Scilab Textbook Companion for Internal Combustion Engine by M. l. Mathur and R. P. Sharma[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 1

Introduction

Scilab code Exa 1.1 Calculation of cubic capacity and clearance volume

```
//Calculation of cubic capacity and clearance volume
clc,clear
//Given:
n=4 //Number of cylinders
d=68/10 //Bore in cm
l=75/10 //Stroke in cm
r=8 //Compression ratio
//Solution:
V_s=(%pi/4)*d^2*l //Swept volume of one cylinder in cm^3
cubic_capacity=n*V_s //Cubic capacity in cm^3
//Since, r = (V_c + V_s)/V_c
V_c=V_s/(r-1) //Clearance volume in cm^3
//Results:
printf("\n The cubic capacity of the engine = %.1f cm^3",cubic_capacity)
printf("\n The clearance volume of a cylinder, V_c = %.1f cm^3\n\n",V_c)
```

Scilab code Exa 1.2 Calculation of brake power and friction power

```
//Calculation of brake power and friction power
clc,clear
//Given:
ip=10 //Indicated power in kW
eta_m=80 //Mechanical efficiency in percent
//Solution:
//Since, eta_m = bp/ip
bp=(eta_m/100)*ip //Brake power in kW
fp=ip-bp //Friction power in kW
//Results:
printf("\n The brake power delivered, bp = %d kW\n",
   bp)
printf(" The friction power, fp = %d kW\n\n",fp)
```

Scilab code Exa 1.3 Calculation of mechanical efficiency

```
//Calculation of mechanical efficiency
clc,clear
//Given:
bp=100 //Brake power at full load in kW
fp=25 //Frictional power in kW (printing error)
//Solution:
eta_m=bp/(bp+fp) //Mechanical efficiency at full
   load
//(a)At half load
bp=bp/2 //Brake power at half load in kW
eta_m1=bp/(bp+fp) //Mechanical efficiency at half
   load
//(b)At quarter load
bp=bp/2 //Brake power at quarter load in kW
eta_m2=bp/(bp+fp) //Mechanical efficiency at quarter
    load
//Results:
```

```
printf("\n The mechanical efficiency at full load, eta_m = %d percent",eta_m*100)
printf("\n The mechanical efficiency,\n (a)At half load, eta_m = %.1f percent\n (b)At quarter load, eta_m = %d percent\n\n",eta_m1*100,eta_m2*100)
//Data in the book is printed wrong
```

Scilab code Exa 1.4 Calculations on four stroke petrol engine

```
//Calculations on four stroke petrol engine
clc,clear
//Given:
bp=35 //Brake power in kW
eta_m=80 //Mechanical efficiency in percent
bsfc=0.4 //Brake specific fuel consumption in kg/kWh
A_F=14/1 //Air-fuel ratio
CV=43000 //Calorific value in kJ/kg
//Solution:
//(a)
ip=bp*100/eta_m //Indicated power in kW
//(b)
fp=ip-bp //Frictional power in kW
//(c)
//Since, 1 kWh = 3600 kJ
eta_bt=1/(bsfc*CV/3600) //Brake thermal efficiency
//(d)
eta_it=eta_bt/eta_m*100 //Indicated thermal efficiency
//(e)
m_f=bsfc*bp //Fuel consumption in kg/hr
//(f)
m_a=A_F*m_f //Air consumption in kg/hr
//Results:
printf("\n (a)The indicated power, ip = %.2f kW\n (b)The friction power, fp = %.2f kW",ip,fp)
```

```
printf("\n (c)The brake thermal efficiency , eta_bt = %.1f percent\n (d)The indicated thermal efficiency , eta_it = %.1f percent",eta_bt*100,eta_it*100)
printf("\n (e)The fuel consumption per hour, m_f = %.1f kg/hr\n (f)The air consumption per hour, m_a = %d kg/hr\n\n",m_f,m_a)
```

Scilab code Exa 1.5 Calculations on SI engine

```
//Calculations on SI engine
clc,clear
//Given:
F_A=0.07/1 //Fuel-air ratio
bp=75 //Brake power in kW
eta_bt=20 //Brake thermal efficiency in percent
rho_a=1.2 //Density of air in kg/m^3
rho_f=4*rho_a //Density of fuel vapour in kg/m^3
CV=43700 //Calorific value of fuel in kJ/kg
//Solution:
m_f=bp*3600/(eta_bt*CV/100) //Fuel consumption in kg/hr
m_a=m_f/F_A //Air consumption in kg/hr
V_a=m_a/rho_a //Volume of air in m^3/hr
V_f=m_f/rho_f //Volume of fuel in m^3/hr
V_mixture=V_f+V_a //Mixture volume in m^3/hr
//Results:
printf("\n The air consumption, m_a = %.1f kg/hr",m_a)
printf("\n The volume of air required, V_a = %.1f m^3/hr",V_a)
printf("\n The volume of mixture required = %.1f m^3/hr\n\n",V_mixture) //(printing error)
//Answer in the book is printed wrong
```

Scilab code Exa 1.6 Calculations on diesel engine

```
//Calculations on diesel engine
clc,clear
//Given:
bp=5 //Brake power in kW
eta_it=30 //Indicated thermal efficiency in percent
eta_m=75 //Mechanical efficiency in percent (
    printing error)
//Solution:
ip=bp*100/eta_m //Indicated power in kW
CV=42000 //Calorific value of diesel(fuel) in kJ/kg
m_f=ip*3600/(eta_it*CV/100) //Fuel consumption in kg
    /hr
//Density of diesel(fuel) = 0.87 kg/l
rho_f=0.87 //Density of fuel in kg/l
V_f=m_f/rho_f //Fuel consumption in l/hr
isfc=m_f/ip //Indicated specific fuel consumption in
     kg/kWh
bsfc=m_f/bp //Brake specific fuel consumption in kg/
    kWh
//Results:
printf("\n The fuel consumption of engine, m_f in,\n
     (a)kg/hr = %.3f kg/hr\n (b)litres/hr = %.2f l/hr
    ",m_f,V_f)
printf("\n\n (c)Indicated specific fuel consumption,
     isfc = %.3f kg/kWh",isfc)
printf("\n (d)Brake specific fuel consumption, bsfc
    = %.3f kg/kWh\n\n",bsfc)
//Data in the book is printed wrong
```

Scilab code Exa 1.7 Calculations on two stroke CI engine

```
//Calculations on two stroke CI engine
clc,clear
//Given:
bp=5000 //Brake power in kW
fp=1000 //Friction power in kW
m_f=2300 //Fuel consumption in kg/hr
A_F=20/1 //Air-fuel ratio
CV=42000 //Calorific value of fuel in kJ/kg
//Solution:
//(a)
ip=bp+fp //Indicated power in kW
//(b)
eta_m=bp/ip //Mechanical efficiency
//(c)
m_a=A_F*m_f //Air consumption in kg/hr
//(d)
eta_it=ip*3600/(m_f*CV) //Indicated thermal
    efficiency
//(e)
eta_bt=eta_it*eta_m //Brake thermal efficiency
//Results:
printf("\n (a)The indicated power, ip = %d kW",ip)
printf("\n (b)The mechanical efficiency, eta_m = %d
    percent",eta_m*100)
printf("\n (c)The air consumption, m_a = %d kg/hr",
    m_a)
printf("\n (d)The indicated thermal efficiency,
    eta_it = %.1f percent\n (e)The brake thermal
    efficiency, eta_bt = %.1f percent\n\n",eta_it
    *100,eta_bt*100)
```

Chapter 2

Air Standard Cycles

Scilab code Exa 2.1 Calculations on Carnot engine

```
//Calculations on Carnot engine
clc,clear
//Given:
T2=27+273 //Temperature of cooling pond in K
eta=30 //Efficiency in percent
Q2=200 //Heat received by cooling pond in kJ/s
//Solution:
//Since, eta = (Q1-Q2)/Q1 = (T1-T2)/T1
T1=T2/(1-(eta/100)) //Temperature of heat source in
    K
Q1=Q2/(1-(eta/100)) //Heat supplied by source in kJ/
    s
Power=round(Q1-Q2) //Power of engine in kJ/s
//Results:
printf("\n Temperature of heat source, T1 = %.1f
    degreeC",T1-273)
printf("\n Power of engine = %d kW\n\n",Power)
```

Scilab code Exa 2.2 Calculations on the Carnot cycle

```
//Calculations on the Carnot cycle
clc,clear
//Given:
T3=800+273,T1=15+273 //Temperature of a hot and cold reservoir in K
P3=210,P1=1 //Maximum and minimum pressure in bar
//Solution:
//Refer fig 2.21
eta_carnot=1-(T1/T3) //Efficiency of Carnot cycle
T4=T3 //Isothermal process 3-4
g=1.4 //Specific heat ratio(gamma)
P4=P1*(T4/T1)^(g/(g-1)) //Initial pressure of isentropic process 4-1 in bar
R=0.287 //Specific gas constant in kJ/kgK
Q3_4=R*T3*log(P3/P4) //Heat supplied in kJ/kg
W3_4=Q3_4 //Work supplied in kJ/kg
Net_work=eta_carnot*Q3_4 //Net work output in kJ/kg
cv=0.718 //Specific heat at constant volume in kJ/kgK
W4_1=cv*(T4-T1) //Work for isentropic process in kJ/kg
Gross_work=W3_4+W4_1 //Gross work supplied in kJ/kg
work_ratio=Net_work/Gross_work //Work ratio
//Results:
printf("\n The efficiency of the Carnot cycle, eta_carnot = %.1f percent",eta_carnot*100)
printf("\n The work ratio of the Carnot cycle = %.3f \n\n",work_ratio)
```

Scilab code Exa 2.3 Calculation of air standard efficiency of Otto cycle

```
//Calculation of air standard efficiency of Otto cycle
clc,clear
//Given:
```

```
d=17,l=30 //Bore and stroke in cm
V_c=0.001025 //Clearance volume in m^3
//Solution:
V_s=(%pi/4)*d^2*l //Swept volume in cc
V_c=V_c*10^6 //Clearance volume in cc
V=V_c+V_s //Total cylinder volume in cc
r=V/V_c //Compression ratio
g=1.4 //Specific heat ratio(gamma)
eta=1-1/r^(g-1) //Air standard efficiency
//Results:
printf("\n The Air standard efficiency of Otto cycle
    , eta = %.1f percent\n\n",eta*100)
```

Scilab code Exa 2.4 Calculations on constant volume cycle

```
//Calculations on constant volume cycle
clc,clear
//Given:
P1=97 //Pressure at the beginning(1) in kN/m^2
T1=40+273 //Temperature at the beginning(1) in K
r=7 //Compression ratio
Q=1200 //Heat supplied in kJ/kg
g=1.4 //Specific heat ratio(gamma)
cv=0.718 //Specific heat at constant volume in kJ/
    kgK
//Solution:
//(a)
T2=T1*(r)^(g-1),T3=round(Q/cv+T2) //Temperature at
    2, 3 in K
//(b)
eta=1-1/r^(g-1) //Thermal efficiency
//(c)
W=Q*eta //Workdone per cycle in kJ/kg
//Results:
printf("\n (a)The maximum temperature attained in
```

```
    the cycle , T3 = %d degreeC",T3-273)
printf("\n (b)The thermal efficiency of the cycle ,
    eta = %.1f percent",eta*100)
printf("\n (c)The workdone during the cycle/kg of
    working fluid , W = %d kJ\n\n",W)
```

Scilab code Exa 2.5 Calculations on Otto cycle

```
//Calculations on Otto cycle
clc,clear
//Given:
r=8 //Compression ratio
P1=1,P3=50 //Pressure at 1, 3 in bar
T1=100+273 //Temperature at 1 in K
m=1 //Air flow in kg
R=0.287 //Specific gas constant in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 2.22
//Point 1
V1=m*R*10^3*T1/(P1*10^5) //Ideal gas equation ,
    Volume at 1 in m^3
//Point 2
P2=P1*r^g //Pressure at 2 in bar
V2=V1/r //Volume at 2 in m^3
T2=P2*V2*T1/(P1*V1) //Temperature at 2 in K
//Point 3
V3=V2 //Constant volume process , Volume at 3 in m^3
T3=(P3/P2)*T2 //Temperature at 3 in K (Wrong in book
    )
//Point 4
P4=P3*(1/r)^g //Pressure at 4 in bar
V4=V1 //Constant volume process , Volume at 4 in m^3
T4=T1*(P4/P1) //Temperature at 4 in K
cv=R/(g-1) //Specific heat at constant volume in kJ/
```

```
kgK
ratio=(cv*(T3-T2))/(cv*(T4-T1)) //Ratio of heat supplied to the heat rejected (Round off error)
//Results:
printf("\n Point 1:\n Pressure = %d bar, Volume = %.4f m^3, Temperature = %d degreeC",P1,V1,T1-273)
printf("\n\n Point 2:\n Pressure = %.1f bar, Volume = %.4f m^3, Temperature = %.1f degreeC",P2,V2,T2-273)
printf("\n\n Point 3:\n Pressure = %.1f bar, Volume = %.4f m^3, Temperature = %.1f degreeC",P3,V3,T3-273)
printf("\n\n Point 4:\n Pressure = %.2f bar, Volume = %.4f m^3, Temperature = %.1f degreeC",P4,V4,T4-273)
printf("\n\n Ratio of heat supplied to the heat rejected = %.3f\n\n",ratio)
//Textbook answer for T3 is wrong
//Round off error in the value of 'ratio'
```

Scilab code Exa 2.6 Calculations on Otto cycle

```
//Calculations on Otto cycle
clc,clear
//Given:
P1=1 //Pressure at 1 in bar
T1=15+273 //Temperature at 1 in K
r=8 //Compression ratio
Q1=1000 //Heat added in kJ/kg
cv=0.718 //Specific heat at constant volume in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 2.23
//(a)
```

```
P2=P1*(r)^g //Pressure at 2 in bar
T2=T1*r^(g-1) //Temperature at 2 in K
T3=Q1/cv+T2 //Temperature at 3 in K (Round off error)
//(b)
eta=1-1/r^(g-1) //Air standard efficiency
//(c)
W=Q1*eta //Work done in kJ/kg (Round off error)
//(d)
Q2=Q1-W //Heat rejected in kJ/kg
//Results:
printf("\n (a)The maximum temperature in the cycle, T3 = %d degreeC",T3-273)
printf("\n (b)The air standard efficiency, eta = %.1f percent",eta*100)
printf("\n (c)The workdone per kg of air = %d kJ/kg",W)
printf("\n (d)The heat rejected = %d kJ/kg",Q2)
//Round off error in the values of 'T3' and 'W'
```

Scilab code Exa 2.7 Calculations on Otto cycle

```
//Calculations on Otto cycle
clc,clear
//Given:
P1=1.05,P2=13,P3=35 //Pressure at 1, 2, 3 in bar
T1=15+273 //Temperature at 1 in K
cv=0.718 //Specific heat at constant volume in kJ/kgK
R=0.287 //Specific gas constant in kJ/kgK
//Solution:
r="V1/V2" //Compression ratio
g=R/cv+1 //Specific heat ratio(gamma)
r=(P2/P1)^(1/g) //By adiabatic process relation
eta=1-1/r^(g-1) //Air standard efficiency
```

```
T2=P2*T1/(P1*r) //Temperature at 2 in K
T3=(P3/P2)*T2 //Temperature at 3 in K
Q1=cv*(T3-T2) //Heat added in kJ/kg
W=Q1*eta //Work done in kJ/kg
V1=1*R*10^3*T1/(P1*10^5) //Ideal gas equation ,
    Volume at 1 in m^3/kg
V2=V1/r //Volume at 2 in m^3/kg
V_s=V1-V2 //Swept volume in m^3/kg
mep=W*1000/(V_s*10^5) //Mean effective pressire in
    bar
//Results:
printf("\n The air standard efficiency , eta = %.1f
    percent",eta*100)
printf("\n The compression ratio , r = %d",r)
printf("\n The mean effective pressure , mep = %.2f
    bar\n",mep)
```

Scilab code Exa 2.8 Calculations on Otto cycle

```
//Calculations on Otto cycle
clc,clear
//Given:
r=8 //Compression ratio
T1=20+273 //Temperature at 1 in K
P1=1 //Pressure at 1 in bar
Q1=1800 //Heat added in kJ/kg
cv=0.718 //Specific heat at constant volume in kJ/
    kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
T2=T1*r^(g-1) //Temperature at 2 in K
T3=Q1/cv+T2 //Temperature at 3 in K (printing error)
P2=P1*(r)^g //Pressure at 2 in bar
P3=P2*(T3/T2) //Pressure at 3 in bar
T4=T3/r^(g-1) //Temperature at 4 in K
```

```
eta=1-1/r^(g-1) //Air standard efficiency
W1_2=cv*(T1-T2) //Work done for process 1−2 in kJ/kg
W3_4=cv*(T3-T4) //Work done for process 3−4 in kJ/kg
W=W1_2+W3_4 //Net work done for the cycle in kJ/kg
V1=cv*(g-1)*10^3*T1/(P1*10^5) //Ideal gas equation, Volume at 1 in m^3/kg
V2=V1/r //Volume at 2 in m^3/kg
V_s=V1-V2 //Swept volume in m^3/kg
mep=W*1000/(V_s*10^5) //Mean effective pressire in bar
//Results:
printf("\n The maximum temperature, T3 = %d K",T3)
printf("\n The maximum pressure, P3 = %.1f bar",P3)
printf("\n The temperature at the end of the expansion process, T4 = %d K",T4)
printf("\n The air standard efficiency, eta = %.1f percent",eta*100)
printf("\n The mean effective pressure of the cycle, mep = %.1f bar\n\n",mep)
//Answers in the book are wrong
```

Scilab code Exa 2.9 Calculations on Otto cycle

```
//Calculations on Otto cycle
clc,clear
//Given:
power=50 //Internal power in kW
N=4800 //Engine speed in rpm
l=80,d=80 //Stroke and bore of engine in mm
n=4 //Number of cylinders
V_c=50000 //Clearance volume in mm^3
delta_P=45 //Pressure rise during combustion in bar
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 2.24
```

```
V_s=(%pi/4)*d^2*l //Swept volume in mm^3
r=(V_c+V_s)/V_c //Compression ratio
eta=1-1/r^(g-1) //Air standard efficiency
ideal_mep=eta*delta_P/((g-1)*(r-1)) //Ideal mean effective pressure in bar
W=power*60*2/(n*N) //Actual work transfer per cycle per cylinder in kJ
V_s=V_s*1D-9 //Swept volume in m^3
actual_mep=W*1000/(V_s*10^5) //Actual mean effective pressire in bar
//Results:
printf("\n The mean effective pressure of the engine, actual mep = %.2f bar",actual_mep)
printf("\n The mean effective pressure of the Otto cycle, ideal mep = %.2f bar\n\n",ideal_mep)
```

