4=65//Composition by volume of CH4
vH2=2//Composition by volume of H2
vN2=2//Composition by volume of N2
vCO2=31//Composition by volume of CO2
O2=5.3//Composition of O2 in dry exhaust gases when
   analysed in orsat apparatus
N2=83//Composition of N2 in dry exhaust gases when
   analysed in orsat apparatus
```

```
CO=0.3//Composition of CO in dry exhaust gases when analysed in orsat apparatus
CO2=11.4//Composition of CO2 in dry exhaust gases when analysed in orsat apparatus
an=79//Air contains 79% by volume of nitrogen

//Calculations
a=(100/(100-an))*(((vCH4/100)*2)+((vN2/100)*(1/2))) //Total air required for complete combustion of 1 cu.m of gas in cu.m
xCO=(CO/2)//O2 required to burn the CO in cu.m
xCO2=CO//CO2 formed in cu.m
tO2=O2-xCO//Total O2 in cu.m
tN2=N2//Total N2 in cu.m
tCO2=CO2+xCO2//Total CO2 in cu.m
T=tO2+tN2+tCO2//Total mixture in cu.m
pCO2=(tCO2*100)/T//Percentage of CO2 in percent
mm=(a*100)//Minimum air supply required for complete combustion of 100 cu.m of the gas in cu.m
an2=(an/100)*mm//N2 for this air in cu.m
tn2=(an2+vN2)//Total N2 in cu.m
v=(((vCH4+vCO2)*100)/pCO2)-(vCH4+vCO2+tn2)//Increase in air supply for reduction in percentage of CO2 in cu.m
pea=(v*100)/mm//Percentage of excess air. In textbook it is given wrong as 26.7 percent

//Output
printf('(a) the air-fuel ratio by volume to give complete combustion is %3.3f \n (b) the percentage of excess air actually used in the test is %3.1f percent',a,pea)
```

Scilab code Exa 3.32 AIR GAS RATIO

```
clc
clear
//Input data
Vs=9.45//Swept volume in litres
Vc=2.32//Clearance volume in litres
m=4.25//Consumption of gas per hour in cu.m
N=165//Speed in r.p.m
bhp=5.62//Brake horse power in h.p
nm=73.4//Mechanical efficiency in percent
CV=3500//Calorific value in kcal per cubic meter
vn=0.87//Volumetric efficiency
g=1.4//Ratio of specific heats

//Calculations
tV=(Vs+Vc)*1000//Total volume in c.c
rc=(tV/Vc)//Compression ratio
na=(1-(1/rc^(g-1)))*100//Air atandard efficiency in
    percent
W=(bhp*4500)/427//Workdone per minute in kcal
Iw=(W/(nm/100))//Indicated work in kcal/min
q=(m/60)*CV//Heat supplied in kcal/min
ith=(Iw/q)*100//Indicated thermal efficiency in
    percent
rn=(ith/na)*100//Relative efficiency in percent
Vm=(Vs*1000)*vn//Volume of mixture taken in per
    stroke in c.c
Vg=(m*2*10^6)/(60*N)//Volume of gas taken in per
    stroke in c.c
Va=(Vm-Vg)//Volume of air taken in per stroke in c.c
agr=(Va/Vg)//Air gas ratio
CVc=(CV/(agr+1))//Calorific value of charge in kcal

//Output
printf('Ratio of air to gas used is %3.2f \n
    Calorific value of 1 cu.m of the mixture in the
    cylinder is %3.1f kcal',agr,CVc)
```

Scilab code Exa 3.33 FRICTION HORSE POWER

```
clc
clear
//Input data
d=18//Bore in cm
l=37.5//Stroke in cm
N=220//Speed in r.p.m
//Mean effective pressure in kg/cm^2
//Firing
pp=5.9//Positive loop
pn=0.248//Negative loop
//Missing
nn=0.432//Negative loop
bhp=8.62//Brake horse power in h.p
ex=100//Explosions per minute
vg=0.101//Gas used in cu.m per minute

//Calculations
tc=(N/2)//The number of cycles
nw=ex//Number of working cycles
nm=(tc-nw)//Number of missing cycles
ihp=((l/100)*(3.14/4)*(d^2/4500))*((pp-pn)*(100-nn))
    //Net I.H.P in h.p
fhp=(ihp-bhp)//Friction horse power in h.p
W=((pp-pn)*(3.14/4)*(d^2*(l/100)))//Workdone per
    firing done in kg.m
Wp=(nn*(3.14/4)*d^2*(l/100))//Workdone per pumping
    stroke in kg.m
n=((fhp*4500)+(Wp*tc))/(W+Wp)//Number of strokes
gf=(vg/nw)//Gas per firing stroke in cu.m
gl=(n*gf)//Gas per minute at no load in cu.m

//Output
```

```
printf('Friction horse power of the engine is %3.2f
    \n Gas consumption at no load is %3.3f cu.m/min',
    fhp,gl)
```

Chapter 4

FUEL AIR CYCLES AND REAL CYCLES

Scilab code Exa 4.1 WORK DONE

```
clc
clear
//Input data
d=20//Bore in cm
l=38//Stroke in cm
Vc=900//Clearance volume in c.c
p1=1//Pressure at the start of compression stroke in
    kg/cm^2
T1=90+273//Temperature at the start of compression
   stroke in K
x=0.75//Piston travelled 0.75 of the compression
   stroke
n=1.32//Compression curve index
wa=0.0125//Weight of air in kg

//Calculations
Vs=(3.14/4)*d^2*l//Swept volume in c.c
V1=(Vs+Vc)//Volume in c.c
V2=(1-x)*Vs+Vc//Volume in c.c
```

```
p2=p1*(V1/V2)^n//Pressure in kg/cm^2
T2=(T1*(p2/p1)*(V2/V1))//Temperature in K
W=((p1*V1-p2*V2)/(n-1))*10^-2//Workdone in kg.m
dI=wa*0.17*(T2-T1)//Change in internal energy in
    kcal
q=(dI+(W/427))//Heat in kcal

//Output
printf('When the cylinder has travelled %3.2f of the
    compression stroke, \n The volume is %3.0f c.c \
    n The pressure is %3.2f kg/cm^2 \n Temperature is
    %3.0f K \n\n The workdone on the gas is %3.2f kg
    .m \n\n Change in internal energy between the two
    points is %3.3f kcal',x,V2,p2,T2,W,dI)
```

Chapter 5

VARIABLE SPECIFIC HEAT

Scilab code Exa 5.2 CHANGE IN AIR STANDARD EFFICIENCY

```
clc
clear
//Input data
r=8//Compression ratio
n=1.41//Adiabatic index of the medium
cv=0.17//Mean Specific heat at constant volume in
    kcal/kg/degree C
x=2//Percentage with which spcific heat at constant
    volume increases
R=29.3//Characteristic gas constant in mkg/kg/degree
    C
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
e=(1-(1/r^(n-1)))//Air standard efficiency
    neglecting the variation in specific heat
debye=((x/100)*((1-e)/e)*(R/(J*cv))*log(r))*100//
    Ratio of de and e in percent

//Output
printf('The change in air standard efficiency of the
```

```
cycle is %3.3f percent',debye)
```

Scilab code Exa 5.3 WORK DONE

```

clc
clear
//Input data
//Cv=0.125+0.000005T where Cv is Specific heat at constant volume and T is the temperature in K
R=28.9//Characteristic gas constant in mkg/kg/degree C
T=[100+273,50+273]//Temperature in K
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
function y=f(x),y=0.125+(0.00005*x),endfunction
I=J*intg(303,373,f)

//Output
printf('The work done is %i m.kg/kg of gas',I)
```

Scilab code Exa 5.4 PERCENTAGE OF STROKE

```
clc
clear
//Input data
af=25//Air fuel ratio
cv=[0.17,0.00004]//Cv=0.17+0.00004T where Cv is Specific heat at constant volume and T is the temperature in K
r=14//Compression ratio
```

```
p1=1//Pressure at the beginning of compression in kg
    /cm^2
T1=153+273//Temperature at the beginning of
    compression in K
CV=10000//Heating value of fuel in kcal/kg
n=1.35//Adiabatic constant
R=29//Characteristic gas constant in mkg/kg.K
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
T2=(T1*r^(n-1))//Temperature at the end of
    compression in K
a=(cv(2)/2)//For solving T3
b=cv(1)+(R/J)//For solving T3
c=(-T2*cv(1))-((cv(2)/2)*T2^2)-((R/J)*T2)-(CV/(af+1)
    )//Foe solving T3
T3=(-b+sqrt(b^2-(4*a*c)))/(2*a)//Soving for T3 in K
pc=(((T3/T2)-1)/(r-1))*100//Percentage cut off

//Output
printf('The percentage of stroke at which the
    constant pressure combustion stops is %i percent'
    ,pc)
```

Scilab code Exa 5.5 PERCENTAGE OF STROKE

```
clc
clear
//Input data
af=25//Air fuel ratio
CV=10000//Calorific value in kcal/kg
cv=[0.17,0.00004]//Cv=0.17+0.00004T where Cv is
    Specific heat at constant volume and T is the
    temperature in K
r=14//Compression ratio
```

```
T2=800+273//Temperature at the end of compression in
    K
R=29//Characteristic gas constant in mkg/kg/degree C
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
CVm=(CV/(af+1))//Calorific value of mixture in kcal/
   kg
cpv=(R/J)//Difference in mean specific heats in kcal
   /kg mol.K
a=(cv(2)/2)//For solving T3
b=cpv+cv(1)//For solving T3
c=(-T2*(cpv+cv(1)))-((cv(2)/2)*T2^2)-CVm//Foe
   solving T3
T3=(-b+sqrt(b^2-(4*a*c)))/(2*a)//Soving for T3 in K
s=((T3/T2)/(r-1))*100//Percentage of the stroke

//Output
printf('The percentage of the stroke at which the
   combustion will be complete is %3.2f percent',s)
```

Scilab code Exa 5.6 CHANGE IN ENTHALPY

```
clc
clear
//Input data
T=[500,2000]//Change in temperature in K
x=[11.515,-172,1530]//Cp=11.515-172/sqrt(T)+1530/T
   in kcal/kg mole.K
mO2=32//Molecular weight of oxygen

//Calculations
function y=f(T),y=(x(1)+(x(2)/sqrt(T))+(x(3)/T)),
   endfunction
I=-intg(T(2),T(1),f)//Integration
```

```
dh=(I/mO2)//Change in enthalpy in kcal/kg

//Output
printf('The change in enthalpy is %3.1f kcal/kg',dh)
```

Scilab code Exa 5.7 TEMPERATURE AND PRESSURE

```
clc
clear
//Input data
r=14//Compression ratio
s=5//Fuel injection stops at 5% stroke after inner head centre
pm=50//Maximum pressure in kg/cm^2
p4=1//Pressure at the end of suction stroke in kg/cm^2
T4=90+273//Temperature at the end of suction stroke in K
R=29.3//Characteristic gas constant in mkg/kg/degree C
cv=[0.171,0.00003] //Cv=0.171+0.00003T where Cv is Specific heat at constant volume and T is the temperature in K
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
a=(R/J)+cv(1)//a value in kcal/kg.mole.K
g=(a+cv(2)*T4)/(cv(1)+cv(2)*T4)//Adiabatic index of compression
z=1.3//Rounding off 'z' value to one decimal.
T5=(T4*r^(z-1))//Temperature in K
p5=(p4*r^g)//Pressure in kg/cm^2
T1=T5*(pm/p5)//Tmperature in K
T2=(T1*(1+(s/100)*(r-1)))//Temperature in K
T3=(T2*((1+(s/100)*(r-1))/r)^(g-1))//Temperature in
```

```
K
p3=(p4*(T3/T4))//Pressure in kg/cm^2
function y=f1(T),y=cv(1)+(cv(2)*T),endfunction
I1=intg(T5,T1,f1)
function y=f2(T),y=(a+(cv(2)*T)),endfunction
I2=intg(T1,T2,f2)//I2 answer is given wrong in the textbook
qs=(I1+I2)//Heat supplied per kg of air in kcal/kg
function y=f3(T),y=a+(cv(2)*T),endfunction
qre=intg(T4,T3,f3)//Heat required per kg of air in kcal/kg
nth=((qs-qre)/qs)*100//Thermal efficiency in percent

//Output
printf('The tempertautes and pressures at salient points of the cycle are : \n T1 = %3.0f K  p1 = %3.1f kg/cm^2 \n T2 = %3.0f K  p2 = %3.1f kg/cm^2 \n T3 = %3.0f K  p3 = %3.1f kg/cm^2 \n T4 = %3.0f K  p4 = %3.1f kg/cm^2 \n T5 = %3.0f K  p5 = %3.1f kg/cm^2 \n\n Heat supplied per kg of air is %3.1f kcal/kg \n\n The thermal efficiency of the cycle is %3.1f percent',T1,pm,T2,pm,T3,p3,T4,p4,T5,p5,qs,nth)
//Textbook answers are given wrong
```

Scilab code Exa 5.8 TEMPERATURE AND HEAT

```
clc
clear
//Input data
r=14//Compression ratio
c=5//Cut off takes place at 5% of the stroke
p1=1//Pressure at the beginning of compression in kg/cm^2. In texbook, it is given wrong as 10
T1=90+273//Temperature at the beginning of
```

```
compression in K
p3=50//Maximum pressure in kg/cm^2
R=29.3//Characteristic gas constant in mkg/kg/degree C
cv=[0.171,0.00003]//Cv=0.171+0.00003T where Cv is Specific heat at constant volume and T is the temperature in K
g1=1.4//Ratio of specific heats
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
T2x=(T1*r^(g1-1))//Temperature in K
function y=f1(T),y=cv(1)+(cv(2)*T),endfunction
I1=intg(T1,T2x,f1)
Cv=(1/(T2x-T1))*I1//Mean value of Cv in kJ/kg.K
Cp=(Cv+(R/J))//Mean value of Cp in kJ/kg.K
g=1.35//(Cp/Cv) value and rounded off to 2 decimal places for calculation purpose. Ratio of specific heats
T2=(T1*r^(g-1))//Temperature in K
I2=intg(T1,T2,f1)
CV=(1/(T2-T1))*I2//Maen value of Cv in kJ/kg.K
CP=(Cv+(R/J))//Mean value of Cp in kJ/kg.K
g2=1.36//(Cp/Cv) value and rounded off to 2 decimal places for calculation purpose.Ratio of specific heats
T2a=(T1*r^(g2-1))//Temperature in K
p2=(p1*r*(T2a/T1))//Pressure in kg/cm^2
T3=(T2a*(p3/p2))//Temperature in K
T4=(((r-1)*(c/100))+1)*T3//Temperature in K
g3=1.3//Assuming gamma as 1.3 for process 4-5
T5=(T4/(r/(((r-1)*(c/100))+1))^(g3-1))//Temperature in K
cV=cv(1)+(cv(2)/2)*(T5+T4)//Mean value of Cv in kJ/kg.K
cP=cV+(R/J)//Mean value of Cp in kJ/kg.K
g4=(cP/cV)//Ratio of specific heats
T5a=(T4/(r/(((r-1)*(c/100))+1))^(g4-1))
```

```
I3=intg(T2a,T3,f1)
function y=f2(T),y=cv(1)+(R/J)+(cv(2)*T),endfunction
I4=intg(T3,T4,f2)//Textbook answer is wrong
q=I3+I4//Heat supplied per kg of working substance in kcal/kg

//Output
printf('(a) Temperatures at all the points of the cycle are: \n T1 = %i K \n T2 = %3.0f K \n T3 = %3.0f K \n T4 = %3.0f K \n T5 = %i K \n\n (b) heat supplied per kg of the working substance is %3.1f kcal/kg',T1,T2a,T3,T4,T5a,q)
//Textbook answer is wrong
```

Scilab code Exa 5.10 PERCENTAGE CHANGE IN EFFICIENCY

```
clc
clear
//Input data
r=20//Compression ratio
c=5//Cut off at 5%
dc=1//Specific heat at constant volume increases by 1%
Cv=0.171//pecific heat at constant volume in kJ/kg.K
R=29.3//Characteristic gas constant in mkg/kg/degree C
k=1.95//k can be obtained from relation de/e=-dcv/cv*(1-e/e)*(g-1)*((1/g)+ln(r)-(k^g*lnk)/(k^g-1))
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
g=(R/(J*Cv))+1//Ratio of specific heats
e=(1-((1/g)*(1/r^(g-1))*((k^g-1)/(k-1))))//Air standard efficiency of the cycle
dee=((-(dc/100)*((1-e)/e)*(g-1)*((1/g)+log(r)-((k^g*
```

```
log(k))/(k^g-1))))*100)//Change in efficiency due
    to 1% change in cv

//Output
printf('Percentage change in air standard efficiency
    is %3.3f percent \n This indicates that there is
    a decrease in efficiency',dee)
```

Chapter 6

COMBUSTION CHARTS

Scilab code Exa 6.1 EFFICIENCY

```
clc
clear
//Input data
r=7.5//Compression ratio
//Data from combustion chart
p=[1,15.1,26.95,1.95]//Pressure of air fuel mixture in kg/cm^2
T=[60,460,1150,435]//Temperature of air fuel mixture in K
V=[16.98,2.264,2.264,16.98]//Volume in m^3/kg
U=[17,78.8,212,80]//Internal energy in kcal/kg
S=[0.07,0.07,0.22,0.22]//Entropy in kcal/kg.degree C
g=1.4//Ratio of specific heats

//Calculations
n=(((U(3)-U(4))-(U(2)-U(1)))/(U(3)-U(2)))*100//Thermal efficiency in percent
na=(1-(1/r)^(g-1))*100//Air standard efficiency in percent

//Output
```

```
printf('Thermal efficiency is %3.1f percent \n Air
    standard efficiency is %3.1f percent',n,na)
```

Scilab code Exa 6.2 EFFICIENCY

```
clc
clear
//Input data
//Data from combustion chart
p=[1,33,33,1]//Pressure of air fuel mixture in kg/cm
    ^2
T=[65,600,1450,725]//Temperature of air fuel mixture
     in K
V=[16,1.23,3.45,16]//Volume in m^3/kg
U=[11.8,110,295,140]//Internal energy in kcal/kg
H=[22.7,150,395,225]//Enthalpy in kcal/kg
S=[0.068,0.068,0.264,0.264]//Entropy in kcal/kg.
    degree C

//Calculations
r=(V(1)/V(2))//Compression ratio
q=(H(3)-H(2))//Heat supplied in kcal/kg
qre=(U(4)-U(1))//Heat rejected in kcal/kg
nt=((q-qre)/q)*100//Thermal efficiency in percent

//Output
printf('(a)Compression ratio is %3.0f \n (b) Heat
    supplied to the cycle is %3.0f kcal/kg \n (c)
    Heat rejected by the cycle is %3.2f kcal/kg \n (d
    ) Thermal efficiency is %3.2f percent',r,q,qre,nt
    )
```

Scilab code Exa 6.3 EFFICIENCY

```
clc
clear
//Input data
//Data from combustion chart
p=[1,51.5,77.25,77.25,3.75]//Pressure of air fuel
   mixture in kg/cm^2
T=[16,1,1,1.5,16]//Temperature of air fuel mixture
   in K
V=[65,745,1400,2200,1030]//Volume in m^3/kg
U=[14.7,135,275,475,197]//Internal energy in kcal/kg
H=[21.9,85,372,625,280]//Enthalpy in kcal/kg
S=[0.068,0.068,0.19,0.32,0.32]//Entropy in kcal/kg.
   degree C

//Calculations
nth=(((U(3)-U(2))+(H(4)-H(3))-(U(5)-U(1)))/((U(3)-U
   (2))+(H(4)-H(3))))*100//Thermal efficiency in
   percent

//Output
printf('Thermal efficiency is %3.2f percent',nth)
```

Chapter 8

COMBUSTION

Scilab code Exa 8.1 COMPOSITION

```
clc
clear
//Input data
C=88.6//Composition of C in percent
H2=11.4//Composition of H2 in percent

//Calculations
w1=(C/100)//Weight per kg of fuel of C in kg
w2=(H2/100)//Weight per kg of fuel of H2 in kg
O1=(8/3)//Oxygen required per kg of constituent for
   C in kg
O2=8//Oxygen required per kg of constituent for H2
   in kg
O11=(w1*O1)//Oxygen required per kg of fuel for C in
   kg
O22=(w2*O2)//Oxygen required per kg of fuel for H2
   in kg
T=(O11+O22)//Total Oxygen required per kg of fuel in
   kg
P1=(w1+O11)//Composition of CO2 in kg
P2=(w2+O22)//Composition of H2O in kg
```

