Scilab Textbook Companion for
Thermal Engineering
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July 31, 2019

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

Book Description

Title: Thermal Engineering

Author: K. K. Ramalingam

Publisher: Scitech Publications, Chennai

Edition: 1

Year: 2009

ISBN: 9788183711982

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

Gas power cycles

Scilab code Exa 1.1 The pressures

```
clc
clear
//Input data
V1=0.5;//Initial Volume before the commencement of
    compression in m^3
P1=1;//Initial pressure before the commencement of
    compression in bar
T1=300;//Initial temperature in K
P2=12;//Final pressure at the end of compression
    stroke in bar
Q=220;//Heat added during the constant volume
    process in kJ
r=1.4;//Isentropic constant for air
R=0.287;//Characteristic Gas constant in kJ/kg K
Cv=0.718;//Specific heat of mixture in kJ/kg K

//Calculations
r1=(P2/P1)^(1/r);//Compression ratio
T2=T1*(r1)^(r-1);//Final temperature after the end
    of compression stroke in K
V2=(P1*T2*V1)/(P2*T1);//Final volume after the end
```

```
    of compression stroke in m^3
m=(P1*10^5*V1)/(R*T1*1000);//Mass of air flowing in
    kg
T3=(Q/(m*Cv))+T2;//Temperature after constant volume
     heat addition in K
P3=(P2*T3)/T2;//Pressure after constant volume heat
    addition in K
V3=V2;//Volume at 3
P4=P3*(1/r1)^(r);//Pressure after isentropic
    expansion in bar
V4=V1;//Volume after isentropic expansion in m^3
T4=T3*(1/r1)^(r-1);//Temperature at the end of
    isentropic expansion in K

//Output
printf('(a)The pressures at 1 is %3.0fbar\n (b)
    Pressure at 2 is %3.0fbar\n (c)Pressure at 3 is
    %3.2fbar\n (d)Pressure at 4 is %3.2fbar\n (e)
    Temperature at 1 is %3.1fK\n (f)Temperature at 2
    is %3.1fK\n (g)Temperature at 3 is %3.0fK\n (h)
    Temperature at 4 is %3.0fK\n (i)Volume at 1 is %3
    .0fm^3\n (j)Volume at 2 is %3.5fm^3\n (k)Volume
    at 3 is %3.5fm^3\n (l)Volume at 4 is %3.0fm^3',P1
    ,P2,P3,P4,T1,T2,T3,T4,V1,V2,V3,V4)
```

Scilab code Exa 1.2 Compression ratio

```
clc
clear
//Input data
r1=6;//Initial compression ratio
r2=7;//Final compression ratio
r=1.4;//Isentropic coefficient of air

//Calculations
```

```
nr1=(1-(1/r1)^(r-1))*100;//Otto cycle efficiency when compression ratio is 6 in percentage
nr2=(1-(1/r2)^(r-1))*100;//Otto cycle efficiency when compression ratio is 7 in percentage
n=nr2-nr1;//Increase in efficiency in percentage

//Output
printf('The increase in efficiency due to change in compression ratio from 6 to 7 is %3.1fpercent',n)
```

Scilab code Exa 1.3 `Air standard efficiency`

```
clc
clear
//Input data
T1=315;//Temperature at the beginning of isentropic compression in K
T2=600;//Temperature at the end of isentropic compression in K
r=1.4;//Isentropic constant of air

//Calculations
r1=(T2/T1)^(1/(r-1));//Compression ratio
n=(1-(1/r1^(r-1)))*100;//Efficiency of Otto cycle in percent

//Output
printf('(a)The compression ratio is %3.2f\n (b)Efficiency of the Otto cycle is %3.1f percent',r1,n)
```

Scilab code Exa 1.4 `Air standard efficiency`

```
clc
clear
//Input data
D=0.1;//Diameter of the cylinder in m
L=0.15;//Stroke length in m
Vc=0.295*10^-3;//Clearance volume in m^3
r=1.4;//Isentropic constant of air

//Calculations
Vs=(3.14/4)*(D^2*L);//Swept volume in m^3
r1=(Vc+Vs)/Vc;//Compression ratio
n=(1-(1/r1)^(r-1))*100;//Otto cycle efficiency in percentage

//Output
printf('The air standard efficiency of air is %3.2f percent',n)
```

Scilab code Exa 1.5 `Mean effective pressure`

```
clc
clear
//Input data
P1=1;//Initial pressure of air in bar
T1=300;//Initial temperature in K
P2=17;//Pressure at the end of isentropic compression in bar
P3=40;//Pressure at the end of constant volume heat addition in bar
Cv=0.717;//Specific heat of mixture in kJ/kg K
M=28.97;//Molecular weight in kg
Ru=8.314;//Universial gas constant in kJ/kg mole K
m=1;//Mass from which heat is extracted in kg
W=363;//Work done in kN m

```

```
//Calculations
Rc=Ru/M;//Characteristic gas constant in kJ/kg K
Cp=Rc+Cv;//Specific heat at constant pressure in kJ/
    kg K
r=Cp/Cv;//Isentropic gas constant
r1=(P2/P1)^(1/r);//Compression ratio
na=(1-(1/r1)^(r-1))*100;//Air standard efficiency in
     percentage
T2=T1*(P2/P1)^((r-1)/r);//Temperature at the end of
    isentropic compression process in K
T3=(P3/P2)*T2;//Temperature at the end of constant
    volume heat addition in K
Q=m*Cv*(T3-T2);//Heat supplied in kJ/kg
V1=(m*Rc*T1*1000)/(P1*10^5);//Initial volume before
    compression in m^3
V2=V1/r1;//Volume at the end of compression stroke
    in m^3
Vs=V1-V2;//Stroke volume in m^3
MEP=(W/Vs)/100;//Mean effective pressure in bar

//Output
printf('(a)Compression ratio is %3.2f\n (b)The air
    standard efficiency is %3.1f percent\n (c)Mean
    effective pressure is %3.2f bar',r1,na,MEP)
```

Scilab code Exa 1.6 Compression ratio

```
clc
clear
//Input data
V1=0.6;//Initial volume of an engine working on otto
     cycle in m^3
P1=1;//Initial pressure in bar
T1=308;//Initial temperature in K
P2=10;//Pressure at the end of compression stroke in
```

```
bar
Q=210;//Heat added during constant heat process in kJ
r=1.4;//Isentropic constant of air

//Calculations
r1=(P2/P1)^(1/r);//Compression ratio
V2=V1/r1;//Clearance volume in m^3
C=(V2/(V1-V2))*100;//Percentage clearance in percent
na=(1-(1/r1)^(r-1))*100;//Air standard efficiency in percent
W=Q*(na/100);//Work done per cycle in kJ

//Output
printf('(a)Clearance volume as percentage of stroke volume is %3.2f percent\n (b)Compression ratio is %3.2f\n (c)Air standard efficiency is %3.1f percent\n (d)Work done per cycle is %3.2f kJ',C,r1,na,W)
```

Scilab code Exa 1.7 `Ideal power`

```
clc
clear
//Input data
r=5.5;//Compression ratio of an engine working on the otto cycle
Q=250;//Heat supplied during constant volume in kJ
N=500;//Engine operating speed in rpm
r1=1.4;//Isentropic ratio

//Calculations
n=(1-(1/r)^(r1-1))*100;//Otto cycle efficiency in percent
W=Q*(n/100);//Work done per cycle in kJ
```

```
P=W*(N/60);//Work done per second i.e., Power
   developed in kJ/s or kW

//Output data
printf('Ideal power developed by the engine is %3.0f
    kW',P)
```

Scilab code Exa 1.8 Mean effective pressure

```
clc
clear
//Input data
V1=0.53;//Volume of cylinder of an engine working on
    Otto cycle in m^3
V2=0.1;//Clearance volume in m^3
Q=210;//Heat supplied during constant volume in kJ
r=1.4;//Isentropic ratio

//Calculations
r1=V1/V2;//Compression ratio
n=(1-(1/r1)^(r-1))*100;//Otto cycle efficiency in
   percentage
W=Q*(n/100);//Work done per cycle in kJ
P=W/((V1-V2)*100);//Mean effective pressure in bar

//Output data
printf('Mean effective pressure is %3.3f bar',P)
```

Scilab code Exa 1.10 Maximum theoretical power

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

```
T3=1500;//Upper temperature limit of a otto cycle in K
T1=300;//Lower temperature limit in K
a=0.4;//Rate of flow of air through the cycle in kg/min
Cv=0.718;//

//Calculations
T2=(T1*T3)^(1/2);//Temperature at point 2 in K
T4=T2;//Temperature at point 4 in K
W=Cv*((T3-T2)-(T4-T1));//Work done per cycle in kJ/kg
P=W*(a/60);//Maximum power developed by the engine in kW

//Output
printf('Maximum power developed by the engine is %3.3f kW',P)
```

Scilab code Exa 1.11 `Efficiencies for cut off ratio`

```
clc
clear
//Input data
r=1.4;//Air standard ratio
p1=1.25;//Cut off ratio 1
p2=1.50;//Cut off ratio 2
p3=2.00;//Cut off ratio 3
rc=16;//Compression ratio

//Calculations
n1=(1-((1/rc^(r-1)*(p1^r-1)/(r*(p1-1)))))*100;//Thermal efficiency of the diesel cycle for cut off ratio 1.25
n2=(1-((1/rc^(r-1)*(p2^r-1)/(r*(p2-1)))))*100;//
```

```
Thermal efficiency of the diesel cycle for cut off ratio 1.50
n3=(1-((1/rc^(r-1)*(p3^r-1)/(r*(p3-1)))))*100;//Thermal efficiency of the diesel cycle for cut off ratio 2.00

//Output
printf('(a)Thermal efficiency when cut off ratio is 1.25 is %3.2f percent\n (b)Thermal efficiency when cut off ratio is 1.50 is %3.0f percent\n (c)Thermal efficiency when cut off ratio is 2.00 is %3.1f percent\n',n1,n2,n3)
```

Scilab code Exa 1.12 `Air standard efficiency`

```
clc
clear
r=15;//Compression ratio of a diesel engine
Q=5;//Heat supplied upto 5 percent of the stroke
r1=1.4;//Isentropic ratio

//Calculations
p=1+(Q/100)*(r-1);//Cut off ratio
n=(1-((1/r^(r1-1)*(p^r1-1)/(r1*(p-1)))))*100;//Efficiency of diesel cycle in percent

//Output
printf('Air standard efficiency of the diesel cycle is %3.2f percent',n)
```

Scilab code Exa 1.13 `Efficiency`

```
clc
```

```
clear
//Input data
r=17;//Compression ratio of a diesel engine
e=13.5;//Expansion ratio
r1=1.4;//Isentropic ratio

//Calculations
p=r/e;//Cut off ratio
n=(1-((1/r^(r1-1)*(p^r1-1)/(r1*(p-1)))))*100;//Air
    standard efficiency in percent

//Output
printf('Air standard efficiency is %3.1f percent',n)
```

Scilab code Exa 1.14 `Compression ratio`

```
clc
clear
//Input data
T1=300;//Temperature at the beggining of compression
     stroke in K
T2=873;//Temperature at the end of compression
    stroke in K
T3=2173;//Temperature at the beggining of expansion
    stroke in K
T4=1123;//Temperature at the end of expansion stroke
     in K
r1=1.4;//Isentropic ratio

//Calculations
r=(T2/T1)^(1/(r1-1));//Compression ratio
rho=T3/T2;//Cut off ratio
n=(1-((1/r1)*((T4-T1)/(T3-T2))))*100;//Efficiency of
     diesel cycle in percent

```

```
//Output data
printf('(a)Compression ratio is %3.2f \n (b)Cut off
    ratio is %3.2f \n (c)Ideal efficiency of the
    diesel cycle is %3.2f percent',r,rho,n)
```

Scilab code Exa 1.15 Pressure

```
clc
clear
//Input data
r=18;//Compression ratio of diesel cycle
Q=2000;//Heat added in kJ/kg
T1=300;//Lowest temperature in the cycle in K
p1=1;//Lowest pressure in the cycle in bar
Cp=1;//Specific heat of air at constant pressure in
    kJ/kg K
Cv=0.714;//Specific heat of air at constant volume
    in kJ/kg K

//Calculations
r1=Cp/Cv;//Isentropic ratio
v1=((1-Cv)*T1)/(p1*10^5);//Initial volume at point 1
     in the graph in m^3/kg
v2=v1/r;//Volume at point 2 in m^3/kg
p2=p1*(v1/v2)^(r1);//Pressure at point 2 in bar
T2=T1*(v1/v2)^(r1-1);//Temperature at point 2 in K
T3=(Q/Cp)+T2;//Temperature at point 3 in K
v3=v2*(T3/T2);//Volume at point 3 in K
v4=v1;//Since Constant volume heat rejection in m^3/
    kg
T4=T3/(v4/v3)^(r1-1);//Temperature at point 4 in K
    for isentropic expansion
p4=p1*(T4/T1);//Pressure at point 4 in bar

//Output
```

```
printf('(a)Pressure at point 1 in the cycle is %3.0f
  bar\n (b)Pressure at point 2 & 3 is %3.1f bar\n
  (c)Pressure at point 4 is %3.2f bar\n (d)
  Temperature at point 1 is %3.0f K\n (e)
  Temperature at point 2 is %3.0f K\n (f)
  Temperature at point 3 is %3.0f K\n (g)
  Temperature at point 4 is %3.0f K',p1,p2,p4,T1,T2
  ,T3,T4)
```

Scilab code Exa 1.16 `Thermal efficiency`

```
clc
clear
//Input data
r=16;//Compression ratio for the air standard diesel
  cycle
Q1=2200;//Heat added in kJ/kg
T4=1500;//Temperature at the end of isentropic
  expansion in K
T1=310;//Lowest temperature in the cycle in K
m=0.3;//Air flow rate in kg/sec
Cv=0.714;//Specific heat at constant volume in kJ/kg
  K

//Calculations
Q2=Cv*(T4-T1);//Heat rejected in kJ/kg
n=((Q1-Q2)/Q1)*100;//Efficiency in percent
P=m*(Q1-Q2);//Power developed in kW

//Output
printf('(a)Thermal efficiency is %3.2f percent\n (b)
  Power developed is %3.0f kW',n,P)
```

Scilab code Exa 1.17 Air standard efficiency

```
clc
clear
//Input data
T1=303;//Temperature at the beginning of compression
    in K
T2=823;//Temperature at the end of compression in K
T3=3123;//Temperature at the end of heat addition in
    K
T4=1723;//Temperature at the end of isentropic
    expansion in K
r=1.4;//Isentropic ratio

//Calculations
n=(1-((T4-T1)/(r*(T3-T2))))*100;//Efficiency of the
    cycle in percent

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

Scilab code Exa 1.18 Mean effective pressure