Scilab code Exa 2.10 Calculations on Otto cycle

```
//Calculations on Otto cycle
clc,clear
//Given:
CV=42000 //Calorific value of the fuel in kJ/kg
a=30/100,b=70/100 //Fraction of compression stroke at point a, b
P_a=1.33,P_b=2.66 //Pressure at point a, b
n=1.33 //Polytropic index
eta_cycle=50/100 //Air standard cycle efficiency
//Solution:
//Refer fig 2.25
//Since, compression follows PV^n = C
//Thus, P_a*V_a^n = P_b*V_b^n
//Assume a_b = V_a/V_b
a_b=(P_b/P_a)^(1/n) //Ratio of volume at a to volume at b
//Defining the function, ratio of r(compression
```

```
ratio)
function [ratio]=Volume(r)
    V_a=1+0.7*(r-1)
    V_b=1+0.3*(r-1)
    ratio=V_a/V_b-a_b
endfunction
funcprot(0)
r=fsolve(1,Volume) //Compression ratio
g=1.4 //Specific heat ratio(gamma)
eta=round(1000*(1-1/r^(g-1)))/1000 //Air standard efficiency
eta_it=eta_cycle*eta //Indicated thermal efficiency
//Since, 1 kWh = 3600 kJ
Q1=3600/eta_it //Heat supplied in kJ/kWh
isfc=Q1/CV //Indicated specific fuel consumption in kg/kWh
//Results:
printf("\n The compression ratio, r = %.2f",r)
printf("\n The fuel consumption, isfc = %.3f kg/kWh\n\n",isfc)
```

Scilab code Exa 2.11 Calculations on diesel cycle

```
//Calculations on diesel cycle
clc,clear
//Given:
r=14 //Compression ratio
P1=1 //Pressure at 1 in bar
T1=27+273,T3=2500+273 //Temperature at 1 and 3 in K
//Solution:
//Refer fig 2.26
g=1.4 //Specific heat ratio(gamma)
T2=T1*(r)^(g-1) //Temperature at 2 in K
P2=P1*(T2/T1)^(g/(g-1)) //Pressure at 2 in bar
rho=T3/T2 //Cut off ratio
```

```
T3_T4=(r/rho)^(g-1) //Temperature ratio T3/T4
T4=round(T3/T3_T4) //Temperature at 4 in K
eta=1-((T4-T1)/(g*(T3-T2))) //Efficiency of diesel cycle
R=0.287,cp=1.005,cv=0.718 //Specific gas constant, heat capacities at constant pressure and volume in kJ/kgK
V1=R*T1*10^3/(P1*10^5) //Volume at 1 in m^3/kg
V_s=V1*(1-1/r) //Stroke volume in m^3/kg
mep=(cp*(T3-T2)-cv*(T4-T1))*10^3/(V_s*10^5) //Mean effective pressure in bar
//Results:
printf("\n The thermal efficiency of the diesel cycle, eta = %.1f percent",eta*100)
printf("\n The mean effective pressure of the cycle, pm = %.2f bar\n\n",mep)
```

Scilab code Exa 2.12 Calculations on diesel cycle

```
//Calculations on diesel cycle
clc,clear
//Given:
P1=1,P2=50 //Pressure at 1, 2 in bar
V1=1,V3=0.1 //Volume at 1, 3 in m^3
T1=18+273 //Temperature at 1 in K
g=1.4 //Specific heat ratio(gamma)
//Solution:
T2=T1*(P2/P1)^((g-1)/g) //Temperature at 2 in K
V2=V1*(P1/P2)*(T2/T1) //Volume at 2 in m^3
T3=round(T2*(V3/V2)) //Temperature at 2 in K (printing error)
V4=V1 //Constant volume process, volume at 4 in m^3
T4=T3*(V3/V4)^(g-1) //Temperature at 4 in K
eta=1-((T4-T1)/(g*(T3-T2))) //Efficiency of diesel cycle
```

```
//Results:
printf("\n Temperature at 1, T1 = %d K\n Temperature
     at 2, T2 = %.1f K\n Temperature at 3, T3 = %d K\
    n Temperature at 4, T4 = %.1f K",T1,T2,T3,T4)
printf("\n The thermal efficiency of the cycle, eta
    = %.1f percent\n\n",eta*100)
//Answer in the book is printed wrong
```

Scilab code Exa 2.13 Calculations on diesel cycle

```
//Calculations on diesel cycle
clc,clear
//Given:
r=18 //Compression ratio
p=10 //percentage of stroke at which constant
    pressure process ends
P1=1,T1=20+273 //Pressure and temperature at 1 in
    bar and K
V_a=100 //Volume of air used per hour in m^3/hr
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 2.27
//Calculation of cut off ratio (rho)
V_c=1 //Assume clearance volume in unit
V_s=r-V_c //Swept volume in unit
V3=V_c+V_s*p/100 //Volume at constant pressure
    process ends or point 3 in unit
V2=V_c //Volume at constant pressure process starts
    or point 2 in unit
rho=V3/V2 //Cut off ratio
eta=1-((rho^g-1)/(r^(g-1)*g*(rho-1))) //Thermal
    efficiency
P2=P1*(r)^g //Pressure at 2(maximum) in bar (
    printing error)
P3=P2 //Constant pressure process, pressure at 3 in
```

```
bar
T2=T1*(r)^(g-1) //Temperature at 2 in K
T3=T2*rho //Temperature at 3(maximum) in K
//Consider the cycle for 100 m^3 of swept volume with air, thus
V_s=V_a //Swept volume in m^3/hr
V2=V_s/(r-1) //Volume at 2 in m^3/hr
V1=V_s+V2 //Volume at 1 in m^3/hr
V3=rho*V2 //Volume at 3 in m^3/hr
V4=V1 //Constant volume process, volume at 4 in m^2
P4=P3*(V3/V4)^g //Pressure at 4 in bar
W=(P2*(V3-V2)+((P3*V3-P4*V4)-(P2*V2-P1*V1))/(g-1))*10^5 //Work done in cycle in Nm
ip=W/3600
//Results:
printf("\n (a)The maximum temperature, T3 = %d degreeC and the maximum pressure, P2 = %.1f bar",T3-273,P2)
printf("\n (b)The thermal efficiency of the engine, eta = %d percent",eta*100)
printf("\n (c)The indicated power of the engine, ip = %.2f kW\n\n",ip/1000)
//Answers in the book are wrong
```

Scilab code Exa 2.14 Calculations on diesel cycle

```
//Calculations on diesel cycle
clc,clear
//Given:
d=15,l=20 //Diameter and stroke of cylinder in cm
p1=10 //Percentage of stroke volume equal to clearance volume
p2=6 //Percentage of stroke at which cut off takes place
g=1.4 //Specific heat ratio(gamma)
```

```
//Solution:
//Refer fig 2.28
V_s=(%pi/4)*d^2*l //Stroke volume in cm^3
V_c=p1*V_s/100 //Clearance volume in cm^3
V1=V_s+V_c //Total volume at 1 in cm^3
V2=V_c //Volume at 2 in cm^3
V3=V2+p2*V_s/100 //Volume at 3 in cm^3
r=V1/V2 //Compression ratio
rho=V3/V2 //Cut off ratio
eta=1-((rho^g-1)/(r^(g-1)*g*(rho-1))) //Thermal
    efficiency
//Results:
printf("\n The air standard efficiency of the engine
    , eta = %d percent\n\n",eta*100)
```

Scilab code Exa 2.15 Calculations on dual combustion cycle

```
//Calculations on dual combustion cycle
clc,clear
//Given:
r=15 //Compression ratio
P1=1,T1=25+273,V1=.1 //Pressure, temperature, volume
     at 1 in bar, K, m^3
P4=65,T4=1500+273 //Pressure and temperature at 4 in
     bar and K
cv=0.718 //Specific heat at constant volume in kJ/
    kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 2.29
V2=V1/r //Volume at 2 in m^3
P2=P1*(r)^g //Pressure at 2 in bar
T2=T1*(r)^(g-1) //Temperature at 2 in K
P3=P4 //Pressure at 3 in bar
T3=T2*(P3/P2) //Temperature at 3 in K
```

```
V3=V2 //Volume at 3 in m^3
V4=V3*(T4/T3) //Volume at 4 in m^3
V5=V1 //Volume at 5 in m^3
P5=P4*(V4/V5)^g //Pressure at 5 in bar
T5=T4*(V4/V5)^(g-1) //Temperature at 5 in K
eta=1-(T5-T1)/((T3-T2)+g*(T4-T3)) //Thermal efficiency
//Results:
printf("\n Point 1:\n Pressure = %d bar, Volume = %.1f m^3, Temperature = %d degreeC",P1,V1,T1-273)
printf("\n\n Point 2:\n Pressure = %.1f bar, Volume = %.4f m^3, Temperature = %d degreeC",P2,V2,T2-273)
printf("\n\n Point 3:\n Pressure = %d bar, Volume = %.4f m^3, Temperature = %d degreeC",P3,V3,T3-273)
printf("\n\n Point 4:\n Pressure = %d bar, Volume = %.4f m^3, Temperature = %d degreeC",P4,V4,T4-273)
printf("\n\n Point 5:\n Pressure = %.2f bar, Volume = %.1f m^3, Temperature = %d degreeC",P5,V5,T5-273)
printf("\n\n The thermal efficiency of the cycle, eta = %d percent",eta*100)
//Answers in the book are wrong
```

Scilab code Exa 2.16 Calculations on dual combustion cycle

```
//Calculations on dual combustion cycle
clc,clear
//Given:
r=18 //Compression ratio
P1=1.01,P3=69 //Pressure at 1, 3 in bar
T1=20+273 //Temperature at 1 in K
cv=0.718 //Specific heat at constant volume in kJ/kgK
cp=1.005 //Specific heat at constant pressure in kJ/
```

```
kgK
g=1.4 //Specific heat ratio(gamma)
R=0.287 //Specific gas constant in kJ/kgK
//Solution:
T2=T1*r^(g-1) //Temperature at 2 in K
P2=P1*r^g //Pressure at 2 in bar
T3=T2*(P3/P2) //Temperature at 3 in K
Q_v=cv*(T3-T2) //Heat added at constant volume in kJ/kg
//Given, Heat added at constant volume is equal to heat added at constant pressure
T4=Q_v/cp+T3 //Temperature at 4 in K
rho=T4/T3 //Cut off ratio
T5=T4*(rho/r)^(g-1) //Temperature at 5 in K
Q1=2*Q_v //Heat supplied in cycle in kJ/kg
Q2=cv*(T5-T1) //Heat rejected in kJ/kg
eta=1-Q2/Q1 //Thermal efficiency
W=Q1-Q2 //Work done by the cycle in kJ/kg
V1=1*R*T1/(P1*100) //Volume at 1 in m^3/kg
V2=V1/r //Volume at 2 in m^3/kg
V_s=V1-V2 //Swept volume in m^3/kg
mep=W/(V_s*100) //Mean effective pressure in bar
//Results:
printf("\n The air standard efficiency, eta = %.1f percent",eta*100)
printf("\n The mean effective pressure, mep = %.2f bar\n\n",mep)
```

Scilab code Exa 2.17 Calculations on dual combustion cycle

```
//Calculations on dual combustion cycle
clc,clear
//Given:
P1=1 //Pressure at 1 in bar
T1=50+273 //Temperature at 1 in K
```

```
r=14,rho=2,alpha=2 //Compression ratio, cut off ratio, pressure ratio
g=1.4 //Specific heat ratio(gamma)
cp=1.005 //Specific heat at constant pressure in kJ/kgK
cv=0.718 //Specific heat at constant volume in kJ/kgK
//Solution:
//Refer fig 2.30
T2=T1*ceil(100*r^(g-1))/100 //Temperature at 2 in K
P2=round(P1*r^g) //Pressure at 2 in bar
P3=alpha*P2 //Pressure at 3 in bar
T3=T2*(P3/P2) //Temperature at 3 in K
T4=T3*rho //Temperature at 4 in K
e=r/rho //Expansion ratio
T5=T4/e^(g-1) //Temperature at 5 in K (Round off error)
Q1=cv*(T3-T2)+cp*(T4-T3) //Heat added in kJ/kg
Q2=cv*(T5-T1) //Heat rejected in kJ/kg
eta=1-Q2/Q1 //Air standard efficiency
//Results:
printf("\n The temperature\n\tT1 = %d K\n\tT2 = %d K\n\tT3 = %d K\n\tT4 = %d K\n\tT5 = %d K",T1,T2,T3,T4,T5)
printf("\n\n The ideal thermal efficiency, eta = %.1f percent\n\n",eta*100)
//Round off error in the value of 'T5'
```

Scilab code Exa 2.18 Calculations on dual combustion cycle

```
//Calculations on dual combustion cycle
clc,clear
//Given:
r=15 //Compression ratio
P1=1,P3=55 //Pressure at 1, 3 in bar
```

```
T1=27+273 //Temperature at 1 in K
g=1.4 //Specific heat ratio(gamma)
cp=1.005 //Specific heat at constant pressure in kJ/kgK
cv=0.718 //Specific heat at constant volume in kJ/kgK
//Solution:
//Refer fig 2.31
T2=T1*r^(g-1) //Temperature at 2 in K
P2=P1*r^g //Pressure at 2 in bar
alpha=P3/P2 //Constant volume pressure ratio
T3=T2*(P3/P2) //Temperature at 3 in K
Q1_v=cv*(T3-T2) //Heat supplied at constant volume in kJ/kg
T4=poly(0,"T4") //Defining temperature at 4 as unknown in K
//Given, heat supplied at constant volume, Q1_v is twice of heat supplied at constant pressure, Q1_p
Q1_p=cp*(T4-T3) //Heat supplied at constant pressure in kJ/kg
T4=roots(Q1_v-2*Q1_p) //Temperature at 4 in K
rho=T4/T3 //Cut off ratio
e=r/rho //Expansion ratio
T5=T4/e^(g-1) //Temperature at 5 in K
eta=1-(T5-T1)/((T3-T2)+g*(T4-T3)) //Thermal efficiency
eta=round(100*eta)
//Results:
printf("\n The constant volume pressure ratio, alpha = %.2f",alpha)
printf("\n The cut off ratio, rho = %.2f",rho)
printf("\n The thermal efficiency of the cycle, eta = %d percent\n\n",eta)
```

Scilab code Exa 2.19 Calculations for comparision of Otto cycle and Diesel cycle

```
//Calculations for comparision of Otto cycle and
    Diesel cycle
clc,clear
//Given:
n=6 //Number of cylinders
V_s=300 //Engine swept volume in cm^3 per cylinder
r=10 //Compression ratio
N=3500 //Engine speed in rpm
bp=75 //Brake power in kW
P1=1 //Pressure at 1 in bar
T1=15+273 //Temperature at 1 in K (misprint)
cv=0.718 //Specific heat at constant volume in kJ/
    kgK
cp=1.005 //Specific heat at constant pressure in kJ/
    kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 2.32
//Otto cycle
eta_o=1-1/r^(g-1) //Cycle efficiency
Q1=bp/eta_o //Rate of heat addition in kW
P_o=bp/n //Power output per cylinder in kW
W_o=P_o/(N/(2*60)) //Work output per cycle per
    cylinder in kJ
mep_o=W_o/V_s*10^6/100 //Mean effective pressure in
    bar
T2=T1*r^(g-1) //Temperature at 2 in K
Q1=Q1/(n*N/(2*60)) //Heat supplied per cycle per
    cylinder in kJ
R=0.287 //Specific gas constant in kJ/kgK
v1=R*T1/(P1*100) //Volume of air in m^3/kg
V1=V_s/(1-1/r)*10^-6 //Volume at 1 in m^3
m=V1/v1 //Mass of the air in kg
T3=T2+Q1/(m*cv) //Temperature at 3 in K
//Diesel cycle
```

```
T3!=T2+Q1/(m*cp) //Temperature at 3 in diesel cycle in K
rho=T3!/T2 //Cut off ratio for diesel cycle
eta_d=1-((rho^g-1)/(r^(g-1)*g*(rho-1))) //The air standard efficiency
Power=eta_d*bp/(eta_o) //Power output in kW
P_d=Power/n //Power output per cylinder in kW
W_d=P_d/(N/(2*60)) //Work output per cycle per cylinder in kJ
mep_d=W_d/V_s*10^6/100 //Mean effective pressure in bar
//Results:
printf("\n The rate of heat addition same for both Petrol and Diesel engine, Q1 = %.1f kW",bp/eta_o)
printf("\n For Petrol engine\n\t Cycle efficiency, eta = %.3f\n\t Mean effective pressure, mep = %.2f bar\n\t The maximum temperature of the cycle, Tmax = %.0f K",eta_o,mep_o,T3)
printf("\n For Diesel engine\n\t Cycle efficiency, eta = %.2f\n\t Mean effective pressure, mep = %.2f bar\n\t The maximum temperature of the cycle, Tmax = %.0f K\n\t Power output = %.1f kW",eta_d,mep_d,T3!,Power)
```