```
w=(T*(100/23))//Weight of air required in kg per kg of fuel

//Output
printf('The weight of air required for complete combustion of liquid fuel is %3.2f kg per kg of fuel \n \n The composition of CO2 is %3.3f kg \n The composition of H2O is %3.3f kg',w,P1,P2)
```

Scilab code Exa 8.2 WEIGHT OF AIR

```
clc
clear
//Input data
C=12//Molecular weight of carbon
H2=2//Molecular weght of H2
O2=32//Molecular weight of O2

//Calculations
C7H16=(7*C+8*H2)//Molecular weight of C7H16
O2x=(11*O2)//Molecular weight of 22O2
wt=(O2x/C7H16)*(100/23.2)//Weight of air in kg per kg of fuel
//Now in actual experiment, we have
//1[C7H16] +x[O2] +...[N2] = a[CO2] +8[H2O] +a[O2] +...[N2]
//This is the new equation written in volumes. The volumes of CO2 and O2 being equal, with no CO present, and the usual assumption that all the hydrogen is burnt to H2O
//Now, if all the carbon is burnt, we must have 7 mols of CO2
x=(7+4+7)//Total number of mols from CO2,H2O and O2 terms respectively
W=((x*O2)/100)*(100/23.2)//Weight of air in kg per
```

```
   kg of fuel

//Output
printf('The weight of air is %3.1f kg per kg of fuel
    which would just suffice for theoretically
   complete combustion \n The ratio of air to fuel
   by weight as actually supplied is %3.1f kg of air
    per kg of fuel',wt,W)
```

Scilab code Exa 8.3 AIR AND VOLUME

```
clc
clear
//Input data
H=15//Percentage of Hydrogen by volume
CO=25//Percentage of carbon monoxide by volume
CH4=4//Percentage of methane by volume
CO2=4//Percentage of carbon dioxide by volume
O2=2//Percentage of oxygen by volume. In textbook it
    is given wrong as 25
N2=50//Percentage of nitrogen  by volume

//Calculations
O21=(H/100)*(1/2)//Volume of oxygen required in m^3
   by 15 percent of H2
O22=(CO/100)*(1/2)//Volume of oxygen required in m^3
    by 25 percent of CO
CO21=(CO/100)*1//Volume of CO2 produced in m^3 by 25
    percent of CO
O23=(CH4/100)*2//Volume of oxygen required in m^3 by
    4 percent of CH4
CO22=(CH4/100)*1//Volume of CO2 produced in m^3 by 4
    percent of CH4
H2O1=(CO/100)*2//Volume of H2O produced in m^3 by 4
   percent of CH4
```

```
TO2=(O21+O22+O23-(O2/100))//Total vol. of oxygen in
    m^3
wa=(TO2*(100/21))//Theoretical volume of air
    required in m^3
vN2=(wa*(79/100))//Volume of N2 present in air in m
    ^3
TvN2=(vN2+(N2/100))//Total volume of N2 after
    combustion of 1 m^3 of fuel in m^3
xCO2=(CO21+CO22)//CO2 produced due to combustion of
    fuel in m^3
TCO2=(xCO2+(CO2/100))//Total volume of CO2 in the
    flue gas in m^3

//Output
printf('The air required for complete combustion of
    one m^3 of the fuel is %3.3f cu.m \n The dry flue
     gas contains %3.3f cu.m volume of N2 and %3.2f
    cu.m volume of CO2',wa,TvN2,TCO2)
```

Scilab code Exa 8.4 WEIGHT OF AIR

```
clc
clear
//Input data
C=88.1//Composition of C in percent
H2=10.7//Composition of H2 in percent
O2=1.2//Composition of O2 in percent

//Calculations
w1=(C/100)//Weight per kg of fuel of C in kg
w2=(H2/100)//Weight per kg of fuel of H2 in kg
w3=(O2/100)//Weight per kg of fuel of O2 in kg
O1=(8/3)//Oxygen required per kg of constituent for
    C in kg
O2=8//Oxygen required per kg of constituent for H2
```

```
    in kg
O11=(w1*O1)//Oxygen required per kg of fuel for C in
     kg
O22=(w2*O2)//Oxygen required per kg of fuel for H2
    in kg
T=(O11+O22-w3)//Total Oxygen required per kg of fuel
     in kg
P1=(w1+O11)//Composition of CO2 in kg
P2=(w2+O22)//Composition of H2O in kg
w=(T*(100/23))//Weight of air required in kg per kg
    of fuel
wN2=(w*(77/100))//Weight of N2 in 'w' kg of fuel in
    kg
T1=(P1+P2+wN2)//Total weight of all products of
    combustion in kg
pCO2=(P1/T1)*100//Percentage composition of CO2 by
    weight
pH2O=(P2/T1)*100//Percentage composition of H2O by
    weight
pN2=(wN2/T1)*100//Percentage composition of N2 by
    weight

//Output
printf('The weight of air required to burn one kg of
     the fuel is %3.1f kg \n The composition of
    products of combustion by weight is %3.2f percent
     of CO2, %3.2f percent of H2O and %3.2f percent
    of N2',w,pCO2,pH2O,pN2)
```

Scilab code Exa 8.5 MASS OF AIR

```
clc
clear
//Input data
C=85//Composition of C in percent
```

```
H2=15//Composition of H2 in percent
CV=10600//Calorific value in kcal/kg
eO2=60//Percentage of air in excess
bhp=240//Brake horse power in h.p
nth=30//Thermal efficiency in percent
O2=23//Percentage of oxygen contained in air by weight
wC=12//Molecular weight of carbon
wH2=2//Molecular weght of H2
wO2=32//Molecular weight of O2

//Calculations
mma=(100/23)*(((C/100)*(wO2/wC))+((H2/100)*(wO2/(wH2*2))))//Minimum air in kg per kg oil
aa=((100+eO2)/100)*mma//Actual air supplied in kg per kg oil
q=((bhp*(4500/427))/(nth/100))//Heat supplied in kcal/min
mf=(q/CV)//Mass of fuel supplied in kg/min
ma=(aa*mf)//Mass of air supplied in kg/min

//Output
printf('The weight of air is %3.2f kg/min',ma)
```

Scilab code Exa 8.6 VOLUMETRIC ANALYSIS

```
clc
clear
//Input data
//C + O2 -> CO2
// 12 + 32 -> 44
C=12//Molecular weight of carbon
O2=32//Molecular weight of O2
CO2=44//Molecular weight of CO2
N2=28//Molecular weight of N2
```

```

//Calculations
wair=(O2/C)*(100/23)//Air required per kg of C in kg
wN2=(O2/C)*(77/23)//N2 associated with the air in kg
pCO2=(CO2/C)/CO2//Parts by volume/k for CO2
pN2=(wN2/N2)//Parts by volume/k for N2
Tv=(pCO2+pN2)//Total parts by volume
ppCO2=(pCO2/Tv)*100//Percentage volume of CO2
ppN2=(pN2/Tv)*100//Percentage volume of N2

//Output
printf('The volumetric analysis of the flue gas when
    pure carbon is burnt with a minimum quantity of
    air is given by \n CO2 -> %3.1f percent \n N2 ->
    %3.1f percent',ppCO2,ppN2)
```

Scilab code Exa 8.7 PERCENTAGE COMBUSTION

```
clc
clear
//Input data
C=90//Percentage composition of C
H2=3.3//Percentage composition of H2
O2=3//Percentage composition of O2
N2=0.8//Percentage composition of N2
S=0.9//Percentage composition of S
Ash=2//Percentage composition of Ash
eO2=50//Percentage of excess air
mC=12//Molecular weight of carbon
mS=32//Molecular weight of sulphur
mCO2=44//Molecular weight of CO2
mO2=32//Molecular weight of O2
mSO2=64//Molecular weight of SO2
mN2=28//Molecular weight of N2

```

```
//Calculations
w1=(C/100)//Weight per kg of fuel of C in kg
w2=(H2/100)//Weight per kg of fuel of H2 in kg
w3=(S/100)//Weight per kg of fuel of S in kg
O1=(8/3)//Oxygen required per kg of constituent for C in kg
O2=8//Oxygen required per kg of constituent for H2 in kg
O3=1//Oxygen requred per kg of constituent for S in kg
O11=(w1*O1)//Oxygen required per kg of fuel for C in kg
O22=(w2*O2)//Oxygen required per kg of fuel for H2 in kg
O33=(w3*O3)//Oxygen required per kg of fuel for S in kg
T=(O11+O22+O33-(O2/100))//Total Oxygen required per kg of fuel in kg
ma=(T*(100/23))//Minimum air required in kg
aN2=(ma*((100+eO2)/100)*(77/100))//N2 in actual air supply in kg
TN2=(aN2+(N2/100))//Total N2 in kg
wt=(ma*(eO2/100)*(23/100))//Weight of air due to excess O2 in kg
TSO2=(w3*(mSO2/mS))//Total SO2 in kg
TCO2=(w1*(mCO2/mC))//Total CO2 in kg
pCO2=(TCO2/mCO2)//Parts by volume of CO2
pSO2=(TSO2/mSO2)//Parts by volume of SO2
pO2=(wt/mO2)//Parts by volume of O2
pN2=(TN2/mN2)//Parts by volume of N2
Tv=(pCO2+pSO2+pN2+pO2)//Total parts by volume
ppCO2=(pCO2/Tv)*100//Percentage volume of CO2
ppSO2=(pSO2/Tv)*100//Percenatge volume of SO2
ppO2=(pO2/Tv)*100//Percentage volume of O2
ppN2=(pN2/Tv)*100//Percentage volume of N2

//Output
printf('Percentage combustion of the dry flue gases
```

```
by volume is \n CO2 %3.2f percent \n SO2 %3.2f percent \n O2 %3.1f percent \n N2 %3.2f percent',ppCO2,ppSO2,ppO2,ppN2)
```

Scilab code Exa 8.8 PARTIAL PRESSURE

```
clc
clear
//Input data
C=85//Composition of C in percent
H2=12.3//Composition of H2 in percent
i=2.7//Incombustible residue composition in percent
ma=25//Mass of air supplied in kg of air per kg of fuel
pO2=23//Percentage of oxygen in gemetric analysis of air
pN2=77//Percentage of nitrogen in gemetric analysis of air
p=1.03//Total pressure of the exhaust gases in kg/cm^2
mC=12//Molecular weight of carbon
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mH2=2//Molecular weght of H2
mH2O=18//Molecular weight of H2O
mN2=28//Molecular weight of N2

//Calculations
xCO2=((C/100)*(mCO2/mC))//per kg of fuel, the products formed in kg
xH2O=((H2/100)*((2*mH2O)/(2*mH2)))//per kg of fuel, the products formed in kg
xO2=(((C/100)*(mO2/mC))+((H2/100)*(mO2/(2*mH2))))//Oxygen used in kg
xN2=(pN2/pO2)*xO2//Associated nitrogen in kg
```

```
mma=(xO2+xN2)//Minimum air required in kg
ea=(ma-mma)//Excess air supplied in kg
XO2=((pO2/100)*ea)//Mass of O2 in excess air in kg
XN2=((pN2/100)*ea)//Mass of N2 in excess air in kg
wCO2=xCO2/mCO2//Parts by volume for CO2
wO2=XO2/mO2//Parts by volume for O2
wN2=((XN2+xN2)/mN2)//Parts by volume for N2
wH2O=(xH2O/mH2O)//Parts by volume for H2)
Tv=(wCO2+wO2+wN2+wH2O)//Total parts by volume
ppCO2=(wCO2/Tv)*100//Percentage volume of CO2
ppO2=(wO2/Tv)*100//Percentage volume of O2
ppN2=(wN2/Tv)*100//Percentage volume of N2
ppH2O=(wH2O/Tv)*100//Percenatage volume of H2O
Tv1=(wCO2+wO2+wN2)//Total parts by volume for dry products
pp1CO2=(wCO2/Tv1)*100//Percentage volume of CO2 for dry analysis
pp1O2=(wO2/Tv1)*100//Percentage volume of O2 for dry analysis
pp1N2=(wN2/Tv1)*100//Percentage volume of N2 for dry analysis
papH2O=(ppH2O/100)*p//Partial pressure of H2O in kg/cm^2

//Output
printf('The volumetric analysis for wet products gives (in percent) \n CO2 -> %3.1f \n O2 -> %3.1f \n N2 -> %3.1f \n H2O -> %3.1f \n\n The volumetric analysis for dry products gives (in percent) \n CO2 -> %3.1f \n O2 -> %3.1f \n N2 -> %3.1f \n\n The partial pressure of the vapour is %3.4f kg/cm^2',ppCO2,ppO2,ppN2,ppH2O,pp1CO2,pp1O2,pp1N2,papH2O)
```

Scilab code Exa 8.9 ANALYSIS BY WEIGHT

```
clc
clear
//Input data
CO2=15//Volumetric analysis composition in percent
CO=2.2//Volumetric analysis composition in percent
O2=1.6//Volumetric analysis composition in percent
N2=81.2//Volumetric analysis composition in percent
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO2
mN2=28//Molecular weight of N2

//Calculations
pCO2=(CO2/100)*mCO2//Proportional weight for CO2
pCO=(CO/100)*mCO//Proportional weight for CO
pO2=(O2/100)*mO2//Proportional weight for O2
pN2=(N2/100)*mN2//Proportional weight for N2
T=(pCO2+pCO+pO2+pN2)//Total proportional weight
ppCO2=(pCO2/T)*100//Weight per kg of exhaust gas for
    CO2
ppCO=(pCO/T)*100//Weight per kg of exhaust gas for
   CO
ppO2=(pO2/T)*100//Weight per kg of exhaust gas for
   O2
ppN2=(pN2/T)*100//Weight per kg of exhaust gas for
   N2

printf('The analysis by weight is given by (in
   percent) \n CO2 -> %3.1f \n CO -> %3.1f \n O2 ->
   %3.1f \n N2 -> %3.1f',ppCO2,ppCO,ppO2,ppN2)
```

Scilab code Exa 8.10 GRAVIMETRIC ANALYSIS

```
clc
clear
```

```
CO2=10.9//Volumetric analysis composition in percent
CO=1//Volumetric analysis composition in percent
O2=7.1//Volumetric analysis composition in percent
N2=81//Volumetric analysis composition in percent
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO
mN2=28//Molecular weight of N2

//Calculations
pCO2=(CO2/100)*mCO2//Proportional weight for CO2
pCO=(CO/100)*mCO//Proportional weight for CO
pO2=(O2/100)*mO2//Proportional weight for O2
pN2=(N2/100)*mN2//Proportional weight for N2
T=(pCO2+pCO+pO2+pN2)//Total proportional weight
ppCO2=(pCO2/T)*100//Weight per kg of exhaust gas for
    CO2
ppCO=(pCO/T)*100//Weight per kg of exhaust gas for
    CO
ppO2=(pO2/T)*100//Weight per kg of exhaust gas for
    O2
ppN2=(pN2/T)*100//Weight per kg of exhaust gas for
    N2

printf('The gravimetric analysis is given by (in
    percent) \n CO2 -> %3.2f \n CO -> %3.2f \n O2 ->
    %3.2f \n N2 -> %3.2f',ppCO2,ppCO,ppO2,ppN2)
```

Scilab code Exa 8.11 WEIGHT OF AIR

```
clc
clear
//Input data
CO2=10//Volumetric analysis composition in percent
N2=80//Volumetric analysis composition in percent
```

```
C=80//Carbon content of the fuel in percent
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mN2=28//Molecular weight of N2
mC=12//Molecular weight of carbon

//Calculations
O2=100-(N2+CO2)//Volumetric analysis composition in percent
pCO2=(CO2/100)*mCO2//Proportional weight for CO2
pO2=(O2/100)*mO2//Proportional weight for O2
pN2=(N2/100)*mN2//Proportional weight for N2
T=(pCO2+pO2+pN2)//Total proportional weight
ppCO2=(pCO2/T)//Weight per kg of exhaust gas for CO2
ppO2=(pO2/T)//Weight per kg of exhaust gas for O2
ppN2=(pN2/T)//Weight per kg of exhaust gas for N2
wC=(ppCO2*(mC/mCO2))//Weight of carbon per kg of exhaust gases in kg
WC=((C/100)/wC)//Weight of exhaust gases per kg of fuel burned in kg
wa=(WC-(ppCO2+ppO2+ppN2))//Weight of air supplied per kg fuel in kg

//Output
printf('Weight of air supplied per kg of fuel is %i kg',wa)
```

Scilab code Exa 8.12 AIR SUPPLIED

```
clc
clear
//Input data
CO2=12//Volumetric analysis composition in percent
CO=4//Volumetric analysis composition in percent
N2=84//Volumetric analysis composition in percent
```

```
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO
mN2=28//Molecular weight of N2
mC=12//Molecular weight of carbon
mH2=2//Molecular weight of H2

//Calculations
pCO2=(CO2/100)*mCO2//Proportional weight for CO2
pCO=(CO/100)*mCO//Proportional weight for CO
pN2=(N2/100)*mN2//Proportional weight for N2
T=(pCO2+pCO+pN2)//Total proportional weight
ppCO2=(pCO2/T)//Weight per kg of exhaust gas for CO2
ppCO=(pCO/T)//Weight per kg of exhaust gas for CO
ppN2=(pN2/T)//Weight per kg of exhaust gas for N2
wC=((ppCO2*(mC/mCO2))+(ppCO*(mC/mCO)))//Weight of
    carbon per kg of flue gases
pC=((6*mC)/(6*mC+7*mH2))//Percentage by weight of
    carbon in C6H14
we=(pC/wC)//Weight of exhaust gases per kg of fuel
    in kg
wa=(we-(ppCO2+ppCO+ppN2))//Weight of air supplied
    per kg of fuel in kg
tw=((100/23)*(((mO2/mC)*pC)+((mO2/(2*mH2))*0.163)))
    //Theoretical amount of air required for complete
     combustion of C6H14 in kg
exc=(wa-tw)//Excess air supplied per kg of fuel in
    kg

//Output
printf('Excess air supplied per kg of fuel is %3.1f
    kg(deficient)',exc)
```

Scilab code Exa 8.13 PERCENTAGE COMPOSITION

```
clc
clear
//Input data
C=84//Gravimetric analysis composition in percent
H2=12//Gravimetric analysis composition in percent
S=1.5//Gravimetric analysis composition in percent
O2=1.5//Gravimetric analysis composition in percent
ma=20//Mass of air in kg
pC=4//Percent of carbon in the fuel which is burnt
    to form CO
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO
mN2=28//Molecular weight of N2
mC=12//Molecular weight of carbon
mH2=2//Molecular weight of H2
mS=32//Molecular weight of S
mSO2=64//Molecular weight of SO2

//Calculations
mm=((100/23)*((C/100)*(mO2/mC)+(H2/100)*(mO2/(2*mH2)
    )+(S/100)*(mO2/mS)-(O2/100)))//Minimum air in kg/
    kg of fuel
//When 20 kg of air is supplied
xCO2=((C/100)*(mCO2/mC))//Mass of CO2 in kg
xSO2=((S/100)*(mSO2/mS))//Mass of SO2 in kg
xO2=((23/100)*(ma-mm))//Mass of O2 in kg
xN2=((77/100)*ma)//Mass of N2 in kg
nCO2=(xCO2/mCO2)//Parts by volume of CO2
nSO2=(xSO2/mSO2)//Parts by volume of SO2
nO2=(xO2/mO2)//Parts by volume of O2
nN2=(xN2/mN2)//Parts by volume of N2
T=(nCO2+nSO2+nO2+nN2)//Total parts by volume
pCO2=(nCO2/T)*100//Percentage volume of CO2
pSO2=(nSO2/T)*100//Percentage volume of SO2
pO2=(nO2/T)*100//Percentage volume of O2
pN2=(nN2/T)*100//Percentage volume of N2
//4% of available carbon is burnt to CO then per kg
```