```
clc
clear
//Input data
r=15;//Compression Ratio of a diesel engine
P1=1;//Operating Pressure of a diesel engine in bar
r1=1.4;//Isentropic constant
V1=15;//Volume at the start of compression stroke in
    m^3
V3=1.8;//Volume at the end of constant Pressure heat
    addition in m^3
V4=V1;//Volume at the end of Isentropic expansion
```

```
stroke in m^3
V2=1;//Volume at the end of isentropic compression stroke in m^3
Vs=V1-V2;//Swept volume in m^3

//Calculations
P2=P1*(r)^r1;//Pressure at the end of Isentropic compression of air
P3=P2;//Pressure at the end of constant pressure heat addition in bar
P4=P3*(V3/V4)^r1;//Pressure at the end of Isentropic expansion stroke in bar
Pm=(V2/Vs)*(P2*((V3/V2)-1)+(P3*(V3/V2)-P4*(V4/V2))/(r1-1)-(P2-P1*(V1/V2))/(r1-1));//Mean effective pressure in bar

//Output
printf('Mean effective pressure of the cycle is %3.2f bar',Pm)
```

Scilab code Exa 1.19 Compression ratio

```
clc
clear
//Input data
P1=1.5;//Pressure at the 7/8th stroke of compression in bar
P2=16;//Pressure at the 1/8th stroke of compression in bar
n=1.4;//Polytropic index
c=8;//Cutoff occurs at 8% of the stroke in percentage

//Calculations
R1=(P2/P1)^(1/n);//Ratio of volumes
```

```
R2=(R1-1)/((7/8)-(R1/8));//Ratio of stroke volume to the clearance volume
r=1+R2;//Compression ratio
rho=1+((c/100)*r);//Cut off ratio
na=(1-((1/r^(n-1))*(((rho^n)-1)/(n*(rho-1)))))*100;//Air standard efficiency in percentage

//Output
printf('(a)Compression ratio of the engine is %3.3f\n (b)Air standard efficiency is %3.2f percent',r,na)
```

Scilab code Exa 1.20 Loss in efficiency

```
clc
clear
//Input data
r=16;//Compression ratio of diesel engine
r1=1.4;//Isentropic ratio

//Calculations
rho1=1+(r-1)*(6/100);//Cutoff ratio at 6% of stroke
rho2=1+(r-1)*(9/100);//Cutoff ratio at 9% of stroke
n1=(1-(1/r^(r1-1))*(1/r1)*(rho1^r1-1)/(rho1-1))*100;//Efficiency of the cycle at 6% of the stroke in percent
n2=(1-(1/r^(r1-1))*(1/r1)*(rho2^r1-1)/(rho2-1))*100;//Efficiency of the cycle at 9% of the stroke in percent
L=n1-n2;//The loss in efficiency in percent

//Output
printf('The loss in efficiency is %3.2f percent',L)
```

Scilab code Exa 1.21 Compression ratio

```
clc
clear
//Input data
P1=1.03;//Pressure at the beginning of compression stroke in bar
T1=303;//Initial temperature in K
P2=40;//Maximum pressure in the cycle in bar
Q=550;//The heat supplied during the cycle in kJ/kg
r=1.4;//Isentropic compression ratio
Cp=1.004;//Specific heat at constant pressure in kJ/kg K

//Calculations
r1=(P2/P1)^(1/r);//Compression ratio
T2=(P2/P1)^((r-1)/r)*T1;//Temperature at the end of compression stroke in K
T3=(Q/Cp)+T2;//Temperature at the end of heat addition in K
rho=T3/T2;//Cut off ratio
n=(1-(1/r1^(r-1))*(1/r)*(rho^r-1)/(rho-1))*100;//Air standard efficiency in percentage

//Output\n
printf('(a)Compression ratio is %3.2f \n (b)Temperature at the end of compression is %3.1f K\n (c)Temperature at the end of comstant pressure heat addition is %3.0f K \n (d)Air standard efficiency is %3.2f percent',r1,T2,T3,n)
```

Scilab code Exa 1.22 Air standard efficiency

```
clc
clear
//Input data
r=12;//Compression ratio of an oil engine, working
   on the combustion cycle
r1=1.4;//Isentropic ratio
P1=1;//Pressure at the
P3=35;//Pressure at the end of constant volume heat
   addition in bar

//Calculations
rho=1+(1/10)*(r-1);//Cut off ratio at 1/10th of the
   stroke
P2=P1*(r)^r1;//Pressure at the end of isentropic
   compression in bar
a=P3/P2;//Pressure ratio
n=(1-(1/r^(r1-1))*(a*rho^r1-1)/((a-1)+(r1*a*(rho-1))
   ))*100;//Air standard efficiency in percent

//Output
printf('The air standard efficiency of an oil engine
    working on the combustion cycle is %3.2f percent
   ',n)
```

Scilab code Exa 1.23 Cut off ratio

```
clc
clear
//Input data
P1=1;//Pressure at the beginning of compression
   stroke of an oil engine working on a air standard
    dual cycle in bar
T1=303;//Temperature at the beginning of compression
    stroke in K
P3=40;//The maximum pressure reached in bar
```

```
T4=1673;//Maximum temperature reached in K
P4=P3;//Pressure at the start of constant pressure heat addition in bar
Cp=1.004;//Specific heat at constant pressure in kJ/kg K
Cv=0.717;//Specific heat at constant volume in kJ/kg K
r1=10;//Compression ratio

//Calculations
r=Cp/Cv;//Isentropic ratio
T2=T1*r1^(r-1);//Temperature at the end of compression stroke in K
P2=P1*r1^r;//Pressure at the end of compression stroke in bar
T3=T2*(P3/P2);//Temperature at the end of constant volume heat addition in K
rho=T4/T3;//Cut off ratio

//Output
printf('(a)Temperature at the end of constant volume heat addition is %3.1f K\n (b)Cut off ratio is %3.3f',T3,rho)
```

Scilab code Exa 1.24 `Work done`

```
clc
clear
//Input data
P1=1;//pressure at the beginning of compression stroke in bar
T1=298;//Temperature at the beginning of compression stroke in K
P3=38;//Pressure at the end of constant volume heat addition in bar
```

```
T4=1573;//Temperature at the end of constant volume heat addition in K
r=9.5;//Compression ratio
Cp=1.004;//Specific heat of air at constant pressure
Cv=0.717;//Specific heat of air at constant volume

//Calculations
r1=Cp/Cv;//Isentropic ratio
T2=T1*r^(r1-1);//Temperature at the end of compression stroke in K
P2=P1*r^r1;//Pressure at the end of compression stroke in bar
T3=T2*(P3/P2);//Temperature at the end of constant volume heat addition in K
rho=T4/T3;//Cut off ratio
T5=T4*(rho/r)^(r1-1);//Temperature at the end of expansion stroke in K
Qs=Cv*(T3-T2)+Cp*(T4-T3);//Heat supplied per kg in kJ
Qr=Cv*(T5-T1);//Heat rejected per kg in kJ
W=Qs-Qr;//Work done per kg of air in kJ
n=(W/Qs)*100;//Efficiency of the air standard dual cycle in percent

//Output
printf('(a)The work done per kg of air is %3.1f kJ\n (b)Cycle efficiency is %3.2f percent',W,n)
```

Scilab code Exa 1.25 `Cycle efficiency`

```
clc
clear
//Input data
r=10.5;//Compression ratio
P3=65;//Maximum pressure in bar
```

```
P4=P3;//Pressure at the end of constant volume heat
    addition in bar
qs=1650;//Heat supplied in kJ/kg
P1=1;//Pressure at the beginning of compression
    stroke in bar
T1=368;//Temperature at the beginning of compression
     stroke in K
Cp=1.004;//Specific heat of air at constant pressure
     in kJ/kg K
Cv=0.717;//Specific heat of air at constant volume
    in kJ/kg K

//Calculations
r1=Cp/Cv;//Compression ratio
P2=P1*r^r1;//Pressure at the end of compression
    stroke in bar
T2=T1*r^(r1-1);//Temperature at the end of
    compression stroke in K
T3=T2*(P3/P2);//Temperature at the end of constant
    volume heat addition in K
qv=Cv*(T3-T2);//Heat supplied at constant volume in
    kJ/kg
qp=qs-qv;//Heat supplied at constant pressure in kJ/
    kg
T4=(qp/Cp)+T3;//Temperature at the end of constant
    volume heat addition in K
rho=T4/T3;//Cut off ratio
T5=T4*(rho/r)^(r1-1);//Temperature at the end of
    expansion stroke in K
P5=P4*(rho/r)^r1;//Pressure at the end of expansion
    stroke in K
q=Cv*(T5-T1);//Heat rejected in kJ/kg
n=((qs-q)/qs)*100;//Efficiency of the cycle in
    percent

//Output
printf('(a)Pressure at the end of compression stroke
     is %3.1f bar\n (b)Temperature at the end of
```

```
compression stroke is %3.1f K\n (c)Temperature at the end of constant volume heat addition is %3.1f K\n (d)Temperature at the end of constant pressure heat addition is %3.2f K\n (e)Temperature at the end of expansion stroke is %3.2f K\n (e)Pressure at the end of expansion stroke is %3.2f bar\n (f)Efficiency of the cycle is %3.2f percent',P2,T2,T3,T4,T5,P5,n)
```

Scilab code Exa 1.26 `Air standard efficiency`

```
clc
clear
//Input data
r=8.5;//Compression ratio
e=5.5;//Expansion ratio
P1=1;//Pressure at the beginning of compression stroke in bar
T1=313;//Temperature at the beginning of compression stroke in K
n=1.3;//polytropic constant
Cp=1.004;//Specific heat of air at constant pressure in kJ/kg K
Cv=0.717;//Specific heat of air at constant volume in kJ/kg K

//Calculations
rho=r/e;//Cut off ratio
T2=T1*r^(n-1);//Temperature at the end of compression stroke in K
T3=(2*Cv*T2)/(2*Cv-Cp*rho+1);//Temperature at the end of constant volume heat addition in K
T4=rho*T3;//Temperature at the end of constant pressure heat addition in K
a=T3/T2;//Pressure ratio i.e.,P3/P2
```

```
n1=(1-(1/r^(n-1))*(a*rho^n-1)/((a-1)+(n*a*(rho-1))))
    *100;//Air standard efficiency in percent

//Output
printf('The air standard efficiency is %3.2f percent
    ',n1)
```

Scilab code Exa 1.27 `Ideal thermal efficiency`

```
clc
clear
//Input data
P1=1;//Initial pressure in a compression engine
    working on a dual combustion engine in bar
T1=300;//Initial Temperature in K
P2=25;//Pressure at the end of compression stroke in
     bar
Q=400;//Heat supplied per kg of air during constant
    volume heating in kJ/kg
P5=2.6;//Pressure at the end of isentropic expansion
     in bar
Cp=1.005;//Specific heat of air at constant pressure
     in kJ/kg K
Cv=0.715;//Specific heat of air at constant volume
    in kJ/kg K

//Calculations
r=Cp/Cv;//Isentropic index
r1=(P2/P1)^(1/r);//Compression ratio
T2=T1*(r1)^(r-1);//Temperature at the end of
    compression stroke in K
T3=(Q/Cv)+T2;//Temperature at the end of constant
    volume heat addition in K
a=T3/T2;//Pressure ratio
P3=a*P2;//Pressure ratio at the end of constant
```

```
volume heat addition in bar
P4=P3;//Pressure at the end of constant pressure heat addition in bar
x=(P5/P4)^(1/r);//Ratio of volume at the end of constant pressure heat addition to the volume at the end of isentropic expansion
rho=x*(r1);//Cut off ratio
n=(1-(1/r1^(r-1))*(a*rho^r-1)/((a-1)+(r*a*(rho-1))))*100;//Air standard efficiency in percent of a dual combustion engine

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

Scilab code Exa 1.28 Temperature

```
clc
clear
//Input data
P1=1;//Initial pressure of an enfine working on a dual combustion cycle in bar
T1=318;//Initial temperature before compression in K
r1=14;//Compression ratio
r=1.4;//Isentropic index
a=2;//Pressure ratio in the compression process
rho=2;//Cut off ratio

//Calculations
T2=T1*r1^(r-1);//Temperature at the end of compression stroke in K
T3=T2*a;//Temperature at the end of constant volume heat addition in K
T4=rho*T3;//Temperature at the end of constant pressure heat addition in K
```

```
T5=T4*(rho/r1)^(r-1);//Temperature at the end of isentropic compression in K
n=(1-((T5-T1)/(r*(T4-T3)+(T3-T2))))*100;//Efficiency of an engine working on a dual combustion cycle in percent

//Output
printf('(a)Temperature at the end of compression stroke is %3.0f K\n (b)Temperature at the end of constant volume heat addition is %3.0f K\n (c)Temperature at the end of constant pressure heat addition is %3.0f K\n (d)Temperature at the end of isentropic expansion process is %3.0f K\n (e)Efficiency of the cycle is %3.2f percent',T2,T3,T4,T5,n)
```

Scilab code Exa 1.29 Pressure ratio

```
clc
clear
//Input data
r=15;//Compression ratio
Vs=0.01;//Stroke volume in m^3
P1=1;//Initial pressure in bar
T1=310;//Initial temperature in K
P3=65;//Pressure in constant pressure heat addition stroke in bar
Cp=1;//Specific heat of air at constant pressure in kJ/kg K
Cv=0.714;//Specific heat of air at constant volume in kJ/kg K
R=287;//Molar gas constant

//Calculations
r1=Cp/Cv;//Isentropic index
```

```
P2=P1*(r)^r1;//Pressure at the end of compression stroke in bar
a=P3/P2;//Pressure ratio
rho=1+((5/100)*(r-1))
V2=Vs/(r-1);//Volume at the end of compression stroke in m^3
V1=Vs+V2;//Initial volume in m^3
m=P1*10^5*V1/(R*T1);//Mass of air contained in the cylinder in kg
T2=T1*r^(r1-1);//Temperature at the end of compression stroke in K
a=P3/P2;//Pressure ratio
T3=T2*a;//Temperature at the end of constant volume heat addition in K
T4=T3*rho;//Temperature at the end of constant pressure heat addition in K
T5=T4/(r/rho)^(r1-1);//Temperature at the end of isentropic expansion in K
Qs=(Cv*(T3-T2)+Cp*(T4-T3))*m;//Heat supplied in kJ
Qr=m*Cv*(T5-T1);//Heat rejected in kJ
W=Qs-Qr;//Work done per cycle in kJ
n=(W/Qs)*100;//Efficiency of the cycle in percent
Mep=(W/Vs)/100;//Mean effective pressure in bar

//Output
printf('(1)Pressure ratio is %3.3f\n (2)Cut off ratio is %3.2f\n (3)Heat supplied per cycle is %3.0f kJ\n (4)Heat rejected per cycle is %3.2f kJ\n (5)Work done per cycle is %3.2f kJ\n (6)Thermal efficiency of the cycle is %3.0f percent\n (7)Mass of air contained in the cylinder is %3.4f kg\n (8)Mean effective pressure is %3.2f bar',a,rho,Qs,Qr,W,n,m,Mep)
```