Scilab code Exa 2.20 Calculations for Otto cycle and Limited pressure cycle

```
//Calculations for Otto cycle and Limited pressure cycle
clc,clear
//Given:
r=10 //Compression ratio
P1=1 //Pressure at 1 in bar
T1=40+273 //Temperature at 1 in K
Q1=2700 //Heat added in kJ
```

```
//Solution:
//Refer fig 2.33
g=1.4 //Specific heat ratio(gamma)
R=0.287 //Specific gas constant in kJ/kgK
cp=1.005 //Specific heat at constant pressure in kJ/kgK
V1=1*R*T1/(P1*100) //Volume at 1 in m^3/kg
V5=V1 //Volume at 5 in m^3/kg
V2=V1/r //Volume at 2 in m^3/kg
V3=V2 //Volume at 3 in m^3/kg
V_s=V1-V2 //Swept volume in m^3/kg
T2=T1*r^(g-1) //Temperature at 2 in K
P2=P1*r^g //Pressure at 2 in bar
//(a)Limited-pressure cycle
P3=70 //Limited maximum pressure in bar
T3=T2*(P3/P2) //Temperature at 3 in K
cv=0.718 //Specific heat at constant volume in kJ/kgK
Q_v=cv*(T3-T2) //Heat supplied at constant volume in kJ
Q_p=Q1-Q_v //Heat supplied at constant pressure in kJ
T4=Q_p/cp+T3 //Temperature at 4 in K
V4=V3*(T4/T3) //Volume at 4 in m^3/kg
T5=T4*(V4/V5)^(g-1) //Temperature at 5 in K
Q2=cv*(T5-T1) //Heat rejected in kJ/kg
W=Q1-Q2 //Work done in kJ/kg
eta1=W/Q1 //Efficiency of Limited pressure cycle
mep1=W/(V_s*100) //Mean effective pressure in bar
//(b)Constant volume cycle
//All the heat is supplied at constant volume in constant volume cycle
T6=Q1/cv+T2 //Temperature at 6 in K
P6=P2*T6/T2 //Pressure at 6 in bar
T7=T6*(1/r)^(g-1) //Temperature at 7 in K
Q2=cv*(T7-T1) //Heat rejected in kJ/kg
W=Q1-Q2 //Work done in kJ/kg
eta2=W/Q1 //Efficiency of constant volume cycle
```

```
mep2=W/(V_s*100) //Mean effective pressure in bar
//If gases expanded isentropically to their original
    pressure of 1 bar, this point is named as 8
P8=P1 //Pressure at 8 in bar
T8=T6*(P8/P6)^((g-1)/g) //Temperature at 8 in K
Q3=cp*(T8-T1) //Heat rejected at constant pressure
   in kJ/kg
W_inc=Q2-Q3 //Work increased if gas expanded
   isentropically in kJ/kg
//Results:
printf("\n (a)For Limited pressure cycle\n\t The
   mean effective pressure, mep = %.2f bar\n\t The
   thermal efficiency, eta = %.1f percent",mep1,eta1
   *100)
printf("\n\n (a)For Constant volume cycle\n\t The
   mean effective pressure, mep = %.1f bar\n\t The
   thermal efficiency, eta = %.1f percent",mep2,eta2
   *100)
printf("\n\n   Additional work per kg of charge = %
   .1f kJ\n\n",W_inc)
```

Scilab code Exa 2.21 Calculations for comparision of Atkinson and Otto cycle

```
//Calculations for comparison of Atkinson and Otto
   cycle
clc,clear
//Given:
r=6 //Compression ratio
P1=1,P3=20 //Pressure at 1, 3 in bar
T1=27+273 //Temperature at 1 in K
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 2.34
eta_otto=1-1/r^(g-1) //Efficiency of Otto cycle (
```

```
printing error)
//For Atkinson cycle
e=(P3/P1)^g //Expansion ratio
eta_atk=1-g*(e-r)/(e^g-r^g) //Efficiency of Atkinson cycle
//Results:
printf("\n Efficiency of Otto cycle = %.2f percent",eta_otto*100)
printf("\n Efficiency of Atkinson cycle = %.1f percent\n\n",eta_atk*100)
//Answer in the book is printed wrong
```

Scilab code Exa 2.22 Calculations on Joule cycle

```
//Calculations on Joule cycle
clc,clear
//Given:
P1=1.02,P2=6.12 //Pressure at 1, 2 in bar
T1=15+273,T3=800+273 //Temperature at 1, 3 in K
g=1.4 //Specific heat ratio(gamma)
cp=1.005 //Specific heat at constant pressure in kJ/kgK
//Solution:
//Refer fig 2.18
r_p=P2/P1 //pressure ratio
eta=1-1/r_p^((g-1)/g) //Thermal efficiency
r_w=1-(T1/T3)*r_p^((g-1)/g) //Work ratio
//Results:
printf("\n The thermal efficiency, eta = %.1f percent",eta*100)
printf("\n The work ratio, r_w = %.2f\n\n",r_w)
```

Chapter 3

Fuel Air Cycles

Scilab code Exa 3.1 Effect of variable specific heat on efficiency

```
//Effect of variable specific heat on efficiency
clc,clear
//Given:
r=7 //Compression ratio
g=1.4 //Specific heat ratio(gamma)
cv=0.718 //(Assume)Specific heat at constant volume
    in kJ/kgK
dcv=1*cv/100 //Change in specific heat in kJ/kgK
//Solution:
R=cv*(g-1) //Specific gas constant in kJ/kgK
eta=round(100*(1-1/r^(g-1)))/100 //Efficiency when
    there is no change in specific heat
function [eta]=Otto(cv) //Defining efficiency as a
    function of specific heat
  eta=1-1/r^(R/cv)
endfunction
funcprot(0)
detaBydcv=derivative(Otto,cv) //Derivative of
    efficiency wrt to specific heat at initial value
    of specific heat
detaByeta=detaBydcv*dcv/eta //Change in efficiency
```

```
   wrt to initial value of efficiency
//Results:
printf("\n The percentage change in the efficiency
   of Otto cycle = %.3f percent",detaByeta*100)
if (detaByeta < 0) then
    disp("decrease")
end
```

Scilab code Exa 3.2 Effect of variable specific heat on maximum pressure

```
//Effect of variable specific heat on maximum
   pressure
clc,clear
//Given:
r=6 //Compression ratio
CV=44000 //Calorific value in kJ/kg of fuel
A_F=15/1 //Air-fuel ratio
P1=1 //Pressure at 1 in bar
T1=60+273 //Temperature at 1 in K
n=1.32 //Index of compression
T=poly(0,"T") //Defining temperature(T) as unknown
   in K
cv=0.71+20D-5*T //Specific heat at constant volume
   as a function of temperature(T) in kJ/kgK
cv_c=0.71 //Constant specific heat in kJ/kgK
//Solution:
//Refer fig 3.19
P2=P1*r^n //Pressure at 2 in bar
T2=floor(T1*r^(n-1)) //Temperature at 2 in K
T3=poly(0,"T3") //Defining temperature(T3) as
   unknown in K
T_av=(T3+T2)/2 //Average temperature during
   combustion of charge in K
cv_mean=horner(cv,T_av) //Mean specific heat in kJ/
   kgK
```

```
//Assume cycle consumes 1 kg of air
m_a=1,m_f=m_a/A_F,m_c=m_f+m_a //Mass of air , fuel ,
    and charge in kg
Q1=CV*m_f //Heat added per kg of air in kJ/kg
T3_v=roots(Q1-cv_mean*m_c*(T3-T2)),T3_v=T3_v(2) //
    Temperature at 3 in K
P3_v=P2*T3_v/T2 //Pressure at 3 in bar
//For constant specific heat
T3_c=roots(Q1-cv_c*m_c*(T3-T2)) //Temperature at 3
    for constant specific heat in K
P3_c=P2*T3_c/T2 //Pressure at 3 for constant
    specific heat in bar
//Results:
printf("\n The maximum pressure in the cycle for
    variable specific heat, P3 = %.1f bar",P3_v)
printf("\n The maximum pressure in the cycle for
    constant specific heat, P3 = %.1f bar\n\n",P3_c)
```

Scilab code Exa 3.3 Calculations on diesel engine

```
//Calculations on diesel engine
clc,clear
//Given:
A_F=28/1 //Air-fuel ratio
CV=42000 //Calorific value in kJ/kg
cv='0.71+20D-5*T' //Specific heat at constant volume
     as a function of temperature(T) in kJ/kgK
R='0.287' //Specific gas constant in kJ/kgK
r=14/1 //Compression ratio
T2=800 //Temperature at the end of the compression
    process (2) in K
//Solution:
//Refer fig 3.20
//Assume cycle consumes 1 kg of fuel
m_c=A_F*1+1 //Mass of charge in kg
```

```
cp=addf(cv,R) //Specific heat at constant pressure as a function of temperature(T) in kJ/kgK
//Since, heat transfer at constant pressure, Q1 = integration(cp*dt) from T2 to T3
//Thus, Q1 is the function of T3. Defining the function Q1 of T3
function [Q1toCV]=difference(T3)
    Q1=integrate(cp,'T',T2,T3)
    Q1toCV=Q1-CV/m_c
endfunction
//Since, heat transfer at constant pressure must be equal to calorific value per kg of charge
//Thus, their difference must be zero, function Q1toCV is solve for zero
T3=fsolve(1,difference)
T3=round(T3) //Temperature at the end of constant pressure proces (3) in K
rho=T3/T2 //Cut off ratio
V2=1 //Assume clearance volume in unit
V3=rho //Volume at 3 in units
p=(V3-V2)*100/(r-V2) //percentage of stroke at which constant pressure process ends
//Results:
printf("\n At %.2f percentage of stroke combustion is completed.\n\n",p)
```

Scilab code Exa 3.4 Calculations on dual combustion cycle

```
//Calculations on dual combustion cycle
clc,clear
//Given:
P1=1 //Pressure at 1 in bar
T1=90+273 //Temperature at 1 in K
r=13 //Compression ratio
Q1=1675 //Heat supplied per kg of air in kJ/kg
```

```
Q1_v=Q1/2,Q1_p=Q1/2 //Heat supplied at constant volume and pressure per kg of air in kJ/kg
g=1.4 //Specific heat ratio(gamma)
R='0.287' //Specific gas constant in kJ/kgK
cv='0.71+20D-5*T' //Specific heat at constant volume as a function of temperature(T) in kJ/kgK
//Solution:
//Refer fig 3.21
P2=P1*r^g //Pressure at 2 in bar
T2=T1*r^(g-1) //Temperature at 2 in K
//Since, heat transfer at constant volume, Q1_v = integration(cv*dt) from T2 to T3
//Thus, Q1_v is the function of T3. Defining the function Q1_v of T3
function [Q1_vtoQ1]=Volume(T3)
    Q1_v=integrate(cv,'T',T2,T3)
    Q1_vtoQ1=Q1_v-Q1/2
endfunction
//Since, heat transfer at constant volume must be equal to half of total heat added
//Thus, their difference must be zero, function Q1_vtoQ1 is solve for zero
T3=fsolve(1,Volume) //Temperature at 3 in K
P3=P2*T3/T2 //Pressure at 3 in bar
cp=addf(cv,R) //Specific heat at constant pressure as a function of temperature(T) in kJ/kgK
//Since, heat transfer at constant pressure, Q1_p = integration(cp*dt) from T3 to T4
//Thus, Q1_p is the function of T4. Defining the function Q1_p of T4
function [Q1_ptoQ1]=Pressure(T4)
    Q1_p=integrate(cp,'T',T3,T4)
    Q1_ptoQ1=Q1_p-Q1/2
endfunction
//Since, heat transfer at constant pressure must be equal to half of total heat added
//Thus, their difference must be zero, function Q1_ptoQ1 is solve for zero
```

```
T4=fsolve(1,Pressure) //Temperature at 4 in K
rho=T4/T3 //Cut off ratio
p=(rho-1)*100/(r-1) //Percentage of stroke at which cut off occurs
//Results:
printf("\n The maximum pressure in the cycle, P3 = %.1f bar",P3)
printf("\n The percentage of stroke at which cut off occurs = %.2f percent\n\n",p)
```

Scilab code Exa 3.5 Effect of molecular contraction

```
//Effect of molecular contraction
clc,clear
//Given:
r=7 //Compression ratio
CV=44000 //Calorific value of the fuel in kJ/kg
A_F=13.67 //Air fuel ratio of the mixture
cv=0.718 //Specific heat at constant volume in kJ/kgK
n=1.3 //Polytropic index
P1=1,T1=67+273 //Pressure and temperature at the beginning in bar and K
//Solution:
//Refer fig 3.22
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
p=23 //Percentage of oxygen in air by mass
//Stoichiometric equation of combustion of fuel (C6H14)
//    [C6H14] + x[O2]    =    y[CO2] + z[H2O]
//Equating coefficients
x=9.5,y=6,z=7 //Coefficients of stoichiometric equation
```

```
A_F_g=x*2*O/(6*C+14*H)*100/p //Gravimetric air fuel ratio
MS=A_F_g/A_F*100 //Actual mixture strength in percent
//Combustion is incomplete
//Stoichiometric equation of incomplete combustion of fuel (C6H14)
//    MS/100[C6H14] + x[O2] = a[CO2] + b[CO] + c[H2O]
//Equating coefficients
a=4.39,b=2.36,c=7.87 //Coefficients of stoichiometric equation
//Stoichiometric equation of combustion of fuel (C6H14) by adding Nitrogen
//   MS/100[C6H14] + x[O2] + x*79/21[N2] = a[CO2] + b[CO] + c[H2O] + x*79/21[N2]
m1=MS/100+x+x*79/21 //Moles before combustion
m2=a+b+c+x*79/21 //Moles after combustion
Me=(m2-m1)/m1*100 //Molecular expansion in percent
T2=T1*r^(n-1) //Temperature at 2 in K
m_c=A_F+1 //Mass of charge in kg
T3=CV/(m_c*cv)+T2 //Temperature at 3 in K
T3=round(T3)
P3=P1*r*(T3/T1) //Pressure at 3 in bar (printing error)
//Temperature and pressure considering molecular expansion
T3!=T3 //Temperature remains same at 3 in K
P3!=P3*m2/m1 //Pressure at 3 in bar
//Results:
printf("\n\t The molecular expansion = %.2f percent\n",Me)
printf("\n (a)Without considering the molecular contraction\n\t The maximum pressure, P3 = %.2f bar\n\t The maximum temperature, T3 = %.0f K",P3,T3)
printf("\n (b)Considering the molecular contraction\n\t The maximum pressure, P3 = %.2f bar\n\t The
```

```
maximum temperature, T3 = %.0f K",P3!,T3!)
//Answer in the book is wrong
```

Scilab code Exa 3.6 Calculations on Otto cycle

```
//Calculations on Otto cycle
clc,clear
//Given:
p=15 //Clearance volume in percentage of displacement volume
V_s=2.8 //Swept volume in litres
N=2500 //Engine speed in rpm
Q1=1400 //Heat added in kJ/kg
T1=27+273 //Temperature at inlet in K
P1=100 //Pressure at inlet in kPa
R=0.287 //Specific gas constant in kJ/kgK
//Solution:
//Refer fig 3.23
//By using gas tables
//Refer Ideal-gas properties of air
V2=(p/100)*(V_s/1000) //Volume at 2 (Clearance volume) in m^3
V3=V2 //Volume at 3 in m^3
V1=V_s/1000+V2,V4=V1 //Volume at 1, 4 in m^3
//  Process 1-2
vr1=621.2,pr1=1.3860,u1=214.09,phi1=5.7016 //Relative specific volume, relative pressure, specific internal energy(kJ/kg), specific entropy (kJ/kgK) at 1 (from air tables)
vr2=vr1*(V2/V1) //Relative specific volume at 2
vr=[81.89 78.61],T=[660 670],pr=[23.13 24.46],u=[481.01 488.81] //Relative specific volume, temperature(K), relative pressure, specific internal energy(kJ/kg) (extracted from air tables)
```

```
//Finding the corresponding temperature at vr2 by interpolation
T2=interpln([vr;T],vr2) //Temperature at 2 in K
//Finding the corresponding relative pressure at T2 by interpolation
pr2=interpln([T;pr],T2) //Relative pressure at 2
//Finding the corresponding specific internal energy at T2 by interpolation
u2=interpln([T;u],T2) //specific internal energy at 2 in kJ/kg
P2=P1*(pr2/pr1) //Pressure at 2 in kPa
//  Process 2-3
u3=Q1+u2 //Specific internal energy at 3 in kJ/kg
vr=[2.356 2.175 2.012],T=[2100 2150 2200],pr=[2559 2837 3138],u=[1775.3 1823.8 1872.8] //Relative specific volume, temperature(K), relative pressure, specific internal energy(kJ/kg) (extracted from air tables)
//Finding the corresponding relative specific volume at u3 by interpolation
vr3=interpln([u;vr],u3) //Relative specific volume at 3
//Finding the corresponding relative pressure at u3 by interpolation
pr3=interpln([u;pr],u3) //Relative pressure at 3
//Finding the corresponding temperature at u3 by interpolation
T3=interpln([u;T],u3) //Temperature at 3(maximum) in K (Round off error)
P3=P2*(T3/T2) //Pressure at 3(maximum) in kPa
//  Process 3-4
vr4=vr3*(V4/V3) //Relative specific volume at 4
vr=[15.241 14.470],T=[1180 1200],pr=[222.2 238.0],u=[915.57 933.33],phi=[7.1586 7.1684] //Relative specific volume, temperature(K), relative pressure, specific internal energy(kJ/kg), specific entropy(kJ/kgK) (extracted from air tables)
```

```
//Finding the corresponding temperature at vr4 by interpolation
T4=interpln([vr;T],vr4) //Temperature at 4 in K
//Finding the corresponding specific internal energy at T4 by interpolation
u4=interpln([T;u],T4) //Specific internal energy at 4 in kJ/kg
//Finding the corresponding relative pressure at T4 by interpolation
pr4=interpln([T;pr],T4) //Relative pressure at 4
P4=P3*(pr4/pr3) //Pressure at 4 in kPa
//Finding the corresponding specific entropy at T4 by interpolation
phi4=interpln([T;phi],T4) //Specific entropy at 4 in kJ/kgK
//  Process 4-1
Q2=u1-u4 //Heat rejected in kJ/kg
W=Q1+Q2 //Work done in kJ/kg
eta=W/Q1 //Efficiency
m=P1*V1/(R*T1) //Mass of air in cycle in kg
W=m*W*N/60 //Rate of work in kW
Delta_s=phi1-phi4-R*log(P1/P4) //Change in specific entropy between 1 and 4 in kJ/kgK
AE=Q2-T1*(Delta_s) //Available portion of energy of Q2 in kJ/kg (Round off error)
p_AE=AE/Q2 //Available energy in percentage of Q2
//  Without using gas tables
g=1.4 //Specific heat ratio(gamma)
cv=0.718 //Specific heat at constant volume in kJ/kgK
r=V1/V2 //Compression ratio
eta!=1-1/r^(g-1) //Efficiency
//  Process 1-2
T2=T1*(r)^(g-1) //Temperature at 2 in K
P2=P1/100*(r)^g //Pressure at 2 in bar
//  Process 2-3
T3!=Q1/cv+T2 //Temperature at 3(maximum) in K
P3!=P2*T3!/T2 //Pressure at 3(maximum) in bar
```

```
//  Process 3-4
T4=T3!*(1/r)^(g-1) //Temperature at 4 in K
Q2=cv*(T1-T4) //Heat rejected in kJ/kg
W!=Q1+Q2 //Work done in kJ/kg
eta!=W!/Q1 //Efficiency
power=m*W!*N/60 //Power in kW
Delta_s=cv*log(T1/T4) //Change in specific entropy between 1 and 4 in kJ/kgK
AE!=Q2-T1*Delta_s //Available portion of energy of Q2 in kJ/kg (Round off error)
p_AE!=AE!/Q2 //Available energy in percentage of Q2 (Round off error)
//Results:
printf("\n Constant specific heat:\n\t Maximum temperature, Tmax = %.1f K\n\t Maximum pressure, Pmax = %.1f bar\n\t Thermal efficiency, eta = %.2f percent\n\t Power = %.1f kW\n\t Available portion of heat rejected = %.1f kJ/kg (%.1f percent)",T3!,P3!,eta!*100,power,abs(AE!),p_AE!*100)
printf("\n Variable specific heat:\n\t Maximum temperature, Tmax = %.0f K\n\t Maximum pressure, Pmax = %.1f bar\n\t Thermal efficiency, eta = %.1f percent\n\t Power = %.1f kW\n\t Available portion of heat rejected = %.1f kJ/kg (%.1f percent)",T3,P3/100,eta*100,W,abs(AE),p_AE*100)
//Round off error in 'T3', 'AE', 'AE!', 'p_AE!'
```