```
of fuel
yCO2=((C/100)/(1+(pC/100)))*(mCO2/mC)//Mass of CO2 in kg
yCO=(((C/100)-((C/100)/(1+(pC/100))))*(mCO/mC))//Mass of CO in kg
yO2=((C/100)*(mO2/mC))//Mass of O2 in kg
eO2=(yO2-(((C/100)/(1+(pC/100)))*(mO2/mC)+(((C/100)-((C/100)/(1+(pC/100))))*(mO2/(2*mC)))))
nnCO2=(yCO2/mCO2)//Parts by volume of CO2
nnCO=(yCO/mCO)//Parts by volume of CO
nnSO2=(xSO2/mSO2)//Parts by volume of SO2
nnO2=((xO2+eO2)/mO2)//Parts by volume of O2
nnN2=(xN2/mN2)//Parts by volume of N2
TT=(nnCO2+nnCO+nnSO2+nnO2+nnN2)//Total parts by volume
ppCO2=(nnCO2/TT)*100//Percentage volume of CO2

//Output
printf('Minimum weight of air required for complete combustion of 1 kg of the fuel is %3.1f kg/kg of fuel \n\n Percentage composition by volume when %i kg of air is supplied (in percent) \n CO2 -> %3.1f \n SO2 -> %3.1f \n O2 -> %3.1f \n N2 -> %3.1f \n\n The percentage volume of CO2 when %i percent of the carbon in the fuel is burnt to form CO is %3.1f percent',mm,ma,pCO2,pSO2,pO2,pN2,pC,ppCO2)
```

Scilab code Exa 8.14 EXCESS AIR

```
clc
clear
//Input data
C=85//Composition by weight in percent
H2=14//Composition by weight in percent
```

```
x=50//Percentage of excess air
Ta=[70+273,500+273]//Temperature of air entering and
    leaving in K
Cp=0.24//Mean specific heat of air in kJ/kg.K
qC=8080//Heat liberated in kcal/kg
qH2=34250//Heat liberated in kcal/kg
a=23//Air contains 23% by weight of O2
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO
mN2=28//Molecular weight of N2
mC=12//Molecular weight of carbon
mH2=2//Molecular weight of H2

//Calculations
mm=((100/a)*((C/100)*(mO2/mC)+(H2/100)*(mO2/(2*mH2))
   ))//Minimum air required in kg/kg of fuel
Q1=((C/100)*qC+(H2/100)*qH2)//Heat in kcal/kg fuel
ea=((x/100)*mm)//Excess air supplied in kg/kg fuel
Q2=((mm/2)*Cp*(Ta(2)-Ta(1)))//Heat in kcal/kg fuel

//Output
printf('(a) Minimum quantity of air necessary for
   the complete combustion of 1 kg of fuel is %3.2f
   kg/kg of fuel \n (b) Heat released per kg of fuel
    when the carbon is burnt to CO2 and hydrogen is
   burnt to H2O is %3.0f kcal/kg fuel \n (c) Heat
   carried away by the excess air is %3.0f kcal/kg
   fuel',mm,Q1,Q2)
```

Scilab code Exa 8.15 VOLUME OF GAS

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

```
CO=17//Percentage composition by volume
H2=53.4//Percentage composition by volume
CH2=28.8//Percentage composition by volume
O2=0.8//Percentage composition by volume
ea=30//Percentage of excess air
v=1//Volume in m^3

//Calculations
ta=((100/21)*((CO/100)/2+(H2/100)/2+(CH2/100)*2-(O2
    /100)))//Theoretical air in m^3/m^3 of gas
aa=((1+(ea/100))*ta)//Actual air in m^3/m^3 of gas
Vg=(v+aa)//Volume of gas air mixture in m^3/m^3 of
    gas

//Output
printf('Total quantity of air required is %3.2f m^3/
   m^3 of gas \n The volume of gas air mixture is %3
   .2f m^3/m^3 of gas',ta,Vg)
```

Scilab code Exa 8.16 VOLUME OF AIR

```
clc
clear
//Input data
CH4=20//Percentage volumetric analysis
C2H4=2//Percentage volumetric analysis
H2=50//Percentage volumetric analysis
CO=16//Percentage volumetric analysis
CO2=4//Percentage volumetric analysis
O2=1.5//Percentage volumetric analysis
N2=6.5//Percentage volumetric analysis
v=6.8//Volume of air supplied in m^3 per m^3 of coal
     gas

//Calculations
```

```
mmO2=((2*CH4)+(3*C2H4)+(H2/2)+(CO/2))-O2//Minimum moles of O2
mCO2=(CH4+(2*C2H4)+CO+CO2)//Moles of CO2
mH2O=((2*CH4)+(2*C2H4)+H2)//Moles of H2O
mN2=(N2+(79/21)*mmO2)//Moles of N2
ma=((100/21)*(mmO2/100))//Minimum air in m^3/m^3 of gas
ea=(v-ma)//Excess air in m^3/m^3 of gas
tm=(mCO2+mN2+ea)*2//Total moles of dry products per 100 moles of gas
pCO2=(mCO2/tm)*100//Percentage of CO2 by volume in dry flue gases

//Output
printf('Minimum volume of air necessary for the complete combustion of 1 m^3 of coal gas is %3.2f m^3/m^3 of gas \n Percentage volume of CO2 in dry flue gases is %3.2f percent',ma,pCO2)
```

Scilab code Exa 8.17 VOLUMETRIC COMPOSITION

```
clc
clear
//Input data
C=86//Percentage of carbon
H2=14//Percentage of Hydrogen
ea=20//Percentage of excess air
O2=23//Weight of oxygen in air in percent
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO
mN2=28//Molecular weight of N2
mC=12//Molecular weight of carbon
mH2=2//Molecular weight of H2
mH2O=18//Molecular weight of H2O
```

```
//Calculations
ma=((100/O2)*((C/100)*(mO2/mC)+(H2/100)*(mO2/(2*mH2))))//Minimum weight of air required in kg/kg petrol
//Products of combustion by weight per kg- petrol
XCO2=(C/100)*(mCO2/mC)//CO2 in kg
XH2O=(H2/100)*(mH2O/mH2)//H2O in kg
XO2=(XCO2+XH2O-1)*(ea/100)//O2 in kg
XN2=(ma*(1+(ea/100))*((100-O2)/100))//N2 in kg
XT=(XCO2+XH2O+XO2+XN2)//Total weight in kg
//Percentage analysis by weight
xCO2=(XCO2/XT)*100//CO2
xH2O=(XH2O/XT)*100//H2O
xO2=(XO2/XT)*100//O2
xN2=(XN2/XT)*100//N2
//Percentage by weight to molecular weight
xxCO2=(xCO2/mCO2)//CO2
xxH2O=(xH2O/mH2O)//H2O
xxO2=(xO2/mO2)//O2
xxN2=(xN2/mN2)//N2
xxt=(xxCO2+xxH2O+xxO2+xxN2)//Total percentage by weight to molecular weight
//Percentage by volume
pCO2=(xxCO2/xxt)*100//CO2
pH2O=(xxH2O/xxt)*100//H2O
pO2=(xxO2/xxt)*100//O2
pN2=(xxN2/xxt)*100//N2

//Output
printf('Volumetric composition of the products of combustion (in percent) \n CO2 -> %3.1f \n H2O -> %3.1f \n O2  -> %3.2f \n N2  -> %3.2f',pCO2,pH2O,pO2,pN2)
```

Scilab code Exa 8.18 WEIGHT

```
clc
clear
//Input data
bhp=20//Brake horse in h.p
N=320//Speed in r.p.m
C=84//Percentage of carbon
H2=16//Percentage of hydrogen
CV=10800//Calorific value in kcal/kg
bth=30//Brake thermal efficiency in percent
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO
mN2=28//Molecular weight of N2
mC=12//Molecular weight of carbon
mH2=2//Molecular weight of H2
mH2O=18//Molecular weight of H2O

//Calculations
W=(bhp*4500)/427//Work done in kcal
Wc=(W*2)/N//Work done per cycle in kcal
qs=(Wc/(bth/100))//Heat supplied per cycle in kcal
wf=(qs/CV)//Weight of fuel used per cycle in kg
tO2=((C/100)*(mO2/mC)+(H2/100)*(mO2/(2*mH2)))//Total
    O2/kg fuel in kg
mw=(tO2/(23/100))//Minimum weight of air required in
    kg/kg fuel
aw=(mw*2)//Actual weight of air supplied in kg/kg
   fuel
wac=(aw*wf)//Wt. of air supplied/ cycle in kg. In
   textbook, it is given wrong as 0.1245 kg

//Output
printf('(a) the weight of fuel used per cycle is %3
   .6f kg \n (b) the actual weight of air taken in
   per cycle is %3.4f kg',wf,wac)
```

Scilab code Exa 8.19 WEIGHT OF AIR

```
clc
clear
//Input data
CO2=8.85//Percentage composition by volume
CO=1.2//Percentage composition by volume
O2=6.8//Percentage composition by volume
N2=83.15//Percentage composition by volume
C=84//Percentage composition by weight
H2=14//Percentage composition by weight
aO2=2//Percentage composition by weight
mO2=32//Molecular weight of O2
mCO2=44//Molecular weight of CO2
mCO=28//Molecular weight of CO
mN2=28//Molecular weight of N2
mC=12//Molecular weight of carbon
mH2=2//Molecular weight of H2
mH2O=18//Molecular weight of H2O

//Calculations
//O2 required per kg of fuel
xC=((C/100)*(mO2/mC))//C
xH2=((H2/100)*(mO2/(2*mH2)))//H2
xO2=-(aO2/100)//O2
ttO2=(xC+xH2-xO2)//Theoretical total oxygen required in kg/kg fuel
twa=(ttO2/(23/100))//Theoretical weight of air in kg/kg fuel
//Conversion of volumetric analysis of the flue gas into a weight analysis
//Percenatge by volume * mol. wt
xxCO2=(CO2*mCO2)//CO2
xxCO=(CO*mCO)//CO
```

```
xxO2=(O2*mO2)//O2
xxN2=(N2*mN2)//N2
xxt=(xxCO2+xxCO+xxO2+xxN2)//Total
//Percentage by weight
yCO2=(xxCO2/xxt)*100//CO2
yCO=(xxCO/xxt)*100//CO
yO2=(xxO2/xxt)*100//O2
yN2=(xxN2/xxt)*100//N2
wcd=((yCO2/100)*(mC/mCO2))+((yCO/100)*(mC/mCO))//
   Weight of carbon/ kg of dry flue gas in kg
wdf=((C/100)/wcd)//Wt. of dry flue gas/kg fuel in kg
wxf=(wdf*(yO2/100))//Weight of excess O2/kg fuel in
   kg
weO2=(wxf/(23/100))//Weight of excess air in kg/kg
   fuel
was=(twa+weO2)//Weight of air supplied/kg fuel in kg

//Output
printf('Weight of air supplied per kg fuel burnt is
   %3.2f kg',was)
```

Chapter 9

SPARK IGNITION ENGINES

Scilab code Exa 9.1 WEIGHT

```
clc
clear
//Input data
d=0.001//Diameter of the jet in m
vd=104//Venturi depression in cm of water. In textbook, it is given as 10 cm
Cd=0.65//Coefficient of discharge
g=0.76//Specific gravity of petrol
w=1000//Weight of water per one cu.m in kg

//Calculations
pa=(vd/100)*w//Venturi depression in kg/m^2
dp=(g*w)//Density of petrol in kg/m^3
wf=(((3.14*d^2)/4)*Cd*sqrt(2*9.81*dp*pa))/10^-3//Petrol discharge in gm/sec neglecting nozzle lip

//Output
printf('The weight of petrol discharged is %3.2f gm/sec',wf)
```

Scilab code Exa 9.2 AIR FUEL RATIO

```
clc
clear
//Input data
d1=0.075//Throat diameter in m
Ca=0.93//Coefficient of air flow
d2=0.005//Orifice diameter in m
Cf=0.68//Coefficient of fuel discharge
ap=1//Approach factor
dp=0.15//Pressure drop in kg/cm^2
da=1.29//Density of air in kg/m^3
df=720//Density of fuel in kg/m^3

//Calcultions
w=(((3.14/4)*d1^2)/((3.14/4)*d2^2))*(Ca/Cf)*sqrt(da/
   df)//The air-fuel ratio neglecting the nozzle lip

//Output
printf('The air-fuel ratio neglecting the nozzle lip
    is %3.1f',w)
```

Scilab code Exa 9.3 THEORETICAL RATIO OF DIAMETER

```
clc
clear
//Input data
af=15//Air fuel ratio
dp=753//Density of petrol in kg/m^3
da=1.28//Density of air in kg/m^3
C=[0.84,0.7]//Coefficient of discharge for air and
   fuel respectively
```

```
//Calculations
A=1/(af*(C(2)/C(1))*sqrt(dp/da))//Ratio of areas
d=sqrt(A)//Ratio of diamter of jet to diameter of
    venturi
x=(1/d)//Reverse of ratio

//Output
printf('The ratio of diameter of jet to diameter of
    venturi is 1 : %3.1f',x)
```

Scilab code Exa 9.4 SECTION AT THE THROAT

```
clc
clear
//Input data
D=[10,12]//Dimensions of four cylinder in 10 cm* 12
    cm
n=4//Four cylinder
N=2000//Speed in r.p.m
d=0.03//Venturi throat in m
nv=70//Volumetric efficiency of the engine in
    percent
Ca=0.8//Coefficient of air flow
da=1.29//Density of air in kg/m^3

//Calculations
Vs=(3.14/4)*(D(1)/100)^2*(D(2)/100)//Stroke volume
    of one cylinder in m^3
Va=(Vs*n*(nv/100)*(N/2))//Volume of air drawn per
    minute in m^3
w=(Va*da)/60//Weight of air drawn per sec
dp=((w/((3.14/4)*d^2*Ca))^2/(2*9.81*da))//Venturi
    depression in kg/cm^2

```

```
//Output
printf('The venturi depression is %3.1f kg/m^2',dp)
```

Scilab code Exa 9.5 SIZE OF THE VENTURI

```
clc
clear
//Input data
D=[8.25,11.5]//Dimensions of four cylinder in 8.25 cm* 11.5 cm
n=4//Four cylinder
N=3000//Speed in r.p.m
v=150//Venturi depression in cm of water
nv=80//Volumetric efficiency of the engine in percent
af=14//Air fuel ratio
Ca=0.84//Coefficient of air flow
Cf=0.7//Coefficient of fuel orifice
da=1.29//Density of air in kg/m^3
df=700//Density of fuel in kg/m^3
dw=1000//Density of water in kg/m^3

//Calculations
Va=((3.14/4)*(D(1)/100)^2*(D(2)/100)*n*(nv/100)*(N/(2*60)))//Maximum amount of air passing through the venturi in m^3
vd=(v/100)*dw//Venturi depression in kg/m^2
va=(Ca*sqrt((2*9.81*vd)/da))//Velocity of air in m/s
d=sqrt((Va/va)*(4/3.14))//Throat diameter of venturi in m
Af=1/(af*(va/Va)*sqrt(df/da)*(Cf/Ca))//Area of orifice in m^2
df=sqrt((Af*4)/3.14)*1000//Diameter of orifice in mm

//Output
```

```
printf('The size of venturi is %i kg/m^2 \n The diameter of fuel orifice is %3.2f mm',vd,df)
```

Scilab code Exa 9.6 FUEL CONSUMPTION

```
clc
clear
D=[7.5,10]//Dimensions of four cylinder in 7.5 cm diameter and 10 cm stroke
n=6//Six cylinder
pC=84//Percentage of carbon in volatile fuel
pH2=16//Percentage of hydrogen in volatile fuel
dc=(38.5/1000)//Diameter of the throat of the choke tube in m
N=3000//Speed in r.p.m
nv=0.8//Volumetric efficiency in ratio
p=0.914//Pressure at the throat of the choke tube in kg/cm^2
T=15.5+273//Temperature at the throat of the choke tube in K
Ts=273//Temperature of 0 degree C in K
ps=1.027//Atmospheric pressure in kg/cm^2
Ra=29.27//Universal gas constant for air in kg.m/kg.K
Rf=9.9//Gas constant for fuel in kg.m/kg.K
pO2=23//Composition by weight of oxygen in air in percent
pN2=77//Composition by weight of nitogen in air in percent
mO2=32//Molecular weight of O2
mH2=2//Molecular weight oh H2
mC=12//Molecular weight of carbon

//Calculations
Vm=((3.14/4)*(D(1)/100)^2*(D(2)/100)*n*(N/2)*nv)//
```

```
Volume of mixture supplied per sec in m^3
qa=((100/pO2)*(((pC/100)*(mO2/mC))+((pH2/100)*(mO2
   /(2*mH2)))))//Quantity of air required for
   complete combustion of fuel in kg
vf=(Rf*Ts)/(ps*10^4)//Specific volume of volatile
   fuel in m^3/kg
va=(Ra*Ts)/(ps*10^4)//Specific volume of air in m^3/
   kg
wf=(Vm/(qa*va+vf))//Flow rate of fuel in kg/min
Fc=(wf*60)//Fuel consumption in kg/hour
da=(p*10^4)/(Ra*T)//Density of air at the throat of
   the choke in kg/m^3
Va=((qa*wf)/((3.14/4)*dc^2*da*60))//Speed of air at
   throat in m/s

//Output
printf('(a) The fuel consumption is %3.1f kg/hr \n (
   b) The speed of the air through the choke is %3.1
   f m/s',Fc,Va)
```

Scilab code Exa 9.7 DIAMETER OF JET

```
clc
clear
//Input data
mf=7.5//Consumption of petrol per hour
gf=0.75//Specific gravity of fuel
Tf=25+273//Temperature of fuel in K
af=15//Air fuel ratio
dc=22//diameter of choke tube in mm
l=4//Top of the jet is 4 mm above the petrol level
   in the float chamber
Ca=0.82//Coefficient of discharge for air
Cf=0.7//Coefficient of discharge for fuel
R=29.27//Characteristic gas constant for air in kg.m
```

```
/kg.K
p=1.03//Atmospheric pressure in kg/cm^2

//Calculations
da=(p*10^4)/(R*Tf)//Density of air in kg/m^3
dp=(gf*1000)//Density of petrol in kg/cm^3
dpa=((af*mf*10^6)/(60*60*3.14*Ca*(dc/2)^2))^2/(2*9.81*da)//Change in pressure in kg/m^2
df=sqrt((mf/(60*60*Cf*sqrt(2*9.81*dp*(dpa-((l/100)*dp)))))*(4/3.14))*1000//Diameter of the fuel jet in mm

//Output
printf('Diameter of the jet of the carburettor is %3.2f mm',df)
```

Scilab code Exa 9.8 AIR FUEL RATIO

```
clc
clear
//Input data
td=7.5//Throat diameter in cm
Ca=0.85//Coefficient of air flow
fd=0.5//Diameter of fuel orifice in cm
Cd=0.7//Coefficient of discharge
l=5//Nozzle lip in mm
x=1//Approach factor
dpa=0.15//Pressure drop in kg/cm^2
da=1.29//Density of air in kg/m^3
dp=720//Density of fuel in kg/m^3

//Calculations
afr1=(((3.14*td^2)/(3.14*fd^2))*(Ca/Cd)*sqrt(da/dp))//Air fuel ratio
afr2=((3.14*td^2)/(3.14*fd^2))*(Ca/Cd)*sqrt((da*dpa)
```

```
/(dp*(dpa-((1/100)*(dp/10^6)))))//Air fuel ratio

//Output
printf('The air fuel ratio \n (a) neglecting nozzle
   lip is %3.2f \n (b) nozzle lip is taken into
   account is %3.2f',afr1,afr2)
```

Scilab code Exa 9.9 VELOCITY

```
clc
clear
//Input data
td=7.5//Throat diameter in cm
Ca=0.85//Coefficient of air flow
fd=0.5//Diameter of fuel orifice in cm
Cd=0.7//Coefficient of discharge
l=5//Nozzle lip in mm
x=1//Approach factor
dpa=0.15//Pressure drop in kg/cm^2
da=1.29//Density of air in kg/m^3
dp=720//Density of fuel in kg/m^3

//Calculations
v=sqrt(2*9.81*(1/1000)*(dp/da))//Velocity of air in
   m/s

//Output
printf('Velocity of air flow is %3.1f m/s',v)
```

Scilab code Exa 9.10 PETROL CONSUMPTION

```
clc
clear
```

```
//Input data
x=2.8//Height above the nozzle in mm
va=58//Velocity of air in m/s
da=1.28//Density of air in kg/m^3
dp=750//Density of petrol in kg/m^3
An=1.8//Area of cross section of nozzle in mm^2
Cd=0.6//Coefficient of discharge of nozzle
Ca=0.84//Coefficient of discharge of air