Scilab code Exa 1.30 Thermal efficiency

```
clc
clear
//Input data
P1=1;//Initial pressure of air received by gas
    turbine plant in bar
T1=310;//Initial tamperature in K
P2=5.5;//Pressure at the end of compression in bar
r=1.4;//isentropic index

//Calculations
rp=P2/P1;//pressure ratio
n=(1-(1/rp)^((r-1)/r))*100;//Thermal efficiency of
    the turbine in percent

//Output data
printf('Thermal efficiency of the turbine unit is %3
    .2f percent',n)
```

Scilab code Exa 1.31 Power developed

```
clc
clear
//Input data
P1=1;//Initial pressure of a simple closed cycle gas
     turbine plant in bar
T1=298;//Initial temperature in K
P2=5.1;//Pressure of gas after compression in bar
T3=1123;//Temperature at the end of compression in K
P3=P2;//Pressure at the end of constant pressure
    stroke
P4=1;//Pressure of hot air after expansion in the
    turbine in bar
r=1.4;//Isentropic constant
Cp=1.005;//Specific heat of air in kJ/kg K

```

```
//Calculations
T2=T1*(P2/P1)^((r-1)/r);//Temperature at the end of process 1-2 in K
T4=T3*(P4/P3)^((r-1)/r);//Temperature at the end of process 3-4 in K
Wt=Cp*(T3-T4);//Work done by the turbine in kJ/kg
Wc=Cp*(T2-T1);//Work required by the compressor in kJ/kg
W=Wt-Wc;//Net work done by the turbine in kJ/kg
P=1*W;//Power developed by the turbine assembly per kg per second in kW

//Output
printf('Power developed by the turbine assembly per kg of air supplied per second is %3.2f kW',P)
```

Scilab code Exa 1.32 `Maximum temperature`

```
clc
clear
//Input data
P1=1;//The pressure of air entering the compressor of a gas turbine plant operating on Brayton cycle in bar
T1=293;//Initial temperature in K
r=6.5;//Pressure ratio of the cycle
r1=1.4;//Isentropic ratio

//Calculations
T2=T1*(r)^((r1-1)/r1);//Temperature at the end of compression in K
T4=2.3*(T2-T1)/0.708;//Temperature at point 4 in K
T3=T4*(r)^((r1-1)/r1);//Maximum temperature in K
n=(1-((T4-T1)/(T3-T2)))*100;//Turbine plant efficiency in percent
```

```

//Output
printf('(a)The maximum temperature of the cycle is %3.1f K\n (b)Cycle efficiency is %3.2f percent',T3,n)
```

Scilab code Exa 1.33 `Air fuel ratio`

```
clc
clear
//Input data
P1=1;//Pressure in an oil gas turbine installation in bar
T1=298;//Initial Temperature in K
P2=4;//Pressure after compression in bar
CV=42100;//Calorific value of oil in kJ/kg
T3=813;//The temperature reached after compression in K
m=1.2;//Air flow rate in kg/s
Cp=1.05;//Specific heat of air at constant pressure in kJ/kg K
r=1.4;//Isentropic ratio

//Calculations
r1=P2/P1;//Pressure ratio
T2=(r1)^((r-1)/r)*T1;//Temperature at the end of compression stroke in K
T4=T3/(r1)^((r-1)/r);//Temperature at the end of isentropic expansion in K
Wt=m*Cp*(T3-T4);//Work done by the turbine in kJ/s or kW
Wc=m*Cp*(T2-T1);//Work to be supplied to the compressor in kJ/s or kW
Wn=Wt-Wc;//Net work done by the turbine unit in kW
qs=m*Cp*(T3-T2);//Heat supplied by the oil in kJ/s
```

```
M=qs/CV;//Mass of fuel burnt per second in kg/s
a=m/M;//Air fuel ratio

//Output
printf('(a)The net power output of the installation
    is %3.2f kW\n (b)Air fuel ratio is %3.1f',Wn,a)
```

Scilab code Exa 1.34 Net power

```
clc
clear
//Input data
T1=300;//Minimum temperature of the plant containing
    a two stage compressor with perfect intercooling
    and a single stage turbine in K
T5=1100;//Maximum temperature of the plant in K
P1=1;//Initial Pressure in bar
P5=15;//Final pressure in bar
Cp=1.05;//Specific heat of air in kJ/kg K
r=1.4;//Isentropic ratio
P6=P1;//Pressure at 6 in bar

//Calculations
P3=(P1*P5)^(1/2);//The intermediate pressure for
    cooling in bar
P2=P3;//Pressure at point 2 in bar
T2=T1*(P2/P1)^((r-1)/r);//Temperature at the end of
    process 1-2
T3=T1;//Intermediate temperature in K
T4=1.473*T3;//Temperature at point 4 in K
T6=T5/(P5/P6)^((r-1)/r);//Temperature at point 6 in
    k
Wt=Cp*(T5-T6);//Work done by the turbine per kg of
    air in kJ/s
Wc=Cp*(T4-T3)+Cp*(T2-T1);//Work done by the
```

```
   compressor per kg of air in kJ/s
Wn=Wt-Wc;//Net work done in kJ/s
Pn=Wn;//Net power developed in kW

//Output
printf('The net power of the plant per kg of air/s
   is %3.2f kW',Pn)
```

Scilab code Exa 1.35 Maximum power

```
clc
clear
//Input data
P1=1;//Initial Pressure of a gas turbine power plant
    in bar
P2=8;//Final pressure in bar
T1=300;//Initial temperature in K
T5=850;//Temperature of air expanded in the turbine
   in K
m=1.8;//Mass of air circulated per second in kg
Cp=1.05;//Specific heat of air at constant pressure
   in kJ/kg K
r=1.4;//Ratio of specific heat

//Calculations
P4=(P1*P2)^(0.5);//Pressure for maximum power output
    in bar
P3=P2;//Pressure after the constant pressure process
    in bar
T3=T5;//For reheating condition Temperature in K
T2=T1*(P2/P1)^((r-1)/r);//Temperature at the end of
   constant entropy process in K
T4=T3/((P3/P4)^((r-1)/r));//Temperature after the
   process 3-4 in K
T6=T4;//Temperature at the end of process 5-6 in K
```

```
Wt=m*Cp*((T3-T4)+(T5-T6));//Work done by the turbine
     in kJ/s
Wc=m*Cp*(T2-T1);//Work absorbed by the compressor in
     kJ/s
P=Wt-Wc;//Power that can be obtained from gas
    turbine installation in kW

//Output
printf('The maximum power that can be obtained from
    turbine installation is %3.0f kW',P)
```

Scilab code Exa 1.36 Mass of fluid

```
clc
clear
//Input data
P1=1.5;//Pressure at the inlet of the low pressure
    compressor in bar
T1=300;//Temperature at the inlet of the low
    pressure compressor in K
P5=9;//Maximum pressure in bar
T5=1000;//Maximum temperature in K
P=400;//Net power developed by the turbine in kW
Cp=1.0;//Specific heat of air at constant pressure
    in kJ/kg K
r=1.4;//Ratio of specific heat

//Calculations
P8=P1;//For perfect intercooling and perfect
    reheating in bar
P4=P5;//For perfect intercooling and perfect
    reheating in bar
P2=(P1*P4)^0.5;//Pressure at the end of Isentropic
    compression in LP compressor in bar
P6=P2;//Pressure at the end of process 5-6 in bar
```

```
T2=T1*(P2/P1)^((r-1)/r);//Temperature at the end of
    isentropic compression in K
T3=T1;//For perfect intercooling in K
T4=T2;//For perfect intercooling in K
T6=T5/(P5/P6)^((r-1)/r);//Temperature at the end of
    process 5-6 in K
T7=T5;//Temperature in K
T8=T6;//Temperature in K
Wt=Cp*((T5-T6)+(T7-T8));//Work done by the turbine
    in kg/s
Wc=Cp*((T2-T1)+(T4-T3));//Work absorbed by the
    compressor in kJ/s
Wn=Wt-Wc;//Net work output in kJ/s
m=P/Wn;//Mass of fluid flow per second in kg/s
qs=m*Cp*((T5-T4)+(T7-T6));//Heat supplied from the
    external source in kJ/s

//Output
printf('(a)Mass of fluid to be circulated in the
    turbine is %3.3f kg/s\n (b)The amount of heat
    supplied per second from the external source is
    %3.1f kJ/s',m,qs)
```

Scilab code Exa 1.37 Mass of air

```
clc
clear
//Input data
T1=293;//Temperature of a constant pressure open
    cycle gas turbine plant in K
T3=1043;//The maximum temperature in K
a=6.5;//The pressure ratio
P=1000;//Power developed by the installation in kW
Cp=1.05;//Specific heat at constant pressure in kJ/
    kg K
```

```
r=1.4;//Isentropic ratio

//Calculations
T2=T1*a^((r-1)/r);//Temperature after the isentropic
    compression stroke in K
T4=T3/a^((r-1)/r);//Temperature after the isentropic
    expansion process in K
Wt=Cp*(T3-T4);//Work done by the turbine per kg of
   air per second in kJ
Wc=Cp*(T2-T1);//Work absorbed by the compressor per
   kg of air per second in kJ
Wn=Wt-Wc;//Net work output in kJ/s
m=P/Wn;//Mass of fluid circulated per second in kg/s
Q=m*Cp*(T3-T2);//Heat supplied by the heating
   chamber in kJ/s

//Output
printf('(a)Mass of air circulating in the
   installation is %3.2f kg/s\n (b)Heat supplied by
   the heating chamber is %3.1f kJ/s',m,Q)
```

Scilab code Exa 1.38 `Overall efficiency`

```
clc
clear
//Input data
a=6;//Pressure ratio of a gas turbine plant
T1=293;//Inlet temperature of air in K
T3=923;//Maximum temperature of the cycle in K
P=2000;//Power developed in the cycle in kW
nc=85;//Efficiency of the compressor in percentage
nt=85;//Efficiency of the turbine in percentage
Cp=1;//Specific heat of gas at constant pressure in
   kJ/kg K
Cv=0.714;//Specific heat of gas at constant volume
```

```
in kJ/kg K

//Calculations
r=Cp/Cv;//Ratio of specific heats
T2a=a^((r-1)/r)*T1;//Temperature at 2' in K
T2=((T2a-T1)/(nc/100))+T1;//Temperature at point 2 in K
T4a=T3/a^((r-1)/r);//Temperature at the point 4' in K
T4=T3-((T3-T4a)*(nt/100));//Temperature at the point 4 in K
Wt=Cp*(T3-T4);//Work done by the turbine per kg of air in kJ
Wc=Cp*(T2-T1);//Work done by the compressor per kg of air in kJ
Wn=Wt-Wc;//Net work output of the turbine per kg of air in kJ
qA=Cp*(T3-T2);//Heat supplied per kg of air in kJ
n=(Wn/qA)*100;//Overall efficiency of the turbine plant in percentage
m=P/Wn;//Mass of air circulated per second in kg

//Output
printf('(1)Overall efficiency of the turbine is %3.0f percentage\n (2)Mass of air circulated by the turbine is %3.2f kg',n,m)
```

Scilab code Exa 1.39 Isentropic efficiency

```
clc
clear
//Input data
T1=293;//Initial temperature of a gas turbine plant in K
P1=1;//Initial pressure in bar
```

```
P2=4.5;//Pressure after the compression in bar
nc=80;//Isentropic efficiency of a compressor in percentage
T3=923;//Temperature of the gas whose properties may be assumed to resemble with those of air in the combustion chamber in K
deltaP=0.1;//Pressure drop in a combustion chamber in bar
nt=20;//Thermal efficiency of the plant in percentage
r=1.4;//Isentropic index
P4=1;//Pressure at point 4 in bar

//Calculations
P3=P2-deltaP;//Pressure at point 3 in bar
T21=T1*(P2/P1)^((r-1)/r);//Temperature after the compression process in K
T2=(T21-T1)/(nc/100)+T1;//Temperature at the point 2 in K
T41=T3/(P3/P4)^((r-1)/r);//Temperature at the end of expansion process in K
Ac=T2-T1;//Work done by the compressor per kg of air per specific heat at constant pressure Ac=Wc/Cp
At=T3;//Work done by the turbine per kg of air per specific heat at constant pressure At=Wt/Cp
An=At-Ac;//Net work done per kg of air
Bs=T3-T2;//Heat supplied per kg of air per specific heat at constant pressure Bs=qs/Cp;qs=heat supplied
T4=An-((nt/100)*Bs);//Temperature at point 4 in K
nT=((T3-T4)/(T3-T41))*100;//Isentropic efficiency of the turbine in percentage

//Output
printf('The isentropic efficiency of the turbine is %3.2f percent',nT)
```

Scilab code Exa 1.40 Overall efficiency

```
clc
clear
//Input data
P1=1;//Pressure of air received by the gas turbine
    plant in bar
T1=300;//Initial Temperature in K
P2=5;//Pressure of air after compression in bar
T3=850;//Temperature of air after the compression in
     K
nc=80;//Efficiency of the compressor in percent
nt=85;//Efficiency of the turbine in percent
r=1.4;//Isentropic index of gas
P3=P2;//Since 2-3 is constant pressure process in
    bar
P41=1;//Pressure at the point 41 in bar
Cp=1.05;//Specific heat of the gas at constant
    pressure in kJ/kg K

//Calculations
T21=T1*(P2/P1)^((r-1)/r);//Temperature at the point
    21 on the curve in K
T2=(T21-T1)/(nc/100)+T1;//Temperature at the point 2
     in K
T41=T3/(P3/P41)^((r-1)/r);//Temperature at the point
     41 in K
T4=T3-((nt/100)*(T3-T41));//Temperature of gas at
    the point 4 in K
Wt=Cp*(T3-T4);//work done by the turbine in kJ/kg of
     air
Wc=Cp*(T2-T1);//Work done by the compressor in kJ/kg
     of air
Wn=Wt-Wc;//Net work done by the plant in kJ
```

```
nt=(Wn/(Cp*(T3-T2)))*100;//Thermal efficiency of the plant in percentage

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

Scilab code Exa 1.41 `Overall efficiency`

```
clc
clear
//Input data
P1=1;//Initial pressure of a gas turbine plant in bar
T1=310;//Initial temperature in K
P2=4;//Pressure of air after compressing in a rotary compressor in bar
P3=P2;//Constant pressure process
P41=P1;//Since 1-41 is a constant pressure process in bar
T3=900;//Temperature of air at the point 3 in constant process in K
nc=80;//Efficiency of the compressor in percentage
nt=85;//Efficiency of the turbine in percentage
E=70;//Effectiveness of the plant in percentage
r=1.4;//Isentropic index
Cp=1;//Specific heat of air at constant pressure in kJ/kg K