Chapter 5

Combustion in SI Engines

Scilab code Exa 5.1 Calculation of optimum spark timing

```
//Calculation of optimum spark timing
clc,clear
//Given:
theta_s=25 //Angle at which spark occured before top dead centre in degrees
theta_d=3 //Angle at which delay ended before top dead centre in degrees
theta_c=-12 //Angle at which combustion finish after top dead centre in degrees
p=15 //Percentage increase of delay period at half closing the throttle
//Solution:
DP=theta_s-theta_d //Delay period in degrees
CP=theta_d-theta_c //Combustion period in degrees
//(a)Full throttle , half speed
DA1=DP/2 //Delay angle in degrees
TP1=DA1+CP //Total period in degrees
TS1=TP1+theta_c //Time of spark before top dead centre in degrees
//(b)Half throttle , half speed
DA2=(DP/2)+(DP/2)*p/100 //Delay angle in degrees
```

```
TP2=DA2+CP //Total period in degrees
TS2=TP2+theta_c //Time of spark before top dead
    centre in degrees
//Results:
printf("\n (a)Full throttle, half speed\n\t Time of
    spark before top dead centre is %d degree",TS1)
printf("\n (a)Half throttle, half speed\n\t Time of
    spark before top dead centre is %.2f degree\n\n",
    TS2)
```

Chapter 7

Comparison of SI and CI Engines

Scilab code Exa 7.1 Calculations for comparison of SI and CI engine

```
//Calculations for comparison of SI and CI engine
clc,clear
//Given:
//For SI engine
F_A1=1/13.5 //Fuel air ratio
CV1=44000 //Calorific value in kJ/kg
eta_bt1=25 //Brake thermal efficiency in percent
m_f1=1 //Fuel consumption in kg/hr
//For CI engine
A_F2=25/1 //Air fuel ratio
CV2=42000 //Calorific value in kJ/kg
eta_bt2=38 //Brake thermal efficiency in percent
//Solution:
//(a)SI engine
bp1=m_f1*CV1*eta_bt1/(100*3600) //Brake power in kW
bsfc1=m_f1/bp1 //Brake specific fuel consumption in
   kg/kWh
m_a1=bsfc1/F_A1 //Air consumption in kg/kWh
//(a)CI engine
```

```
m_f2=1 //Fuel consumption in kg/hr
bp2=m_f2*CV2*eta_bt2/(3600*100) //Brake power in kW
bsfc2=m_f2/bp2 //Brake specific fuel consumption in
    kg/kWh
m_a2=bsfc2*A_F2 //Air consumption in kg/kWh
//Comparison
R_bp=bp1/bp2 //Ratio of brake power of SI to CI
R_bsfc=bsfc1/bsfc2 //Ratio of brake specific fuel
    consumption of SI to CI
R_m_a=m_a1/m_a2 //Ratio of fuel consumption of SI to
     CI
//Results:
printf("\n For SI engine\n\tBrake output, bp = %.2f
   kW/kg of fuel\n\tBrake specific fuel consumption,
     bsfc = %.3f kg/kWh",bp1,bsfc1)
printf("\n For CI engine\n\tBrake output, bp = %.1f
   kW/kg of fuel\n\tBrake specific fuel consumption,
     bsfc = %.3f kg/kWh",bp2,bsfc2)
printf("\n The air consumption\n\tfor SI engine, m_a
    = %.2f kg/kWh\n\tfor CI engine, m_a = %.2f kg/
   kWh",m_a1,m_a2)
printf("\n Comparison of SI to CI\n\tbp = %.3f\n\
    tbsfc = %.3f\n\tair consumption = %.3f\n\n",R_bp,
    R_bsfc,R_m_a)
```

Scilab code Exa 7.2 Calculations for comparison of SI and CI engine

```
//Calculations for comparison of SI and CI engine
clc,clear
//Given:
//For SI engine
s1=0.72 //Specific gravity of gasoline fuel
CV1=44800 //Calorific value of gasoline fuel in kJ/
    kg
eta_bt1=20 //Brake thermal efficiency in percent
```

```
A_F1=14 //Air fuel ratio
//For CI engine
s2=0.87 //Specific gravity of diesel oil
CV2=43100 //Calorific value of diesel oil in kJ/kg
eta_bt2=30 //Brake thermal efficiency in percent
A_F2=21 //Air fuel ratio
//Solution:
//SI engine
bsfc_SI=3600*100/(eta_bt1*CV1) //Brake specific fuel
    consumption in kg/kWh
m_a_SI=A_F1*bsfc_SI //Air consumption in kg/kWh
//CI engine
bsfc_CI=3600*100/(eta_bt2*CV2) //Brake specific fuel
    consumption in kg/kWh
m_a_CI=A_F2*bsfc_CI //Air consumption in kg/kWh
//Results:
printf("\n For SI engine\n\tBrake specific fuel
   consumption, bsfc_SI = %.3f kg/kWh\n\tAir
   consumption = %.2f kg/kWh",bsfc_SI,m_a_SI)
printf("\n For CI engine\n\tBrake specific fuel
   consumption, bsfc_CI = %.3f kg/kWh\n\tAir
   consumption = %.2f kg/kWh",bsfc_CI,m_a_CI)
```

Chapter 8

Fuels

Scilab code Exa 8.1 Calculation of lowest calorific value

```
//Calculation of lowest calorific value
clc,clear
//Given:
HCV=46900 //Highest calorific value(HCV) of petrol
    in kJ/kg
pH2=14.4/100 //Composition of Hydrogen in petrol by
    mass
ufg=2304.4 //Latent heat of evaporation for water in
     kJ/kg
//Solution:
//  2[H2] + [O2] = 2[H2O]
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
//Assume 1 kg of fuel consume
mH2=1*pH2 //Mass of Hydrogen in kg/kg of fuel
m_a=2*(2*H+O)/(2*2*H)*mH2 //Mass of water produced
    in kg/kg of fuel
LCV=HCV-m_a*ufg //Lowest calorific value in kJ/kg
//Results:
printf("\n The LCV of petrol = %.0f kJ/kg\n",LCV)
```

Scilab code Exa 8.2 Calculation of relative fuel air ratio by volume

```
//Calculation of relative fuel air ratio by volume
clc,clear
//Given:
pCO2=13/100 //Composition of Carbon di oxide in dry
    exhaust gas
//Solution:
p_v=21/100 //Composition of Oxygen in air by volume
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
//Combustion equation
//  [C8H18] + a[O2] + (1-p_v)/p_v*a[N2] = x[CO2] + y
    [H2O] + z[O2] + w[N2]
//On balancing the reaction
x=8,y=9 //Coefficients of combustion equation
function M=f(a) //Defining the function, M of
    coefficient a for calculation of a
    z=a-x-y/2 //On balancing O
    w=(1-p_v)/p_v*a //On balancing N
    M=x/(x+z+w)-pCO2
endfunction
//Since, Composition of CO2 calculated from the
    equation must be equal to the given composition
    of CO2
//Thus, function M solve for zero to get value of a
a=fsolve(1,f) //Moles of air required
A_F_act=a/p_v //Air fuel ratio by volume
//For chemically correct mixture
a=x+y/2 //Moles of air required
A_F_cc=a/p_v //Chemically correct air fuel ratio
ratio=(1/A_F_act)/(1/A_F_cc)*100 //Ratio of actual
    to chemically correct fuel air ratio by volume
```

```
//Results:
printf("\n The ratio by volume of fuel to air
    supplied = 1/%.0f",A_F_act)
printf("\n The volume fuel air ratio = %.1f
    percentage of chemically correct ratio\n",ratio)
```

Scilab code Exa 8.3 Calculations on Petrol engine

```
//Calculations on Petrol engine
clc,clear
//Given:
pC=84,pH2=16 //Percentage of Carbon, Hydrogen in
    fuel
p_v=20.9 //Percentage of Oxygen in air by volume
//Solution:
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
N=14 //Atomic mass of Nitrogen(N)
m_f=100 //Mass of fuel (assume) in kg
//Combustion equation
//pC/C[C] + pH2/2[H2] + [a[O2] + (100-p_v)/p_v*a[N2
    ]] = b[CO2] + d[O2] + e[N2] + f[H2O]
//Equating coefficients
b=pC/C,f=pH2/2,d=b/6,a=b+d+f/2 //Coefficients of
    combustion equation
m_a=a*2*O + (100-p_v)/p_v*a*2*N //Mass of air
    supplied in kg
A_F=m_a/m_f //Air fuel ratio
P_e=d/(a-d)*100 //Percentage excess air
//Results:
printf("\n (a)The air fuel ratio by mass, A_F = %.1f
    /1",A_F)
printf("\n (b)The percentage excess air supplied = %
    .1f percent\n\n",P_e)
```

Scilab code Exa 8.4 Calculation of mass of air

```
//Calculation of mass of air
clc,clear
//Given:
MS=25 //Mixture strength in percent
p=23.1 //Percentage of oxygen in air by mass
//Solution:
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
N=14 //Atomic mass of Nitrogen(N)
m_f=1 //Mass of fuel(C6H14) in kg
mC=(6*C)/((6*C)+(14*H)) //Mass of Carbon in kg
mH=(14*H)/((6*C)+(14*H)) //Mass of Hydrogen in kg
m_a=(2*O/C*mC+O/(2*H)*mH)*100/p //Mass of air in kg
//For 25 percent rich mixture
m_f=m_f+m_f*MS/100 //Mass of fuel(C6H14) in kg
A_F=m_a/m_f //Air fuel ratio
mO2=p/100*A_F //Mass of Oxygen available in kg
mO2_1=O/(2*H)*mH //Oxygen required for combustion of
    H to H2O in kg
mH2O=mH*(1+O/(2*H)) //Mass of H2O produced in kg
mO2_2=O/C*mC //Oxygen required for combustion of C
    to CO in kg
mCO=mC*(1+O/C) //Mass of CO produced in kg
mO2_3=mO2-(mO2_1+mO2_2) //Mass of Oxygen remaining
    for combustion of CO to CO2
mCO_b=mO2_3*(C+O)/O //Mass of CO burned to CO2 in kg
mCO2=mCO_b*(1+O/(C+O)) //Mass of CO2 produced in kg
mCO_ub=mCO-mCO_b //Mass of CO unburned in kg
nH2O=mH2O/(2*H+O) //Moles of H2O
nCO2=mCO2/(C+2*O) //Moles of CO2
nCO=mCO_ub/(C+O) //Moles of CO
```

```
mN2=A_F*(1-p/100) //Mass of Nitrogen (N2) in kg
nN2=mN2/(2*N) //Moles of N2
nT=nH2O+nCO2+nCO+nN2 //Total number of moles
pH2O=nH2O/nT,pCO2=nCO2/nT,pCO=nCO/nT,pN2=nN2/nT //
    Composition of products
//Results:
printf("\n The theoretical mass of air required , m_a
     = %.2f kg",m_a)
printf("\n The composition of the products in
    percent\n\t H2O = %.2f\n\t CO2 = %.2f\n\t CO = %
    .2f\n\t N2 = %.2f\n\n",pH2O*100,pCO2*100,pCO*100,
    pN2*100)
```

Scilab code Exa 8.5 C7H16 in Petrol engine

```
//C7H16 in Petrol engine
clc,clear
//Given:
p_v=21 //Percentage of Oxygen in air by volume
p_e=50 //Percentage of excess air supplied
//Solution:
m_f=100 //Mass of fuel (assume) in kg
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
N=14 //Atomic mass of Nitrogen(N)
a=poly(0,'a') //Defining unknown number of moles of
    stoichiometric oxygen
//Combustion equation
//m_f/(7*C+16*H)[C7H16] + (1+p_e/100)*[a[O2] + (100-
    p_v)/p_v*a[N2]]  =  b[CO2] + d[O2] + e[N2] + f[
    H2O]
//Equating coefficients
b=m_f/(7*C+16*H)*7 //Moles of CO2 on balancing of C
f=m_f/(7*C+16*H)*16/2 //Moles of H2O on balancing of
```

```
H
d=p_e/100*a //Excess moles of oxygen
a=roots((1+p_e/100)*a-(b+d+f/2)) //Balancing Oxygen of both sides
m_a=a*2*O+(100-p_v)/p_v*a*2*N //Mass of air supplied in kg
A_F=m_a/m_f //Air fuel ratio
d=p_e/100*a //Moles of Oxygen in products of combustion
e=(1+p_e/100)*(100-p_v)/p_v*a //Moles of Nitrogen in products of combustion
nT=b+d+e+f //Total number of moles in product of combustion
pH2O=f/nT*100,pCO2=b/nT*100,pO2=d/nT*100,pN2=e/nT*100 //Percentage volumetric composition of the products of combustion
//Results:
printf("\n (a)The stoichiometric air fuel consumption by mass, A_F = %.2f:1",A_F)
printf("\n (b)The percentage volumetric composition of the products\n\t CO2 = %.2f\n\t O2 = %.2f\n\t N2 = %.1f\n\t H2O = %.2f\n\n",pCO2,pO2,pN2,pH2O)
```

Scilab code Exa 8.6 Incomplete combustion of Petrol

```
//Incomplete combustion of Petrol
clc,clear
//Given:
pC=85,pH2=15 //Percentage of Carbon, Hydrogen in fuel
A_F=14 //Air fuel ratio by mass
p_m=23.2 //Percentage of oxygen in air by mass
//Solution:
m_f=100 //Mass of fuel (assume) in kg
m_a=A_F*m_f //Mass of air in kg
```

```
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
N=14 //Atomic mass of Nitrogen(N)
p_v=20.9 //Percentage of Oxygen in air by volume
//Combustion equation
//pC/C[C] + pH2/2[H2] + [a[O2] + (100-p_v)/p_v*a[N2]] = b[CO2] + d[CO] + e[N2] + f[H2O]
//Equating coefficients
f=pH2/2 //Moles of H2O on balancing of H
a=m_a/(2*O+(100-p_v)/p_v*2*N) //Balancing Oxygen of both sides
//On balancing C of both sides we get, b + d = pC/C    eq(1)
//On balancing O of both sides we get, b + d/2 + f/2 = a    eq(2)
//Solving equations (1) and (2)
A=[1 1;1 1/2],B=[pC/C;a-f/2],SOL=A\B //Taking matrix A, B to get solution matrix, SOL = [b;d]
b=SOL(1),d=SOL(2) //Moles of CO2 and CO
e=(100-p_v)/p_v*a //Moles of Nitrogen in products of combustion
mC=b/m_f*C //Mass of carbon burning to CO2 in kg per kg of fuel
mCO2=b/m_f*(C+2*O) //Mass of CO2 produced in kg
mCO=d/m_f*(C+O) //Mass of CO produced in kg
mN2=e/m_f*(2*N) //Mass of N2 produced in kg
mH2O=f/m_f*(2*H+O) //Mass of H2O produced in kg
//Results:
printf("\n (a)The mass of the carbon burning to CO2 = %.3f kg",mC)
printf("\n (b)The mass of each of the gases in the exhaust per kg of fuel\n\t CO2 = %.2f kg\n\t CO = %.2f kg\n\t N2 = %.2f kg\n\t H2O = %.2f kg\n\n",mCO2,mCO,mN2,mH2O)
```

Scilab code Exa 8.7 Analysis of fuel from exhaust gas analysis

```
//Analysis of fuel from exhaust gas analysis
clc,clear
//Given:
pCO2=12/100,pCO=2/100,pCH4=4/100,pH2=1/100,pO2
    =4.5/100 //Composition of Carbon di oxide(CO2),
    Carbon mono oxide(CO), Methane(CH4), Hydrogen(H2)
    , Oxygen(O2) in dry exhaust gas
pN2=1-(pCO2+pCO+pCH4+pH2+pO2) //Composition of
    Nitrogen(N2) in dry exhaust gas
//Solution:
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
p_v=21 //Percentage of Oxygen in air by volume
//Let X be the mass of the fuel per mole dry exhaust
     gas
//Let Y be the mole of O2 per mole dry exhaust gas
//Let 1 kg of fuel contain p kg of C and q kg of H2
//Combustion equation
//X*(p/C[C] + q/(2*H)[H2]) + Y[O2] + (100-p_v)/p_v*Y
    [N2] = pCO2[CO2] + pCO[CO] + pCH4[CH4] + pH2[H2]
    + pO2[O2] + a[H2O] + pN2[N2]
//Equating coefficients
Y=pN2/((100-p_v)/p_v) //Nitrogen(N) balance
a=2*(Y-(pCO2+pCO/2+pO2)) //Oxygen(O) balance
Xp=C*(pCO2+pCO+pCH4) //Carbon(C) balance; X*p
Xq=(2*H)*(2*pCH4+pH2+a) //Hydrogen(H) balance; X*q
p_q=Xp/Xq //Ratio of C to H2 in fuel
//Results:
printf("\n The proportion by mass of Carbon to
    Hydrogen in the fuel = %.2f/1\n",p_q)
```