//Calculations
dpa=((va/Ca)^2*(da/(2*9.81)))//Change in pressure in
    kg/m^2
wf=((An*10^-6)*Cd*sqrt(2*9.81*dp*(dpa-((x/1000)*dp))
   ))//Petrol consumption in kg/sec

//Output
printf('Petrol consumption is %3.4f kg/sec',wf)
```

Scilab code Exa 9.11 AIR FUEL RATIO

```
clc
clear
//Input data
d=0.155//Diameter of orifice in mm
Cd=0.94//Coefficient of discharge
td=3.18//Throat diameter in cm
Ca=0.84//Coefficient of discharge
x=29//Venturi depression
dw=0.89//Minimum depression of water in cm
sa=1.1//Specific weight of air in kg/m^3
sg=0.72//Specific gravity of petrol
cyd=[7.75,10.75]//Cylinder dimensions in cm
fc=10.9//Fuel consumption in kg/hr
N=3200//Speed in r.p.m
n=4//Number of cylinders
```

```
//Calculations
w=(((3.14/4)*td^2)/((3.14/4)*d^2))*(Ca/Cd)*sqrt((sa
    /(sg*1000))*(x/(x-dw)))//Air fuel ratio
Va=(3.14/4)*(td/100)^2*Ca*sqrt(2*9.81*sa*x*6)//
    Volume of air drawn/sec
vn=(Va/((3.14/4)*(cyd(1)/100)^2*(cyd(2)/100)*n*(N
    /(2*60))))*100//Volumetric efficiency in percent

//Output
printf('Air fue ratio is %3.1f \n Volumetric
    efficiency is %3.1f percent',w,vn)
```

Scilab code Exa 9.12 THROAT PRESSURE

```
clc
clear
//Input data
af=0.066//Air fuel ratio
p=0.83//Pressure at the venturi throat in kg/cm^2
pd=0.04//Pressure drop in kg/cm^2
va=245//Air flow at sea level in kg per hour

//Calculations
dpa=1.03-p//Pressure at air cleaner in kg/cm^2
d=(1.03-pd-dpa)//Throat pressure when the air
    cleaner is fitted in kg/cm^2
naf=(af*sqrt((1.03-d)/dpa))//New air fuel ratio

//Output
printf('(a) Throat pressure when the air cleaner is
    fitted is %3.2f kg/cm^2 \n (b) New air fuel ratio
     is %3.4f',d,naf)
```

Scilab code Exa 9.13 DROP IN PRESSURE

```
clc
clear
//Input data
x=3//Petrol stands 3 mm below
Ta=15.5+273//Temperature of air in K
pa=1.027//Pressure of air in kg/cm^2
R=29.27//Characteristic gas constant in kg.m/kg.K
sg=0.76//Specific gravity of fuel
fc=6.4//Consumption of fuel in kg/hour
jd=1.27//Jet diameter in mm
Cd=0.6//Nozzle discharge coefficienct
Ca=0.8//Discharge coefficient of air
af=0.066//Air fuel ratio

//Calculations
df=(sg*1000)//Density of fuel in kg/m^3
da=(pa*10^4)/(R*Ta)//Density of air in kg/m^3
va=Ca*sqrt((2*9.81*x*df)/(da*1000))//Critical
    velocity of air in m/s
dpa=(((fc/(60*60))/((3.14/4)*(jd/1000)^2*Cd))
    ^2/(2*9.81*df))+((x/1000)*df)//Drop in pressure
    in kg/m^3
dpaw=(dpa/1000)*100//Drop in pressure in cm of water
dj=sqrt(((fc/(3600*af))/(Ca*sqrt(2*9.81*da*dpa)))
    /(3.14/4))*1000//Effective throat diameter in mm

//Output
printf('Critical air velocity is %3.2f m/sec \n
    Effective throat diameter of the venturi is %3.1f
    mm \n The drop in pressure in the venturi is %3
    .2f cm of water',va,dj,dpaw)
```

Scilab code Exa 9.14 ORIFICE DIAMETER

```
clc
clear
//Input data
ma=6.11//Flow rate of air in kg/min
mf=0.408//Flow arte of petrol in kg/min
dp=768//Density of petrol in kg/m^3
Ta=15.5+273//Temperature of air in K
pa=1.027//Pressure of air in kg/cm^2
R=29.27//Characteristic gas constant in kg.m/kg.K
va=97.5//Speed of air in m/sec
Cv=0.84//Velocity coefficient
g=1.4//Ratio of specific heats
x=0.8//pressure at the venturi is 0.8 of the
    pressure drop at the choke
Cd=0.66//Coefficient of discharge

//Calculations
rp=(1-((va/Cv)^2/((((2*9.81*g)/(g-1))*R*Ta)))^(g/(g
    -1))//Pressure ratio
p2=(pa*rp)//Pressure in kg/cm^2
T2=(Ta*rp^((g-1)/g))//Temperature in K
da=(p2/(R*T2))*10^4//Density in kg/m^3
daa=sqrt((ma/(60*va*da))/(3.14/4))*1000//Throat
    diameter in mm
df=sqrt((mf/(60*Cd*sqrt(2*9.81*dp*x*(pa-p2)*10^4)))
    /(3.14/4))*1000//Orifice diameter in mm

//Output
printf('Throat diameter of the choke is %i mm \n The
    orifice diameter is %3.2f mm',daa,df)
```

Scilab code Exa 9.15 ORIFICE DIAMETER

```
clc
clear
//Input data
ma=6.8//Mass flow rate of air in kg/min
mf=0.45//Mass flow rate of petrol in kg/min
pa=1.033//Pressure of air in kg/cm^2
Ta=20+273//Temperature of air in K
va=97.5//Velocity of air in m/s
Cv=0.8//Velocity coefficient
g=1.4//Ratio of specific heats
R=29.27//Characteristic gas constant in kg.m/kg.K
x=0.75//pressure at the venturi is 0.8 of the pressure drop at the choke
Cd=0.65//Coefficient of discharge
pw=800//Weight of petrol in kg per cu.m

//Calculations
rp=(1-((va/Cv)^2/((((2*9.81*g)/(g-1))*R*Ta)))^(g/(g-1))//Pressure ratio
p2=(pa*rp)//Pressure in kg/cm^2
T2=(Ta*rp^((g-1)/g))//Temperature in K
da=(p2/(R*T2))*10^4//Density in kg/m^3
daa=sqrt((ma/(60*va*da))/(3.14/4))*100//Throat diameter in mm
df=sqrt((mf/(60*Cd*sqrt(2*9.81*pw*x*(pa-p2)*10^4)))/(3.14/4))//Orifice diameter in mm

//Output
printf('Throat diameter of the choke is %3.2f cm \n The orifice diameter is %3.5f m',daa,df)
```

Scilab code Exa 9.16 POWER DEVELOPED

```
clc
clear
//Input data
n=6//Number of cylinders
d=100//Diameter in mm
L=100//Stroke in mm
N=1500//Speed in r.p.m
ap=13.5//Air fuel ratio
Ta=80+273//Temperature of air in K
x=(7/8)//Ratio of volume drawn
nth=22//Thermal efficiency in percent
p=76//Pressure in cm of mercury
CV=9000//Calorific value of petrol in kcal/kg
l=1524//Altitude in m
dp=2.54//Drop in pressure in cm of barometric
    reading
lx=274//Altitude rise in m

//Calculations
Vs=(3.14/4)*(d/10)^2*(L/10)//Swept volume in c.c
Va=(x*Vs)//Volume of air drawn in per cylinder per
    stroke in c.c
wa=(Va*10^-6*(N/2)*n)//Weight of air supplied to the
     engine per minute in kg
wf=(wa/ap)//Weight of fuel consumed per minute in kg
q=(wf*CV)//Heat supplied to the engine per minute in
     kcal
P=(q*(nth/100)*427)/4500//Power developed at ground
    level in H.P
db=(l/lx)*dp//Drop in barometric reading at an
    altitude of 1524 m in cm
Pd=(P/p)*(p-db)//Power developed at 1524 m altitude
```

```
    in H.P

//Output
printf('Power developed at the ground level is %i H.
   P \n Power developed at an altitude of %i m is %i
    H.P',P,l,Pd)
```

Chapter 11

FOUR STROKE SPARK IGNITION ENGINE

Scilab code Exa 11.1 WEIGHT

```
clc
clear
//Input data
d=0.0625//Diameter in m
L=0.09//Stroke in m
nv=0.75//Volumetric efficiency
p=1.03//Pressure at N.T.P in kg/cm^2
T=273//Temperature at N.T.P in K
R=29.27//Characteristic gas constant in kg.m/kg.
    degree C

//Calculations
Vs=((3.14/4)*d^2*L)//Swept volume in cu.m
V=(nv*Vs)//Volume of charge at N.T.P in cu.m
w=(p*10^4*V)/(R*T)//Weight of the charge in kg/cycle

//Output
printf('The weight of the charge is %3.6f kg/cycle',
    w)
```

Scilab code Exa 11.2 INDICATED THERMAL EFFICIENCY

```
clc
clear
//Input data
n=9//Number of cylinder
d=0.145//Bore in m
l=0.19//Stroke in m
r=5.9//Compression ratio
bhp=460//Brake horse power in B.H.P
N=2000//Speed in r.p.m
x=20//Percentage rich in mixture
CV=11200//Calorific value in kcal/kg
pC=85.3//Percentage of carbon
pH2=14.7//Percentage of Hydrogen
nv=70//Volumetric efficiency in percent
T=15+273//Temperature in K
nm=90//Mechanical efficiency in percent
wO2=23.3//Percentage of oxygen by weight in air
da=1.29//Density of air in kg/m^3
mC=12//Molecular weight of carbon
mO2=32//Molecular weight of O2
mH2=2//Molecular weight of H2

//Calculations
hihp=((bhp/(nm/100))*(4500/427))//Heat equivalent in
    kcal
Vs=((3.14/4)*d^2*l*(N/2)*n)//Swept volume in c.m per
    min
cw=(Vs/da)//Charge weight of air per minute in kg
ma=(100/wO2)*((pC/100)*(mO2/mC)+(pH2/100)*(mO2/(2*
   mH2)))//Wt. of air required per kg of fuel in kg
mf=(cw/ma)//Minimum fuel inkg
ith=(hihp/(mf*(100+x)/100*CV))*100//Indicated
```

```
thermal efficiciency in percent'

//Output
printf('Indicated thermal efficiency of the engine is %3.1f percent',ith)
```

Scilab code Exa 11.3 PROPERTIES

```
clc
clear
//Input data
n=8//Number of cylinders
d=8.57//Bore in cm
l=8.25//Stroke in cm
r=7//Compression ratio
N=4000//Speed in r.p.m
la=53.35//Length of the arm in cm
t=10//Test duration in min
br=40.8//Beam reading in kg
gas=0.455//gasoline in kg. In textbook, it is given wrong as 4.55
CV=11400//Calorific value in kcal/kg
Ta=21+273//Temperature of air in K
pa=1.027//Pressure of air in kg/cm^2
wa=5.44//Rate of air in kg/min
J=427//Mechanical equivalent of heat in kg.m/kcal
R=29.27//Characteristic gas constant in kg.m/kg.K

//Calculations
bhp=(2*3.14*N*br*la)/(4500*100)//Brake horse power in B.H.P
pb=(bhp*4500)/((n/2)*(l/100)*(3.14/4)*d^2*N)//Brake mean effective pressure in kg/cm^2
bsfc=(gas*60)/bhp//Brake specific fuel consumption in kg/b.h.p.hr
```

```
bsac=((wa*60)/bhp)//Brake specific fuel consumption
    in kg/b.h.p.hr
nb=((bhp*4500)/(J*gas*CV))*100//Brake thermal
    efficiency in percent
Vd=((3.14/4)*d^2*l)//Piston displacement in c.c/
    cycle
Pd=(Vd/10^6)*(N/2)*n//Piston displacement in m^3/min
Va=((wa*R*Ta)/(pa*10^4))//Volume of air used in m^3/
    min
nv=(Va/Pd)*100//Volumetric efficiency in percent
af=(wa/gas)//Air fel ratio

//Output
printf('(a) the B.H.P delivered s %3.0f h.p \n (b)
    the b.m.e.p is %3.1f kg/cm^2 \n (c) the b.s.f.c
    is %3.3f kg/b.h.p.hr \n (d) the brake specific
    air consumption is %3.3f kg/b.h.p.hr \n (e) the
    brake thermal efficiency is %3.1f percent \n (f)
    the volumetric efficiency is %3.0f percent \n (g)
     the air fuel ratio is %3.2f',bhp,pb,bsfc,bsac,nb
    ,nv,af)
```

Scilab code Exa 11.4 WEIGHT OF AIR

```
clc
clear
//Input data
n=4//Number of cylinders
N=2000//Speed in r.p.m
m=13.15//Mass of fuel in kg/hour
Vd=655.5//Displacement volume in c.c
da=1.2//Density of air in kg/m^3
d=12.7//Manometer depression in cm
//Qa=0.231*sqrt(ha); Qa is the flow rate in cu.m/min
     and ha is the pressure difference in metres
```

```

//Calculations
Qa=(0.231*sqrt(((d*1000)/da)/100))//Flow rate in cu.m/min
Wa=(Qa*da)//Weight of air in kg/min
Va=(Qa*(2/N)*(1/n))*10^6//Volume of air drawn in per cycle per cylinder in c.c
nv=(Va/Vd)*100//Volumetric efficiency in percent
af=(Wa/(m/60))//Air fuel ratio

//Output
printf('(a) the weight of air drawn is %3.3f kg/min \n (b) volumetric efficiency taking air into account is %3.1f percent \n (c) the air-fuel ratio is %i',Wa,nv,af)
```

Scilab code Exa 11.5 CLEARANCE VOLUME

```
clc
clear
//Input data
d=10//Diameter in cm
l=15//Stroke in cm
r=6//Compression ratio
ihp=20//Indicated horse power in h.p
N=1000//Speed in r.p.m
n=4//Number of cylinders
nt=30//Thermal efficiency in percent
CV=10000//Calorific value in kca/kg
g=1.4//Ratio of specific heats

//Output
Vs=((3.14/4)*d^2*l)//Swept volume in c.c
Vc=(Vs/(r-1))//Clearance volume in c.c
na=(1-(1/r)^(g-1))*100//Air standard efficiency in
```

```
percent
pm=((ihp*4500)/((l/100)*(3.14/4)*(d/100)^2*(N/2)*n))
   //Pressure in kg/cm^2
pc=(ihp*4500*60)/(427*(nt/100)*CV)//Petrol
   consumption in kg/hr

//Output
printf('Clearance volume is %3.1f c.c \n The air
   standard efficiency is %3.1f percent \n Petrol
   consumption is %3.2f kg/hr',Vc,na,pc)
```

Scilab code Exa 11.6 CYLINDER PROPERTIES

```
clc
clear
//Input data
n=6//Number of cylinders
P=62//Power in HP
N=3000//Speed in r.p.m
nv=85//Volumetric efficiency in percent
nt=25//Thermal efficiency in percent
CV=10500//Calorific value in kcal/kg
af=15//Air fuel ratio
T=273//Standard atmosphere temperature in K
p=1.03//Standard atmosphere pressure in kg/cm^2
R=29.27//Characteristic gas constant in kg.m/kg.K
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
q=(P*4500)/(J*(nt/100))//Heat supplied in kcal/min
F=(q/CV)//Fuel supplied per minute in kg
Fc=(F/N)*(2/n)//Fuel supplied per cycle per cylinder
    in kg
wt=(af*Fc)//Weight of air supplied per cycle in kg
d=((((wt)*R*T)/(p*10^4*(3.14/4)*(nv/100)))^(1/3))
```

```
    *100//Diameter in cm

//Output
printf('Cylinder bore = stroke = %3.2f cm',d)
```

Chapter 14

THE DIESEL ENGINE

Scilab code Exa 14.1 WEIGHT OF OIL

```
clc
clear
//Input data
r=14.3//Compression ratio
c=5//Fuel cutoff in percent of stroke
w=0.006//Weight of charge in kg
T4=912//Final temperature in degree C abs
q=8300//Heat in kcal
x=[0.258,0.000048]//Temperature expression is 0.258T
    +0.000048T^2, where T is in degree C abs

//Calculations
v4=1//Assuming clearance volume as unity
v1=1.665//v1 from fig. 14.2 on page no. 352
T1=(T4*v1)/v4//Temperature in degree C abs
qp1=(x(1)*T1+x(2)*T1^2)//Constant pressure heat of
    mixture at temperature T1 in kcal/kg
qp4=(x(1)*T4+x(2)*T4^2)//Constant pressure heat of
    mixture at temperature T4 in kcal/kg
qre=(qp1-qp4)//Heat required by the mixture in kcal/
    kg
```

```
wf=(w*qre)/q//Weight of oil in kg

//Output
printf('The weight of oil that must be injected is
   %3.6f kg',wf)
```

Scilab code Exa 14.2 RATIO OF MASS

```
clc
clear
//Input data
r=14//Compression ratio
p=1.2//Induction pipe pressure in kg/cm^2
bp=0.65//Exhaust back pressure in kg/cm^2
Tc=87+273//Charge temperature in K
Te=850+273//Exhaust temperature in K
T1=111+273//Temperature at the beginning of
   compression in K
g=1.2//Ratio of specific heats

//Calculations
Cw1=((bp*10^4)/Te)//specific heat in kJ/kg.K
Cw2=((p*10^4*(r-1))/Tc)//specific heat in kJ/kg.K
T3=((g*Te*Cw1+Cw2*Tc)/(Cw1*g+Cw2))//Temperature in K
t3=T3-273//Temperature in degree C
rw=(Cw1/Cw2)//Ratio of specific heats

//Output
printf('The ratio of the mass residuals to fresh
   charge is %3.4f',rw)
```

Chapter 15

FUEL INJECTION

Scilab code Exa 15.1 QUANTITY OF FUEL

```
clc
clear
//Input data
n=6//Number of cylinders
p=720//Horse power in h.p
N=180//Speed in r.p.m
f=250//Fuel rate in gm per horse power hour

//Calculations
w=(((f/1000)*p)/((N/2)*60*n))*1000//Weight of fuel
    per cycle in gm/cycle

//Outptut
printf('The quantity of fuel to be injected per
    cylinder is %3.2f gm/cycle',w)
```

Scilab code Exa 15.2 QUANTITY OF FUEL

```
clc
clear
//Input data
n=4//Number of cylinders
fc=0.215//Brake specific fuel consumption in kg/B.H.P hour
BHP=400//Brake horse power in B.H.P
N=250//Speed in r.p.m
sg=0.9//Specific gravity

//Calculations
Fc=(fc*BHP)//Fuel consumption per hour in kg/hr
Fcy=(Fc/n)//Fuel consumption per cylinder in kg/hr
Fcyc=((Fcy/(60*(N/2)))/(sg*1000))*10^6//Fuel consumption per cycle in kg. In textbook it is given wrong as 0.0287 instead of 3.185

//Output
printf('The quantity of fuel to be injected per cycle per cylinder is %3.3f c.c',Fcyc)
```

Scilab code Exa 15.3 QUANTITY OF FUEL

```
clc
clear
//Input data
n=4//Number of cylinders
p=450//Brake Horse power in B.H.P
N=200//Speed in r.p.m
f=0.2//Fuel rate in kg per horse power hour
g=0.9//Specific gravity of fuel

//Output
Fc=(p*f)//Fuel consumption per hour in kg/hr
Fcy=(Fc/n)//Fuel consumption per cylinder in kg/hr
```

```
Fcyc=(Fcy/(60*(N/2)))//Fuel consumption per cycle in
    kg
q=(Fcyc/(g*1000))*10^6//Quantity of fuel injected
   per cylinder per cycle in c.c

//Output
printf('The quantity of fuel to be injected per
   cycle per cylinder is %3.3f c.c',q)
```

Scilab code Exa 15.4 SIZE OF PUMP

```
clc
clear
//Input data
//Data from problem 1
n=6//Number of cylinders
p=720//Horse power in h.p
N=180//Speed in r.p.m
f=250//Fuel rate in gm per horse power hour

Vo=20//Volume of oil in the suction chamber in c.c
dp=80//Discharge pressure in kg/cm^2
voi=6//Volume of oil in the injector in c.c
g=0.9//Specific gravity of oil
b=78.8*10^-6//Coefficient of compressibility in cm
   ^2/kg when pressure is taken as atmospheric