//Calculations
T21=T1*(P2/P1)^((r-1)/r);//Temperature at the point 21 in the temperature versus entropy graph in K
T2=T1+((T21-T1)/(nc/100));//Temperature of air after the compression process in K
T41=T3/((P3/P41)^((r-1)/r));//Temperature at the
```

```
point 41 after the isentropic expansion process in K
T4=T3-((T3-T41)*(nt/100));//Temperature at the point 4 in K
Wt=Cp*(T3-T4);//Work done by the turbine in kJ
Wc=Cp*(T2-T1);//Work done by the compressor in kJ
Wn=Wt-Wc;//Net work done in kJ
qs=Cp*(T3-T2);//Heat supplied in kJ
qa=Cp*(T4-T2);//Heat available in the exhaust gases in kJ
H=qa*(E/100);//Actual heat recovered from the exhaust gases in the heat exchanger in kJ
Hs=qs-(H);//Heat supplied by the combustion chamber in kJ
nt=(Wn/Hs)*100;//Thermal efficiency of the gas turbine plant with heat exchanger in percent

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

Chapter 7

Performance of IC engines

Scilab code Exa 7.1 Brake torque

```
clc
clear
//Input data
N=1500;//Engine speed in rpm
p=110;//Load on brakes in kg
L=900;//Length of brake arm in mm
g=9.81;//Gravitational force in N/m^2
pi=3.14;//Mathematical constant

//Calculations
T=((p*g)*(L/1000));//Braking torque in Nm
P=((T/1000)*((2*3.14*N)/60));//Power available at
   the brakes of the engine in kW

//Output
printf('(a) Brake torque is %3.1f Nm \n (b)Power
   available at the brakes of the engine is %3.2f kW
   ',T,P)
```

Scilab code Exa 7.2 `Power available at brakes`

```
clc
clear
//Input data
N=700;//Engine speed in rpm
D=0.6;//Diameter of brake drum in m
d=0.05;//Diameter of rope in m
W=35;//Dead load on the brake drum in kg
S=4.5;//Spring balance reading in kg
g=9.81;//Gravitational constant in N/m^2
pi=3.14;//Mathematical constant

//Calculations
P=(((W-S)*g*pi*(D+d))/1000)*(N/60);//Power in kW

//Output
printf('The power available at the brakes is %3.3f
   kW',P)
```

Scilab code Exa 7.3 `Brake thermal efficiency`

```
clc
clear
//Input data
W=950;//Load on hydraulic dynamometer in N
C=7500;//Dynamometer constant
f=10.5;//Fuel used per hour in kg
h=50000;//Calorific value of fuel in kJ/kg
N=400;//Engine speed in rpm

//Calculations
P=(W*N)/C;//Power available at the brakes in kW
H=P*60;//Heat equivalent of power at brakes in kJ/
    min
```

```
Hf=(f*h)/60;//Heat supplied by fuel per minute in kJ/min
n=(H/Hf)*100;//Brake thermal efficiency in percentage

//Output
printf(' Brake thermal efficiency of the engine is %3.2f percent',n)
```

Scilab code Exa 7.4 Specific fuel consumption

```
clc
clear
//Input data
n1=50.5;//Air standard efficiency in percentage
n2=50;//Brake thermal efficiency in percentage
N=3000;//Engine speed in rpm
H=10500;//Heating value of fuel in kcal/kg
T=7.2;//Torque developed in kgf*m
B=6.3;//Bore diameter in cm
S=0.095;//stroke in m

//Calculations
nbt=(n1/100)*(n2/100);//Brake thermal efficiency in percentage
B1=(2*(22/7)*N*T)/4500;//Brake horse power in kW
B2=B1/4;//Brake horse power per cylinder in kW
Bsf=(4500*60)/(H*427*nbt);//Brake specific fuel consumption in kg/BHP hr
bmep=(B2*4500)/(S*(3.14*B^2/4)*(N/2));//Brake mean effective pressure in kgf/cm^2

//Output
printf('(a)Specific fuel consumption is %3.3f kg/BHP hr\n (b)Brake mean effective pressure is %3.3f
```

```
kgf/cm^2',Bsf,bmep)
```

Scilab code Exa 7.5 Mechanical efficiency

```
clc
clear
//Input data
W=30;//The net dynamometer load in kg
R=0.5;//Radius in m
N=2400;//Speed in rpm
FHP=6.5;//Engine power in hp

//Calculations
BHP=(2*3.14*R*N*W)/4500;//Brake horse power in kW
IHP=BHP+FHP;//Indicated horse power in kW
nm=(BHP/IHP)*100;//Mechanical efficiency in
    percentage

//Output
printf('Mechanical efficiency of the engine is %3.2f
    percent',nm)
```

Scilab code Exa 7.6 IHP

```
clc
clear
//Input data
d=25;//Diameter of cylinder in cm
l=0.4;//Stroke of piston in m
N=200;//Speed in rpm
m=10;//Misfires per minute
M=6.2;//Mean effective pressure in kgf/cm^2
nm=0.8;//Mechanical efficiency in percent
```

```

//Calculations
np=(N/2)-m;//Number of power strokes per minute
A=(3.14*d^2)/4;//Area of the cylinder
I=(M*l*A*np)/4500;//Indicated horse power in kW
B=I*nm;//Brake horse power in kW
F=I-B;//Friction horse power in kW

//Output
printf('(a)The indicated horse power is %3.2f kW \n
    (b)The brake horse power is %3.2f kW \n (c)
    Friction horse power is %3.2f kW',I,B,F)
```

Scilab code Exa 7.7 `Average piston speed`

```
clc
clear
//Input data
I=5;//Indicated power developed by single cylinder
    of 2 stroke petrol engine
M=6.5;//Mean effective pressure in bar
d=0.1;//Diameter of piston in m

//Calculations
A=(3.14*d^2)/4;//Area of the cylinder
LN=(I*1000*60)/(M*10^5*A);//Product of length of
    stroke and engine speed
S=2*LN;//Average piston speed in m/s

//Output
printf('The average piston speed is %3.2f m/s',S)
```

Scilab code Exa 7.8 `Dimensions of cylinder`

```
clc
clear
//Input data
P=60;//Power developed by oil engine in kW
M=6.5;//Mean effective pressure in kgf/cm^2
N=85;//Number of explosions per minute
r=1.75;//Ratio of stroke to bore diameter
nm=0.8;//Mechanical efficiency

//Calculations
I=P/nm;//Indicated horse power
d=((I*100*4*4500)/(M*r*3.14*N))^(1/3);//Bore
    diameter in cm
l=r*d;//Stroke length in cm

//Output
printf('(a)Diameter of the bore is %3.2f cm \n (b)
    Stroke length of the piston is %3.2f cm',d,l)
```

Scilab code Exa 7.9 Bore and stroke of piston

```
clc
clear
//Input data
I=45;//Power developed by two cylinder internal
    combustion engine operating on two stroke
    principle
N=1100;//Speed in rpm
M=6;//Mean effective pressure in kgf/cm^2
r=1.3;//Ratio of stroke to the bore
nc=2;//Number of cylinders

//Calculations
d=((I*4500*4)/(M*(r/100)*3.14*N*nc))^(1/3);//
    Diameter of the bore in cm
```

```
l=1.3*d;//Stroke length in cm

//Output
printf('(a)The bore diameter of the cylinder is %3.2f cm\n (b)Stroke length of the piston is %3.2f cm',d,l)
```

Scilab code Exa 7.10 `Volumetric efficiency`

```
clc
clear
//Input data
d=6;//Diameter of the bore in cm
l=9;//Length of the stroke in cm
m=0.00025;//Mass of charge admitted in each suction stroke
R=29.27;//Gas constant Kgfm/kg K
p=1;//Normal pressure in kgf/cm^2
T=273;//Temperature in K

//Calculations
V=(m*R*T)*10^6/(p*10^4);//Volume of charge admitted in each cycle in m^3
Vs=(3.14*d^2*l)/4;//Swept volume of the cylinder
nv=(V/Vs)*100;//Volumetric efficiency in percentage

//Output
printf('The volumetric efficiency is %3.1f percent',nv)
```

Scilab code Exa 7.11 `Volumetric efficiency`

```
clc
```

```
clear
//Input data
d=0.12;//Diameter of the bore in m
l=0.13;//Length of stroke in m
N=2500;//Speed of the engine in rpm
d1=0.06;//Diameter of the orifice in m
Cd=0.70;//Discharge coefficient of orifice
hw=33;//Heat causing air flow through orifice in cm of water
p=760;//Barometric reading in mm of Hg
T1=298;//Ambient temperature in degree K
p1=1.013;//Pressure of air at the end of suction in bar
T2=22;//Temperature of air at the end of suction in degree C
R=0.287;//Universal gas constant
n=6;//Number of cylinders in the engine
n1=1250;//Number of strokes per minute for a four stroke engine operating at 2500 rpm

//Calculations
V=(3.14*d^2*l)/4;//Swept volume of piston in m^3
Ao=(3.14*d1^2)/4;//Area of the orifice in m^2
rho=p1*10^5/((R*T1)*1000);//Density of air at 1.013 bar and 22 degrees C
Va=840*Cd*Ao*(hw/rho)^(1/2);//Volume of air passing through the orifice in m^3/min
V1=8.734/n;//Actual volume of air per cylinder in m^3/min
As=V1/n1;//Air supplied per cycle per cylinder in m^3
nv=(As/V)*100;//Volumetric efficiency of the engine in percentage

//Output
printf('The volumetric efficiency of the engine is %3.2f percent',nv)
```

Scilab code Exa 7.12 Air standard efficiency

```
clc
clear
//Input data
d=0.15;//Diameter of the piston in m
l=0.19;//Length of the stroke in m
V=0.00091;//Clearance volume in m^3
N=250;//Speed of the engine in rpm
M=6.5;//Indicated mean effective pressure in bar
c=6.3;//Gas consumption in m^3/hr
H=16000;//Calorific value of the has in kJ/m^3
r1=1.4;//Polytropic index

//Calculations
Vs=(3.14*d^2*l)/4;//Swept volume in m^3
Vt=Vs+V;//Total cylinder volume in m^3
r=Vt/V;//Compression ratio
na=(1-(1/r^(r1-1)))*100;//Air standard efficiency in
    percent
A=(3.14*d^2)/4;//Area of the bore in m
I=(M*10^5*l*A*N)/(1000*60);//Indicated power in kW
Hs=(c*H)/(60*60);//Heat supplied per second
nt=(I/Hs)*100;//Indicated thermal efficiency in
   percent

//Output
printf('(a)The air standard efficiency is %3.1f
   percent\n (b)Indicated power is %3.3f kW\n (c)
   Indicated thermal efficiency is %3.1f percent',na
   ,I,nt)
```

Scilab code Exa 7.13 Diameter of venturi

```
clc
clear
//Input data
ma=6;//Air supplied per minute by a single jet
    carburetor in kg/min
mf=0.44;//Mass flow rate of petrol in kg/min
s=0.74;//Specific gravity of petrol in kg/m^3
p1=1;//Initial pressure of air in bar
T1=300;//Initial temperature of air in K
Ci=1.35;//Isentropic coefficient of air
V=90;//Speed of air in the venturi in m/s
Vc=0.85;//Velocity coefficient of the venturi in m/s
Cf=0.66;//Coefficient of discharge for the jet
Cp=1005;//Coefficient of pressure in J/kg K
n=1.35;//Isentropic coefficient of air
R=0.281;//Real gas constant in Nm/kg K
rhof=740;//Density of fuel in mm of Hg

//Calculations
p2=(1-((V/Vc)^(2)/(2*T1*Cp)))^((n)/(n-1));//Pressure
     at the venturi in bar
V1=((R*T1)/(p1*10^5))*1000;//Initial volume in m^3/
    kg
V2=V1*((p1/p2)^(0.741));//Final volume in m^3/kg
A2=((ma*V2)/(V*60))*10^4;//Throat area of venturi in
     cm^2
d=((A2*4)/3.14)^(0.5);//Diameter of venturi in cm
deltaPa=1-p2;//Pressure drop causing air flow in bar
deltaPf=0.8*deltaPa;//Pressure drop causing fuel
    flow in bar
Af=(mf/60)*(10^4)/((Cf)*(2*rhof*deltaPf*10^5)^(1/2))
    ;//Area through which fuel flows in cm^2
df=((Af*(4/3.14))^(1/2))*10;//Diameter of fuel jet
    in mm

printf('(a)The diameter of the venturi of the
```

```
venturi if the air speed is 90 m/s is %3.2f cm\n
(b)The diameter of the jet if the pressure drop
at the jet is 0.8 times the pressure drop at the
venturi is %3.4f mm',d,df)
```

Scilab code Exa 7.14 Fuel supplied

```
clc
clear
//Input data
r=14;//The compression ratio of a diesel engine
Vc=1;//Clearance volume in m^3
c=0.08;//Fuel supply cut off point
nr=0.55;//Relative efficiency
H=10000;//Calorific value of fuel in kcal/kg
r1=1.4;//Ratio of specific heat of air
Vs=13;//Stroke volume in m^3

//Calculations
rho=Vc+(c*Vs);//Cut off ratio
na=1-(1*(rho^r1-1)/((r^(r1-1)*r1)*(rho-1)));//Air
   standard efficiency of diesel cycle in percent
In=(na*nr);//Indicated thermal efficiency in percent
H1=(4500*60)/(In*427);//Heat in fuel supplied/1HP hr
W=H1/10^4;//Weight of fuel required/1HP hr

//Output
printf('The weight of fuel required per 1HP hr is %3
   .4f kg',W)
```

Scilab code Exa 7.15 Fuel to be injected

```
clc
```

```
clear
//Input data
P=120;//Power developed by a six cykinder four stroke diesel engine
N=2400;//Speed in rpm
f=0.2;//Brake specific fuel consumption in kg/kWh
s=0.85;//Specific gravity of fuel

//Calculations
F=f*P;//Fuel consumed per hour in kg
F1=F/6;//Fuel consumed per cylinder in kg/h
n=(N*60)/2;//Number of cycles per hour
F2=(F1/n)*10^3;//Fuel consumption per cycle in gm
V=F2/s;//Volume of fuel to be injected per cycle in cc

//Output
printf('The quantity kof fuel to be injected per cycle per cylinder is %3.4f cc',V)
```

Scilab code Exa 7.16 Diameter of orifice

```
clc
clear
//Input data
P=20;//Power developed by a four stroke diesel engine per cylinder in kW
N=2000;//Operating speed of the diesel engine in rpm
s=0.25;//Specific fuel consumption in kh/kW
p1=180;//Pressure of fuel injected in bar
d=25;//Distance travelled by crank in degrees
p2=38;//Pressure in the combustion chamber in bar
Cd=0.85;//Coefficient of velocity
A=30;//API in degrees