Scilab code Exa 8.8 Orsat analysis

```
//Orsat analysis
clc,clear
//Given:
pCO2=7.5,pCO=1,pO2=9.4 //Percentage of Carbon di oxide(CO2), Carbon mono oxide(CO), Oxygen(O2) in dry exhaust gas
P=1.02 //Pressure of the exhaust gas in bar
pO_v=21 //Percentage of Oxygen in air by volume
pN_v=79 //Percentage of Nitrogen in air by volume
M=29 //Molecular weight of air
//Solution:
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
//Let 100*x moles of air be used with fuel per 100 mole of dry exhaust products
pN2=100-(pCO2+pCO+pO2) //Composition of Nitrogen(N2) in dry exhaust gas
//Combustion equation
//      a[C] + b[H2]) + pO_v*x[O2] + pN_v*x[N2] = pCO2[CO2] + pCO[CO] + pO2[O2] d[H2O] + pN2[N2]
//Equating coefficients
a=pCO2+pCO //Carbon(C) balance
x=pN2/pN_v //Nitrogen(N) balance
d=2*(pO_v*x-(pCO2+pO2+pCO/2)) //Oxygen(O) balance
d=round(10*d)/10
b=d //Hydrogen(H) balance
m_a=100*x*M //Mass of air in kg
m_f=a*C+b*2*H //Mass of fuel in kg
A_F=m_a/m_f //Air fuel ratio
pC=a*C/m_f*100 //Percentage of Carbon(C) in fuel
pH2=100-pC //Percentage of Hydrogen(H2) in fuel
nT=pCO2+pCO+pO2+pN2+d //Total number of moles in
```

```
    product of combustion
CO2=pCO2/nT*100,O2=pO2/nT*100,CO=pCO/nT*100,N2=pN2/
    nT*100,H2O=d/nT*100 //Percentage volumetric
    composition of the products of combustion
PP=d/nT*P //Partial pressure of H2O in bar
//From steam tables
if (PP==0.0825) then
    T=42.8 //Saturation temperature in degreeC
end
//Results:
printf("\n (a)The air fuel ratio used, A_F = %.1f",
    A_F)
printf("\n (b)The mass analysis of the fuel\n\t
    Carbon = %.1f percent\n\t Hydrogen = %.1f percent
    ",pC,pH2)
printf("\n (c)The wet products analysis in percent\n
    \t CO2 = %.1f\n\t O2 = %.2f\n\t CO = %.1f\n\t N2
    = %.2f\n\t Steam = %.1f",CO2,O2,CO,N2,H2O)
printf("\n (d)The minimum temperature to which the
    exhaust may be cooled before condensation occurs
    = %.1f degreeC\n\n",T)
```

Scilab code Exa 8.9 Calculations on gas engine

```
//Calculations on gas engine
clc,clear
//Given:
pH2=49.4/100,pCO=18/100,pCH4=20/100,pC4H8=2/100,pO2
    =0.4/100,pN2=6.2/100,pCO2=4/100 //Composition of
    Coal gas
MW=20 //Mixture weakness in percent
//Solution:
//Combustion equations for determining the moles of
    Oxygen used
//2[H2] + [O2] ---> 2[H2O]        //For Hydrogen
```

```
//2[CO] + [O2] ---> 2[CO2]        //For Carbon mono oxide
//[CH4] + 2[O] ---> [CO2] + 2[H2O]        //For Methane
//[C4H8] + 6[O2] ---> 4[CO2] + 4[H2O]      //For C4H8
nO2=sum([pH2/2 pCO/2 2*pCH4 6*pC4H8 pO2]) //Moles of O2 required (error)
nCO2=sum([pCO pCH4 4*pC4H8 pCO2]) //Moles of CO2
nH2O=sum([pH2 2*pCH4 4*pC4H8]) //Moles of H2O
p_v=21 //Percentage of Oxygen in air by volume
n_a=nO2/p_v*100 //Moles of air required
n_f=1 //For 1 mole of fuel
A_F=n_a/n_f //Air fuel ratio
//For weak mixture
A_F_act=A_F*(1+MW/100) //Actual air fuel ratio
nN2=(1-p_v/100)*A_F_act //Moles of N2
nO2=p_v/100*A_F_act-nO2 //Excess moles of Oxygen in products
nN2=nN2+pN2 //Moles of Nitrogen in products
nT_d=nCO2+nO2+nN2 //Total dry moles of product
nT_w=nT_d+nH2O //Total wet moles of product
p_d=[nCO2 nO2 nN2]*100/nT_d //Percentage volumetric composition of the dry products of combustion
p_w=[nCO2 nH2O nO2 nN2]*100/nT_w //Percentage volumetric composition of the wet products of combustion
//Results:
printf("\n The stoichiometric air fuel ratio used, A_F = %.1f/1",A_F)
printf("\n The wet products analysis in percent\n\t CO2 = %.0f\n\t H2O = %.2f\n\t O2 = %.2f\n\t N2 = %.2f",p_w(1),p_w(2),p_w(3),p_w(4))
printf("\n The dry products analysis in percent\n\t CO2 = %.2f\n\t O2 = %.2f\n\t N2 = %.2f\n\n",p_d(1),p_d(2),p_d(3))
//Answers in the book are wrong
```

Chapter 10

Air Capacity of Four Stroke Engines

Scilab code Exa 10.1 Calculations on SI engine

```
//Calculations on SI engine
clc,clear
//Given:
n=6 //Number of cylinders
V_d=700 //Displaced volume per cylinder in cm^3
bp=78 //Brake power in kW
N=3200 //Angular speed of engine in rpm
m_f=27 //Petrol consumption in kg/hr
CV=44 //Calorific value in MJ/kg
//Solution:
//(1)
A_F=12 //Air-fuel ratio
P1=0.9,T1=32+273 //Intake air pressure and temperature in bar and K
m_a=A_F*m_f //Air consumption in kg/hr
R=287 //Specific gas constant in J/kgK
rho_a=P1*10^5/(R*T1) //Density of air in kg/m^3
eta_vol=m_a/(60*rho_a*V_d*n*10^-6*N/2) //Volumetric efficiency
```

```
//(2)
eta_bt=bp*3600/(m_f*CV*1000) //Brake thermal
    efficiency
//(3)
T=bp*60/(2*%pi*N) //Brake torque in kNm
//Results:
printf("\n (1)The volumetric efficiency, eta_vol = %
    .2f percent",eta_vol*100)
printf("\n (2)The brake thermal efficiency, eta_bt =
    %.2f percent",eta_bt*100)
printf("\n (3)The brake torque, T = %.0f Nm\n\n",T
    *1000)
```

Chapter 11

Carburetion

Scilab code Exa 11.1 Calculation of the throat diameter

```
//Calculation of the throat diameter
clc,clear
//Given:
m_a=5 //Mass of air in kg/min
P1=1.013 //Pressure of air in bar
T1=27+273 //Temperature of air in K
C1=0,C2=90 //Flow velocity at opening and throat in
    m/s
Cv=0.8 //Velocity coefficient
cp=1.005 //Specific heat at constant pressure in kJ/
    kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 11.32
//Defining, y as a function of P2
//This function is the difference of C2 actual and
    C2 given
function [y]=f(P2)
    C2_act=0.8*sqrt(2*cp*1000*T1*(1-(P2/P1)^((g-1)/g
        )))
    y=C2_act-C2
```

```
endfunction
funcprot(0);
//The function f is solve for zero to get the value of P2
P2=fsolve(1,f) //Pressure at throat in bar
R=0.287 //Specific gas constant in kJ/kgK
rho1=P1*100/(R*T1) //Mass density at opening in kg/m^3
rho2=rho1*(P2/P1)^(1/g) //Mass density at throat in kg/m^3
A2=m_a/(60*rho2*C2) //Cross section area at throat in m^2
d2=sqrt(4*A2/%pi) //Diameter of cross section in m
//Results:
printf("\n The throat diameter of the choke, d2 = %.2f cm\n\n",d2*100)
```

Scilab code Exa 11.2 Calculation of throat diameter and orifice diameter

```
//Calculation of throat diameter and orifice diameter
clc,clear
//Given:
m_a=6,m_f=.45 //Mass of air and fuel in kg/min
rho_f=740 //Density of fuel in kg/m^3
P1=1.013 //Pressure of air in bar
T1=27+273 //Temperature of air in K
C2=92 //Flow velocity at throat in m/s
Cv=0.8 //Velocity coefficient
Cd_f=0.60 //Coefficient of discharge of fuel
cp=1.005 //Specific heat at constant pressure in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Defining, y as a function of P2
```

```
//This function is the difference of C2 actual and C2 given
function [y]=f(P2)
    C2_act=Cv*sqrt(2*cp*10^3*T1*(1-(P2/P1)^((g-1)/g)))
    y=C2_act-C2
endfunction
funcprot(0);
//The function f is solve for zero to get the value of P2
P2=fsolve(1,f) //Pressure at throat in bar
R=0.287 //Specific gas constant in kJ/kgK
rho1=P1*100/(R*T1) //Mass density at opening in kg/m^3
rho2=rho1*(P2/P1)^(1/g) //Mass density at throat in kg/m^3
A2=m_a/(60*rho2*C2) //Cross section area at throat in m^2
d2=sqrt(4*A2/%pi) //Diameter of cross section in m
deltaP_v=P1-P2 //Pressure drop at venturi in bar
deltaP_f=0.75*deltaP_v //Given, Pressure drop at fuel metering orifice in bar
A_f=m_f/(60*Cd_f*sqrt(2*rho_f*deltaP_f*10^5)) //Area of cross section of fuel nozzle in m^2
d_f=sqrt(4*A_f/%pi) //Diameter of cross section of fuel nozzle in m
//Results:
printf("\n The throat diameter of the choke, d2 = %.3f cm",d2*100)
printf("\n The orifice diameter, d_f = %.2f mm\n\n",d_f*1000)
```

Scilab code Exa 11.3 Calculation of suction at throat

```
//Calculation of suction at throat
```

```
clc,clear
//Given:
d=10,l=12 //Bore and stroke in cm
n=4 //Number of cylinders
N=2000 //Speed of engine in rpm
d2=3 //Diameter of throat in cm
eta_vol=70 //Volumetric efficiency
rho_a=1.2 //Density of air in kg/m^3
Cd_a=0.8 //Coefficient of discharge for air
//Solution:
V_s=(%pi/4)*d^2*l*n*10^-6 //Swept volume of engine
    in m^3
V_act=eta_vol*V_s*N/(2*100*60) //Actual volume
    sucked in m^3/s
m_a=V_act*rho_a //Mass of air sucked in kg/s
deltaP_v=(m_a*4/(Cd_a*%pi*d2^2*10^-4))^2/(2*rho_a)
    //Pressure drop at venturi in pascal
//Results:
printf("\n The suction at the throat = %.4f bar\n\n"
    ,deltaP_v/10^5)
//Answer in the book is wrong
```

Scilab code Exa 11.4 Calculation of the diameter of fuel jet

```
//Calculation of the diameter of fuel jet
clc,clear
//Given:
m_f=7.5 //Mass of fuel in kg/hr
s=0.75 //Specific gravity of the fuel
T1=25+273 //Temperature of air in K
A_F=15 //Air fuel ratio
d=22 //Diameter of choke tube in mm
z=4 //Elevation of the jet in mm
Cd_a=0.82,Cd_f=0.7 //Coefficient of discharge for
    air and fuel
```

```
P1=1.013 //Pressure of air in bar
g=9.81 //Accelaration due to gravity in m/s^2
//Solution:
R=0.287 //Specific gas constant in kJ/kgK
rho_a=P1*100/(R*T1) //Mass density of air in kg/m^3
rho_f=s*1000 //Mass density of fuel in kg/m^3
m_a=A_F*m_f/3600 //Mass of air in kg/s
deltaP_v=(m_a*4/(Cd_a*%pi*d^2*10^-6))^2/(2*rho_a) //Pressure drop at venturi in pascal
A_f=m_f/(3600*Cd_f*sqrt(2*rho_f*(deltaP_v-z*10^-3*g*rho_f))) //Area of cross section of fuel nozzle in m^2
d_f=sqrt(4*A_f/%pi) //Diameter of cross section of fuel nozzle in m
//Results:
printf("\n The diameter of the fuel jet of a simple carburettor, d_f = %.3f mm\n\n",d_f*1000)
//Answer in the book is wrong
```

Scilab code Exa 11.5 Calculations on carburettor

```
//Calculations on carburettor
clc,clear
//Given:
V_s=1489 //Capacity of the engine in cc
N=4200 //Speed of the engine in rpm
eta_v=70 //Volumetric efficiency
A_F=13 //Air fuel ratio
C2=90 //Flow velocity at throat in m/s
Cd_a=0.85,Cd_f=0.66 //Coefficient of discharge for air and fuel
s=0.74 //Specific gravity of the fuel
z=6 //Elevation of the jet in mm
P1=1.013 //Pressure of air in bar
T1=27+273 //Temperature of air in K
```

```
g=1.4 //Specific heat ratio(gamma)
cp=1.005 //Specific heat at constant pressure in kJ/
    kgK
//Solution:
V_s=V_s*10^-6 //Swept volume in m^3
V_act=eta_v*V_s*N/(2*100*60) //Actual volume sucked
    in m^3/s
R=0.287 //Specific gas constant in kJ/kgK
m_a=P1*10^5*V_act/(R*10^3*T1) //Mass of air sucked
    in kg/s
//Defining, y as a function of P2
//This function is the difference of C2 actual and
    C2 given
function [y]=f(P2)
    C2_act=sqrt(2*cp*10^3*T1*(1-(P2/P1)^((g-1)/g)))
    y=C2_act-C2
endfunction
funcprot(0);
//The function f is solve for zero to get the value
    of P2
P2=fsolve(1,f) //Pressure at throat in bar
V2=V_act*(P1/P2)^(1/g) //Volume at throat in m^3/s
A2=V2/(C2*Cd_a) //Cross section area at throat in m
    ^2
d2=poly(0,'d2') //Defining the diameter of choke as
    unknown in m
d_f=d2/2.5 //Given
d2=roots(%pi/4*(d2^2-d_f^2)-A2) //Diameter of choke
    in m
m_f=m_a/A_F //Mass of fuel sucked in kg/s
A_f=m_f/(Cd_f*sqrt(2*s*1000*(P1*10^5-P2*10^5-z
    *10^-3*9.81*s*1000))) //Area of cross section of
    fuel nozzle in m^2
d_f=sqrt(4*A_f/%pi) //Diameter of cross section of
    fuel nozzle in m
//Results:
printf("\n The diameter of the fuel jet of a simple
    carburettor, D_jet = %.2f mm\n\n",d_f*1000)
```

Scilab code Exa 11.6 Calculations on carburettor

```
//Calculations on carburettor
clc,clear
//Given:
V_s=1710 //Capacity of the engine in cc
N=5400 //Speed of the engine in rpm
eta_vol=70 //Volumetric efficiency
n=2 //Number of carburettor
A_F=13 //Air fuel ratio
C2=107 //Flow velocity at throat in m/s
Cd_a=0.85,Cd_f=0.66 //Coefficient of discharge for air and fuel
s=0.75 //Specific gravity of the fuel
z=6 //Elevation of the jet in mm
P1=1.013 //Pressure of air in bar
T1=27+273 //Temperature of air in K
g=1.4 //Specific heat ratio(gamma)
cp=1.005 //Specific heat at constant pressure in kJ/kgK
//Solution:
V_s=V_s*10^-6 //Swept volume in m^3
V_act=eta_vol*V_s*N/(2*100*60) //Actual volume sucked in m^3/s
V_act=V_act/n //Actual volume of air sucked through each carburettor in m^3/s
R=0.287 //Specific gas constant in kJ/kgK
m_a=P1*10^5*V_act/(R*10^3*T1) //Mass of air sucked in kg/s
//Defining, y as a function of P2
//This function is the difference of C2 actual and C2 given
function [y]=f(P2)
    C2_act=sqrt(2*cp*10^3*T1*(1-(P2/P1)^((g-1)/g)))
```

```
    y=C2_act-C2
endfunction
funcprot(0);
//The function f is solve for zero to get the value of P2
P2=fsolve(1,f) //Pressure at throat in bar
V2=V_act*(P1/P2)^(1/g) //Volume at throat in m^3/s
A2=V2/(C2*Cd_a) //Cross section area at throat in m^2
d2=poly(0,'d2') //Defining the diameter of choke as unknown in m
d_f=d2/2.5 //Given
d2=roots(%pi/4*(d2^2-d_f^2)-A2) //Diameter of choke in m
m_f=m_a/A_F //Mass of fuel sucked in kg/s
A_f=m_f/(Cd_f*sqrt(2*s*1000*(P1*10^5-P2*10^5-z*10^-3*9.81*s*1000))) //Area of cross section of fuel nozzle in m^2
d_f=sqrt(4*A_f/%pi) //Diameter of cross section of fuel nozzle in m
//Results:
printf("\n The diameter of the choke tube, D = %.2f cm",d2(1)*100)
printf("\n The diameter of the fuel jet of a simple carburettor, D_f = %.2f mm\n\n",d_f*1000)
```

Scilab code Exa 11.7 Change in air fuel ratio at altitude

```
//Change in air fuel ratio at altitude
clc,clear
//Given:
ha=5000 //Altitude in m
A_F=14 //Air fuel ratio at sea level
P1=1.013 //Pressure of air in bar at sea level
T1=27+273 //Temperature of air in K at sea level
```

```
R=0.287 //Specific gas constant in kJ/kgK
function t=f1(h),t=ts-0.0065*h,endfunction //Temperature(t in degreeC) as a function of altitude(h in m)
function h=f2(P),h=19200*log10(1.013/P),endfunction //Altitude(h in m) as a function of pressure(P in bar)
//Solution:
ts=T1-273 //Sea level temperature in degreeC
T2=f1(ha) //Temperature at altitude(ha = 5000 m) in degreeC
T2=T2+273 //in K
//Defining, y as a function of P
//This function is the difference of function(f2) and ha given
function y=f(P),y=f2(P)-ha,endfunction
//The function f is solve for zero to get the value of P2
P2=fsolve(1,f) //Pressure at altitude(ha = 5000 m) in bar
rho_a=P2/(R*T2) //Density of air at altitude in kg/m^3
rho_s=P1/(R*T1) //Density of air at sea level in kg/m^3
A_F_a=A_F*sqrt(rho_a/rho_s) //Air fuel ratio at altitude
//Results:
printf("\n The air fuel ratio supplied at 5000 m altitude by a carburettor = %.2f\n\n",A_F_a)
```