//Calculations
w=(((f/1000)*p)/((N/2)*60*n))*1000//Weight of fuel
   per cycle in gm/cycle
Va=(w/g)//Volume of air per cycle in c.c
V1=(Vo+Va)//Initial volume in c.c
dV12=(b*V1*dp)//Change in volume in c.c
//Assuming in accordance with average practice that
   s=2d, nv=0.94 and full load in this pump type x
```

```
    =0.5
d=((voi+dV12)/((3.14/4)*2*0.94*0.5))^(1/3)//Diameter
     in cm
l=(2*d)//Stroke in cm

//Output
printf('The diameter of the pump is %3.2f cm \n The
    total stroke is %3.2f cm',d,l)
```

Scilab code Exa 15.5 VELOCITY

```
clc
clear
//Input data
p=110//Oil pressure in kg/cm^2
pc=25//Pressure in the combustion chamber in kg/cm^2
q=0.805//Velocity coefficient. In textbook it is
    given wrong as 9.805
d=0.906//Specific gravity

//Calculations
v=(37.1*q*sqrt((p-pc)/d))//Velocity in m/s

//Output
printf('The velocity of injection is %3.0f m/s',v)
```

Scilab code Exa 15.6 PUMP DISPLACEMENT

```
clc
clear
//Input data
Vf=6.2//Volume of fuel in c.c
l=65//Length of fuel line in cm
```

```
di=2.5//Inner diameter in mm
V=2.75//Volume of fuel in the injector valve in c.c
Vd=0.15//Volume of fuel to be delivered in c.c. In
    textbook it is given wrong as 0.047
p=140//Pressure in kg/cm^2
pp=1//Pump pressure in kg/cm^2
patm=1.03//Atmospheric pressure in kg/cm^2
b=78.8*10^-6//Coefficient of compressibility in cm
    ^2/kg when pressure is taken as atmospheric

//Calculations
V1=(Vf+(3.14/4)*(di/10)^2*l+V)//Initial volume in c.
    c
dV=((b*V1*(p-pp)/patm))//Change in volume in c.c
d=(dV+Vd)//Total displacement of the plunger in c.c

//Output
printf('The total displacement of the plunger is %3
    .3f c.c',d)
```

Scilab code Exa 15.7 PUMP DISPLACEMENT

```
clc
clear
//Input data
Vf=6.75//Volume of fuel in c.c
l=65//Length of fuel line in cm
di=2.5//Inner diameter in mm
V=2.45//Volume of fuel in the injector valve in c.c
Vd=0.15//Volume of fuel to be delivered in c.c.
p=150//Pressure in kg/cm^2
pp=1//Pump pressure in kg/cm^2
patm=1.03//Atmospheric pressure in kg/cm^2
b=78.8*10^-6//Coefficient of compressibility in cm
    ^2/kg when pressure is taken as atmospheric
```

```
//Calculations
V1=(Vf+(3.14/4)*(di/10)^2*l+V)//Initial volume in c.
    c
dV=((b*V1*(p-pp)/patm))//Change in volume in c.c
d=(dV+Vd)//Total displacement of the plunger in c.c

//Output
printf('The total displacement of the plunger is %3
    .3f c.c',d)
```

Scilab code Exa 15.8 PLUNGER STROKE

```
clc
clear
//Input data
Vf=6.75//Volume of fuel in c.c
l=65//Length of fuel line in cm
di=2.5//Inner diameter in mm
V=2.45//Volume of fuel in the injector valve in c.c
Vd=0.15//Volume of fuel to be delivered in c.c.
p=150//Pressure in kg/cm^2
pp=1//Pump pressure in kg/cm^2
patm=1.03//Atmospheric pressure in kg/cm^2
b=78.8*10^-6//Coefficient of compressibility in cm
    ^2/kg when pressure is taken as atmospheric
dp=0.75//Diameter of the plunger in cm

//Calculations
V1=(Vf+(3.14/4)*(di/10)^2*l+V)//Initial volume in c.
    c
dV=((b*V1*(p-pp)/patm))//Change in volume in c.c
d=(dV+Vd)//Total displacement of the plunger in c.c
s=((4/3.14)*(d/dp^2))*10//Stroke in mm

```

```
//Output
printf('The effective plunger stroke is %3.1f mm',s)
```

Scilab code Exa 15.9 DIAMETER

```
clc
clear
//Input data
n=6//Number of cylinders
p=300//Horse power in H.P
N=1200//Speed in r.p.m
f=0.2//Fuel rate in kg per B.H.P hour
ip=200//Injection pressure in kg/cm^2
cp=40//Pressure in the combustion chamber in kg/cm^2
pic=33//Period of injection of the crank angle in
   degrees
g=0.83//Specific gravity of fuel. In textbook, it is
    given wrong as 0.89
Cd=0.9//Coefficient of discharge

//Output
Fc=(p*f)//Fuel consumption per hour in kg/hr
Fcy=(Fc/n)//Fuel consumption per cylinder in kg/hr
Fcyc=(Fcy/(60*(N/2)))//Fuel consumption per cycle in
    kg
q=(Fcyc/(g*1000))*10^6//Quantity of fuel injected
   per cylinder per cycle in c.c
I=((pic/360)*(1/N)*60)//Injection period in sec
df=(g/1000)//Density of fuel in kg/m^3
v=sqrt(2*981*((ip-cp)/df))//Velocity of fuel through
    orifice in m/s
A=(q/(Cd*v*I))//Area of orifice in cm^2
d=sqrt(A/(3.14/4))*10//Diameter in mm

//Output
```

```
printf('The diameter of the single orifice injector is %3.2f mm',d)
```

Scilab code Exa 15.10 AMOUNT OF FUEL

```
clc
clear
//Input data
n=6//Number of cylinders
d=11.5//Bore in cm
l=14//Stroke in cm
af=16//Air fuel ratio
pa=1.03//Pressure of air intake in kg/cm^2
Ta=24+273//Temperature of air intake in K
nv=76.5//Volumetric efficiency in percent
R=29.27//Characteristic gas constant in kg.m/kg.K
N=1500//Speed in r.p.m
ip=125//Injection pressure in kg/cm^2
cp=40//Compression pressure in kg/cm^2
q=18.5//Fuel injection occupies 18.5 degrees of crenk travel
fsw=760//Fuel specific weight in kg/m^2
dc=0.94//Orifice discharge coefficient

//Calculations
Vs=((3.14/4)*d^2*l)//Stroke volume in c.c
Va=(Vs*(nv/100))//Volume of air supplied in c.c
wa=((pa*10^4*Va*10^-6)/(R*Ta))//Weight of air supplied per cylinder per cycle in kg
wf=(wa/af)//Weight of fuel injected per cylinder per cycle in kg
I=((60*q)/(N*360))//Injection time per cycle in sec
F=(wf/I)//Fuel injected per cylinder per sec in kg/sec
Af=(F/(dc*sqrt(2*9.81*fsw*(ip-cp)*10^4)))//Area of
```

```
orifice in sq.m
df=sqrt(Af/(3.14/4))*1000//Diameter of orifice in mm

//Output
printf('Maximum amount of fuel injected per cylinder per sec is %3.2f kg/sec \n Diameter of orifice is %3.3f mm',F,df)
```

Chapter 16

COMBUSTION IN COMPRESSION IGNITION ENGINES

Scilab code Exa 16.1 DELAY TIME

```
clc
clear
//Input data
s=0.005//Delay in sec
d=30//Bore in cm
N=600//Speed in r.p.m
dx=[10,15,20]//Bore diameters in cm

//Calculations
t=(s/d)*dx//Time of delay in sec. In textbook, t(2)
    is given wrong as 0.00025 sec instead of 0.0025
    sec

//Output
printf('The delay time for %i cm diameter bore is %3
    .5f sec \n The delay time for %i cm diameter bore
     is %3.5f sec \n The delay time for %i cm
```

```
diameter bore is %3.5f sec',dx(1),t(1),dx(2),t(2)
,dx(3),t(3))
```

Scilab code Exa 16.2 PRESSURE

```
clc
clear
//Input data
d=[15,60]//Bore in cm
N=[1600,400]//Speed in r.p.m respectively
q=30//Injection of oil occupies 30 degrees of crank travel in each case
pc=30//Compression pressure in kg/cm^2
d=0.001//Delay time in sec
rp=5//Rapid combustion period is 5 degree of crank travel
pe=60//Compression pressure at the end of rapid compression in kg/cm^2

//Calculations
//For small engine
It1=(60/N(1))*(q/360)//Injection time in sec
pf1=((d/It1)+(rp/pc))*100//Percent fuel
//For large engine
It2=(60/N(2))*(q/360)//Injection time in sec
pf2=((d/It2)+(rp/pc))*100//Percent fuel
pr=(pc*(pf2/pf1))//Pressure rise in kg/cm^2
mp=(pc+pr)//Maximum pressure in kg/cm^2

//Output
printf('Pressure in the large engine is %3.1f kg/cm^2',mp)
```

Scilab code Exa 16.3 BRAKE THERMAL EFFICIENCY

```
clc
clear
//Input data
n=4//Number of cylinders
d=105//Bore in mm
l=127//Stroke in mm
BHP=63//Brake horse power in h.p
N=1800//Speed in r.p.m
t=15//Test time in min
mf=2.75//Mass of fuel in kg
CV=11000//Calorific value in kcal/kg
af=14.8//Air fuel ratio
v=0.805//Specific volume in m^3/kg
nv=80//Volumetric efficiency in percent
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
bth=((BHP*4500)/(J*(mf/t)*CV))*100//Brake thermal
    efficiency in percent
Vs=((3.14/4)*(d/10)^2*(l/10))//Stroke volume in c.c
Vsw=(Vs*n*(N/2)*t)//Swept volume in c.c
Va=(Vsw*10^-6*(nv/100))//Volume of air sucked in m^3
wa=(Va/v)//Weight of air sucked in kg
wr=(af*mf)//Weight of air reqired in kg
pei=(wr/wa)*100//Percentage of air available for
    combustion

//Output
printf('Brake thermal efficiency is %3.1f percent \n
    The percentage of air used for combustion is %i
    percent',bth,pei)
```

Chapter 18

SUPERCHARGING

Scilab code Exa 18.1 PRESSURE AND AIR CONSUMPTION

```
clc
clear
//Input data
n=6//Number of cylinders
d=9//Bore in cm
l=10//Stroke in cm
N=2500//Speed in r.p.m
Ta=25+273//Temperature of air entering the
   compressor in K
q=16800//Heat rate in kcal/hour
T=60+273//Temperature of air leaving the cooler in K
p=1.6//Pressure of air leaving the cooler in kg/cm^2
t=14.5//Engine torque in kg.m
nv=75//Volumetric efficiency in percent
nm=74//Mechanical efficiency in percent
R=29.27//Characteristic gas constant in kg.m/kg.K
Cp=0.24//Specific heat at constant pressure n kcal/
   kg.K

//Calculations
BHP=(2*3.14*N*t)/4500//Brake horse power in B.H.P
```

```
IHP=(BHP/(nm/100))//Indicated horse power in I.H.P
pm=((IHP*4500)/((l/100)*(3.14/4)*d^2*(N/2)*n))//Mean effective pressure in kg/cm^2
Vs=(n*(3.14/4)*(d/100)^2*(l/100)*(N/2))//Swept volume in m^3/min
Va=(Vs*(nv/100))//Aspirated Volume of air into engine in m^3/min
ma=(p*10^4*Va)/(R*T)//Aspirated mass flow into the engine in kg/min
mcdT=((BHP*4500/427)/Cp)//Product of mass flow rate and change in temperature
msdT=((q/60)/Cp)//Product of mass flow rate and change in temperature
x=(mcdT/msdT)//Ratio
T2=((Ta-(x*T)))/(1-x)//Temperature in K
mc=(msdT/(T2-T))//Air flow in kg/min

//Output
printf('(a) the mean effective pressure is %3.2f kg/cm^2 \n (b) the air consumption is %3.3f kg/min \n (c) the air flow into the compressor is %3.2f kg/min',pm,ma,mc)
```

Scilab code Exa 18.2 PERCENTAGE INCREASE IN IMEP

```
clc
clear
//Input data
IMEP=10//Indicated mean effective pressure in kg/cm^2
x=20//Mixture strength 20% richer tan chemically correct
pIMEP=0.41//Pumping Indicated mean effective pressure in kg/cm^2
p1=0.97//Charge pressure at the beginning of
```

```
compression in kg/cm^2
T1=100+273//Charge temperature at the beginning of compression in K
pm=0.91//Mean pressure during the conduction stroke in kg/cm^2
bn=70//Blower adiabatic efficiency in percent
T2=50//Temperature of the charge after delivery by the blower in degree C
dp=0.07//Pressure drop in kg/cm^2
pi=1.47//Charge pressure in the cylinder during the induction stroke in kg/cm^2
Ta=15+273//Atomspheric temperature in K
pa=1.03//Atmospheric pressure in kg/cm^2
g=1.4//Ratio of specific heats

//Calculations
T2x=((((pi/pa)^((g-1)/g)-1)/(bn/100))+1)*Ta+T2//Temperature in K
rIMEP=((pi/pa)*(T1/T2x))//Ratio of I.M.E.P
gIMEP=(rIMEP*IMEP)//Gross I.M.E.P in kg/cm^2
nsIMEP=(gIMEP+(pi-pa))//Net I.M.E.P supercharged in kg/cm^2
nuIMEP=(IMEP-pIMEP)//Net I.M.E.P unsupercharged in kg/cm^2
iIMEP=(nsIMEP-nuIMEP)//Increase in I.M.E.P in kg/cm^2
pei=(iIMEP*100)/nuIMEP//Percentage increase

//Output
printf('Percentage increase in the net I.M.E.P due to supercharging is %3.1f percent',pei)
```

Scilab code Exa 18.3 PERCENTAGE INCREASE IN BHP

```
clc
```

```
clear
//Input data
l=4.5//Capacity in litres
P=20//Power in H.P per m^3 of free air induced per minute
N=1700//Speed in r.p.m
nv=75//Volumetric efficiency in percent
Ta=27+273//Atomspheric temperature in K
pa=1.03//Atmospheric pressure in kg/cm^2
pr=1.75//Pressure ratio
ie=70//Isentropic efficiency in percent
nm=75//Mechanical efficiency in percent
g=1.4//Ratio of specific heats
nb=80//Efficiency of blower in percent
R=29.27//Characteristic gas constant in kg.m/kg.K
Cp=0.24//Specific heat at constant pressure in kJ/kg.K
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
Vs=(l/1000*(N/2))//Swept volume in m^3/min
uVs=((nm/100)*Vs)//Unsupercharged swept volume in m^3/min
dp=(pr*pa)//Blower delivery pressure in kg/cm^2
Tc=(Ta*pr^((g-1)/g))//Temperature after isentropic compression in K
dT=(Ta+(Tc-Ta)/(ie/100))//Blow delivery temperature in K
Va=(Vs*(dp*Ta)/(pa*dT))//Equivalent volume at free air condition in m^3/min
iiv=(Va-uVs)//Increase in the induced volume in m^3/min
iIHP=(P*iiv)//ncrease in I.H.P
iBHP=(iIHP*(nm/100))//Increase in B.H.P
ma=(dp*10^4*Vs)/(R*dT)//Mass of air delivered by blower in kg/min
HP=(ma*Cp*(dT-Ta)*J)/(4500*(80/100))//H.P required for blower
```

```
nibhp=(iBHP-HP)//Net increse in engine b.h.p
pei=(nibhp/(P*uVs))*100//Percentage increase

//Output
printf('Percentage net increase in B.H.P is %3.1f
   percent',pei)
```

Chapter 19

TWO STROKE ENGINES

Scilab code Exa 19.3 PROPERTIES

```
clc
clear
//Input data
d=11.25//Bore in cm
l=15//Stroke in cm
r=7//Compression ratio
N=1800//Speed in r.p.m
a=4.5//Air supply in kg/min
Ta=72+273//Temperature of air in K
af=14.3//Air fuel ratio
ep=1//Exhaust pressure in kg/cm^2
R=29.27//Characteristic gas constant in kg.m/kg.degree C

//Calculations
Vc=((r/(r-1))*(3.14/4)*(d/100)^2*(l/100))//Swept volume in m^3
Wa=(Vc*N*ep*10^4)/(R*Ta)//Ideal air capacity in kg/min
sr=(a/Wa)//Scavenging ratio
sn=(1-exp(-sr))//Scavenging efficiency
```

```
nt=(sn/sr)//Trapping efficiency

//Output
printf('(a) Ideal air capacity is %3.2f kg/min \n (b
    ) Scavenging ratio is %3.2f \n (c) Scavenging
    efficiency is %3.3f \n (d) Trapping efficiency is
     %3.2f',Wa,sr,sn,nt)
```

Chapter 23

TESTING OF ENGINES

Scilab code Exa 23.1 THERMAL EFFICIENCY

```
clc
clear
//Input data
n=4//Four cylinder engine
N=1200//Speed in r.p.m
BHP1=26.3//Brake horse power in B.H.P
T=11.3//Average torque in kg
CV=10000//Calorific value of the fuel in kcal/kg
m=270//Flow rate in gm of petrol per B.H.P hour

//Calculations
BHP2=(T*2*3.14*N)/4500//Average B.H.P on 3 cylinders
IHP=BHP1-BHP2//Average I.H.P of one cylinder
TIHP=(n*IHP)//Total I.H.P
p=((m/1000)*BHP1)/TIHP//Petrol used in kg/I.H.P hr
nth=((4500*60)/(427*p*CV))*100//Indicated Thermal
   efficiency in percent

//Output
printf('Thermal efficiency is %3.1f percent',nth)
```

Scilab code Exa 23.2 INDICATED HORSE POWER

```
clc
clear
n=4//Four cylinder engine
d=0.1//Diameter of piston in m
l=0.15//Stroke in m
RPM=1600//Speed in r.p.m
ap=(5.76*10^-4)//Area of positive loop of indicator
    diagram in sq.m
an=(0.26*10^-4)//Area of negative loop of indicator
    diagram in sq.m
L=0.055//Length of the indicator diagram in m
k=(3.5/10^-6)//Spring constant in kg/m^2 per m

//Calculations
NA=(ap-an)//Net area of the indicator diagram in sq.
   m
h=(NA/L)//Average height of diagram in m
Pm=(h*k)//Mean effective pressure in kg/m^2
IHP=(Pm*l*(3.14/4)*d^2*RPM*n)/4500//Indicated Horse
    Power

//Output
printf('Indicated horse power of a four cylinder two
     stroke petrol engine is %3.1f',IHP)
```

Scilab code Exa 23.3 CALORIFIC VALUE

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

```
n=6//Number of cylinders
d=0.089//Bore in m
l=0.1016//Stroke in m
vc=3.183//Compression ratio
rn=55//Relative efficiency in percent
m=0.218//Petrol consumption in kg/hp.hr
Pm=(8.4/10^-4)//Indicated mean effective pressure in
    kg/m^2
N=2500//Speed in r.p.m

//Calculations
an=(1-(1/(vc-1)))*100//Air standard efficiency in
   percent
nth=(rn*an)/100//Thermal efficiency in percent
CV=((4500*60)/(m*(nth/100)*427))//Calorific value in
    kcal/kg
IHP=((Pm*(3.14/4)*d^2*l*N*n)/(4500*2))//Indicated
   horse power
p=(m*IHP)//Petrol consumption in kg/hour

//Output
printf('(1) The calorific value of petrol is %i kcal
   /kg \n (2) Corresponding petrol consumption is %3
   .1f kg/hour',CV,p)
```

Scilab code Exa 23.4 BHP OF ENGINE

```
clc
clear
//Input data
n=4//Number of cylinders
d=0.2//Bore in m
l=0.3//Stroke in m
N=300//Speed in r.p.m
af=5//Air to fuel ratio by volume. In textbook it is
```

```
    given as 4 which is wrong
nv=78//Volumetric efficiency in percent
CV=2200//Calorific value in kcal/cu.m at N.T.P
bth=23//Brake thermal efficiency in percent

//Calculations
Vs=((3.14/4)*d^2*l)//Swept volume in cu.m
c=((nv/100)*Vs)//Total charge per stroke in cu.m
Vg=((c/af)*N)//Volume of gas used per min in cu.m at
    N.T.P
q=(CV*Vg)//Heat supplied in kcal/min
BHP=((bth/100)*q)/(4500/427)//Brake horse power

//Output
printf('The volume of gas used per min is %3.3f cu.m
    at N.T.P \n B.H.P of engine is %3.1f',Vg,BHP)
```

Scilab code Exa 23.5 THERMAL EFFICIENCY