```

```
//Calculations
T=d/(360*(N/60));//Duration of fuel injection in s
SG=(141.5/(131.5+A))*10^3;//Specific gravity of fuel
V=Cd*(2*(p1-p2)*10^5/SG)^(1/2);//Velocity of fuel
    injection in m/s
Vf=(s/60)*P/((N/2)*SG);//Volume of fuel injected per
     cycle in m^3/cycle
Na=Vf/(V*T);//Nozzle orifice area in m^2
d=(((4*Na)/3.14)^(1/2))*10^3;//Diameter of the
    orifice of the fuel injector in mm

//Output
printf('The diameter of the orifice is %3.4f mm',d)
```

Scilab code Exa 7.17 Total orifice area

```
clc
clear
//Input data
P=200;//Power developed by a six cylinder diesel
    engine in kW
N=2000;//Operating speed of the engine in rpm
bs=0.2;//The brake specific fuel consumption in kg/
    kWh
p1=35;//The pressure of air in the cylinder at the
    beginning of injection in bar
p2=55;//Maximum cylinder pressure in bar
p3=180;//Initial injection pressure in bar
p4=520;//Maximum pressure at the injector in bar
Cd=0.75;//Coefficient of discharge
S=850;//Specific gravity of fuel
p5=1;//Atmospheric pressure in bar
a=16;//The crank angle over which injection takes
    place in degrees

```

```
//Calculations
Po=P/6;//Power output per cylinder in kW
F=(Po*bs)/60;//Fuel consumed per cylinder in kg/min
Fi=F/(N/2);//Fuel injected per cycle in kg
T=a/(360*(N/60));//Duration of injection in s
deltaP1=p3-p1;//Pressure difference at the beginning of injection in bar
deltaP2=p4-p2;//Pressure difference at the end of injection in bar
avP=(deltaP1+deltaP2)/2;//Average pressure difference in bar
V=Cd*(2*(avP*10^5)/S)^(1/2);//Velocity of injection of fuel jet in m/s
Vo=Fi/S;//Volume of fuel injected per cycle in m^3/cycle
A=(Vo/(V*T))*10^6;//Area of fuel orifices in mm^2

//Output
printf('The total orifice area required per injector if the injection takes place over 16 degree crank angle is %3.4f mm^2',A)
```

Scilab code Exa 7.18 Indicated power

```
clc
clear
//Input data
A=450;//Area of indicator diagram in mm^2
l=60;//Length of indicator diagram in mm
s=1.1;//Spring number in bar/mm
d=0.1;//Diameter of piston in m
L=0.13;//Length of stroke in m
N=400;//Operating speed of the engine in rpm

//Calculations
```

```
Av=A/l;//Average height of indicator diagram in mm
pm=Av*s;//Mean effective pressure in bar
np=N/2;//Number of power strokes per minute for a
    four stroke diesel engine
Ar=(3.14*d^2)/4;//Area of the piston in m^2
I=(pm*10^5*L*Ar*np)/(1000*60);//Indicated power in
    kW

//Output
printf('(a)The indicated mean effective pressure is
    %3.2f bar\n (b)Indicated power is %3.2f kW',pm,I)
```

Scilab code Exa 7.19 BHP

```
clc
clear
//Input data
d=25;//Diameter of the bore in cm
l=0.4;//Stroke length in m
N=300;//Operating speed of the engine in rpm
n=120;//Number of explosions per minute
pm=6.7;//Mean effective pressure in kgf/cm^2
Tnet=90;//Net brake load in kg
R=0.75;//Radius of brake drum in m
f=0.22;//Fuel supplied per minute in m^3
C=4500;//Calorific value of fuel in kcal/m^3

//Calculations
BHP=(2*3.14*R*N*Tnet)/4500;//Brake horse power in kW
A=(3.14*d^2)/4;//Area of the cylinder in cm^2
IHP=(pm*l*A*n)/4500;//Indicated horse power in kW
H=f*C;//Heat supplied by fuel per minute in kcal
nt1=((IHP*C)/(990*427))*100;//Thermal efficiency on
    IHP basis in percent
nt2=((BHP*C)/(990*427))*100;//Thermal efficiency on
```

```
BHP basis in percent

//Output
printf('(a)The brake horse power is %3.2f kW\n (b)Indicated horse power is %3.3f kW\n (c)Thermal efficiency on IHP basis is %3.2f percent\n (d)Thermal efficiency on BHP basis is %3.2f percent',BHP,IHP,nt1,nt2)
```

Scilab code Exa 7.20 IHP

```
clc
clear
//Input data
D=0.6;//Brake wheel diameter of a constant speed compression ignition engine operating on four stroke cycle in m
t=0.01;//Thickness of brake band in m
N=500;//Operating speed of the engine in rpm
W=20;//Load on brake band in kgf
S=3;//Spring balance reading in kgf
l=6.25;//Length of indicator diagram in cm
A=4.35;//Area of indicator diagram in cm^2
Sn=11;//Spring number in kgf/cm^2/cm
d=10;//Diameter of the bore in cm
L=0.13;//Length of the stroke in m
F=0.23;//Specific fuel consumption in kg/BHP hr
CV=10000;//Heating value of fuel in kcal/kg

//Calculations
BHP=(3.14*(D+t)*N*(W-S))/4500;//Brake horse power in kW
MEP=(A*Sn)/l;//Mean effective pressure in kgf/cm^2
Ar=(3.14*d^2)/4;//Area of the cylinder in cm^2
np=N/2;//Number of explosions per minute
```

```
IHP=(MEP*L*Ar*np)/4500;//Indicated horse power in kW
nm=(BHP/IHP)*100;//Mechanical efficiency in percentage
Wf=F*BHP;//Fuel consumption per hr in kg/hr
nt=((IHP*4500*60)/(Wf*CV*427))*100;//Indicated thermal efficiency in percentage
nb=((BHP*4500*60)/(Wf*CV*427))*100;//Brake thermal efficiency in kW

//Output
printf('(a)The brake horse power is %3.2f kW\n (b)Indicated horse power is %3.3f kW\n (c)Mechanical efficiency is %3.1f percent\n (d)Indicated thermal efficiency is %3.0f percent\n (e)Brake thermal efficiency is %3.1f percent',BHP,IHP,nm,nt,nb)
```

Scilab code Exa 7.21 Indicated thermal efficiency

```
clc
clear
//Input data
N=1200;//Operating speed of a four cylinder engine in rpm
BHP=25.3;//The brake horse power when all 4 cylinders are operating in kW
T=10.5;//The average torque when one cylinder was cut out in mkgf
CV=10000;//Calorific value of the fuel used in kcal/kg
f=0.25;//The amount of petrol used in engine per BHP hour
J=427;//

//Calculations
```

```
BHP1=(2*3.14*N*T)/4500;//BHP for 3 cylinders when 1
    cylinder is cut out in kW
IHP=BHP-BHP1;//IHP of one cylinder in kW
IHPt=IHP*4;//Total IHP of the engine with 4
    cylinders
Wf=(f*BHP)/60;//Fuel used per minute in kg
ni=((IHPt*4500)/(Wf*CV*J))*100;//Indicated thermal
    efficiency in percent
nm=(BHP/IHPt)*100;//Mechanical efficiency in percent
nb=(IHPt*nm)/100;//Brake thermal efficiency in
    percent

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

Scilab code Exa 7.22 IHP

```
clc
clear
//Input data
B=32;//Brake horse power in kW with all cylinders
    working
B1=21.6;//BHP with number 1 cylinder cut out in kW
B2=22.3;//BHP with number 2 cylinder cut out in kW
B3=22.5;//BHP with number 3 cylinder cut out in kW
B4=23;//BHP with number 4 cylinder cut out in kW

//Calculations
I1=B-B1;//Indicated horse power of number 1 cylinder
     in kW
I2=B-B2;//IHP of number 2 cylinder in kW
I3=B-B3;//IHP of number 3 cylinder in kW
I4=B-B4;//IHP of number 4 cylinder in kW
I=I1+I2+I3+I4;//Total IHP of the engine in kW
```

```
nm=(B/I)*100;//Mechanical efficiency in percent

//Output
printf('(a)The IHP of the engine is %3.1f kW\n (b)
   Mechanical efficiency is %3.1f percent',I,nm)
```

Scilab code Exa 7.23 Compression ratio

```
clc
clear
//Input data
r=15;//The air fuel ratio by weight
CV=45000;//Calorific value of fuel in kJ/kg
nm=85;//Mechanical efficiency of 4 stroke 4 cylinder
    engine in percent
na=53;//Air standard efficiency of the engine in
   percent
nr=65;//Relative efficiency of the engine in percent
nv=80;//Volumetric efficiency of the engine in
   percent
r1=1.3;//Stroke to bore ratio
p1=1;//Suction pressure in bar
T=303;//Suction temperature in K
S=3000;//The operating speed of the engine in rpm
P=75;//Power at brakes in kW
r2=1.4;//Ratio of specific heats for air
R1=0.287;//Characteristic gas constant for air fuel
   mixture in kJ/kg K

//Calculations
R=(1/(1-(na/100)))^(1/(r2-1));//Compression ratio of
    the engine
nti=((na/100)*(nr/100))*100;//The indicated thermal
   efficiency in percent
Pi=P/(nm/100);//Indicated power in kW
```

```
F=Pi/((nti*CV)/100);//Fuel per second injected in kg/sec
B=F/P;//Brake specific fuel consumption in kg/kWsec
A=1+r;//Mass of fuel mixture entering the engine foe every one kg of fuel in kg
m=A*F;//Mass of air fuel mixture per second in kg
V=(m*R1*T)/(p1*10^5/1000);//Volume of air fuel mixture supplied to the engine per sec
Vs=V/(nv/100);//Swept volume per second in m^3/sec
d=((Vs*2*60*4)/(S*3.14*r1*4))^(1/3)*1000;//Diameter of the bore in mm
L=r1*d;//Stroke length in mm

//Output
printf('(a)Compression ratio is %3.1f \n (b)Indicated thermal efficiency is %3.1f percent\n (c)Brake specific fuel consumption is %3.7f kg/kWsec\n (d)Bore diameter of the engine is %3.1f mm\n (e)Stroke length of the engine is %3.1f mm',R,nti,B,d,L)
```

Scilab code Exa 7.24 Heat balance

```
clc
clear
//Input data
d=0.3;//Diameter of the bore in m
L=0.45;//Stroke length in m
N=220;//Operating speed of the engine in rpm
T=3600;//Duration of trial in sec
F=7;//Fuel consumption in kg per minute
CV=45000;//Calorific value of fuel in kJ/kg
A=320;//Area of indicator diagram in mm^2
l=60;//Length of indicator diagram in mm
S=1.1;//Spring index in bar/mm
```

```
W=130;//Net load on brakes in kg
D=1.65;//Diameter of brake drum in m
W1=500;//Total weight of jacket cooling water in kg
t=40;//Temperature rise of jacket cooling water in
    degrees celsius
t1=300;//Temperature of exhaust gases in degrees
    celsius
ma=300;//Air consumption in kg
sg=1.004;//Specific heat of exhaust gas in kJ/kgK
sw=4.185;//Specific heat of water in kJ/kgK
t2=25;//Room temperature in degrees celsius
g=9.81;//gravity

//Calculations
P=(W*g*3.14*D*N)/(1000*60);//Power available at
    brakes in kW
pm=(A*S)/l;//Mean effective pressure in bar
I=(pm*10^5*L*((3.14*d^2)/4)*N)/(1000*2*60);//
    Indicated power developed in kW
nm=(P/I)*100;//Mechanical efficiency in percent
nt=(P/((F/T)*CV))*100;//Brake thermal efficiency in
    percent
ni=(I/((F/T)*CV))*100;//Indicated thermal efficiency
     in percent
Hs=F*CV;//Heat supplied on one hour basis
Hp=P*T;//Heat equivalent of brake power in kJ
Hf=I-P;//Heat lost in friction in kJ
Hc=W1*t*sw;//Heat carried away by cooling water in
    kJ
He=(ma+F)*(t1-t2)*sg;//Heat carried away by exhaust
    gas in kJ
Hu=Hs-(He+Hf+Hc+He);//Heat unaccounted in kJ
nb=(He/Hs)*100;//Heat equivalent of power at brakes
    in percent
nf=(Hf/Hs)*100;//Heat lost in friction in percent
nw=(Hc/Hs)*100;//Heat removed by jacket water in
    percent
ne=(He/Hs)*100;//Heat carried away by exhaust gases
```

```
in percent
nu=(Hu/Hs)*100;//Heat unaccounted in percent

//Output
printf('(a)Power available at brakes is %3.2f kW\n (b)Indicated power developed is %3.2f kW\n (c) Mechanical efficiency is %3.2f percent\n (d)Brake Thermal efficiency is %3.2f percent\n (e) Indicated thermal efficiency is %3.2f percent',P,I,nm,nt,ni)
```

Scilab code Exa 7.25 BHP

```
clc
clear
//Input data
d=25;//The bore diameter of a single cylinder 4 stroke engine in cm
l=0.38;//Stroke length in m
t=3600;//Duration of test in sec
r=19710;//Total number of revolutions
F=6.25;//Fuel oil used in kg
A=5.7;//Area of indicator diagram in cm^2
L=7.6;//Length of indicator diagram in cm
S=8.35;//Spring number in kgf/cm^3
P=63.5;//Net load on brake drum in kg
R=1.2;//Radius of brake drum in m
Ww=5.7;//Rate of coolant flow in kg/min
deltaT=44;//Temperature rise of coolant in degrees celsius
T1=15.5;//Atmospheric temperature in degrees celsius
As=30;//Air supplied per kg of fuel
CV=10600;//Calorific value of fuel in kcal/kg
Te=390;//Exhaust gas temperature in degrees celsius
sm=0.25;//Mean specific heat of exhaust gas
```

```
//Calculations
Hs=(F*CV)/60;//Heat supplied by fuel per minute in
    kcal
pm=(A*S)/L;//Mean effective pressure in kgf/cm^2
I=(pm*l*(3.14*d^2)*r)/(4*60*2*4500);//Indicated
    horse power in kW
B=(P*R*2*3.14*r)/(4500*60);//Brake horse power in kW
Hei=(I*4500)/427;//Heat equivalent of IHP/min in
    kcal
Heb=(B*4500)/427;//Heat equivalent of BHP/min in
    kcal
Hf=Hei-Heb;//Heat in friction per minute in kcal
Hc=Ww*deltaT;//Heat carried away by coolant in kcal
We=(F+(As*F))/60;//Weight of exhaust gases per
    minute
He=We*(Te-T1)*sm;//Heat carried away by exhaust
    gases in kcal