Scilab code Exa 11.8 Calculation of air fuel ratio

```
//Calculation of air fuel ratio
clc,clear
//Given:
```

```
d2=20,d_f=1.25 //Diameter of throat and fuel nozzle in mm
Cd_a=0.85,Cd_f=0.66 //Coefficient of discharge for air and fuel
z=5 //Elevation of the jet in mm
rho_a=1.2,rho_f=750 //Mass density of air and fuel in kg/m^3
deltaP_a=0.07 //Pressure drop of air in bar
g=9.806 //Accelaration due to gravity in m/s^2
//Solution:
//(a)Nozzle lip is neglected
A_f=(%pi/4)*d_f^2,A2=(%pi/4)*d2^2 //Area of cross section of fuel nozzle and venturi in mm^2
m_a1=Cd_a*A2*sqrt(2*rho_a*deltaP_a),m_f1=Cd_f*A_f*sqrt(2*rho_f*deltaP_a) //Air flow and fuel flow
A_F1=m_a1/m_f1 //Air fuel ratio
//(b)Nozzle lip is taken into account
m_a2=m_a1 //Air flow remain same
m_f2=Cd_f*A_f*sqrt(2*rho_f*(deltaP_a-z*10^-3*g*rho_f*10^-5)) //Fuel flow
A_F2=m_a2/m_f2 //Air fuel ratio
//(c)Minimum velocity required to start the fuel flow when nozzle lip is provided
//To just start the fuel flow pressure difference in venturi must be equivalent to the nozzle lip pressure
deltaP_a=z*10^-3*g*rho_f //Pressure difference in N/m^2
C2=sqrt(2*deltaP_a/rho_a) //Minimum velocity of air at throat in m/s
//Results:
printf("\n The air fuel ratio when the nozzle lip is neglected = %.1f",A_F1)
printf("\n The air fuel ratio when the nozzle lip is taken into account = %.3f",A_F2)
printf("\n The minimum velocity required to start the fuel flow when lip is provided = %.2f m/s",C2)
```

Scilab code Exa 11.9 Effect of air cleaner

```
//Effect of air cleaner
clc,clear
//Given:
A_F=14 //Air fuel ratio at sea level
P2=0.834 //Pressure at venturi throat without an air
    cleaner in bar
P1=1.013 //Pressure of air in bar at sea level
deltaP_ac=30 //Pressure drop to air cleaner in mm of
    mercury
m_a=250 //Air flow in kg/hr
//Solution:
//No air cleaner
deltaP_a1=P1-P2 //Pressure difference at venturi
    throat in bar
//When air cleaner is fitted
deltaP_ac=deltaP_ac/750 //Pressure drop to air
    cleaner in bar
p=poly(0,'p') //Defining pressure at venturi throat
    with an air cleaner as unknown in bar
deltaP_a2=P1-deltaP_ac-p //Pressure difference at
    venturi throat in bar
//For same air flow and constant coefficients
    pressure difference in above two cases is same
p=roots(deltaP_a2-deltaP_a1) //Pressure at venturi
    throat with an air cleaner in bar
deltaP_f=P1-p //Pressure difference at venturi
    throat when air cleaner is fitted in bar
A_F_f=A_F*sqrt(deltaP_a1/deltaP_f) //Air fuel ratio
    when air cleaner is fitted
//Results:
printf("\n (a)The throat pressure when the air
    cleaner is fitted, P = %.3f bar",p)
```

```
printf("\n (b)Air fuel ratio with air cleaner is
    fitted = %.2f\n\n",A_F_f)
```

Chapter 12

Fuel Injection

Scilab code Exa 12.1 Calculation of quantity of fuel injected

```
//Calculation of quantity of fuel injected
clc,clear
//Given:
n=6 //Number of cylinders
bsfc=245 //Brake specific fuel consumption in gm/kWh
bp=89 //Brake power in kW
N=2500 //Engine speed in rpm
s=0.84 //Specific gravity of the fuel
//Solution:
m_f=bsfc*bp/(1000) //Fuel consumption in kg/hr
m_f=m_f/n //Fuel consumption per cylinder in kg/hr
m_f=(m_f/3600)/(N/(2*60)) //Fuel consumption per
   cycle in kg
V_f=m_f*1000/s //Volume of fuel consume per cycle in
    cc
//Results:
printf("\n The quantity of fuel to be injected per
   cycle per cylinder, V_f = %.4f cc",V_f)
```

Scilab code Exa 12.2 Calculation of orifice area

```
//Calculation of orifice area
clc,clear
//Given:
n=8 //Number of cylinders
bp=368 //Brake power in kW
N=800 //Engine speed in rpm
bsfc=0.238 //Brake specific fuel consumption in kg/kWh
P1=35,P2=60 //Beginning pressure and maximum pressure in cylinder in bar
P1_i=210,P2_i=600 //Expected pressure and maximum pressure at injector in bar
theta_i=12 //Period of injection in degrees
Cd=0.6 //Coefficient of discharge for the injector
s=0.85 //Specific gravity of the fuel
P_atm=1.013 //Atmospheric pressure in bar
//Solution:
m_f=bsfc*bp/(n*60) //Fuel consumption per cylinder in kg/min
m_f=m_f/(N/2) //Fuel consumption per cycle in kg
t=theta_i/360*60/N //Time for injection in s
m_f=m_f/t //Fuel consumption per cycle in kg/s
deltaP1=P1_i-P1 //Pressure difference at beginning in bar
deltaP2=P2_i-P2 //Pressure difference at end in bar
deltaP_av=(deltaP1+deltaP2)/2 //Average pressure difference in bar
A_f=m_f/(Cd*sqrt(2*s*1000*deltaP_av*10^5)) //Orifice area of fuel injector in m^2
//Results:
printf("\n The Orifice area of fuel injector, Af = %.5f cm^2",A_f*10000)
```

Scilab code Exa 12.3 Calculation of orifice diameter

```
//Calculation of orifice diameter
clc,clear
//Given:
bp=15 //Brake power per cylinder in kW
N=2000 //Engine speed in rpm
bsfc=0.272 //Brake specific fuel consumption in kg/kWh
API=32 //American Petroleum Institute specific gravity in degreeAPI
theta_i=30 //Period of injection in degrees
P_i=120 //Fuel injection pressure in bar
P_c=30 //Combustion chamber pressure in bar
Cd=0.9 //Coefficient of discharge for the injector
function rho=specificgravity(API),rho=141.5/(131.5+API),endfunction //Specific gravity(rho) as a function of API
//Solution:
s=specificgravity(API) //Specific gravity of fuel
m_f=bsfc*bp*2/(N*60) //Fuel consumption in kg
t=theta_i/360*60/N //Time for injection in s
m_f=m_f/t //Fuel consumption per cycle in kg/s
A_f=m_f/(Cd*sqrt(2*s*1000*(P_i-P_c)*10^5)) //Orifice area of fuel injector in m^2
A_f=A_f*10^6 //Orifice area of fuel injector in mm^2
d_f=sqrt(4*A_f/%pi) //Diameter of fuel orifice in mm
//Results:
printf("\n The diameter of the fuel orifice, d = %.2f mm\n\n",d_f)
```

Scilab code Exa 12.4 Calculations on spray penetration

```
//Calculations on spray penetration
clc,clear
```

```
//Given:
s1=20 //Distance of penetration in cm
t1=16 //Penetration time in millisec
P_i1=140 //Injection pressure in bar
s2=s1 //Same distance of penetration in cm
P_i2=220 //Injection pressure in bar
P_c=15 //Combustion chamber pressure in bar
//Solution:
deltaP1=P_i1-P_c //Pressure difference for 140 bar injection pressure
deltaP2=P_i2-P_c //Pressure difference for 220 bar injection pressure
t2=t1*(s2/s1)*sqrt(deltaP1/deltaP2) //Penetration time for 220 bar injection pressure in millisec
//Results:
printf("\n Penetration time for 220 bar injection pressure, t2 = %.1f milli-seconds\n\n",t2)
//Answer in the book is wrong
```

Scilab code Exa 12.5 Calculations on diesel engine fuel pump

```
//Calculations on diesel engine fuel pump
clc,clear
//Given:
V_b=7 //Volume of fuel in the barrel in cc
D_l=3,L_l=700 //Diameter and length of fuel delivery line in mm
V_iv=3 //Volume of fuel in the injection valve in cc
P2=200 //Delivery pressure in bar
P1=1 //Sump pressure in bar
V_d=0.15 //Volume to be delivered in cc
C=78.8D-6 //Coefficient of compressibility
d=8 //Diameter of the plunger in mm
//Solution:
V_l=%pi/4*D_l^2*L_l*10^-3 //Volume of fuel in
```

```
delivery line in cc
V1=V_b+V_l+V_iv //Total initial fuel volume in cc
deltaV=C*(P2-P1)*V1 //Change in volume due to compression in cc
V_p=deltaV+V_d //Displaced volume by plunger in cc
A_p=%pi/4*d^2*10^-2 //Area of the plunger in cm^2
l=V_p/A_p //Effective stroke of plunger in cm
//Results:
printf("\n The plunger displacement = %.3f cc",V_p)
printf("\n The effective stroke of the plunger, l = %.2f mm\n\n",l*10)
```

Chapter 14

Engine Friction and Lubrication

Scilab code Exa 14.1 Calculation of saving in fuel

```
//Calculation of saving in fuel
clc,clear
//Given:
bp=80 //Brake power in kW
eta_m=80 //Mechanical efficiency in percent
bsfc=258 //Brake specific fuel consumption in gm/kWh
Reduction=3.7 //Reduction in friction power in kW
//Solution:
ip1=bp*100/eta_m //Initial indicated power in kW
fp1=ip1-bp //Initial friction power in kW
fp2=fp1-Reduction //Final friction power in kW
ip2=bp+fp2 //Final indicated power in kW
eta_m2=bp/ip2 //Final mechanical efficiency
bsfc2=bsfc*(eta_m/(100*eta_m2)) //Final brake specific fuel consumption in gm/kWh
Saving=bp*(bsfc-bsfc2)/1000 //Saving in fuel in kg/hr
//Results:
printf("\n (a)The new mechanical efficiency, eta_m = %.3f",eta_m2)
printf("\n (b)The new bsfc = %.1f gm/kWh",bsfc2)
```

```
printf("\n (c)The saving in fuel per hour = %.2f kg/hr\n\n",Saving)
//Answers in the book are wrong
```

Scilab code Exa 14.2 Variation of bsfc with speed

```
//Variation of bsfc with speed
clc,clear
//Given:
eta_it=30 //Indicated thermal efficiency in percent
fp_1500=18 //Friction power at 1500 rpm in kW
fp_2500=45 //Friction power at 2500 rpm in kW
bp=75 //Brake power in kW
CV=44000 //Calorific value of fuel in kJ/kg
//Solution:
isfc=3600/(CV*eta_it/100) //Indicated specific fuel consumption in kg/kWh
eta_m_1500=bp/(bp+fp_1500) //Mechanical efficiency at 1500 rpm
bsfc_1500=isfc/eta_m_1500 //Brake specific fuel consumption at 1500 rpm in kg/kWh
eta_m_2500=bp/(bp+fp_2500) //Mechanical efficiency at 2500 rpm
bsfc_2500=isfc/eta_m_2500 //Brake specific fuel consumption at 2500 rpm in kg/kWh
//Results:
printf("\n The brake specific fuel consumption\n\tat 1500 rpm, bsfc_1500 = %.3f kg/kWh\n\tat 2500 rpm, bsfc_2500 = %.3f kg/kWh\n\n",bsfc_1500,bsfc_2500)
```

Chapter 15

Engine Cooling

Scilab code Exa 15.1 Comparison of cooling water required

```
//Comparison of cooling water required
clc,clear
//Given:
bp=100 //Brake power in kW
deltaT=30 //Temperature raised of water in degreeC
p_p=30,p_d=26 //Percentage of energy going to
   coolent in petrol and diesel
eta_p=26,eta_d=31 //Efficiency of petrol and diesel
   engine in percent
s=4.1868 //Specific heat capacity of water in J/kgK
//Solution:
//Petrol engine
CW_p=bp*(p_p/100)/((eta_p/100)*deltaT*s) //Amount of
    cooling water required in petrol engine in kg/s
//Diesel engine
CW_d=bp*(p_d/100)/((eta_d/100)*deltaT*s) //Amount of
    cooling water required in diesel engine in kg/s
//Results:
printf("\n Amount of cooling water required in
   petrol engine = %d kg/hr",CW_p*3600)
printf("\n Amount of cooling water required in
```

```
    diesel engine = %.1f kg/hr\n\n",CW_d*3600)
```

Chapter 16

Two Stroke Engines

Scilab code Exa 16.1 Calculations on 2 stroke IC engine

```
//Calculations on 2 stroke IC engine
clc,clear
//Given:
n=2 //Number of cylinders
N=4000 //Angular speed of engine in rpm
eta_v=0.77 //Volumetric efficiency
eta_m=0.75 //Mechanical efficiency
V_f=10 //Fuel consumption in l/hr
s=0.73 //Specific gravity
h=10500 //Enthalpy of fuel in kcal/kg
A_F=18 //Air-fuel ratio
v_p=600 //Speed of piston in m/min
imep=5 //Indicated mean effective pressure in atm
T=298,P=1.013 //Standard temperature and pressure in
    K and bar
//Solution:
R=0.287 //Specific gas constant in kJ/kgK
m_f=V_f*s //Fuel consumption in kg/hr
m_a=A_F*m_f //Air consumption in kg/hr
m_c=m_f+m_a //Mass of total charge in kg/hr
m=round(m_c/eta_v) //Mass of charge corresponding to
```

```
the swept volume in kg/hr
V=(m/2)*R*T/(P*100) //Volume of charge consumed in m^3/hr
V_s=V*10^6/(60*N) //Swept volume by piston per stroke in cc
L=v_p*100/(2*N) //Stroke length of cylinder in cm
d=sqrt(4*V_s/(%pi*L)) //Bore of cylinder in cm
IHP=round(imep*V_s*N*n/450000) //Indicated horse power in metric HP
BHP=IHP*eta_m //Brake horse power in metric HP
eta_t=BHP*736*3600/(V_f*s*h*4187) //Thermal efficiency
//Results:
printf("\n The engine dimensions\n\t Stroke length, L = %.1f cm\n\t Bore, d = %.1f cm",L,d)
printf("\n The brake power output, BHP = %.1f metric HP",BHP)
printf("\n The thermal efficiency, eta_t = %.1f percent\n\n",eta_t*100)
```

Chapter 17

Supercharging

Scilab code Exa 17.1 Estimation of increase in brake power

```
//Estimation of increase in brake power
clc,clear
//Given:
V_s=3000 //Total swept volume in cc
ip=14 //Indicated power in kW/m^3
N=3500 //Engine speed in rpm
eta_v=80 //Volumetric efficiency in percent
T1=27+273 //Atmospheric temperature in K
P1=1.013 //Atmospheric pressure in bar
r_p=1.7 //pressure ratio
eta_C=75 //Isentropic efficiency of blower in
    percent
eta_m=80 //Mechanical efficiency in percent
g=1.4 //Specific heat ratio(gamma)
//Solution:
V_s=V_s*N/2*1D-6 //Total swept volume in m^3/min
Vi=V_s*eta_v/100 //Unsupercharged induced volume in
    m^3/min
P2=P1*r_p //Blower delivery pressure in bar
T2!=T1*r_p^((g-1)/g) //Isentropic temperature at 2
    in K
```

```
T2!=ceil(T2!)
T2=(T2!-T1)/(eta_C/100)+T1 //Temperature at 2 in K
V1=V_s*(P2/T2)*(T1/P1) //Volume at atmospheric
    conditions in m^3/min
Vi_inc=V1-Vi //Increase in induced volume in m^3/min
ip_inc1=ip*Vi_inc //Increased in ip from air induced
     in kW
ip_inc2=(P2-P1)*100*V_s/60 //Increased in ip due to
    increased induction pressure in kW
ip_inc=ip_inc1+ip_inc2 //Total increase in ip in kW
bp_inc=eta_m/100*ip_inc //Total increase in bp in kW
R=0.287 //Specific gas constant in kJ/kgK
cp=1.005 //Specific heat in kJ/kgK
m2=P2*100*V_s/(R*T2*60) //Mass of air delivered by
    the blower in kg/s
Power=m2*cp*(T2-T1)/(eta_m/100) //Power required by
    the blower in kW
bp_inc=bp_inc-Power //Net increase in brake power in
     kW
//Results:
printf("\n The net increase in the brake power = %.1
    f kW\n\n",bp_inc)
```

Scilab code Exa 17.2 Supercharged diesel engine

```
//Supercharged diesel engine
clc,clear
//Given:
T1=10+273 //Temperature at sea level in K
P1=1.013 //Pressure at sea level in bar
bp=250 //Brake power in kW
eta_v=78 //Volumetric efficiency in percent
bsfc=0.245 //Brake specific fuel consumption in kg/
    kWh
A_F=17 //Air fuel ratio
```

```
N=1500 //Engine speed in rpm
h=2700 //Altitude in m
P_a=0.72 //Pressure at altitude in bar
p=8 //Percentage of gross power taken by the supercharger
T2=32+273 //Temperature of air leaving the supercharger in K
//Solution:
//Unsupercharged
m_f=bsfc*bp/60 //Fuel consumption in kg/min
m_a=A_F*m_f //Air consumption in kg/min
m_a=m_a/(N/2) //Air consumption per cycle in kg
m1=m_a/eta_v*100 //Mass of air corresponding to swept volume
R=0.287 //Specific gas constant in kJ/kgK
V_s=m1*R*T1/(P1*100) //Swept volume in m^3
bmep=bp/(V_s*N/(60*2)) //Brake mean effective pressure in kN/m^2
//Supercharged
bp2=bp/(1-p/100) //Gross power produced by the engine in kW
m_a2=bp2/bp*m_a //Mass of air required per cycle in kg
m2=m_a2/eta_v*100 //Mass of air corresponding to swept volume
P2=m2*R*T2/(V_s*100) //Pressure of air leaving the supercharger in bar
deltaP=P2-P_a //Increase in pressure required in bar
//Results:
printf("\n The required engine capacity, V_s = %.4f m^3",V_s)
printf("\n The anticipated brake mean effective pressure, bmep = %.1f bar",bmep/100)
printf("\n The increase of air pressure required at the supercharger = %.3f bar\n\n",deltaP)
```