```
clc
clear
//Input data
d=20//Bore in cm
l=37.5//Stroke in cm
r=6//Compression ratio
IPm=5//Indicated Mean effective pressure in kg/cm^2
ag=6//Air to gas ratio
CV=3070//Calorific value of gas in kcal/cu.m
T=75+273//Temperature in K
p=0.975//Pressure in kg/cm^2
RPM=240//Speed in r.p.m
g=1.4//Ratio of specific heats

//Calculations
Vs=(3.14/4)*d^2*l//Stroke Volume in cu.m
```

```
Vg=(1/(r+1))*Vs//Volume of gas in cylinder in cu.m
    per cycle
x=(Vg*(p/1.03)*(273/T))//Volume at 'Vg' cu.m at 'p'
    kg/cm^2 and 'T' K are equivalent in cu.m
q=(CV*x)/10^6//Heat added in kcal per cycle
IHP=(IPm*(Vs/100)*(RPM/2))/4500//Indicated horse
    power
nth=((IHP*4500)/(427*q*(RPM/2)))*100//Thermal
    efficiency in percent
na=(1-(1/r^(g-1)))*100//Air standard efficiency in
    percent
rn=(nth/na)*100//Relative effeciency in percent

//Output
printf('The thermal efficiency is %3.1f percent \n
    The relative efficiency is %3.1f percent \n
    Indicated horese power is %3.1f H.P',nth,rn,IHP)
```

Scilab code Exa 23.6 FUEL CONSUMPTION

```
clc
clear
//Input data
n=4//Number of cylinders
d=6.25//Diametre in cm
l=9.5//Stroke in cm
t=678//Torque in kg.m
N=3000//Speed in r.p.m
Vc=60//Clearance volume in c.c
be=0.5//Brake efficiency ratio based on the air
    standard cycle
CV=10000//Calorific value in kcal/kg
g=1.4//Ratio of specific heats

//Calculations
```

```
Vs=(3.14/4)*d^2*l//Stroke volume in c.c per cylinder
r=((Vs+Vc)/Vc)//Compression ratio
na=(1-(1/r^(g-1)))//Air standard efficiency
bth=(be*na)*100//Brake thermal efficiency in percent
bhp=((t/100)*2*3.14*N)/4500//B.H.P in H.P
q=(bhp*(4500/427))/(bth/100)//Heat supplied in kcal/min
F=(q*60)/CV//Fuel consumption in kg/hour
P=(bhp*4500*2*100)/(n*Vs*N)//pressure in kg/cm^2

//Output
printf('The fuel consumption is %3.2f kg/hour \n The brake mean effective pressure is %3.2f kg/cm^2',F,P)
```

Scilab code Exa 23.7 PROPERTIES

```
clc
clear
//Input data
n=1//Number of cylinders
t=30//Trail time in min
m=5.6//Oil consumption in l
CV=9980//Calorific value of oil in kcal/kg
g=0.8//Specific gravity of oil
a=8.35//Average area of indicator diagram in sq.cm
l=8.4//Length of the indicator diagram in cm
is=5.5//Indicator spring scale
L=147.5//Brake load in kg
sp=20//Spring balance reading in kg
d=1.5//Effective brake wheel diameter in m
N=200//Speed in r.p.m
cyd=30//Cylinder diameter in cm
l1=45//Stroke in cm
mw=11//Jacket cooling water in kg/min
```

```
Tc=35+273//Temperature rise of cooling water in K

//Calculations
mp=(a/l)*is//Mean effective pressure
ihp=((mp*(l1/100)*(3.14/4)*cyd^2*(N/2))/4500)//
    Indicated horse power in h.p
bhp=(L*3.14*d*N)/4500//Brake horse power in h.p
nm=(bhp/ihp)*100//Mechanical efficiency in percent
F=(m*(60/t)*g)//Fuel consumption in kg/hour
Fc=(F/bhp)//Specific fuel consumption in kg/B.H.P/
    hour
ith=((ihp*(4500/427))/((F/60)*CV))*100//Indicated
    thermal efficiency in percent

//Output
printf('(a) I.H.P is %3.1f \n (b) B.H.P is %3.1f \n
    (c) Mechanical efficiency is %3.1f percent \n (d)
     Specific fuel consumption is %3.2f kg/B.H.P/hour
     \n (e) Indicated thermal efficiency is %3.1f
    percent',ihp,bhp,nm,Fc,ith)
```

Scilab code Exa 23.8 HEAT BALANCE SHEET

```
clc
clear
//Input data
d=15//Diameter in cm. In textbook it is given wrong
    as 39
l=45//Stroke in cm
f=9.5//Total fuel used in litres
CV=10500//Calorific value in kcal/kg
n=12624//Total no. of revolutions
imep=7.24//Gross i.m.e.p in kg/cm^2
pimep=0.34//Pumping i.m.e.p in kg/cm^2
L=150//Net load on brake in kg
```

```
db=1.78//Diameter of the brake wheel drum in m
dr=4//Diameter of rope in cm
cw=545//Cooling water circulated in litres
Tc=45//Cooling water temperature rise in degree C
g=0.8//Specific gravity of oil

//Calculations
ihp=((imep-pimep)*(l/100)*3.14*d^2*n)/(4500*60)//I.H
    .P in h.p
q=(f*g*CV)/60//Heat supplied in kcal/min
bhp=(L*3.14*(db+(dr/100))*n)/(4500*60)//B.H.P in h.p
qbhp=(bhp*4500)/427//Heat equivalent of B.H.P in
    kcal/min
qw=(cw*Tc)/60//Heat lost to jacket cooling water in
    kcal/min
dq=(q-(qbhp+qw))//Heat unaccounted in kcal/min

//Output
printf('Heat supplied is %3.0f kcal/min \n Heat
    equivalent of B.H.P is %3.0f kcal/min \n Heat
    lost to jacket cooling water is %3.0f kcal/min \n
     Heat unaccounted is %3.0f kcal/min',q,qbhp,qw,dq
    )
```

Scilab code Exa 23.9 HEAT BALANCE SHEET

```
clc
clear
//Input data
d=27//Diameter in cm
l=45//Stroke in cm
db=1.62//Effective diameter of the brake in m
t=(38*60+30)//Test duration in sec
CV=4650//Calorific value in kcal/m^3 at N.T.P
n=8080//Total no. of revolutions
```

```
en=3230//Total number of explosions
p=5.75//Mean effective pressure in kg/cm^2
V=7.7//Gas used in m^3
T=15+273//Atmospheric temperature in K
pg=135//pressure of gas in mm of water above
    atmospheric pressure
hb=750//Height of barometer in mm of Hg
L=92//Net load on brake in kg
w=183//Weigh of jacket cooling water in kg
Tc=47//Cooling water temperature rise in degree C

//Calculations
ihp=(p*(l/100)*(3.14/4)*d^2*en)/(4500*(t/60))//I.H.P
     in h.p
bhp=(L*3.14*db*n)/(4500*(t/60))//B.H.P in h.p
pa=(hb+(pg/13))//Pressure of gas supplied in mm of
    Hg
Vg=(V*(273/T)*(pa/760))//Volume of gas used at N.T.P
     in m^3
q=(Vg*CV)/(t/60)//Heat supplied per minute in kcal
qbhp=(bhp*4500)/427//Heat equivalent of B.H.P in
    kcal/min
qc=(w/(t/60))*Tc//Heat lost to jacket cooling water
    in kcal/min
qra=(q-(qbhp+qc))//Heat lost to exhaust, etc in kcal
    /min

//Output
printf('Heat supplied is %3.1f kcal/min \n Heat
    equivalent of B.H.P is %3.0f kcal/min \n Heat
    lost to jacket cooling water is %3.1f kcal/min \n
     Heat lost to exhaust radiation etc. is %3.1f
    kcal/min',q,qbhp,qc,qra)
```

Scilab code Exa 23.10 VOLUMETRIC EFFICIENCY

```
clc
clear
//Input data
d=25//Bore in cm
l=50//Stroke in cm
N=240//Speed in r.p.m
n=100//Number of times fires per minute
qc=0.3//Quantity of coal gas used in cu.m per minute
h=100//Head in mm of water
bp=1.03//Barometric pressure in kg/cm^2
T=15+273//Temperature in K
ma=2.82//Mass of air used in kg per minute
R=29.45//Characteristic gas constant in kg.m/kg.K

//Calculations
gp=(bp+(100/13.6)*(bp/76))//Gas pressure in kg/cm^2
Vc=(qc*(gp/bp)*(273/T))//Volume of coal gas at N.T.P
    in cu.m per minute
Vce=(Vc/n)//Volume of coal gas per explosion in cu.m
    at N.T.P
va=(ma*R*273)/(bp*10^4)//Volume of air taken in at N
   .T.P in cu.m per min
V=((va-(((N/2)-n)*Vce))/(N/2))//Volume in cu.m
tV=(V+Vce)//Total volume of charge in cu.m at N.T.P
Vs=((3.14/4)*(d^2*l)*10^-6)//Swept volume in cu.m
nv=(tV/Vs)*100//Volumetric efficiency in percent

//Output
printf('(a) the charge of air per working cycle as
   measured at N.T.P is %3.5f cu.m \n (b) the
   volumetric efficiency is %3.1f percent',tV,nv)
```

Scilab code Exa 23.11 HEAT BALANCE SHEET

```
clc
```

```
clear
//Input data
d=18//Diameter in cm
l=24//Stroke in cm
t=30//Duration of trail in min
r=9000//Total number of revolutins
e=4445//Total number of explosions
mep=5.85//Mean effective pressure in kg/cm^2
Nl=40//Net load on brake wheel in kg
ed=1//Effective diameter of brake wheel in meter
tg=2.3//Total gas used at N.T.P in m^3
CV=4600//Calorific value of gas in kcal/m^3 at N.T.P
ta=36//Total air used in m^3
pa=720//Pressure of air in mm of Hg
Ta=18+273//Temperature of air in K
da=1.293//Density of air at N.T.P in kg/m^3
Te=350+273//Temperature of exhaust gases in K
Tr=18+273//Room temperature in K
Cp=0.24//Specific heat of exhaust gases in kJ/kg.K
twc=81.5//Total weight of cylinder jacket cooling water in kg
dT=33//Rise in temperature of jacket cooling water in degree C
R=29.45//Characteristic gas constant in kg.m/kg.degree C

//Calculations
ihp=(mep*(l/100)*(3.14/4)*d^2*(e/t))/4500//Indicated horse power in h.p
bhp=(Nl*3.14*r*ed)/(4500*t)//Brake horse power in h.p
qs=(tg/t)*CV//Heat supplied at N.T.P in kcal
qbhp=(bhp*4500)/427//Heat equivalent of B.H.P in kcal/min
ql=(twc/t)*dT//Heat lost to cylinder jacket cooling water in kcal/min
VA=(ta*(273/Ta)*(pa/760))//Volume of air used at N.T.P in m^3
```

```
WA=(VA*da)/t//Weight of air used per min in kg
WG=(1.03*tg*10^4)/(R*273)//Weight of gas in kg
Wg=(WG/t)//Weight of gas per minute in kg
We=(WA+Wg)//Total weight of exhaust gases in kg
qle=(We*(Te-Tr)*Cp)//Heat lost of exhaust gases in
    kcal/min
qra=(qs-(qbhp+ql+qle))//Heat lost by radiation in
    kcal/min
nm=(bhp/ihp)*100//Mechanical efficiency in percent
ith=((ihp*4500)/(427*qs))*100//Indicated thermal
    efficiency in percent

//Output
printf('           HEAT BALANCE SHEET\n
   ——————————————— \n\n Heat supplied per minute
    is %3.1f kcal/min \n\n Heat expenditure
                (kcal per minute) \n 1.Heat
    equivalent of B.H.P is          %3.1f \n 2.Heat
    lost to jacket cooling water is %3.1f \n 3.Heat
    lost in exhaust gases is        %3.1f \n 4.Heat
    lost by radiation, etc., is     %3.1f \n
                                               ————————\n
                                                %3.1f\n
                                               ————————',qs
    ,qbhp,ql,qle,qra,qs)
```

Scilab code Exa 23.12 HEAT BALANCE SHEET

```
clc
clear
//Input data
gu=0.135//Gas used in m^3/min at N.T.P
CV=3990//Calorific value of gas in kcal/m^3 at N.T.P
dg=0.64//Density of gas in kg/m^3 at N.T.P
au=1.52//Air used in kg/min
```

```
C=0.24//Specific heat of exhaust gases in kJ/kg.K
Te=397+273//Temperature of exhaust gases in K
Tr=17+273//Room temperature in K
cw=6//Cooling water per minute in kg
rT=27.5//Rise in temperature in degree C
ihp=12.3//Indicated horse power in h.p
bhp=10.2//Brake horse power in h.p

//Calculations
qs=(gu*CV*60)//Heat supplied in kcal/hour
qbhp=((bhp*4500*60)/427)//Heat equivalent of B.H.P
    in kcal/hr
ql=(cw*60*rT)//Heat lost in jacket cooling water in
    kcal/hr
mg=(gu*dg)//Mass of gas used per minute in kg
me=(mg+au)//Mass of exhaust gases per minute in kg
qe=(me*C*(Te-Tr)*60)//Heat carried away by exhaust
    gases in kcal/hour
qun=(qs-(qbhp+ql+qe))//Heat unaccounted in kcal/hour

//Output
printf('Heat supplied is %3.0f kcal/hour \n Heat
    equivalent of B.H.P is %3.0f kcal/hr \n Heat lost
     in jacket cooling water is %3.0f kcal/hr \n Heat
     carried away by exhaust gases is %3.0f kcal/hour
     \n Heat unaccounted is %3.0f kcal/hour',qs,qbhp,
    ql,qe,qun)
```

Scilab code Exa 23.13 BRAKE MEAN EFFECTIVE PRESSURE

```
clc
clear
//Input data
n=4//Number of cylinders
r=1//Radius in metre
```

```
N=1400//Speed in r.p.m
bl=14.5//Net brake load in kg
P=[9.8,10.1,10.3,10]//Loads on the brake in kg
d=9//Bore in cm
l=12//Stroke in cm

//Calculations
bhp=(bl*2*3.14*r*N)/4500//Brake horse power in h.p
bhp1=(P(1)*2*3.14*r*N)/4500//Brake horse power in h.
    p
bhp2=(P(2)*2*3.14*r*N)/4500//Brake horse power in h.
    p
bhp3=(P(3)*2*3.14*r*N)/4500//Brake horse power in h.
    p
bhp4=(P(4)*2*3.14*r*N)/4500//Brake horse power in h.
    p
ihp1=bhp-bhp1//Indicated horse power in h.p
ihp2=bhp-bhp2//Indicated horse power in h.p
ihp3=bhp-bhp3//Indicated horse power in h.p
ihp4=bhp-bhp4//Indicated horse power in h.p
ihp=(ihp1+ihp2+ihp3+ihp4)//Indicated horse power in
    h.p
nm=(bhp/ihp)*100//Mechanical efficiency in percent
pm=((4500*bhp)/((l/100)*(3.14/4)*d^2*(N/2)))//Brake
    mean effective pressure in kg/cm^2

//Output
printf('I.H.P is %3.1f h.p \n Mechanical efficiency
    is %3.1f percent \n Brake mean effective pressure
     is %3.0f kg/cm^2',ihp,nm,pm)
```

Scilab code Exa 23.14 HEAT BALANCE SHEET

```
clc
clear
```

```
//Input data
N=350//Speed in r.p.m
L=60//Net brake load in kg
mep=2.75//Mean effective pressure in kg/cm^2
oc=4.25//Oil consumption in kg/hour
jcw=490//Jacket cooling water in kg/hour
Tw=[20+273,45+273]//Temperature of jacket water at inlet and outlet in K
au=31.5//Air used per kg of oil in kg
Ta=20+273//Temperature of air in the test room in K
Te=390+273//Temperature of exhaust gases in K
d=22//Cylinder diameter in cm
l=28//Stroke in cm
bd=1//Effective brake diameter in m
CV=10500//Calorific value of oil in kcal/kg
pH2=15//Proportion of hydrogen in fuel oil in percent
C=0.24//Mean specific heat of dry exhaust gases
Cs=9.5//Specific heat of steam in kJ/kg.K

//Calculations
ibp=(mep*(l/100)*(3.14/4)*d^2*N)/4500//Indicated brake power in h.p
bhp=(L*3.14*N*bd)/4500//Brake horse power in h.p
qs=(oc*CV)/60//Heat supplied per minute in kcal
qbhp=(bhp*4500)/427//Heat equivalent of B.H.P in kcal/min
pqbhp=(qbhp/qs)*100//Percenatge of  heat
ql=(jcw/60)*(Tw(2)-Tw(1))//Heat lost to cooling water in kcal/min
pql=(ql/qs)*100//Percenatge of  heat
wH2O=(9*(pH2/100)*(oc/60))//Weight of H2O produced per kg of fuel burnt in kg/min
twe=(oc*(au+1))/60//Total weight of wet exhaust gases per minute in kg
twd=(twe-wH2O)//Weight of dry exhaust gases per minute in kg
qle=(twd*C*(Te-Ta))//Heat lost to dry exhaust gases/
```

```
   min in kcal
pqle=(qle/qs)*100//Percenatge of  heat
qx=(100+538.9+0.5*(Te-373))//Heat in kcal/kg
qst=(wH2O*qx)//Heat to steam in kcal/min
pqst=(qst/qs)*100//Percenatge of  heat
qra=(qs-(qbhp+ql+qle+qst))//Heat lost by radiation
   in kcal/min
pqra=(qra/qs)*100//Percenatge of  heat

//Output
printf('            HEAT BALANCE SHEET\n
   ——————————————— \n\n Heat supplied per minute
   is         %3.0f kcal/min  100 percent \n\n Heat
   expenditure                  (kcal per minute)       (
   percent) \n 1.Heat equivalent of B.H.P is
                %3.1f       %3.1f \n 2.Heat lost to
   cooling water is               %3.0f         %3.1f \n
    3.Heat lost to dry exhaust gases is         %3.1f
         %3.1f\n 4.Heat lost of steam in exhaust
   gases is  %3.0f           %3.1f\n 5.Heat lost by
   radiation, etc., is             %3.0f         %3.1f \n

   ———————————————\n          Total
                                   %3.0f          %3.0f
   \n
   ———————————————',qs,qbhp,pqbhp,ql,pql,qle,pqle
   ,qst,pqst,qra,pqra,qs,(pqbhp+pql+pqle+pqst+pqra))
```

Scilab code Exa 23.15 HEAT BALANCE SHEET

```
clc
clear
//Input data
d=20//Diameter in cm
l=40//Stroke in cm
```

```
mep=5.95//Mean effective pressure in kg/cm^2
bt=41.5//Brake torque in kg.m
N=250//Speed in r.p.m
oc=4.2//Oil consumption in kg per hour
CV=11300//Calorific value of fuel in kcal/kg
jcw=4.5//Jacket cooling water in kg/min
rT=45//Rise in temperature in degree C
au=31//Air used in kg
Te=420//Temperature of exhaust gases in degree C
Tr=20//Room temperature in degree C
Cm=0.24//Mean specific heat of exhaust gases in kJ/kg.K

//Calculations
ihp=(mep*(l/100)*(3.14/4)*d^2*(N/2))/4500//Indicated horse power in h.p
bhp=(bt*2*3.14*N)/4500//Brake horse power in h.p
q=(oc*CV)//Heat supplied in kcal/hour
qbhp=(bhp*4500*60)/427//Heat equivalent of B.H.P in kcal/hour
qfhp=((ihp-bhp)*4500*60)/427//Heat equivalent F.H.P in kcal/hour
qc=(jcw*rT*60)//Heat lost in cooling water in kcal/hour
qe=(oc*32*Cm*(Te-Tr))//Heat lost in exhaust gases in kcal/hour
hu=(q-(qbhp+qfhp+qc+qe))//Heat unaccounted in kcal/hour

//Output
printf('Indicated horse power is %3.1f h.p \n Brake horse power is %3.2f h.p \n Heat supplied is %3.0f kcal/hour \n Heat equivalent of B.H.P is %3.0f kcal/hour \n Heat equivalent of F.H.P is %3.0f kcal/hour \n Heat lost in cooling water is %3.0f kcal/hour \n Heat lost in exhaust gases is %3.0f kcal/hour \n Heat unaccounted is %3.0f kcal/hour',ihp,bhp,q,qbhp,qfhp,qc,qe,hu)
```

Scilab code Exa 23.16 HEAT BALANCE SHEET