//Output
printf('(a)Indicated horse power is %3.2f kcal\n (b)
    Brake horse power developed is %3.2f kcal\n (c)
    Heat equivalent of friction is %3.1f kcal',I,B,Hf
    )
```

Scilab code Exa 7.26 Percentage of heat carried away by exhaust gas

```
clc
clear
//Input
F=10;//Quantity of fuel supplied during the trial of
     a diesel engine in kg/hr
CV=42500;//Calorific value of fuel in kJ/kg
r=20;//Air fuel ratio
T=20;//Ambient temperature in degrees celsius
```

```
mw=585;//Water circulated through the gas
    calorimeter in litres/hr
T1=35;//Temperature rise of water through the
    calorimeter in degrees celsius
T2=95;//Temperature of gases at exit from the
    calorimeter in degrees celsius
se=1.05;//Specific heat of exhaust gases in kJ/kgK
sw=4.186;//Specific heat of water in kJ/kgK

//Calculations
M=(F/60)*(r+1);//Mass of exhaust gases formed per
    minute
H=((mw/60)*sw*T1)+(M*se*(T2-T));//Heat carried away
    by the exhaust gases per minute in kJ/min
Hs=(F/60)*CV;//Heat supplied by fuel per minute in
    kJ/min
nh=(H/Hs)*100;//Percentage of heat carried away by
    the exhaust gas

//Output
printf('Percentage of heat carried away by exhaust
    gas is %3.2f percent',nh)
```

Scilab code Exa 7.27 Percentage of heat carried away by exhaust gases

```
clc
clear
//Input data
F=11;//Fuel used per hour observed during the trial
    of a single cylinder four stroke diesel engine in
     kg
mc=85;//Carbon present in the fuel in percent
mh=14;//Hydrogen present in the fuel in percent
mn=1;//Non combustibles present in the fuel in
    percent
```

```
CV=50000;//Calorific value of fuel in kJ/kg
Vc=8.5;//Percentage of carbon dioxide present in exhaust gas by Volumetric analysis
Vo=10;//Oxygen present in exhaust gases in percent
Vn=81.5;//Nitrogen present in exhaust gases in percent
Te=400;//Temperature of exhaust gases in degrees celsius
se=1.05;//Specific heat of exhaust gas in kJ/kg
Pp=0.030;//Partial pressure of steam in the exhaust in bar
Ta=20;//Ambient temperature in degrees celsius
hs=2545.6;//Enthalpy of saturated steam in kJ/kg
Tsa=24.1;//Saturation temperature from graph in degrees celcius
Cp=2.1;//Specific heat in kJ/kg K
hst=3335;//Enthalpy of super heated steam in kJ/kg

//Calculations
Ma=(Vn*mc)/(33*Vc);//Mass of air supplied per kg of fuel in kg
Me=Ma+1;//Mass of exhaust gases formed per kg of fuel in kg
me=(Me*F)/60;//Mass of exhaust gases formed per minute in kg
ms=F*(mh/100);//Mass of steam formed per kg of fuel in kg
ms1=(ms*F)/60;//Mass of steam formed per minute in kg
mde=me-ms1;//Mass of dry exhaust gases formed per minute in kg
H=mde*se*(Te-Ta);//Heat carried away by the dry exhaust gases per minute in kJ/min
Es=hs+(Cp*(Te-Tsa));//Enthalpy of superheated steam in kJ/kg
He=ms1*hst;//Heat carried away by steam in the exhaust gases in kJ/min
Hl=H+He;//Total heat lost through dry exhaust gases
```

```
   and steam in kJ/min
Hf=(F/60)*CV;//Heat supplied by fuel per minute in
   kJ/min
nh=(Hl/Hf)*100;//Percentage of heat carried away by
   exhaust gases

//Output
printf('Percentage of heat carried away by exhaust
   gases is %3.1f percent',nh)
```

Scilab code Exa 7.28 Increase in brake power of engine due to supercharging

```
clc
clear
//Input data
C=0.0033;//The capacity of a four stroke engine of
   compression ignition type
I=13;//Average indicated power developed in kW/m^3
N=3500;//Operating speed of the engine
nv=80;//Volumetric efficiency in percentage
p1=1.013;//Initial pressure in bar
T1=298;//Initial temperature in K
r=1.75;//Pressure ratio of the engine
ni=75;//The isentropic efficiency in percentage
nm=80;//mechanical efficiency in percentage
r1=1.4;//Polytropic index

//Calculations
Vs=(N/2)*C;//Swept volume in m^3/min
Vi=Vs*(nv/100);//Unsupercharged engine inducted
   volume in m^3/min
Pb=p1*r;//Blower delivery pressure in bar
T2s=((r)^((r1-1)/r1))*T1;//Final temperature in K
T2=((T2s-T1)/(ni/100))+T1;//Blower delivery
   temperature in K
```

```
Ve=((Pb*Vs)*T1)/(T2*p1);//Equivalent volume at 1.013
     bar and 298K in m^3/min
Vin=Ve-Vi;//Increase in inducted volume of air in m
    ^3/min
Pin=Vin*I;//Increase in indicated power due to extra
     air inducted in kW
Pinp=((Pb-p1)*Vs*100)/60;//Increase in indicated
    power due to increase in induction pressure in kW
Pt=Pin+Pinp;//Total increase in indicated power in
    kW
nb=Pt*(nm/100);//Total increase in brake power
    efficiency in kW
ma=(Pb*Vs*100)/(60*0.287*T2);//Mass of air delivered
     by the blower in kg/s
Wb=ma*1.005*(T2-T1);//Work input to air by blower in
     kW
Pb1=Wb/(nv/100);//Power required to drive the blower
     in kW
Pb2=nb-Pb1;//Net increase in brake power in kW

//Output
printf('The net increase in brake power is %3.2f kW'
    ,Pb2)
```

Chapter 8

Steam Nozzles and Turbines

Scilab code Exa 8.1 Final velocity of steam

```
clc
clear
//Input data
P1=12;//Pressure of Dry saturated steam entering a
    steam nozzle in bar
P2=1.5;//Discharge pressure of Dry saturated steam
    in bar
f=0.95;//Dryness fraction of the discharged steam
l=12;//Heat drop lost in friction in percentage
hg1=2784.8;//Specific enthalpy of steam at 12 bar
    from steam tables in kJ/kg
hg2=2582.3;//Specific enthalpy of 0.95 dry steam at
    1.5 bar from steam tables in kJ/kg

//Calculations
hd=hg1-hg2;//Heat drop in kJ/kg
V1=44.72*(hd)^(0.5);//Velocity of steam at discharge
     from the nozzle in m/s
n=1-(l/100);//Nozzle coefficient when 12 percent
    heat drop is lost in friction
V2=44.72*(n*hd)^(0.5);//Velocity of steam in m/s
```

```
percentV=((V1-V2)/V1)*100;//Percentage reduction in
    velocity

//Output
printf('(a)Final velocity of steam is %3.1f m/s\n (b
    )Percentage reduction in velocity is %3.2f
    percent',V1,percentV)
```

Scilab code Exa 8.2 Mass of steam discharged

```
clc
clear
//Input data
P1=12;//Initial pressure of dry saturated steam
    expanded in a nozzle in bar
P2=0.95;//Final pressure of dry saturated steam
    expanded in a nozzle in bar
f=10;//Frictional loss in the nozzle of the total
    heat drop in percentage
d=12;//Exit diameter of the nozzle in mm
hd=437.1;//Heat drop in kJ/kg from steam tables
q=0.859;//Dryness fraction of steam at discharge
    pressure
vg=1.777;//Specific volume of dry saturated steam at
     0.95 bar

//Calculations
n=1-(f/100);//Nozzle coefficient from moiller chart
V2=44.72*(n*hd)^(0.5);//Velocity of steam at nozzle
    exit in m/s
A=(3.14/4)*(0.012)^(2);//Area of the nozzle at the
    exit in mm^2
m=((A*V2)/(q*vg))*3600;//Mass of steam discharged
    through the nozzle per hour in kg/hour

```

```
//Output
printf('The mass of steam discharged,when the exit diameter of the nozzle is 12mm is %3.1f kg/hour',m)
```

Scilab code Exa 8.3 Throat area

```
clc
clear
//Input data
P1=12;//Inlet pressure of steam nozzle in bar
T1=250;//Inlet temperature of steam nozzle in degrees celcius
P2=2;//Final pressure of the steam nozzle in bar
n=1.3;//Polytropic constant for superheated steam
St=6.831;//For isentropic expansion, entropy remains constant in kJ/kg
h1=2935.4//Enthalpy of steam at P1 from steam table in kJ/kg
ht=2860;//Enthalpy of steam at pt in kJ/kg
vt=0.325;//Specific volume of steam at the throat conditions in m^3/kg
m=0.2;//Mass of steam discharged through the nozzle in kg/hour
q=0.947;//The dryness fraction of steam at exit from steam tables
hg=2589.6;//Enthalpy of steam at exit in kJ/kg
vs=0.8854;//Specific volume of saturated steam in m^3/kg

//Calculations
pt=(P2/(n+1))^(n/(n-1))*P1;//Critical pressure ratio i.e.,Throat pressure in bar
Vt=(2*1000*(h1-ht))^(0.5);//Velocity of steam at throat in m/s
```

```
At=((m*vt)/Vt)*10^4;//Area of the throat in cm^2
    from continuity equation
ve=q*vs;//Specific volume of steam at exit in m^3/kg
Ve=(2*1000*(h1-hg))^(0.5);//Velocity of steam at
    nozzle exit in m/s
Ae=((m*ve)/Ve)*10^4;//Exit area in cm^2

//Output
printf('(a)Throat area of steam nozzle is %3.3f cm
    ^2\n (b)Exit area of steam nozzle is %3.3f cm^2\n
     (c)Exit velocity of the nozzle is %3.1f m/s',At,
    Ae,Ve)
```

Scilab code Exa 8.4 Final exit velocity of steam

```
clc
clear
//Input data
P1=10;//Pressure of steam in bar
f=0.9;//Dryness fraction of steam
At=350;//Throat area in mm^2
Pb=1.4;//Back pressure in bar
h1=2574.8;//Enthalpy of steam at nozzle inlet from
    steam tables in kJ/kg
ft=0.87;//Dryness fraction of steam at throat
    pressure
fe=0.81;//Dryness fraction of steam at exit pressure
ht=2481;//Enthalpy of steam at throat pressure at ft
     in kJ/kg
vt=0.285;//Specific volume of steam at throat in m
    ^3/kg
he=2266.2;//Enthalpy of steam at exit conditions in
    kJ/kg
ve=1.001;//Specific volume of steam at exit
    conditions in m^3/kg
```

```

//Calculations
Pt=0.582*P1;//Steam pressure at the throat in bar
hd=h1-ht;//Enthalpy drop upto the throat in kJ/kg
Vt=44.7*(hd)^(0.5);//Velocity of steam at the throat in m/s
hde=h1-he;//Enthalpy drop from nozzle entrance to exit in kJ/kg
Ve=44.7*(hde)^(0.5);//Velocity of steam at nozzle exit in m/s
Ae=(At*Vt*ve)/(Ve*vt);//Exit area of nozzle from the mass rate of flow equation in mm^2

//Output
printf('(a)Final exit velocity of steam is %3.1f m/s\n (b)Cross sectional area of the nozzle at exit for maximum discharge is %3.0f mm^2',Ve,Ae)
```

Scilab code Exa 8.5 `Velocity of steam at the throat`

```
clc
clear
//Input data
P1=7;//Inlet pressure of a convergent divergent steam nozzle in bar
T1=275;//Inlet temperature of the nozzle in degrees celcius
P2=1;//Discharge pressure of steam in bar
l=60;//Length of diverging portion of the nozzle in mm
dt=6;//Diameter of the throat in mm
f1=10;//Percent of total available enthalpy drop lost in friction in the diverging portion in percentage
h1=3006.9;//Enthalpy of steam at 7bar pressure and
```

```
275 degrees celcius in kJ/kg
ht=2865.9;//Enthalpy at the throat from Moiller chart in kJ/kg
he=2616.7;//Enthalpy at the exit from moiller chart in kJ/kg
vt=0.555;//Specific volume of steam at throat in m^3/kg
Tt=202.8;//Temperature of steam at throat in degrees celcius from moiller chart
ve=1.65;//Volume of steam at exit in m^3/kg

//Calculations
Pt=0.546*P1;//The throat pressure for maximum discharge in bar
hd=h1-ht;//Enthalpy drop upto throat in kJ/kg
Vt=44.7*(hd)^(0.5);//Velocity of steam at throat in m/s
hid=h1-he;//Total isentropic drop from 7 bar,275 degrees celcius to 1 bar in kJ/kg
hda=(1-(f1/100))*(hid);//Actual heat drop in kJ/kg
Ve=44.7*(hda)^(0.5);//Velocity at exit in m/s
At=(3.14/4)*(6/1000)^(2);//Throat area of the nozzle in m^2
m=(At*Vt)/vt;//Mass flow rate at nozzle throat in kg/s
Ae=((m*ve)/Ve)*10^4;//Exit area of the nozzle in cm^2
de=(((Ae*4)/3.14)^(0.5))*10;//Diameter of the nozzle at exit in mm
alpha=atand((de-dt)/(2*60));//Half of the cone angle of the nozzle in degrees
alpha1=2*alpha;//Cone angle of the nozzle in degrees

//Output
printf('(a)Velocity of steam at throat is %3.0f m/s\n (b)Temperature of steam at the throat is %3.1f degrees celcius\n (c)Cone angle of the divergent portion is %3.3f degrees',Vt,Tt,alpha1)
```

Chapter 9

Air compressors

Scilab code Exa 9.1 Isothermal compression

```
clc
clear
//Input data
m=1;//Mass of air that has to be compressed in kg
P1=1;//Initial pressure of a single stage reciprocating air compressor in bar
P2=6;//Final pressure in bar
T1=303;//Initial temperature of air in K
n=1.2;//Polytropic index of air
R=287;//Gas constant for air in J/kg K
r=1.4;//Isentropic index

//Calculations
W1=(m*R*T1*log(P2/P1))/1000;//Work required for compression in kJ/kg in Isothermal compression process
W2=((n/(n-1))*m*R*T1*((P2/P1)^((n-1)/n)-1))/1000;//Work required for compression in a polytropic compression process in kJ/kg
W3=((r/(r-1))*m*R*T1*((P2/P1)^((r-1)/r)-1))/1000;//Work required for compression in a Isentropic
```

```
    compression process in kJ/kg

//Output
printf('(a)Work required in a isothermal compression
    is %3.3f kJ/kg \n(b)Work required in a
    polytropic compression is %3.3f kJ/kg \n(c)Work
    required in a isentropic compression is %3.3f kJ/
    kg',W1,W2,W3)
```

Scilab code Exa 9.2 Size of the cylinder