Scilab code Exa 17.3 Normally aspirated and supercharged engine

```
//Normally aspirated and supercharged engine
clc,clear
//Given:
V_s=3300 //Swept volume in cc
//For normally aspirated
bmep1=9.3 //Brake mean effective pressure in bar
N1=4500 //Engine speed in rpm
eta_it1=28.5 //Indicated thermal efficiency in percent
eta_m1=90 //Mechanical efficiency in percent
m1=205 //Mass of unboosted engine in kg
//For supercharged
bmep2=12.1 //Brake mean effective pressure in bar
N2=4500 //Engine speed in rpm
eta_it2=24.8 //Indicated thermal efficiency in percent
eta_m2=90 //Mechanical efficiency in percent
m2=225 //Mass of boosted engine in kg
h=poly(0,'h') //Defining the unknown h hours duration
CV=44000 //Calorific value of fuel in kJ/kg
//Solution:
//For normally aspirated
bp1=bmep1*100*V_s/1D+6*N1/(2*60) //Brake power in kW
bp1=round(bp1)
ip1=bp1/eta_m1*100 //Indicated power in kW
m_f1=ip1/(eta_it1/100*CV) //Fuel flow in kg/s
m_f1=m_f1*3600*h //Mass of fuel flow in h hours in kg
Mass1=(m1+m_f1)/bp1 //Specific mass in kg/kW
//For supercharged
bp2=bmep2*100*V_s/1D+6*N2/(2*60) //Brake power in kW
```

```
bp2=round(bp2)
ip2=bp2/eta_m2*100 //Indicated power in kW
m_f2=ip2/(eta_it2/100*CV) //Fuel flow in kg/s
m_f2=m_f2*3600*h //Mass of fuel flow in h hours in kg
Mass2=(m2+m_f2)/bp2 //Specific mass in kg/kW
for h=0:0.01:10; //Defining the range of h(hours)
    if (horner(Mass1,h) > horner(Mass2,h)) then //Specific mass of boosted engine is always be less than unboosted
        continue
    else
        h_max=h
        break
    end
end
//Results:
printf("\n The maximum value of h hours duration, h_max = %.2f hours\n\n",h_max)
```

Scilab code Exa 17.4 Supercharged four stroke oil engine

```
//Supercharged four stroke oil engine
clc,clear
//Given:
T1=20+273 //Temperature of air enters the compressor in K
Q1=1340 //Heat added to air in kJ/min
T3=60+273 //Temperature of air leaves the cooler or enters the engine in K
P3=1.72 //Pressure of air leaves the cooler or enters the engine in bar
eta_v=0.70 //Volumetric efficiency of engine
n=6 //Number of cylinders
d=90,l=100 //Bore and stroke of cylinder in mm
```

```
N=2000 //Engine speed in rpm
T=147 //Output brake torque in Nm
eta_m=0.75 //Mechanical efficiency
//Solution:
bp=2*%pi*N/60*T*10^-3 //Brake power in kW
ip=bp/eta_m //Indicated power in kW
ip=ip/n //Indicated power per cylinder in kW
A=(%pi/4)*d^2*1D-6 //Area of cylinder in m^2
l=l*1D-3 //Stroke of cylinder in m
imep=ip/(l*A*N/(2*60)) //Indicated mean effective pressure in kN/m^2
imep=imep/100 //Indicated mean effective pressure in bar
V_s=n*A*l*N/2 //Engine swept volume in m^3/min
Vi=V_s*eta_v //Induced volume of air in m^3/min
R=0.287 //Specific gas constant in kJ/kgK
cp=1.005 //Specific heat in kJ/kgK
m_e=P3*100*Vi/(R*T3) //Mass of air induced into the engine in kg/min
Q1=1340/60 //Heat added to air in kW
m_c=1 //Assume for calculation
function y=f(T2)
    W_c=m_c*cp*(T2-T1) //Work done on air in compressor kW
    Q_c=m_c*cp*(T2-T3) //Heat given to the air passes through the cooler in kW
    y=W_c/Q_c-bp/Q1
endfunction
T2=fsolve(500,f) //Temperature of air leaving the compressor in K
m_c=bp*60/(cp*(T2-T1)) //Mass of air flow into the compressor in kg/min
//Results:
printf("\n (a)The engine indicated mean effective pressure, imep = %.2f bar",imep)
printf("\n (b)The air consumption in the engine, m_e = %.2f kg/min",m_e)
printf("\n (c)The air flow into the compressor, m_c
```

```
    = %.2f  kg/min\n\n",m_c)
```

Chapter 18

Testing and Performance

Scilab code Exa 18.1 Calculations on petrol engine

```
//Calculations on petrol engine
clc,clear
//Given:
n=4 //Number of cylinders
d_o=7.5 //Diameter of orifice in cm
Cd=0.6 //Coefficient of discharge for orifice
d=11,l=13 //Bore and stroke in cm
N=2250 //Engine speed in rpm
bp=36 //Brake power in kW
m_f=10.5 //Fuel consumption in kg/hr
CV=42000 //Calorific value in kJ/kg
deltaP_o=4.1 //Pressure drop across orifice in cm of
    water
P=1.013 //Atmospheric pressure in bar
T=15+273 //Atmospheric temperature in K
g=9.81 //Accelaration due to gravity in m/s^2
//Solution:
//(a)
eta_bt=bp*3600/(m_f*CV) //Brake thermal efficiency
//(b)
A=%pi/4*d^2*10^-4 //Area of cylinder in m^2
```

```
bmep=bp*1000/(n*l/100*A*N/(2*60)) //Brake mean effective pressure in Pascal
//(c)
rho_w=1000 //Mass density of water in kg/m^3
deltaP_o=rho_w*g*deltaP_o/100 //Pressure drop across orifice in N/m^2
R=0.287 //Specific gas constant in kJ/kgK
rho_a=P*10^5/(R*10^3*T) //Mass density of air in kg/m^3
A_o=%pi/4*d_o^2*10^-4 //Area of orifice in m^2
m_a=Cd*A_o*sqrt(2*deltaP_o*rho_a) //Air inhaled in kg/s
V_s=(%pi/4)*d^2*l*n*N/(2*60)*10^-6 //Swept volume in m^3/s
eta_vol=m_a/V_s //Volumetric efficiency
//Results:
printf("\n (a)Brake thermal efficiency, eta_bt = %.3f",eta_bt)
printf("\n (b)Brake mean effective pressure, bmep = %.3f bar",bmep*10^-5)
printf("\n (c)Volumetric efficiency, eta_vol = %.3f\n\n",eta_vol)
```

Scilab code Exa 18.2 Calculations on Gas engine

```
//Calculations on Gas engine
clc,clear
//Given:
d=24,l=48 //Bore and stroke in cm
D_b=1.25 //Effective diameter of the brake wheel in m
P=1236 //Net load on brake in N
N=77 //Average engine explosions in min
N1=226.7 //Average speed at output shaft in rpm
imep=7.5 //Indicated mean effective pressure in bar
```

```
Vg1=13 //Gas used in m^3/hr
T1=15+273,P1=771 //Temperature and pressure of the gas in K and mm of mercury
T2=0+273,P2=760 //Normal temperature and pressure (N.T.P.) in K and mm of mercury
CV=22000 //Calorific value of the gas in kJ/m^3
m_w=625 //Mass of cooling water used in kg/hr
T1_w=25+273,T2_w=60+273 //Inlet and outlet temperature of cooling water in K
//Solution:
//(a)
T=P*D_b/2 //Brake torque delivered in Nm
bp=2*%pi*N1/60*T //Brake power in W
ip=imep*10^5*l*%pi/4*d^2*N/60*10^-6 //Indicated power in W
eta_m=bp/ip //Mechanical efficiency
//(b)
Vg2=(P1/P2)*(T2/T1)*Vg1 //Gas consumption at N.T.P. in m^3/hr
//(c)
eta_it=ip/1000*3600/(Vg1*CV) //Indicated thermal efficiency
//Heat balance sheet
Q1=Vg2/60*CV //Heat supplied in kJ/min
Q_bp=bp/1000*60 //Heat equivalent to brake power in kJ/min
cp=4.1868 //Specfic heat of water in kJ/kgK
Q_w=m_w/60*cp*(T2_w-T1_w) //Heat in cooling water in kJ/min
Q_r=Q1-Q_bp-Q_w //Heat to exhaust, radiation in kJ/min
//Results:
printf("\n (a)The mechanical efficiency of the engine, eta_m = %.1f percent",eta_m*100)
printf("\n (b)The gas consumption at N.T.P. = %.1f m^3/hr",Vg2)
printf("\n (c)The indicated thermal efficiency, eta_it = %.1f percent",eta_it*100)
```

```
printf("\n\n   Heat balance sheet\n\t Heat supplied by the gas = %.1f kJ/min, %d percent",Q1,Q1/Q1*100)
printf("\n\t Heat equivalent to b.p. = %.1f kJ/min, %.1f percent",Q_bp,Q_bp/Q1*100)
printf("\n\t Heat in cooling water = %.1f kJ/min, %.1f percent",Q_w,Q_w/Q1*100)
printf("\n\t Heat to exhaust, radiation = %.1f kJ/min, %.1f percent",Q_r,Q_r/Q1*100)
```

Scilab code Exa 18.3 Calculations on oil engine

```
//Calculations on oil engine
clc,clear
//Given:
d=18,l=36 //Bore and stroke in cm
N=285 //Average engine speed in rpm
T=393 //Brake torque delivered in Nm
imep=7.2 //Indicated mean effective pressure in bar
m_f=3.5 //Fuel consumption in kg/hr
m_w=4.5 //Mass of cooling water used in kg/min
deltaT_w=36 //Cooling water temperature rise in degreeC
A_F=25 //Air-fuel ratio
T2=415+273 //Exhaust gas temperature in K
P=1.013 //Atmospheric pressure in bar
T1=21+273 //Room temperature in K
CV=45200 //Calorific value in kJ/kg
p=15 //Perentage of hydrogen contained by the fuel
R=0.287 //Specific gas constant in kJ/kgK
cv=1.005,cp=2.05 //Specific heat for dry exhaust gases and superheated steam in kJ/kgK
//Solution:
//(a)
ip=imep*10^2*l*%pi/4*d^2*N/(2*60)*10^-6 //Indicated
```

```
power in kW
ip=round(10*ip)/10
eta_it=ip*3600/(m_f*CV) //Indicated thermal efficiency
//(b)
m_a=m_f*A_F/60 //Mass of air inhaled in kg/min
m_a=round(100*m_a)/100
V_a=m_a*R*T1/(P*100) //Volume of air inhaled in m^3/min
V_s=(%pi/4)*d^2*l*10^-6*N/2 //Swept volume in m^3/min
eta_vol=V_a/V_s //Volumetric efficiency
//Heat balance sheet
Q1=m_f/60*CV //Heat input in kJ/min
bp=2*%pi*N/60*T*10^-3 //Brake power in W
Q_bp=bp*60 //Heat equivalent to brake power in kJ/min
cp_w=4.1868 //Specific heat of water in kJ/kgK
Q_w=m_w*cp_w*deltaT_w //Heat in cooling water in kJ/min
m_e=m_a+m_f/60 //Mass of exhaust gases in kg/min
//Since, 2 mole of hydrogen gives 1 mole of water on combine with 1 mole of oxygen
//Thus, 1 mole of hydrogen gives 1/2 mole or 9 unit mass of water
m_h=m_f/60*p/100 //Mass of hydrogen in kg/min
m_s=9*m_h //Mass of steam in exhaust gases in kg/min
m_d=m_e-m_s //Mass of dry exhaust gases in kg/min
Q_d=m_d*cv*(T2-T1) //Heat in dry exhaust gases in kJ/min
lv=2256.9 //Latent heat of vapourisation of water in kJ/kg
Q_s=m_s*((373-T1)+lv+cp*(T2-373)) //Heat in steam in exhaust gases in kJ/min
Q_r=Q1-Q_bp-Q_w-Q_d-Q_s //Heat in radiation in kJ/min
//Results:
printf("\n (a)The indicated thermal efficiency,
```

```
eta_it = %.1f percent",eta_it*100)
printf("\n (b)The volumetric efficiency , eta_vol = %.1f percent",eta_vol*100)
printf("\n\n   Heat balance sheet\n\t Heat input = %.1f kJ/min, %d percent",Q1,Q1/Q1*100)
printf("\n\t Heat equivalent to b.p. = %.1f kJ/min, %.1f percent",Q_bp,Q_bp/Q1*100)
printf("\n\t Heat in cooling water = %.1f kJ/min, %.1f percent",Q_w,Q_w/Q1*100)
printf("\n\t Heat in dry exhaust gases = %.1f kJ/min, %.1f percent",Q_d,Q_d/Q1*100)
printf("\n\t Heat in steam in exhaust gases = %.1f kJ/min, %.1f percent",Q_s,Q_s/Q1*100)
printf("\n\t Heat in radiation = %.1f kJ/min, %.1f percent",Q_r,Q_r/Q1*100)
```

Scilab code Exa 18.4 Calculations on oil engine

```
//Calculations on oil engine
clc,clear
//Given:
n=4 //Number of cylinders
d_o=5 //Diameter of orifice in cm
Cd=0.6 //Coefficient of discharge for orifice
d=10.5,l=12.5 //Bore and stroke in cm
N=1200 //Engine speed in rpm
T=147 //Brake torque delivered in Nm
m_f=5.5 //Fuel consumption in kg/hr
CV=43100 //Calorific value in kJ/kg
deltaP_o=5.7 //Head across orifice in cm of water
P1=1.013 //Atmospheric pressure in bar
T1=20+273 //Atmospheric temperature in K
g=9.81 //Accelaration due to gravity in m/s^2
//Solution:
//(a)
```

```
bp=2*%pi*N/60*T*10^-3 //Brake power in kW
eta_bt=bp*3600/(m_f*CV) //Brake thermal efficiency
//(b)
A=%pi/4*d^2*10^-4 //Area of cylinder in m^2
bmep=bp*1000/(n*l/100*A*N/(2*60)) //Brake mean effective pressure in N/m^2
//(c)
rho_w=1000 //Mass density of water in kg/m^3
deltaP_o=rho_w*g*deltaP_o/100 //Pressure drop across orifice in N/m^2
R=0.287 //Specific gas constant in kJ/kgK
rho_a=P1*10^5/(R*10^3*T1) //Mass density of air in kg/m^3
rho_a=round(10*rho_a)/10
A_o=%pi/4*d_o^2*10^-4 //Area of orifice in m^2
V_a=Cd*A_o*sqrt(2*deltaP_o/rho_a) //Air inhaled in m^3/s
V_s=(%pi/4)*d^2*l*n*N/(2*60)*10^-6 //Swept volume in m^3/s
eta_vol=V_a/V_s //Volumetric efficiency
//Results:
printf("\n (a)Brake thermal efficiency, eta_bt = %.1f percent",eta_bt*100)
printf("\n (b)Brake mean effective pressure, bmep = %.2f bar",bmep*10^-5)
printf("\n (c)Volumetric efficiency, eta_vol = %.1f percent\n\n",eta_vol*100)
```

Scilab code Exa 18.5 Calculations on six cylinder petrol engine

```
//Calculations on six cylinder petrol engine
clc,clear
//Given:
n=6 //Number of cylinders
d=7.5,l=9 //Bore and stroke in cm
```

```
R_b=38 //Torque arm radius of the brake wheel in cm
P1=324 //Net load when all cylinders operating on brake in N
N=3300 //Engine speed in rpm
P2=245 //Net load when each cylinder is inoperative in N
m_f=.3 //Fuel consumption in kg/min
CV=42000 //Calorific value in kJ/kg
m_w=65 //Mass of cooling water used in kg/min
deltaT_w=12 //Cooling water temperature rise in degreeC
m_a=14 //Mass of air blown in kg/min
T1_a=10+273,T2_a=55+273 //Inlet and outlet temperature of air blown in K
//Solution:
bp=2*%pi*N/60*(P1*R_b/100)*10^-3 //Brake power when all the cylinders operating in kW
bp1=2*%pi*N/60*(P2*R_b/100)*10^-3 //Brake power when each cylinder is inoperative in kW
ip=n*(bp-bp1) //Total ip of the engine in kW
A=%pi/4*d^2*10^-4 //Area of cylinder in m^2
bmep=ip*1000/(n*l/100*A*N/(2*60)) //Brake mean effective pressure in N/m^2
//Heat balance sheet
Q1=m_f*CV //Heat input in kJ/min
Q_bp=bp*60 //Heat equivalent to brake power in kJ/min
cp_w=4.1868 //Specfic heat of water in kJ/kgK
Q_w=m_w*cp_w*deltaT_w //Heat in cooling water in kJ/min
cp_a=1.005 //Specific heat of air in kJ/kgK
Q_a=m_a*cp_a*(T2_a-T1_a) //Heat to ventilating air in kJ/min (Wrong in book)
Q_e=Q1-Q_bp-Q_w-Q_a //Heat to exhaust and other losses in kJ/min
//Results:
printf("\n (a)The indicated mean effective pressure, bmep = %.1f bar",bmep*10^-5)
```

```
printf("\n\n    Heat balance sheet\n\t Heat input =
    %d kJ/min, %d percent",Q1,Q1/Q1*100)
printf("\n\t Heat equivalent to b.p. = %d kJ/min, %
    .1f percent",Q_bp,Q_bp/Q1*100)
printf("\n\t Heat in cooling water = %d kJ/min, %.1f
     percent",Q_w,Q_w/Q1*100)
printf("\n\t Heat to ventilating air = %d kJ/min, %
    .1f percent",Q_a,Q_a/Q1*100)
printf("\n\t Heat to exhaust and other losses = %d
    kJ/min, %.2f percent",Q_e,Q_e/Q1*100)
//Heat to ventilating air is wrong in book
```