```
clc
clear
//Input data
ihp=45//Indicated horse power in h.p
bhp=37//Brake horse power in h.p
fu=8.4//Fuel used in kg/hour
CV=10000//Calorific value in kcal/kg
Tc=[15,70]//Inlet and outlet temperatures of cylinders in degree C
cj=7//Rate of flow of cylinder jacket in kg/min
Tw=[15,55]//Inlet and outlet temperatures of water in degree C
rw=12.5//Rate of water flow in kg per minute
Te=82//Final temperature of exhaust gases in degree C
Tr=17//Room temperature in degree C
af=20//Air fuel ratio
Cm=0.24//Mean specific heat of exhaust gases in kJ/kg.K

//Calculations
q=(fu/60)*CV//Heat supplied in kcal/min
qbhp=(bhp*4500)/427//Heat equivalent of B.H.P in kcal/min
ql=(cj*(Tc(2)-Tc(1)))//Heat lost to cylinder jacket cooling water in kcal/min
qe=(rw*(Tw(2)-Tw(1)))//Heat lost by exhaust gases in kcal/min
qee=(Te-Tr)*Cm*(af+1)*fu/60//Heat of exhaust gas in kcal/min
te=(qe+qee)//Total heat lost to exhaust gases in kcal/min
```

```
hra=(q-(qbhp+ql+te))//Heat lost to radiation in kcal/min
ith=((ihp*4500)/(427*q))*100//Indicated thermal efficiency in percent
bth=((bhp*4500)/(427*q))*100//Brake thermal efficiency in percent
nm=(bhp/ihp)*100//Mechanical efficiency in percent

//Output
printf('Heat supplied is %3.0f kcal/min \n Heat equivalent of B.H.P is %3.0f kcal/min \n Heat lost to cylinder jacket cooling water is %3.0f kcal/min \n Total heat lost to exhaust gases is %3.1f kcal/min \n Heat lost to radiation is %3.1f kcal/min \n Indicated thermal efficiency is %3.1f percent \n Brake thermal efficiency is %3.1f percent \n Mechanical efficiency is %3.1f percent ',q,qbhp,ql,te,hra,ith,bth,nm)
```

Scilab code Exa 23.17 HEAT LOST

```
clc
clear
//Input data
Vs=0.0015//Stroke volume in cu.m
rc=5.5//Volume compression ratio
p2=8//Pressure at the end of compression stroke in kg/cm^2
T2=350+273//Temperature at the end of compression stroke in K
p3=25//Pressure in kg/cm^2
x=(1/30)//Fraction of distance travelled by piston
pa=1/16//Petrol air mixture ratio
R=29.45//Characteristic gas constant in kg.m/kg degree C
```

```
CV=10000//Calorific value of fuel in kcal per kg
Cv=0.23//Specific heat in kJ/kg.K

//Calculations
V2=(Vs*10^6)/(rc-1)//Volume in c.c
V3=(Vs*10^6)*x+V2//Volume in c.c
T3=(T2*p3*V3)/(p2*V2)//Temperature in K
W=((p3+p2)/2)*(V3-V2)//Workdone in kg.cm
mM=((p2*V2)/(T2*R*100))//Mass of mixture present in
    kg
dE=(mM*Cv*(T3-T2))//Change in energy in kcal
q=(dE+(W/(427*100)))//Heat in kcal
qc=(1/(1+(1/pa)))*mM*CV //Heat in kcal
ql=(qc-q)/mM//Heat lost in kcal per kg of charge

//Output
printf('Heat lost per kg of charge during explosion
    is %3.0f kcal',ql)
```

Chapter 25

GAS TURBINES

Scilab code Exa 25.2 OVERALL EFFICIENCY

```
clc
clear
//Input data
p=4//Pressure ratio
T3=1000//Turbine inlet temperature in K
T1=15+273//Inlet temperature in K
p1=1//Inlet pressure in kg/cm^2
m=11//Mass flow rate of air in kg/s
Cp=0.24//Specific heat at constant pressure in kJ/kg.K
R=29.27//haracteristic gas constant in kg.m/kg.K
g=1.4//Ratio of specific heats

//Calculations
Pc=(m*R*T1*(p^((g-1)/g)-1))/75//Power consumed by the compressor in H.P
Pt=(m*R*T3*(1-(1/p)^((g-1)/g)))/75//Power consumed by the turbine in H.P
N=(Pt-Pc)//Net output of the plant in H.P. In textbook answer is given wrong
T2=(T1*(p)^((g-1)/g))//Temperature at the end of
```

```
    compression in K
q=(Cp*(T3-T2))//Heat supplied in kcal/kg of air
n=(((N*4500)/427)/(q*m*60))*100//Overall efficiency
    of the plant in percent

//Output
printf('Horse power developed is %3.0f H.P \n The
    overall efficiency of the plant is %3.2f percent'
    ,N,n)
```

Scilab code Exa 25.3 EFFICIENCY

```
clc
clear
//Input data
T1=15+273//Temperature of air entering the
    compressor in K
rp=5//Pressure ratio
T3=700+273//Temperature of air after heating in K
g=1.4//Ratio of specific heats
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K

//Calculations
T2=(T1*rp^((g-1)/g))//Temperature of air after
    compression in K
T4=(T3/rp^((g-1)/g))//Temperature of air after
    expansion in K
Wc=(Cp*(T2-T1))//Workdone in the compressor in kcal/
    kg of air
Wt=(Cp*(T3-T4))//Workdone in the turbine in kcal/kg
    of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
SHP=(N*427)/75//Shaft horse power in H.P per kg of
    air/sec
```

```
q=(Cp*(T3-T2))//Heat supplied in kcal/kg of air
n=(N/q)*100//Overall efficiency in percent

//Output
printf('Efficiency of plant is %3.1f percent \n The
    shaft horse-power per kg of air per second is %3
    .0f H.P',n,SHP)
```

Scilab code Exa 25.4 NET OUTPUT

```
clc
clear
//Input data
g=1.4//Ratio of specific heats
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K
m=20.5//Air flow rate in kg/sec
p=[5.85,1.03,1.03,5.85]//Inlet and outlet pressure
    of turbine and compressor respectively in kg/cm^2
T=[20+273,250+273,600+273,360+273]//Inlet and outlet
     temperatures of turbine and compressor
    respectively in degree C. In textbook instead of
    360 degree C, 375 degree C is given

//Calculations
T2=(T(1)*(p(4)/p(3))^((g-1)/g))//Temperature at the
    outlet of compressor in ideal cycle in K
T4=(T(3)/(p(1)/p(2))^((g-1)/g))//Temperature at the
    outlet of turbine in ideal cycle in K
ic=((T2-T(1))/(T(2)-T(1)))*100//Isentropic
    efficiency of compressor in percent
it=((T(3)-T(4))/(T(3)-T4))*100//Isentropic
    efficiency of turbine in percent
Wc=(Cp*(T(2)-T(1)))//Workdone in compressor in kcal/
    kg of air
```

```
Wt=(Cp*(T(3)-T(4)))//Workdone in turbine in kcal/kg
    of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
P=(N*427*m)/75//Power output in H.P

//Output
printf('The net output is %3.0f H.P',P)
```

Scilab code Exa 25.5 TEMPERATURE

```
clc
clear
//Input data
rp=5//Pressure ratio
T1=15+273//Inlet temperature in K
nc=80//Adiabatic efficiency of the compressor in
    percent
n=1.4//Adiabatic index

//Calculations
T2=(T1*rp^((n-1)/n))//Temperature at the outlet of
    compressor in ideal cycle in K. The textbook
    answer is wrong. Instead of 456 K, it is given as
     452K
T2i=(((nc/100)*T1)+T2-T1)/(nc/100)//Temperature at
    the outlet of the compressor in the actual cycle
    in K

//Output
printf('The temperature at the end of compression is
     %3.0f K',T2i)
```

Scilab code Exa 25.6 HP DEVELOPED

```
clc
clear
//Input data
p1=5.62//Pressure of gas entering the turbine in kg/cm^2
T1=1000+273//Temperature of gas entering the turbine in K
p2=1.124//Pressure of gas leaving the turbine in kg/cm^2. In textbook it is given as 1.24 instead of 1.124
n1=0.8//Isotropic efficiency of the turbine in ratio
n=1.36//Adiabatic index
Cp=0.25//Specific heat at constant pressure in kJ/kg.K

//Calculations
T2=(T1/(p1/p2)^((n-1)/n))//Temperature at the end of adiabatic expansion in K
dt=(T1-T2)//Isentropic temperature drop in K
adt=(n1*dt)//Actual temperature drop in K
T2i=(T1-adt)//Temperature at the end of actual expansion in K
W=(Cp*(T1-T2i))//Workdone per kg of gas in kcal
q=(W*427)/4500//H.P developed per kg of gas per minute
t2i=(T2i-273)//Exhaust gas temperature in degree C

//Output
printf('(1) H.P developed per kg of gas per min is %3.2f \n (2) Exhaust gas temperature is %3.1f degree C',q,t2i)
```

Scilab code Exa 25.7 THERMAL EFFICIENCY

```
clc
```

```
clear
//Input data
pt1=[1,15+273]//Pressure and temperature at the
   inlet of compressor in kg/cm^2 and K respectively
pt3=[4,650+273]//Pressure and temperature at the
   inlet of turbine in kg/cm^2 and K respectively
n=[85,80]//Isentropic efficiencies of turbine and
   compressor respectively in percent
g=1.4//Ratio of specific heats
Cp=0.24//Specific heat at constant pressure in kJ/kg
   .K

//Calculations
T2=(pt1(2)*(pt3(1)/pt1(1))^((g-1)/g))//Temperature
   at the end of adiabatic compression in K
T2i=(pt1(2)+((T2-pt1(2))/(n(2)/100)))//Temperature
   at the end of actual compression in K
T4=(pt3(2)/(pt3(1)/pt1(1))^((g-1)/g))//Temperature
   at the end of adiabatic expansion in K
T4i=(pt3(2)-((pt3(2)-T4)*(n(1)/100)))//Temperature
   at the end of actual expansion in K
Wt=(Cp*(pt3(2)-T4i))//Workdone in turbine in kcal/kg
    of air
Wc=(Cp*(T2i-pt1(2)))//Workdone in compressor in kcal
   /kg of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
q=(Cp*(pt3(2)-T2i))//Heat supplied in kcal/kg of air
nt=(N/q)*100//Thermal efficiency in percent

//Output
printf('Thermal efficiency of the cycle is %3.2f
   percent',nt)
```

Scilab code Exa 25.8 FLOW RATE

```
clc
clear
//Input data
p1=1.03//Inlet air pressure in kg/cm^2
T1=15.5+273//Inlet temperature of air in K
rp=5//Compression ratio
nc=85//Isentropic efficiency of the compressor in percent
T3=540+273//Temperature of the gas entering the turbine in K
p3=1.03//Pressure of gas entering the turbine in kg/cm^2
nt=80//Isentropic efficiency of the turbine in percent
O=2500//Net output in H.P
fp=0.07//Fall of pressure through the combustion chamber in kg/cm^2
g=1.4//Ratio of specific heats for both air and gas
Cp=0.24//Specific heat at constant pressure in kJ/kg.K for both air and gas

//Calculations
T2=(T1*rp^((g-1)/g))//Temperature of air at the end of adiabatic compression in K
T2i=(T1+((T2-T1)/(nc/100)))//Temperature of air at the end of actual compression in K
T4=(T3/((rp*p3-fp)/p3)^((g-1)/g))//Temperature of air at the end of adiabatic compression in K
T4i=(T3-((T3-T4)*(nt/100)))//Temperature of air at the end of actual compression in K
Wt=(Cp*(T3-T4i))//Workdone in turbine in kcal/kg of air
Wc=(Cp*(T2i-T1))//Workdone in compressor in kcal/kg of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
Fl=(O*4500)/(427*N*60)//Flow rate for 2500 H.P in kg/sec

```

```
//Output
printf('Flow rate of air is %3.1f kg/sec for a net
   output of %i H.P',F1,O)
```

Scilab code Exa 25.9 FLOW RATE

```
clc
clear
//Input data
p1=1//Inlet air pressure in kg/cm^2
T1=16+273//Inlet temperature of air in K
rp=3.5//Pressure ratio
nc=85//Isentropic efficiency of the compressor in
   percent
T3=500+273//Temperature of the gas entering the
   turbine in K
nt=80//Isentropic efficiency of the turbine in
   percent
mc=4//Mass of air entering the compressor in tonnes/
   hour
g=1.4//Ratio of specific heats
Cp=0.24//Specific heat at constant pressure in kJ/kg
   .K

//Calculations
T2=(T1*rp^((g-1)/g))//Temperature of air at the end
   of adiabatic compression in K
dt=(T2-T1)//Isentropic temperature rise in K
adt=(dt/(nc/100))//Actual temperature rise in K
T2i=(T1+((T2-T1)/(nc/100)))//Temperature of air at
   the end of actual compression in K
T4=(T3/rp^((g-1)/g))//Temperature of air at the end
   of adiabatic compression in K
T4i=(T3-((T3-T4)*(nt/100)))//Temperature of air at
   the end of actual compression in K
```

```
Wt=(Cp*(T3-T4i))//Workdone in turbine in kcal/kg of
    air
Wc=(Cp*(T2i-T1))//Workdone in compressor in kcal/kg
    of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
q=(Cp*(T3-T2i))//Heat supplied in kcal/kg of air
NHP=(N*427*mc*1000)/(60*4500)//Net Horse Power
    available in H.P
nt=(N/q)*100//Thermal efficiency in percent

//Output
printf('(i) The net Horse power available from this
    unit is %3.1f H.P \n (ii) The thermal efficiency
    of the plant is %3.2f percent',NHP,nt)
```

Scilab code Exa 25.10 EFFICIENCY

```
clc
clear
//Input data
p1=1.02//Inlet air pressure in kg/cm^2
T1=27+273//Inlet temperature of air in K
p2=4.08//Pressure after compression in kg/cm^2
nc=80//Isentropic efficiency of compressor in
    percent
mf=1//Mass of fuel in kg
ma=80//Mass of air in kg
nt=85//Isentropic efficiency of the turbine in
    percent
CV=10000//Calorific value of fuel n kcal per kg
g=1.4//Ratio of specific heats
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K

//Calculations
```

```
rp=(p2/p1)//Pressure ratio
T2=(T1*rp^((g-1)/g))//Temperature of air at the end
    of adiabatic compression in K
dt=(T2-T1)//Isentropic temperature rise in K
adt=(dt/(nc/100))//Actual temperature rise in K
T2i=(T1+((T2-T1)/(nc/100)))//Temperature of air at
    the end of actual compression in K
q=(mf/ma)*CV//Heat supplied per kg of air in kcal
T3=(q/Cp)+T2i//Temperature of gas at the inlet of
    the turbine in K
T4=(T3/rp^((g-1)/g))//Temperature of air at the end
    of adiabatic expansion in K
T4i=(T3-((T3-T4)*(nt/100)))//Temperature of air at
    the end of actual expansion in K
Wt=(Cp*(T3-T4i)*((ma+mf)/ma))//Workdone in turbine
    in kcal/kg of air
Wc=(Cp*(T2i-T1))//Workdone in compressor in kcal/kg
    of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
nt=(N/q)*100//Thermal efficiency in percent

//Output
printf('(a) The net work output of installation is
   %3.2f kcal/kg of air \n (b) Overall efficiency of
    the plant is %3.1f percent',N,nt)
```

Scilab code Exa 25.11 EFFICIENCY

```
clc
clear
//Input data
rp=5//Pressure ratio
T3=580+273//Temperature of gas at the inlet of the
    turbine in K
p1=1.03//Inlet air pressure in kg/cm^2
```

```
T1=15+273//Inlet temperature of air in K
nc=80//Isentropic efficiency of compressor in
    percent
no=18//Overall efficiency of the plant in percent
Cpa=0.239//Specific heat of air at constant pressure
     in kJ/kg.K
Cpg=0.261//Specific heat of gas at constant pressure
     in kJ/kg.K
R=29.27//haracteristic gas constant in kg.m/kg.K
g=1.4//Ratio of specific heats for air
g1=1.355//Ratio of specific heats for gas

//Calculations
T2=(T1*rp^((g-1)/g))//Temperature of air at the end
    of adiabatic compression in K
T2i=(T1+((T2-T1)/(nc/100)))//Temperature of air at
    the end of actual compression in K
q=(Cpg*(T3-T2i))//Heat supplied in kcal/kg of air
Wc=(Cpa*(T2i-T1))//Workdone in compressor in kcal/kg
     of air
Wt=((no/100)*q)+Wc//Turbine work output in kcal/kg
    of air
T4i=(T3-(Wt/Cpg))//Temperature of air at the end of
    actual expansion in K
T4=(T3/rp^((g1-1)/g1))//Temperature of air at the
    end of adiabatic expansion in K
nt=((T3-T4i)/(T3-T4))*100//Isentropic efficiency of
    turbine in percent

//Output
printf('Isentropic efficiency of turbine is %3.1f
    percent',nt)
```

Scilab code Exa 25.12 FLOW OF AIR

```
clc
clear
//Input data
p1=1.03//Inlet air pressure in kg/cm^2
T1=15+273//Inlet temperature of air in K
rp=5//Pressure ratio
nc=85//Isentropic efficiency of the compressor in
    percent
T3=540+273//Temperature of the gas entering the
    turbine in K
nt=80//Isentropic efficiency of the turbine in
    percent
NHP=2000//Net horse power in H.P
fp=0.1//Fall of pressure through the combustion
    system in kg/cm^2
g=1.4//Ratio of specific heats for both air and gas
Cp=0.25//Specific heat at constant pressure in kJ/kg
    .K for both air and gas

//Calculations
T2i=(T1*rp^((g-1)/g))//Temperature of air at the end
     of adiabatic compression in K
dt=(T2i-T1)//Isentropic temperature rise in K
adt=(dt/(nc/100))//Actual temperature rise in K
Wc=(Cp*adt)//Workdone in compressor in kcal/kg of
    air
e=((rp*p1-fp)/p1)//Expansion ratio
T4i=(T3/e^((g-1)/g))//Temperature of air at the end
    of adiabatic expansion in K
dt1=(T3-T4i)//Isentropic temperature rise in K
adt1=(dt1/(nt/100))//Actual temperature rise in K
Wt=(Cp*adt1)//Workdone in turbine in kcal/kg of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
w=(NHP*75)/(427*9.8)//Flow rate in kg of air per sec

//Output
printf('Flow rate is %3.2f kg of air per sec',w)
```

Scilab code Exa 25.13 POWER OTPUT

```
clc
clear
//Input data
nc=75//Isentropic efficiency of the compressor in
    percent
nt=85//Isentropic efficiency of the turbine in
    percent
nm=98//Mechanical efficiency in percent
rp=6//Pressure ratio
T3=727+273//Temperature of the gas entering the
    turbine in K
p1=1//Inlet air pressure in kg/cm^2
T1=15.5+273//Inlet temperature of air in K
m=2.2//Mass flow rate in kg/sec
Cpa=0.24//Specific heat of air at constant pressure
    in kJ/kg.K
Cpg=0.276//Specific heat of gas at constant pressure
     in kJ/kg.K
g=1.4//Ratio of specific heats for air
g1=1.33//Ratio of specific heats for gas

//Calculations
T2=(T1*rp^((g-1)/g))//Temperature of air at the end
    of adiabatic compression in K
T2i=(T1+((T2-T1)/(nc/100)))//Temperature of air at
    the end of actual compression in K
T4=(T3/rp^((g1-1)/g1))//Temperature of air at the
    end of adiabatic compression in K
T4i=(T3-((T3-T4)*(nt/100)))//Temperature of air at
    the end of actual compression in K
Wt=(Cpg*(T3-T4i))//Workdone in turbine in kcal/kg of
     air
```

```
Wc=(Cpa*(T2i-T1))//Workdone in compressor in kcal/kg
    of air
N=(Wt-Wc)//Net workdone in kcal/kg of air
P=(N*m*427)/(75*(nm/100))//Power output of the plant
    in H.P

//Output
printf('Power output of the plant is %3.0f H.P',P)
```

Scilab code Exa 25.14 EFFICIENCY