```
clc
clear
//Input data
Pi=60000;//Indicated power of a double acting air
    compressor in W
P1=1;//Initial pressure in bar
T1=293;//Initial temperature in K
n=1.2;//Polytropic index of the process
P2=8;//Final pressure in bar
N=120;//Speed at which the cylinder operates in rpm
S=150;//Average piston speed in m/min

//Calculations
L=S/(2*N);//Length of the stroke in m
X=(3.14*L)/4;//X=V/D^2 i.e.,Volume of air before
    compression/square of the diameter in m
Y=((n/(n-1))*P1*10^5*X*(((P2/P1)^((n-1)/n))-1));//Y=
    W/D^2 Work done by the compressor per cycle in N/
    m
Nw=2*N;//Number of working strokes per minute since
    it is a double acting cylinder
D=(((Pi*60)/(Y*Nw))^(0.5))*1000;//Diameter of the
    cylinder in mm

```

```
//Output
printf('(a)Length of the cylinder is %3.3f m \n (b)
   Diameter of the cylinder is %3.0f mm',L,D)
```

Scilab code Exa 9.3 Indicated power

```
clc
clear
//Input data
D=0.15;//Diameter of a cylinder of a single acting
   reciprocating air compressor in m
L=0.2;//Length of the stroke in m
P1=1;//The pressure at which compressor sucks air in
    bar
P2=10;//Final pressure in bar
T1=298;//Initial Temperature in K
N=150;//Operating speed of the compressor in rpm
n=1.3;//Polytropic index of the process

//Calculations
V1=((3.14*D^2*L)/4);//Volume of air before
   compression in m^3
W=((n/(n-1))*P1*10^5*V1*((P2/P1)^((n-1)/n)-1));//
   Work done by the compressor for a polytropic
   compression of air in Nm
Pi=((W*N)/60)/1000;//Indicated power of the
   compressor in kW

//Output
printf('The indicated power of the compressor is %3
   .3f kW',Pi)
```

Scilab code Exa 9.4 Mass of air delivered per minute

```
clc
clear
//Input data
D=0.25;//Diameter of the cylinder of a single acting air compressor in m
L=0.4;//Length of the stroke in m
P1=1;//Initial Pressure of the compressor in bar
T1=303;//Initial temperature of the compressor in K
P2=6;//Pressure during running in bar
N=250;//Operating speed of the compressor in rpm
R=287;//Gas constant in J/kg K

//Calculations
V1=(3.14*D^2*L)/4;//Volume of air before compression in m^3
m=(P1*10^5*V1)/(R*T1);//Mass of air delivered by the compressor per stroke in kg/stroke
Nw=N;//Since single acting cylinder number of working stroke is equal to Operating speed of the compressor in rpm
ma=m*Nw;//Mass of air delivered per minute in kg/min

//Output
printf('Mass of air delivered per minute is %3.2f kg/min',ma)
```

Scilab code Exa 9.5 Temperature

```
clc
clear
//Input data
P1=1;//Initial pressure of a single acting compressor in bar
P2=12;//Final pressure in bar
N=500;//Operating speed of the compressor in rpm
```

```
T1=308;//Inlet air temperature in K
n=1.3;//Polytropic index

//Calculations
T2=T1*(P2/P1)^((n-1)/n);//Temperature of air
    delivered by the compressor in K

//Output
printf('Temperature of air delivered by the
    compressor is %3.2f K',T2)
```

Scilab code Exa 9.6 Isentropic compression

```
clc
clear
//Input data
P1=1;//Pressure at which air is sucked by a
    compressor in bar
T1=293;//Initial temperature in K
P2=9;//Delivery pressure after compression in bar
r=1.41;//Isentropic index
n=1.3;//Polytropic index

//Calculations
T21=T1*((P2/P1)^((r-1)/r));//Temperature at the end
    of isentropic compression process in K
T22=T1*((P2/P1)^((n-1)/n));//Temperature at the end
    of isentropic compression process in K
T23=T1;//Temperature at the end of isotropic
    compression process in K (Temperature remains
    constant)

//Output
printf('(a)Temperature at the end of isentropic
    compression is %3.2f K\n (b)Temperature at the
```

```
end of polytropic compression is %3.2f K\n (c) Temperature at the end of isotropic compression is %3.0f K',T21,T22,T23)
```

Scilab code Exa 9.7 Work done by air during suction

```
clc
clear
//Input data
V1=0.07;//Displacement of the piston of a single stage single cylinder air compressor in m^3
P1=1;//Initial pressure in bar
T1=308;//Initial temperature of air in K
P2=8.5;//Pressure after the compression process in bar
r=1.4;//Isentropic compression

//Calculations
V2=V1*((P1/P2)^(1/1.4));//Final volume of the cylinder in m^3
W1=P1*10^5*V1;//Work done by air during suction in Nm (or) J
W2=(P1*10^5*V1*(1-(P2/P1)^((r-1)/r)))/(r-1);//Work done by air during compression in Nm or J
Wa1=P2*10^5*V2;//Work done on air during delivery in Nm or J
Wa2=((-W2)+Wa1-W1)/1000;//Net work done on air during the cycle in kJ

//Output
printf('(a)Work done by air during suction is %3.0f J\n (b)Work done on air during compression is %3.0f J\n (c)Work done on air during delivery is %3.0f J\n (d)Net work done on air during the cycle is %3.3f kJ',W1,W2,Wa1,Wa2)
```

Scilab code Exa 9.8 Work done on air during delivery

```
clc
clear
//Input data
V1=0.05;//displacement of a piston of a single cylinder single stage reciprocating compressor in m^3
P1=1;//pressure of air sucked in the compressor in bar
T1=300;//Initial Temperature of air in K
P2=7;//Pressure after the compression process in bar

//Calculations
V2=(P1*V1)/P2;//Volume after the compression in m^3
W1=P1*10^5*V1;//Work done by air during suction in Nm
W2=P1*10^5*V1*log(V2/V1);//Work done on sir during isothermal compression in Nm
H=-W2;//Heat transferred to the cylinder walls in Nm or J
W3=P1*10^5*V1;//Work done on air during delivery in Nm
Wn=W1+(-W2)-W3;//Net work done during the cycke in N m

//Output
printf('(a)Work done by air during suction is %3.0f Nm\n (b)Work done on air during Isothermal compression is %3.0f Nm\n (c)Heat transferred during this process is %3.0f J\n (d)Work done on air during delivery is %3.0f Nm\n (e)Net work done during the cycle is %3.0f Nm',W1,W2,H,W3,Wn)
```

Scilab code Exa 9.9 Power required

```
clc
clear
//Input data
m=2;//Mass of air delivered per second in kg
P1=1;//Initial pressure of a single stage compressor
    in bar
T1=293;//Initial temperature in K
P2=7;//Final pressure in bar
n=1.4;//Polytropic index
R=287;//Gas constant in J/kg K

//Calculations
W=((n/(n-1))*m*R*T1*(((P2/P1)^((n-1)/n))-1))
   /(60*1000);//Work done by compressor in kW

//Output
printf('Power required to compress and deliver 2kg
   of air per minute is %3.3f kW',W)
```

Scilab code Exa 9.10 Work done by compressor

```
clc
clear
//Input data
D=0.15;//Diameter of the bore of a single stage
   single acting reciprocating air compressor in m
L=0.225;//Stroke length in m
P1=1;//Pressure of air received in bar
T1=308;//Temperature of initial air in K
P2=6.5;//Delivery pressure in bar
```

```
n=1.3;//Polytropic index

//Calculations
Vs=(3.14*D^2*L)/4;//Stroke volume of the compressor
    in m^3
Vc=0.05*Vs;//Clearance volume in m^3
V1=Vs+Vc;//Initial volume of air in m^3
V4=Vc*(P2/P1)^(1/n);//The air in the clearance
    volume expands during suction stroke in m^3
V=V1-V4;//Effective swept volume in m^3
W=((n/(n-1))*P1*10^5*(V1-V4)*(((P2/P1)^((n-1)/n))-1)
    );//Work done by the compressor per cycle in Nm

//Output
printf('Work done by the compressor per cycle is %3
    .1f Nm',W)
```

Scilab code Exa 9.11 `Volume of free air`

```
clc
clear
//Input data
D=0.1;//Diameter of the bore of a single acting
    compressor in m
L=0.1;//Length of the stroke in m
N=400;//Operating speed of the compressor in in rpm
Vc=0.00008;//Clearance volume in m^3
n=1.2;//Polytropic index
T1=303;//Initial temperature in K
Tf=293;//Final temperature in K
P1=0.95;//Initial pressure in bar
P2=8;//Final pressure in bar
Pf=1.013;//Free air pressure in bar

//Calculations
```

```
Vs=(3.14*D^2*L)/4;//Stroke volume of the compressors
     in m^3
V1=Vc+Vs;//Initial volume of air is equal to
    cylinder volume in m^3
V4=Vc*(P2/P1)^(1/n);//Air in the clearance volume
    expands during suction stroke to V4
Ve=V1-V4;//Effective swept volume in m^3
Vf=(P1*(V1-V4)*Tf)/(T1*Pf);//Free air delivered per
    cycle can be obtained in m^3
A=Vf*N;//Free air delivered per minute in m^3/min

//Output
printf('(a)Free air delivered per cycle is %3.6f m
    ^3\n (b)Free air delivered per minute is %3.4f m
    ^3/min',Vf,A)
```

Scilab code Exa 9.12 Power of the compressor

```
clc
clear
//Input data
P1=1;//Pressure of air drawn by a two stage single
    acting reciprocating air compressor in bar
T1=293;//Initial temperature in K
P3=60;//Final pressure after the compression in bar
P2=10;//Pressure after compression in the LP
    cylinder in bar
T2=303;//Temperature after cooling in K
D=0.16;//Diameter of a cylinder in m
L=0.2;//Stroke length of the cylinder in m
n=1.3;//Polytropic index
N=300;//Operating speed of the compressor in rpm
R=287;//Gas constant in J/kg K

//Calculations
```

```
V1=(3.14*D^2*L)/4;//Volume of the LP cylinder in m^3
V2=(P1*V1*T2)/(T1*P2);//Volume of the HP cylinder in
    m^3
W=(n/(n-1))*(P1*10^5*V1*(((P2/P1)^((n-1)/n))-1)+(P2
    *10^5*V2*(((P3/P2)^((n-1)/n))-1)));//Work done by
     the compressor per working cycle in N m
P=(W*N)/(60*1000);//Power of the compressor in kW

//Output
printf('Power of the compressor when it runs at 300
    rpm is %3.3f kW',P)
```

Scilab code Exa 9.13 Percentage saving in work

```
clc
clear
//Input data
P1=1;//Initial pressure in bar
P3=9;//Final pressure in bar
n=1.3;//Compression index

//Calculations
W1=(n/(n-1))*(P1*10^5*(((P3/P1)^((n-1)/n))-1));//
    Work done in compression in a single stage per
    unit volume per kg of air in N m
P2=(P1*P3)^(0.5);//Intercooler pressure for perfect
    intercooling in bar
W2=2*(n/(n-1))*(P1*10^5*(((P2/P1)^((n-1)/n))-1));//
    Work done in compression in a two stage
    compressor per unit volume per kg of air in N m
Wc=W1-W2;//Saving in work of compression in N m
nw=((W1-W2)/W1)*100;//Percentage saving in work of
    compression in percentage

//Output
```

```
printf('Percentage saving in the work of compression
    of air in two stages instead of single stage is
   %3.2f percent',nw)
```

Scilab code Exa 9.14 Work required

```
clc
clear
//Input data
m=1;//Mass of air to be compressed in kg
P1=1;//Pressure of air before compression in bar
T1=303;//Initial temperature in K
P3=25;//Final pressure of air after compression in
   bar
n=1.3;//Polytropic index
R=287;//Gas constant in J/kg K

//Calculations
P2=(P1*P3)^(0.5);//Intermediate pressure in the case
    of perfect intercooling in bar
W=2*(n/(n-1))*(m*R*T1*(((P2/P1)^((n-1)/n))-1));//
   Work done in compression in a two stage
   compressor per unit volume per kg of air in N m

//Output data
printf('Minimum work required to compress 1kg of air
    for given conditions is %3.0f N m',W)
```

Scilab code Exa 9.15 Power required to drive compressor

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

```
V1=3;//Volume of air sucked in by a two stage compressor in m^3
P1=1.04;//Initial pressure in bar
T1=298;//Initial temperature in K
P2=9;//Delivery pressure in bar
n=1.25;//Polytropic index

//Calculations
P2=(P1*P2)^(0.5);//Intermediate pressure for perfect intercooling and for minimum work of compression in bar
W=2*(n/(n-1))*(P1*10^5*V1*(((P2/P1)^((n-1)/n))-1));//Work done in compression in a two stage compressor per unit volume per kg of air in Nm
P=W/(60*1000);//Power required to drive the compressor in kW

//Output
printf('The minimum power required to drive the compressor is %3.3f kW',P)
```

Scilab code Exa 9.16 Mass of water

```
clc
clear
//Input data
P1=1;//Initial pressure of a two stage air compressor in bar
P3=36;//Final pressure in bar
T1=298;//Initial temperature in K
n=1.35;//Polytropic index
T3=298;//Temperature after intercooling in K
Tc=20;//Permissible temperature rise of the cooling water in K
R=287;//Gas constant in J/kg K
```

```
Cp=1;//Specific heat of air in kJ/kg K
Cw=4.2;//Specific heat of water in kJ/kg K
ma=1;//Mass of air in the compressor in kg

//Calculations
P2=(P1*P3)^(0.5);//Intercooler pressure for complete
     intercooling and for minimum work of compression
     in bar
T2=T1*(P2/P1)^((n-1)/n);//Temperature after the
    compression process in K
mw=(ma*Cp*(T2-T3))/(Cw*(Tc));//Mass of water to
    circulate in the intercooler per kg of air in kg

//Output
printf('Mass of water to circulate in the
    intercooler for abstracting heat is %3.3f kg',mw)
```

Scilab code Exa 9.17 Volume ratio of LP to HP cylinders

```
clc
clear
//Input data
V1=0.2;//Volume of air flow per second in a two
    stage single acting reciprocating compressor in m
    ^3
P1=0.1;//Intake pressure of air in MPa
T1=293;//Initial temperature in K
P3=0.8;//Final pressure after the air is compressed
    in MPa
N=600;//Operating speed of the compressor in rpm

//Calculations
P2=(P1*P3)^(0.5);//Intercooler pressure for perfect
    intercooling and for minimum work of compression
    in bar
```

```
Vl=(V1*60)/600;//Volume of the LP cylinder in m^3
Vh=(P1*Vl)/P2;//Volume of the high pressure cylinder
    in m^3
R=Vl/Vh;//Ratio of cylinder volumes

//Output
printf('The volume ratio of LP to HP cylinders is %3
   .2f',R)
```

Scilab code Exa 9.18 Ratio of cylinder diameters

```
clc
clear
//Input data
P1=1;//Initial pressure of air entering a two stage
   air compressor with complete intercooling in bar
P3=25;//Delivery pressure of air toe the mains in
   bar
T1=303;//Initial temperature in K
n=1.35;//Compression index

//Calculations
P2=(P1*P3)^(0.5);//Inter cooler pressure for perfect
    intercooling in bar
R=(P2/P1)^(0.5);//Ratio of cylindrical diameters

//Output
printf('The ratio of cylinder diameters for the
   efficiency of compression to be maximum is %3.3f'
   ,R)
```

Scilab code Exa 9.19 Number of stages

```
clc
clear
//Input data
P1=1;//Initial pressure of a multistage compression
    in bar
Pn1=120;//Final pressure in bar
r=4;//Permissible pressure ratios per stage

//Calculations
n=log(Pn1/P1)/log(r)
n1=4;//As n=3.45 say 4 stages
P5=Pn1;//Since number of stages is 4
P4=P5/(Pn1/P1)^(1/n1);//Pressure after the stage 3
    in bar
P3=P4/(Pn1/P1)^(1/n1);//Pressure after the stage 2
    in bar
P2=P3/(Pn1/P1)^(1/n1);//Pressure after the stage 1
    in bar

//Output
printf('(a)Number of stages are %3.0f\n (b)
    Intermediate pressures are, P2 = %3.2f bar, P3 =
    %3.2f bar, P4 = %3.2f bar',n1,P2,P3,P4)
```

Scilab code Exa 9.20 Intermediate pressures

```
clc
clear
//Input data
P1=1;//Initial pressure of a 3 stage compressor in
    bar
P4=40;//Final pressure in bar
T1=293;//Initial temperature in K
n=1.3;//Polytropic index
V1=15;//Air delivered per minute in m^3/min
```

```

//Calculations
W=((3*n)/(n-1))*P1*10^5*V1*(((P4/P1)^((n-1)/(3*n)))-1);//Work done by the compressor in kJ/min
P=W/(60*1000);//Power required to deliver 15 m^3/min air in kW
P2=P1*(P4/P1)^(1/3);//Intermediate pressure after stage 1 in bar
P3=P2*(P4/P1)^(1/3);//Intermediate pressure after stage 2 in bar

//Output
printf('(a)Power required to deliver 15 m^3/min air at suction condition is %3.1f kW\n (b)Intermediate pressures are P2 = %3.3f bar P3 = %3.3f bar',P,P2,P3)
```

Scilab code Exa 9.21 `Heat rejected`

```
clc
clear
//Input data
P1=1;//Atmospheric pressure in bar
P4=60;//Delivery pressure in bar
T1=303;//Initial temperature in K
n=1.3;//Index of compression
Cp=1.005;//Specific heat of air at constant pressure in kJ/kg K
S=3;//Number of stages

//Calculations
P2=P1*(P4/P1)^(1/3);//Intermediate pressure in bar
T2=T1*(P2/P1)^((n-1)/n);//Temperature of air entering the intercoolers in K
H=Cp*(T2-T1);//Heat rejected in each intercooler in
```

```
kJ

//Output
printf('Amount of heat rejected in each intercooler is %3.0f kJ',H)
```

Scilab code Exa 9.22 Ratio of cylinder volumes

```
clc
clear
//Input data
P1=1;//Pressure at the end of suction stroke in LP cylinder of a 3 stage single acting reciprocating compressor in bar
T1=293;//Temperature at the end of suction stroke in LP cylinder in K
V=9;//Free air delivered by the compressor in m^3
P4=65;//Pressure delivered by the compressor in bar
n=1.25;//Polytropic index

//Calculations
P2=P1*(P4/P1)^(1/3);//Intermediate pressure after stage 1 in bar
P3=P2*(P4/P1)^(1/3);//Intermediate pressure after stage 2 in bar
V3=1;//The volume of cylinder for the third stage in m^3
V2=V3*(P3/P2);//Volume of the cylinder for second stage in m^3
V1=(P2/P1)*V2;//Volume of the cylinder for first stage in m^3
W=(((3*n)/(n-1))*P1*10^5*V*(((P4/P1)^((n-1)/(3*n)))-1))/1000;//Work done by the compressor in kJ/min
Pi=W/60;//Indicated power in kW

```

```
//Output
printf('(a)L.P. and I.P.compressor delivery pressure is P2 = %3.3f bar P3 = %3.2f bar\n (b)Ratio of cylinder volumes is V1:V2:V3 = %3.2f:%3.3f:%3.0f\n (c)Total indicated power is %3.2f kW',P2,P3,V1,V2,V3,Pi)
```

Chapter 10

Refrigeration and air conditioning

Scilab code Exa 10.1 Power rating

```
clc
clear
//Input data
T1=273;//The temperature of ice in K
T2=298;//Temperature of water at room in K
COP=2.1;//Cop of the plant
ne=90;//Overall electrochemical efficiency in
   percentage
w=15;//Weight of ice produced per day in tonnes
cw=4.187;//Specific heat of water in kJ/kg degrees
   celcius
Li=335;//Latent heat of ice in kJ/kg
mi=1;//Mass of ice produced at 0 degrees celcius

//Calculations
m=(w*1000)/(24*60);//Mass of ice produced in kg/min
h=(mi*cw*(T2-T1))+Li;//Heat extracted from 1kg of
   water at 25 degrees celcius to produce 1kg of ice
    at 0 degrees celcius in kJ/kg
```

```
Q=m*h;//Total heat extracted in kJ
W=Q/COP;//Work done by the compressor in kJ/kg
P=W/(60*(ne/100));//Power of compressor in kW

//Output
printf('Power rating of the compressor-motor unit if
    the cop of the plant is 2.1 is %3.1f kW',P)
```

Scilab code Exa 10.2 Refrigeration capacity

```
clc
clear
//Input data
m=400;//Mass of fruits supplied to a cold storage in
    kg
T1=293;//Temperature at which fruits are stored in K
T2=268;//Temperature of cold storage in K
t=8;//The time untill which fruits are cooled in
   hours
hfg=105;//Latent heat of freezing in kJ/kg
Cf=1.25;//Specific heat of fruit
TR=210;//One tonne refrigeration in kJ/min

//Calculations
Q1=m*Cf*(T1-T2);//Sensible heat in kJ
Q2=m*hfg;//Latent heat of freezing in kJ
Q=Q1+Q2;//Heat removed from fruits in 8 hrs
Th=(Q1+Q2)/(t*60);//Total heat removed in one minute
    in kJ/kg
Rc=Th/TR;//Refrigerating capacity of the plant in TR

//Output
printf('The refrigeration capacity of the plant is
   %3.3f TR',Rc)
```

Scilab code Exa 10.3 COP of a heat pump

```
clc
clear
//Input data
T1=300;//The maximum temperature at which carnot
   cycle operates in K
T2=250;//The minimum temperature at which carnot
   cycle operates in K

//Calculations
COPr=T2/(T1-T2);//COP of the refrigerating machine
COPh=T1/(T1-T2)//COP of heat pump
n=((T1-T2)/T1)*100;//COP or efficiency of the heat
   engine in percentage

//Output data
printf('(a)COP of the machine when it is operated as
    a refrigerating machine is %3.2f\n (b)COP when
   it is operated as heat pump is %3.2f\n (c)COP or
   efficiency of the Heat engine is %3.2f percent',
   COPr,COPh,n)
```

Scilab code Exa 10.4 Time taken to achieve cooling

```
clc
clear
//Input data
m=20000;//The storage capacity of fish in a storage
   plant in kg
T1=298;//Supplied temperature of fish in K
```

```
T2=263;//Temperature of cold storage in which fish are stored in K
T3=268;//Freezing point of fish in K
Caf=2.95;//Specific heat of fish above freezing point in kJ/kg K
Cbf=1.25;//Specific heat of below freezing point in kJ/kg K
W=75;//Work required by the plant in kW
TR=210;//One tonne refrigeration in kJ/min
hfg=230;//Latent heat of fish in kJ/kg

//Calculations
COPr=T2/(T1-T2);//COP of reversed carnot cycle
COPa=0.3*COPr;//Given that actual COP is 0.3 times of reversed COP
Hr=(COPa*W)*60;//Heat removed by the plant in kJ/min
C=Hr/TR;//Capacity of the plant in TR
Q1=m*Caf*(T1-T3);//Heat removed from the fish above freezing point in kJ
Q2=m*Cbf*(T3-T2);//Heat removed from fish below freezing point in kJ
Q3=m*hfg;//Total latent heat of the fish in kJ
Q=Q1+Q2+Q3;//Total heat removed by the plant in kJ
T=(Q/Hr)/60;//Time taken to achieve cooling in hrs

//Output data
printf('(a)Capacity of the plant is %3.2f TR\n (b)Time taken to achieve cooling is %3.2f hours',C,T)
```

Scilab code Exa 10.5 Theoretical COP

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

```
T2=298;//Maximum temperature at which CO2 machine
    works in K
T1=268;//Minimum temperature at which CO2 machine
    works in K
sf1=-0.042;//Liquid entropy at 268 K in kJ/kg K
hfg1=245.3;//Latent heat of gas at 268 K in kJ/kg
sf2=0.251;//Liquid entropy in kJ/kg K
hfg2=121.4;//Latent heat of gas at 298 K in kJ/kg
hf1=-7.54;//Liquid enthalpy at 268 K in kJ/kg
hf2=81.3;//Liquid enthalpy at 298 K in kJ/kg
hf3=81.3;//Enthalpy at point 3 in graph in kJ/kg

//Calculations
s2=sf2+(hfg2/T2);//Entropy at point 2 from the graph
     in kJ/kg K
x1=(s2-sf1)/(hfg1/T1);//Dryness fraction at point 1
h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
h2=hf2+hfg2;//Enthalpy at point 2 in kJ/kg
COP=(h1-hf3)/(h2-h1);//Coefficient of performance
    for a CO2 machine working at given temperatures

//Output data
printf('Theoretical COP for a CO2 machine working at
     given temperatures is %3.2f',COP)
```

Scilab code Exa 10.6 Capacity of refrigerator

```
clc
clear
//Input data
T2=298;//Maximum temperature at which ammonia
    refrigerating system works in K
T1=263;//Minimum temperature at which ammonia
    refrigerating system works in K
mf=5;//Fluid flow rate in kg/min
```

```
sf1=0.5443;//Liquid entropy at 298 K in kJ/kg K
sf2=1.1242;//Liquid entropy at 263 K in kJ/kg K
hfg1=1297.68;//Latent heat at 298 K in kJ/kg
hfg2=1166.94;//Latent heat at 263 K in kJ/kg
hf1=135.37;//Liquid enthalpy at point 1 in graph in
    kJ/kg
hf2=298.9;//Liquid enthalpy at point 2 in graph in
    kJ/kg
TR=210;//One tonne refrigeration in TR

//Calculations
s2=sf2+(hfg2/T2);//Entropy at point 2 in kJ/kg
x1=(s2-sf1)/(hfg1/T1);//Dryness fraction at point 1
h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
h=h1-hf2;//Heat extracted of refrigerating effect
    produced per kg of refrigerant in kJ/kg
ht=mf*h;//Total heat extracted at a fluid flow rate
    of 5 kg/min in kJ/min
C=ht/TR;//Capacity of refrigerating in TR

//Output
printf('The capacity of refrigerator is %3.0f TR',C)
```

Scilab code Exa 10.7 Theoretical COP

```
clc
clear
//Input data
T1=263;//Minimum temperature at which ammonia
    refrigerating machine works in K
T2=303;//Maximum temperature at which ammonia
    refrigerating machine works in K
x1=0.6;//Dryness fraction of ammonia during suction
    stroke
sf1=0.5443;//Liquid entropy at 263 K in kJ/kg K
```

```
hfg1=1297.68;//Latent heat at 263 K in kJ/kg
sf2=1.2037;//Liquid entropy at 303 K in kJ/kg K
hfg2=1145.8;//Latent heat at 303 K in kJ/kg
hf1=135.37;//Liquid enthalpy at 263 K in kJ/kg
hf2=323.08;//Liquid enthalpy at 303 K in kJ/kg

//Calculations
s1=sf1+((x1*hfg1)/T1);//Entropy at point 1 in kJ/kg
   K
x2=(s1-sf2)/(hfg2/T2);//Entropy at point 2 in kJ/kg
   K
h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
h2=hf2+(x2*hfg2);//Enthalpy at point 2 in kJ/kg
COP=(h1-hf2)/(h2-h1);//Theoretical COP of ammonia
    refrigerating machine

//Output
printf('The theoretical COP of a ammonia
    refrigerating machine working between given
    temperatures is %3.2f',COP)
```

Scilab code Exa 10.8 Ice produced

```
clc
clear
//Input data
T1=263;//Minimum temperature at which Vapour
    compression refrigerator using methyl chloride
    operates in K
T2=318;//Maximum temperature at which Vapour
    compression refrigerator using methyl chloride
    operates in K
sf1=0.183;//Entropy of the liquid in kJ/kg K
hfg1=460.7;//Enthalpy of the liquid in kJ/kg
sf2=0.485;//Entropy of the liquid in kJ/kg K
```

```
hfg2=483.6;//Enthalpy of the liquid in kJ/kg
x2=0.95;//Dryness fraction at point 2
hf3=133.0;//Enthalpy of the liquid in kJ/kg
W=3600;//Work to be spent corresponding to 1kW/hour
Cw=4.187;//Specific heat of water in kJ/kg degrees
    celcius
mi=1;//Mass of ice produced at 0 degrees celcius
Li=335;//Latent heat of ice in kJ/kg
hf1=45.4;//Enthalpy of liquid at 263 K in kJ/kg
hf2=133;//Enthalpy of liquid at 318 K in kJ/kg

//Calculations
s2=sf2+((x2*(hfg2-hf2))/T2);//Enthalpy at point 2 in
     kJ/kg
x1=(s2-sf1)/((hfg1-hf1)/T1);//Dryness fraction at
    point 1
h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
h2=hf2+(x2*hfg2);//Enthalpy at point 2 in kJ/kg
COP=(h1-hf3)/(h2-h1);//Theoretical COP
COPa=0.6*COP;//Actual COP which is 60 percent of
    theoretical COP
H=W*COPa;//Heat extracted or refrigeration effect
    produced per kW hour in kJ
Hw=(mi*Cw*10)+Li;//Heat extracted from water at 10
    degrees celcius for the formation of 1 kg of ice
    at 0 degrees celcius
I=H/Hw;//Amount of ice produced in kg/kW hr

//Output
printf('The amount of ice produced is %3.2f kg/kW hr
    ',I)
```