```
clc
clear
//Input data
T1=15+273//Inlet temperature of air in K
rp=4//Pressure ratio
T4=560+273//Maximum temperature of the cycle in K
nc=83//Isentropic efficiency of the compressor in
   percent
nt=86//Isentropic efficiency of the turbine in
   percent
x=75//Heat exchanger making use of heat available in
    percent
g=1.4//Ratio of specific heats

//Calculations
T5i=(T4*(1/rp)^((g-1)/g))//Temperature in K
dt=(T4-T5i)//Isometric temperature drop through
   turbine in degree C
ta=((nt/100)*dt)//Actual temperature drop in degree
   C
T5=(T4-ta)//Temperature in K
T2i=(T1*rp^((g-1)/g))//Temperature in K
tc=(T2i-T1)//Temperature change in degree C
T2=(tc/(nc/100))+T1//Temperature in K
```

```
q=(T5-T2)//Available heat in exchanger in kcal per kg *Cp
T3=((q*(x/100))+T2)//Temperature in K
//Without heat exchanger
qw=(T4-T2)//Heat supplied *Cp in kcal/kg
tw=(T4-T5)//Turbine work *Cp in kcal/kg
cw=(T2-T1)//Compressor work *Cp in kcal/kg
nw=(tw-cw)//Net workdone *Cp in kcal/kg
no=(nw/qw)*100//Overall efficiency in percent
//With heat exchanger
qs=(T4-T3)//Heat supplied *Cp in kcal/kg
no1=(nw/qs)*100//Overall efficiency in percent

//Output
printf('The overall efficiency \n (a) without heat exchanger is %3.1f percent \n (b) with heat exchanger making use of %i percent of heat available is %3.1f percent',no,x,no1)
```

Scilab code Exa 25.15 PRESSURE

```
clc
clear
//Input data
p1=1//Initial pressure in kg/cm^2
T1=15+273//Initial temperature in K
p2=5.5//Pressure after compression in kg/cm^2
T3=750+273//Temperature at the entrance of turbine in K
v=225//Speed in m/s
x=70//Percentage
in=75//Isentropic efficiency of compressor in percent
Cp=0.24//Specific heat at constant pressure in kJ/kg.K
```

```
g=1.4//Ratio of specific heats

//Calculations
T2=(T1*(p2/p1)^((g-1)/g))//Temperature in K
at=(T2-T1)/(in/100)//Actual temperature rise in the
    compressor in K
T2i=(T1+at)//Temperature in K
T4=(T3/(p2/p1)^((g-1)/g))//Temperature in K
to=(Cp*(T3-T4))//Theoritical turbine output in kcal/
    kg of air
ci=(Cp*(T2i-T1))//Actual compressor input in kcal/kg
     of air
ke=(v^2/(2*9.81*427))//Kinetic energy in gas leaving
     the exhaust annulus in kcal/kg
dT34=(ci+ke)/((x/100)*Cp)//Change in temperature in
    K
r=1/(1-(dT34/T3))^(g/(g-1))//Ratio of pressures
p4=(r/p2)//Pressure in kg/cm^2

//Output
printf('The pressure of the gases in the turbine
    exhaust annulus is %3.1f kg/cm^2',p4)
```

Scilab code Exa 25.16 EFFICIENCY

```
clc
clear
//Input data
p=[1,5]//Pressures in atm
T1=288//Temperature in K
T3=650+273//Temperature in K
er=0.85//Efficiency ratio
x=0.72//Effectiveness of heat exchanger
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K
```

```
g=1.4//Ratio of specific heats

//Calculations
T2=(T1*(p(2)/p(1))^((g-1)/g))//Temperature in K
T2i=(T1+((T2-T1)/er))//Temperature in K
T4=(T3/(p(2)/p(1))^((g-1)/g))//Temperature in K
T4i=(T3-(er*(T3-T4)))//Temperature in K
Tc=((x*(T4i-T2i))+T2i)//Temperature in K
W=((Cp*((T3-T4i)-(T2i-T1))))//Workdone in kcal/kg
q=(Cp*(T3-Tc))//Heat supplied in kcal/kg
n=(W/q)*100//Efficiency in percent

//Output
printf('The heat efficiency of the plant is %3.1f
    percent',n)
```

Scilab code Exa 25.17 EFFICIENCY

```
clc
clear
//Input data
T1=15+273//Inlet temperature of air in K
p1=1.03//Inlet pressure of air in kg/cm^2
rp=5//Pressure ratio
T3=815+273//Temperature of air entering the turbine
    in K
nc=0.83//Adiabatic efficiency of the compressor
nt=0.92//Internal engine efficiency of the turbine
nr=0.65//Effectiveness of regenerator
p2=2.45//Pressure in kg/cm^2
T6=T1//Temperature in K
T9=T3//Temperature in K
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K
g=1.4//Ratio of specific heat
```

```

//Calculations
T2=(T1*rp^((g-1)/g))//Temperature in K
T4=(T3/rp^((g-1)/g))//Temperature in K
Wt=(Cp*(T3-T4))//Isentropic work done in the turbine
     in kcal/kg of air
Wc=(Cp*(T2-T1))//Isentropic work done in the
   compressor in kcal/kg of air
Wr=(Wt/Wc)//Work ratio
qa=(Cp*(T3-T2))//Heat added in kcal/kg of air
nth=((Wt-Wc)/qa)*100//Thermal efficiency in percent
T2i=(T1+((T2-T1)/nc))//Temperature in K
T4i=(T3-(nt*(T3-T4)))//Temperature in K
Wti=(Cp*(T3-T4i))//work done in the turbine in kcal/
   kg of air
Wci=(Cp*(T2i-T1))//work done in the compressor in
   kcal/kg of air
Wri=(Wti/Wci)//Work ratio
qai=(Cp*(T3-T2i))//Heat added in kcal/kg of air
nthi=((Wti-Wci)/qai)*100//Thermal efficiency in
   percent
T2ii=(T2i+((T4i-T2i)*nr))//Temperature in K
qaii=(Cp*(T3-T2ii))//Heat added in kcal/kg of air
nthii=((Wti-Wci)/qaii)*100//Thermal efficiency in
   percent
T5=(T1*(p2/p1)^((g-1)/g))//Temperature in K
T5i=(T1+((T5-T1)/nc))//Temperature in K
T7=(T1*((rp*p1)/p2)^((g-1)/g))//Temperature in K
T7i=(T6+((T7-T6)/nc))//Temperature in K
T7ii=(T7i+((T4i-T7i)*nr))//Temperature in K
Wcomp=(Cp*((T5i-T1)+(T7i-T6)))//Compressor work in
   kcal/kg of air
Wratio=(Wti/Wcomp)//Work ratio
qaa=(Cp*(T3-T7ii))//Heat added in kcal/kg of air
nthe=((Wti-Wcomp)/qaa)*100//Thermal efficiency in
   percent
T8=(T3*(p2/(rp*p1))^((g-1)/g))//Temperature in K
T8i=(T3-((T3-T8)*nt))//Temperature in K
```

```
T10=(T9/(p2/p1)^((g-1)/g))//Temperature in K
T10i=(T9-((T9-T10)*nt))//Temperature in K
T2iii=(T2i+((T10i-T2i)*nr))//Temperature in K
Wturb=(Cp*((T3-T8i)+(T3-T10i)))//Compressor work in kcal/kg of air
Wratioi=(Wturb/Wci)//Work ratio
qaai=(Cp*((T3-T2iii)+(T9-T8i)))//Heat added in kcal/kg of air
nthei=((Wturb-Wci)/qaai)*100//Thermal efficiency in percent
T7iii=(T7i+((T10i-T7i)*nr))//Temperature in K
Wratioii=(Wturb/Wcomp)//Work ratio
qaaii=(Cp*((T3-T7iii)+(T9-T8i)))//Heat added in kcal/kg of air
ntheii=((Wturb-Wcomp)/qaaii)*100//Thermal efficiency in percent

//Output
printf('Condition        Work ratio        Thermal efficiency(in percent)\n    (a)             %3.3f             %3.1f\n    (b)             %3.2f             %3.1f\n    (c)             %3.2f             %3.1f\n    (d)             %3.2f             %3.1f\n    (e)             %3.3f             %3.1f\n    (f)             %3.3f             %3.1f',Wr,nth,Wri,nthi,Wri,nthii,Wratio,nthe,Wratioi,nthei,Wratioii,ntheii)
```

Scilab code Exa 25.18 EFFICIENCY

```
clc
clear
//Input data
p=[1,9]//Pressures in ata
T=[25+273,1250+273]//Minimum and maximum
```

```
temperatures in K
n=0.83//Compressor and turbine efficiencies
Cp=0.24//Specific heat at constant pressure in kJ/kg.K
g=1.4//Ratio of specific heats
x=0.65//Cycle with 65% regeneration

//Calculations
//(a)Without regeneration
ip=sqrt(p(1)*p(2))//Intermediate pressure in ata
T2=(T(1)*(ip/p(1))^((g-1)/g))//Temperature in K
T3=(T(1)+((T2-T(1))/n))//Temperature in K
T4=T(1)//Temperature in K
T5=T2//Temperature in K
T6=T3//Temperature in K
T7=T(2)//Temperature in K
T8=T7/(ip/p(1))^((g-1)/g)//Temperature in K
T9=(T7-((T7-T8)*n))//Temperature in K
T10=T7//Temperature in K
T11=T8//Temperature in K
T12=T9//Temperature in K
Wc=(2*Cp*(T3-T(1)))//Work of compression in kcal/kg of air
We=(2*Cp*(T7-T8))//Work of expansion in kcal/kg of air
NW=(We-Wc)//Net output in kcal/kg of air
qi=(Cp*((T7-T6)+(T10-T9)))//Heat input in kcal/kg of air
nth=(NW/qi)*100//Thermal efficiency in percent

//(b)Cycle efficiency with 65% regeneration
Tg=(T6+(x*(T12-T6)))//Temperature in K
q=(Cp*((T7-Tg)+(T10-T9)))//Heat input in kcal/kg of air
nthi=(NW/q)*100//Thermal efficiency in percent

//(c)Cycle efficiency with ideal regeneration
Eg=T12//Temperature in K
```

```
qa=(2*Cp*(T7-Eg))//Heat added in kcal/kg of air
nthii=(NW/qa)*100//Thermal efficiency in percent

//Output
printf('(a)Cycle efficiency without regeneration is
   %3.1f percent \n (b)Cycle efficiency with 65
   percent regeneration is %3.1f percent \n (c)Cycle
    efficiency with ideal regeneration is %3.0f
   percent',nth,nthi,nthii)
```

Scilab code Exa 25.19 EFFICIENCY

```
clc
clear
//Input data
p1=1//Inlet pressure of compressor in atm
T1=27+273//Inle temperature of compressor in K
ic=0.8//Isentropic efficiency of compressor
ma=20.5//Mass flow rate of air in kg/sec
T3=650+273//Inlet temperatures of both turbines in K
p2=5//Inlet pressure of turbine in atm
it=0.92//Internal engine efficiency for both the
   turbines
CV=10000//Calorific value in kcal/kg
Cpa=0.24//Specific heat at constant pressure of air
   in kJ/kg.K
ga=1.4//Ratio of specific heats for air
Cpg=0.276//Specific heat at constant pressure of gas
    in kJ/kg.K
gs=1.33//Ratio of specific heats for gas

//Calculations
T2=(T1*(p2/p1)^((ga-1)/ga))//Temperature in K
T2i=(T1+((T2-T1)/ic))//Temperature in K
T4=(T3/(p2/p1)^((gs-1)/gs))//Temperature in K
```

```
T4i=(T3-((T3-T4)*it))//Temperature in K
Wc=(Cpa*(T2i-T1))//Work of compression in kcal/kg of air
We=(Cpg*(T3-T4i))//Work of expansion in kcal/kg of air
mx=(Wc/We)//Gas required per kg of air compressed in kg
F=((Cpa*T2i)-(Cpg*T3))/(Cpg*T3-CV)//Amount of fuel supplied per kg of air in kg
Wg=1+F//Weight of gases per kg of air in kg
Wt=(Wg-mx)//Gases supplied to turbine in kg
Ot=((Wt*ma*427*We)/75)//Output of turbine in H.P
nth=((Wt*We)/(CV*F))*100//Thermal efficiency in percent

//Output
printf('Output is %3.0f H.P \n Thermal efficiency is %3.2f percent',Ot,nth)
```

Scilab code Exa 25.20 HP

```
clc
clear
//Input data
q=2250//Heat supplied per sec in kcal
//Input data from Fig. 25.34 from page no. 652
T1=200//Temperature in K
T2=100//Temperature in K
T3=625//Temperature in K
T4=550//Temperature in K
Cp=0.24//Specific heat at constant pressure in kJ/kg.K
g=1.4//Ratio of specific heats

//Calculations
```

```
Wc=(2*Cp*(T1-T2))//Work of compression in kcal/kg of
    air
We=(2*Cp*(T3-T4))//Work of expansion in kcal/kg of
   air
NW=(Wc-We)//Net output in kcal/kg of air
qi=(2*Cp*(T3-T4))//Heat input in kcal/kg of air
nth=(NW/qi)*100//Thermal efficiency in percent
rf=(q/qi)//Rate of flow of working substance in kg/
   sec
O=(NW*rf*427)/75//Total output in H.P

//Output
printf('Output is %3.0f H.P \n Thermal efficiency is
    %3.1f percent',O,nth)
```

Scilab code Exa 25.22 EFFICIENCY

```
clc
clear
//Input data
p=[5,20]//Pressure limits in atm
T3=650+273//Temperature in K
T1=60+273//Temperature in K
T2=T1//Temperature in K
Cp=0.24//Specific heat at constant pressure in kJ/kg
   .K
g=1.4//Ratio of specific heats
R=29.27//Characteristic gas constant in kg.m/kg.K
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
T4=T3/(p(2)/p(1))^((g-1)/g)//Temperature in K
Wc=((R*T1)/J)*log(p(2)/p(1))//Compression work in
   kcal/kg
qs=(Cp*(T3-T2))//Heat supplied at constant pressure
```

```
    in kcal/kg
qre=(Cp*(T4-T1))//Heat ejected during process 4−1 in
     kcal/kg
nth=((qs-Wc-qre)/(qs-qre))*100//Thermal efficiency
    in percent
nc=((T3-T1)/T3)*100//Carnot efficiency in percent
r=(nth/nc)*100//Ratio of air standard efficiency to
    carnot efficiency in percent

//Output
printf('(a) air standard efficiency of the cycle is
    %3.1f percent \n (b) carnot efficiency is %3.0f
    percent \n (c) Ratio of air standard efficiency
    to carnot efficiency is %3.1f percent',nth,nc,r)
```

Chapter 26

JET PROPULSION

Scilab code Exa 26.1 PROPERTIES

```
clc
clear
//Input data
Ve=2700//Jet exit velocity in m/s
Vf=1350//Forward flight velocity in m/s
m=78.6//Propellant consumption in kg/s

//Calculations
T=((m/9.81)*(Ve-Vf))//Thrust in kg
TH=((T*Vf)/75)/10^5//Thrust horse power in HP*10^5
pn=(2/(1+(Ve/Vf)))*100//Propulsive efficiency in percent

//Output
printf('(i) Thrust is %3.0f kg \n (ii) Thrust horse power is %3.3f*10^5 H.P \n (iii) Propulsive efficiency is %3.1f percent',T,TH,pn)
```

Scilab code Exa 26.2 AIR FUEL RATIO

```
clc
clear
//Input data
CV=10000//Calorific value in kcal/kg
F=1.4//Fuel consumption in kg per hour per kg of thrust
T=900//Thrust in kg
Va=425//Aircraft velocity in m/s
w=19.5//Weight of air in kg/sec

//Calculations
af=(w/((F*T)/3600))//Air fuel ratio
nv=((T*Va*3600)/(427*F*T*CV))*100//Overall efficiency in percent

//Output
printf('Air fuel ratio is %3.1f \n Overall efficiency is %3.1f percent',af,nv)
```

Scilab code Exa 26.3 PROPERTIES

```
clc
clear
//Input data
a=11500//Altitude in m
n=123//Number of passengers
c=3//Cargo in tonnes
Va=650//Velocity of air craft in km/hour
d=640//Drag in kg
pe=50//Propulsion efficiency in percent
oe=18//Overall efficiency in percent
CV=10000//Calorific value in kcal/kg
da=0.0172//Density of air at 11500 m in kg/cm^2

//Calculations
```

```
Vp=((Va*1000)/3600)//Velocity of aeroplane in m/s
Vr=((2/(pe/100))-1)*Vp//Velocity of working medium
    in m/s
nhp=((d*Vp)/(75*(pe/100)))//Net horse power in H.P
wf=((nhp*75*3600)/((oe/100)*427*CV))//Mass flow rate
     in kg/hr
thp=((Va*Vp)/75)//Thrust horse power in H.P
F=(wf/thp)//Fuel consumption per thrust H.P hour in
    kg
W=((Va*9.81)/Vr)//Air flow in kg/sec
va=(W/da)//Volume of air in cu.m/sec
aa=(va/(3*Vr))//Area of jet in m^2
d=sqrt((4*aa)/3.14)*100//Diameter of jet in cm
af=((W*3600)/wf)//Air fuel ratio

//Output
printf('(a) Absolute velocity of the jet is %3.1f m/
    sec \n (b) Net horse power of the gas plant is %3
    .0f H.P \n (c) Fuel consumption per thrust H.P
    hour is %3.3f kg \n (d) Diameter of the jet is %3
    .1f cm \n (e) Air-fuel ratio of the engine is %3
    .1f',Vr,nhp,F,d,af)
```

Scilab code Exa 26.4 AREA

```
clc
clear
//Input data
p1=7//Pressure of gas before expansion in kg/cm^2
p2=5//Pressure of gas after expansion in kg/cm^2
T1=250+273//Temperature of gas before expansion in K
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K
Cv=0.17//Specific heat at constant volume in kJ/kg.K
nv=0.8//Nozzle efficiency
```

```

//Calculations
R=427*(Cp-Cv)//Characteristic gas constant in kg.m/kg.K
g=(Cp/Cv)//Ratio of specific heats
V1=(R*T1)/(p1*10^4)//Volume in cu.m per kg
V2=(V1*(p1/p2)^(1/g))//Volume in cu.m per kg
Wd=(g/(g-1))*(p1*V1-p2*V2)*10^4//Work done in m.kg per kg
KE=(nv*Wd)//Kinetic energy at exit in m.kg per kg
v3=sqrt(2*9.81*nv*Wd)//Velocity in m/s
T2=(T1*(p2/p1)*(V2/V1))//Temperature in K
T3=(((1-nv)*Wd)/(427*Cp))+T2//Temperature in K
V3=(V2*(T3/T2))//Volume in cu.m per kg
qa=(V3/v3)*10^4//Discharge area unit rate of mass flow in cm^2

//Output
printf('Area of discharge per unit rate of mass flow is %3.2f sq.cm',qa)
```

Scilab code Exa 26.5 POWER AND THRUST

```
clc
clear
//Input data
p=3.5//Pressure at the delivery is 3.5 times that at entrance
T=1.15//Temperature rise during compression is 1.15 times that for frictionless adiabatic compression. In textbook it is given wrong as 1.5
T3=500+273//Temperature of products of combustion in K
pa=1//Atmospheric pressure in kg/cm^2
Ta=15+273//Atmospheric temperature in K
```

```
Cp=0.24//Specific heat at constant pressure in kJ/kg
    .K
g=1.4//Ratio of specific heats
J=427//Mechanical equivalent of heat in kg.m/kcal

//Calculations
p2=p*pa//Pressure in kg/cm^2
T2a=(Ta*(p2/pa)^((g-1)/g))//Temperature in K
T2=(T2a-Ta)*T+Ta//Temperature in K
wcomp=(Cp*(T2-Ta))//Work done by compressor in kcal/
    kg
T5=T3/(p2/pa)^((g-1)/g)//Temperature in K
dh35=(Cp*(T3-T5))//Change in enthalpy in kcal/kg
dhnozzle=(dh35-wcomp)//Change in enthalpy of nozzle
    in kcal/kg
v5=sqrt(2*9.81*J*dhnozzle)//Velocity at the nozzle
    exit in m/sec
Th=(v5/9.81)//Thrust in kg per kg of air/sec

//Output
printf('(a) the power required to drive the
    compressor per kg of air per second is %3.1f kcal
    /kg \n (b) Static thrust developed per kg of air
    per second is %3.1f kg',wcomp,Th)
```