Scilab code Exa 18.6 Calculations on two stroke engine

```
//Calculations on two stroke engine
clc,clear
//Given:
N=450 //Engine speed in rpm
P=450 //Net load on brake in N
imep=2.9 //Indicated mean effective pressure in bar
m_f=5.4 //Fuel consumption in kg/h
deltaT_w=36.1 //Cooling water temperature rise in
    degreeC
m_w=440 //Mass of cooling water used in kg/h
A_F=31 //Air-fuel ratio
T1_g=20+273,T2_g=355+273 //Inlet and outlet
    temperature of exhaust gases blown in K
P1=76 //Atmospheric pressure in cm of Hg
d=22,l=27 //Bore and stroke in cm
D_b=1.5 //Effective diameter of the brake wheel in m
CV=44000 //Calorific value in kJ/kg
p=15 //Percentage of hydrogen by mass contained by
    the fuel
R=0.287 //Specific gas constant in kJ/kgK
cp_g=1.005,cp_s=2.05 //Specific heat for dry exhaust
```

```
gases and superheated steam in kJ/kgK
//Solution:
ip=imep*10^2*l*%pi/4*d^2*N/(60)*10^-6 //Indicated power in kW
eta_it=ip*3600/(m_f*CV) //Indicated thermal efficiency
bp=2*%pi*N/60*(P*D_b/2)*10^-3 //Brake power in kW
bp=round(10*bp)/10
bsfc=m_f/bp*1000 //Brake specific fuel consumption in gm/kWh
V_s=(%pi/4)*d^2*l*10^-6*N //Swept volume in m^3/min
m_a=m_f*A_F/60 //Mass of air inhaled in kg/min
P1=1.0132 //Atmospheric pressure equivalent to 76 cm of Hg in bar
T1=293 //Atmospheric temperature in K
V_a=m_a*R*T1/(P1*100) //Volume of air inhaled in m^3/min
V_a=round(100*V_a)/100
eta_vol=V_a/V_s //Volumetric efficiency
//Heat balance sheet
Q1=m_f/60*CV //Heat input in kJ/min
Q_bp=bp*60 //Heat equivalent to brake power in kJ/min
cp_w=4.1868 //Specfic heat of water in kJ/kgK
Q_w=m_w/60*cp_w*deltaT_w //Heat in cooling water in kJ/min
m_e=m_a+m_f/60 //Mass of exhaust gases in kg/min
//Since, 2 mole of hydrogen gives 1 mole of water on combine with 1 mole of oxygen
//Thus, 1 mole of hydrogen gives 1/2 mole or 9 unit mass of water
m_h=m_f/60*p/100 //Mass of hydrogen in kg/min
m_s=9*m_h //Mass of steam in exhaust gases in kg/min
m_d=m_e-m_s //Mass of dry exhaust gases in kg/min
Q_d=m_d*cp_g*(T2_g-T1_g) //Heat in dry exhaust gases kJ/min
lv=2256.9 //Latent heat of vapourisation of water in kJ/kg
```

```
Q_s=m_s*((373-T1_g)+lv+cp_s*(T2_g-373)) //Heat in steam in exhaust gases in kJ/min
Q_r=Q1-Q_bp-Q_w-Q_d-Q_s //Heat in radiation in kJ/min
//Results:
printf("\n (a)The indicated thermal efficiency, eta_it = %.1f percent",eta_it*100)
printf("\n (b)Brake specific fuel consumption = %.1f gm/kWh",bsfc)
printf("\n (c)The volumetric efficiency, eta_vol = %.1f percent",eta_vol*100)
printf("\n\n  Heat balance sheet\n\t Heat input = %.1f kJ/min, %d percent",Q1,Q1/Q1*100)
printf("\n\t Heat equivalent to b.p. = %.1f kJ/min, %.1f percent",Q_bp,Q_bp/Q1*100)
printf("\n\t Heat in cooling water = %.1f kJ/min, %.1f percent",Q_w,Q_w/Q1*100)
printf("\n\t Heat in dry exhaust gases = %.1f kJ/min, %.1f percent",Q_d,Q_d/Q1*100)
printf("\n\t Heat in steam in exhaust gases = %.1f kJ/min, %.1f percent",Q_s,Q_s/Q1*100)
printf("\n\t Heat in radiation = %.1f kJ/min, %.1f percent",Q_r,Q_r/Q1*100)
```

Scilab code Exa 18.7 Calculations by Morse test

```
//Calculations by Morse test
clc,clear
//Given:
n=12 //Number of cylinders
function bp=f(W),bp=W*N/180,endfunction //Power law of engine
d=38,l=50 //Bore and stroke in cm
N=200 //Engine speed in rpm
Wall1=2000,Wall2=2020 //Brake loads when all
```

```
cylinders are firing in N
Wn=[1795 1814 1814 1795 1804 1819 1800 1824 1785 1804 1814 1795] //Brake load when cylinder number 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 are out in N
//Solution:
W=(Wall1+Wall2)/2 //Average of brake loads when all cylinders are firing in N
bp=f(W) //Total brake power in kW
ipn=bp-f(Wn) //Indicated power of cylinders number 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 in kW
ip=sum(ipn) //Total indicated power equal to sum of individual in kW
eta_m=bp/ip //Mechanical efficiency
A=%pi/4*d^2*10^-4 //Area of cylinder in m^2
bmep=bp*1000/(n*l/100*A*N/(60)) //Brake mean effective pressure in Pascal
//Results:
printf("\n The brake mean effective pressure, bmep = %.2f bar",bmep*10^-5)
printf("\n The mechanical efficiency, eta_m = %.1f percent\n\n",eta_m*100)
```

Scilab code Exa 18.8 Calculations on six cylinder diesel engine

```
//Calculations on six cylinder diesel engine
clc,clear
//Given:
n=6 //Number of cylinders
function bp=f(W),bp=W*N/20000,endfunction //Power law of engine
d=95,l=120 //Bore and stroke in mm
N=2400 //Engine speed in rpm
C_H=83/17 //Carbon Hydrogen ratio by mass in fuel
d_o=30 //Diameter of orifice in mm
```

```
Cd=0.6 //Orifice coefficient of discharge
P=550 //Net load on brake in N
P1=750 //Ambient pressure in mm of Hg
T1=25+273 //Ambient temperature in K
deltaP_o=14.5 //Head over orifice in cm of Hg
s=0.831 //Specific gravity of fuel
t=19.3 //Time to use 100 cc fuel in s
V_f=100 //Volume of fuel used in t seconds in cc
//Solution:
//(a)
bp=f(P) //Brake power at brake load in kW
A=%pi/4*d^2*10^-6 //Area of cylinder in m^2
bmep=bp*1000/(n*l/1000*A*N/(2*60)) //Brake mean effective pressure in Pascal
//(b)
T=bp*1000/(2*%pi*(N/60)) //Brake torque in Nm
//(c)
rho_f=s*1000 //Fuel density in kg/m^3
m_f=V_f*10^-6/t*3600*rho_f //Fuel flow rate in kg/hr
bsfc=m_f/bp //Brake specific fuel consumption in kg/kWh
//(e)
R=0.287 //Specific gas constant in kJ/kgK
P1=P1/760*1.01325 //Ambient pressure in bar
rho_a=P1*10^5/(R*10^3*T1) //Mass density of air in kg/m^3
deltaP_o=13.6*1000*9.81*deltaP_o/100 //Pressure drop across orifice in N/m^2
A_o=%pi/4*d_o^2*10^-6 //Area of orifice in m^2
V_a=Cd*A_o*sqrt(2*deltaP_o/rho_a) //Air inhaled in m^3/s
V_s=(%pi/4)*d^2*l*n*N/(2*60)*10^-9 //Swept volume in m^3/s
eta_vol=V_a/V_s //Volumetric efficiency
//(d)
pH=17,pC=pH*C_H //Percentage of Hydrogen and Carbon in fuel
pO=23.3 //Percentage of Oxygen in air
```

```
H=1,C=12,O=16 //Atomic masses of Hydrogen, Carbon, Oxygen in gm
mO2=pC/100*(2*O/C)+pH/100*(O/(2*H)) //Oxygen required in kg/kg of fuel
m_a=mO2/(pO/100) //Mass of air in kg/kg of fuel
A_F_t=m_a //Theoritical air fuel ratio
m_a_act=V_a*rho_a //Actual air mass flow rate in kg/s
A_F_act=m_a_act/m_f*3600 //Actual air fuel ratio
P_e=(A_F_act-A_F_t)/A_F_t*100 //Percentage excess air
//Results:
printf("\n (a)The brake mean effective pressure, bmep = %.3f bar",bmep*10^-5)
printf("\n (b)The brake torque, T = %.1f Nm",T)
printf("\n (c)The brake specific fuel consumption, bsfc = %.3f kg/kWh",bsfc)
printf("\n (d)The percentage excess air = %.1f percent",P_e)
printf("\n (e)The volumetric efficiency, eta_vol = %.1f percent\n\n",eta_vol*100)
```

Scilab code Exa 18.9 Calculations on six cylinder petrol engine

```
//Calculations on six cylinder petrol engine
clc,clear
//Given:
n=6 //Number of cylinders
d=125,l=190 //Bore and stroke in mm
pC=82/100,pH2=18/100 //Composition of Carbon and Hydrogen in petrol
pCO2=11.19/100,pO2=3.61/100,pN2=85.2/100 //Composition of Carbon di oxide, Oxygen, Nitrogen in dry exhaust
P1=1 //Pressure of mixture entering the cylinder in
```

```
bar
T1=17+273 //Temperature of mixture entering the cylinder in K
m_f=31.3 //Mass of the petrol used in kg/hr
N=1500 //Engine speed in rpm
m=1,T=0+273,P=1.013,V=0.773 //Mass, temperature, pressure, volume, of air in kg, K, bar, m^3
p=23/100 //Composition of Oxygen in air by mass
//Solution:
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
N2=14 //Atomic mass of Nitrogen(N)
A_F_s=(pC*2*O/C+pH2*O/(2*H))/(p) //Stoichiometric air fuel ratio
//Stoichiometric equation of combustion of fuel (petrol)
//   0.82/12[C] + 0.18/2[H2] + [0.21[O2] + 0.79[N2]]*x = a[CO2] + b[CO] + c[H2O] + d1[N2]
//Equating coefficients
a=pC/C,c=pH2/(2*H) //On balancing C and H
d1=pN2/pCO2*a //On taking composition of CO2 and N2 in exhaust
x=d1/0.79 //On balancing N
m_a=(p*2*O)+((1-p)*2*N2) //Mass of air per mole air in kg/mole
A_F_act=x*m_a //Actual air fuel ratio
P_e=(A_F_act-A_F_s)/A_F_s*100 //Percentage excess air
R_a=P*100*V/(m*T) //Specific gas constant for air in kJ/kgK
V_a=A_F_act*R_a*T1/(P1*100) //Volume of air in m^3
//Given, rho_f = 3.35 * rho_a, V_f = 1/3.35 * V_a
V_f=V_a/A_F_act*1/3.35 //Volume of fuel in m^3/kg of fuel
V_m=V_a+V_f //Total volume of mixture in m^3/kg of fuel
V_m1=V_m*m_f/60 //Mixture aspirated in m^3/min
```

```
V_s=(%pi/4)*d^2*l*n*N/2*10^-9 //Swept volume in m^3/
    s
eta_v=V_m1/V_s*100 //Volumetric efficiency in
    percent
//Results:
printf("\n The mass of air supplied per kg of petrol
    , m_a = %.2f kg/kg of fuel",A_F_act)
printf("\n The percentage excess air = %.1f percent"
    ,P_e)
printf("\n The volume of mixture per kg of petrol,
    V_m = %.2f m^3/kg fuel",V_m)
printf("\n The volumetric efficiency of the engine,
    eta_v = %.0f percent\n\n",eta_v)
```

Scilab code Exa 18.10 Calculations on gas engine

```
//Calculations on gas engine
clc,clear
//Given:
d=27,l=45 //Bore and stroke in cm
D_b=1.62 //Effective diameter of the brake wheel in
    m
t=38.5 //Duration of test in min
N=8080,N1=3230 //Number of revolutions and
    explosions
P=903 //Net load on brake in N
imep=5.64 //Indicated mean effective pressure in bar
Vg1=7.7 //Gas used in m^3
T1=27+273 //Temperature of the gas in K
deltaP1=135 //Pressure difference of gas above
    atmospheric pressure in mm of water
Patm=750 //Atmospheric pressure in mm of Hg
CV=18420 //Calorific value of the gas in kJ/m^3 at N
    .T.P.
m_w=183 //Mass of cooling water used in kg
```

```
deltaT_w=47 //Cooling water temperature rise in degreeC
//Solution:
P1=Patm+deltaP1/13.6 //Gas pressure in mm of Hg
P1=P1/750 //Gas pressure in bar
T2=0+273,P2=1.013 //Normal temperature and pressure (N.T.P.) in K and bar
Vg2=(P1/P2)*(T2/T1)*Vg1 //Gas consumption at N.T.P. in m^3
Q1=Vg2/t*CV //Heat supplied in kJ/min
T=P*D_b/2 //Brake torque delivered in Nm
bp=2*%pi*(N/t*1/60)*(T)*10^-3 //Brake power in kW
bp=round(10*bp)/10
Q_bp=bp*60 //Heat equivalent to brake power in kJ/min
A=%pi/4*d^2*10^-4 //Area of cylinder in m^2
ip=imep*10^2*l/100*A*(N1/t*1/60) //Indicated power in kW
ip=round(10*ip)/10
Q_ip=ip*60 //Heat equivalent to indicated power in kJ/min
fp=ip-bp //Frictional power in kW
Q_fp=fp*60 //Heat equivalent to frictional power in kJ/min
cp=4.1868 //Specfic heat of water in kJ/kgK
Q_w=m_w/t*cp*(deltaT_w) //Heat in cooling water in kJ/min
Q_e=Q1-Q_bp-Q_w //Heat to exhaust, radiation in kJ/min
eta_it=Q_ip/Q1 //Indicated thermal efficiency
eta_bt=Q_bp/Q1 //Brake thermal efficiency
//Results:
printf("\n The indicated thermal efficiency, eta_it = %.1f percent",eta_it*100)
printf("\n The brake thermal efficiency, eta_bt = %.1f percent",eta_bt*100)
printf("\n\n  Heat balance sheet\n\t Heat supplied by the gas = %d kJ/min, %d percent",Q1,Q1/Q1*100)
```

```
printf("\n\t Heat equivalent to b.p. = %d kJ/min, %
    .1f percent",Q_bp,Q_bp/Q1*100)
printf("\n\t Heat in cooling water = %d kJ/min, %.1f
     percent",Q_w,Q_w/Q1*100)
printf("\n\t Heat to exhaust, radiation = %d kJ/min,
     %.1f percent",Q_e,Q_e/Q1*100)
```

Scilab code Exa 18.11 Calculations from indicator diagram

```
//Calculations from indicator diagram
clc,clear
//Given:
Li=100 //Length of indicator diagram in mm
Ai=2045 //Area of indicator diagram in mm^2
Pi=2/10 //Pressure increment in cylinder from
    indicator pointer in bar/mm
d=100,l=100 //Bore and stroke in mm
N=900 //Engine speed in rpm
eta_m=75 //Mechanical efficiency in percent
//Solution:
Hi_av=Ai/Li //Mean height of indicator diagram in mm
imep=Hi_av*Pi //Mean effective pressure in bar
ip=imep*100*%pi/4*d^2*l*N/(2*60)*10^-9 //Indicated
    power in kW
bp=ip*eta_m/100 //Brake power in kW
//Results:
printf("\n The mean effective pressure, mep = %.2f
    bar",imep)
printf("\n The indicated power, ip = %.2f kW",ip)
printf("\n The brake power, bp = %.2f kW\n\n",bp)
```

Scilab code Exa 18.12 Calculations on diesel engine

```
//Calculations on diesel engine
clc,clear
//Given:
n=6 //Number of cylinders
bp=110 //Brake power in kW
N=1600 //Engine speed in rpm
CV=43100 //Calorific value in kJ/kg
pC=86.2/100,pH2=13.5/100,pNC=0.3/100 //Composition of Carbon, Hydrogen and non combustibles in fuel
eta_v=78 //Volumetric efficiency in percent
eta_it=38 //Indicated thermal efficiency in percent
eta_m=80 //Mechanical efficiency in percent
MS=110 //Mixture strength in percent
l_d=1.5 //Stroke bore ratio (l/d)
v_a=0.772 //Specific volume of air in m^3/kg
p_m=23.1/100,p_v=20.8/100 //Composition of Oxygen in air by mass and volume
//Solution:
C=12 //Atomic mass of Carbon(C)
H=1 //Atomic mass of Hydrogen(H)
O=16 //Atomic mass of Oxygen(O)
N2=14 //Atomic mass of Nitrogen(N)
A_F_s=(pC*2*O/C+pH2*O/(2*H))/p_m //Stoichiometric air fuel ratio
A_F_act=(1+MS/100)*A_F_s //Actual air fuel ratio
Ma=(p_m*2*O)+((1-p_m)*2*N2) //Molecular mass of air per mole air in kg/mole
//Stoichiometric equation of combustion of fuel (petrol)
//    0.862/12[C] + 0.135/2[H2] + [p_v[O2] + (1-p_v)[N2]]*x = a[CO2] + b[H2O] + c[O2] + d[N2]
//Equating coefficients
a=pC/C,b=pH2/(2*H) //On balancing C and H
x=A_F_act/Ma //Moles of air
c=p_v*x-a-b/2 //On balancing O
d=(1-p_v)*x //On balancing N
pCO2=a/(a+c+d),pO2=c/(a+c+d),pN2=d/(a+c+d) //Composition of Carbon di oxide, Oxygen, Nitrogen
```

```
    in dry exhaust
ip=bp/eta_m*100 //Indicated power in kW
m_f=ip/(eta_it/100*CV)*60 //Mass of fuel in kg/min
m_a=m_f*A_F_act //Mass of air in kg/min
V_a=m_a*v_a //Volume of air in m^3/min
V_s=V_a/eta_v*100 //Swept volume in m^3/min
V_s=V_s/(n*N/2) //Swept volume in m^3
function y=f(d) //Defining a function, f of unknown
    bore, d
    l=l_d*d //Stroke in terms of bore
    y=%pi/4*d^2*l-V_s
endfunction
d=fsolve(1,f) //Function f solve for zero, bore in m
l=l_d*d //Stroke in m
//Results:
printf("\n The volumetric composition of dry exhaust
    gas,\n\tCO2 = %.2f percent\n\tO2 = %.2f percent\
    n\tN2 = %.2f percent",pCO2*100,pO2*100,pN2*100)
printf("\n The bore of the engine, d = %.2f cm\n The
    stroke of the engine, l = %.2f cm\n\n",d*100,l
    *100)
```

Scilab code Exa 18.13 Calculations on four stroke engine

```
//Calculations on four stroke engine
clc,clear
//Given:
d=150,l=250 //Bore and stroke in mm
Li=50 //Length of indicator diagram in mm
Ai=450 //Area of indicator diagram in mm^2
ISR=1.2 //Indicator spring rating in mm
N=420 //Engine speed in rpm
T=217 //Brake torque delivered in Nm
m_f=2.95 //Fuel consumption in kg/hr
CV=44000 //Calorific value in kJ/kg
```

```
m_w=0.068 //Mass of cooling water used in kg/s
deltaT_w=45 //Cooling water temperature rise in K
cp=4.1868 //Specfic heat capacity of water in kJ/kgK
//Solution:
Hi_av=Ai/Li //Mean height of indicator diagram in mm
imep=Hi_av/ISR //Mean effective pressure in bar
ip=imep*100*%pi/4*d^2*l*N/(2*60)*10^-9 //Indicated power in kW (Error in book)
bp=2*%pi*(N/60)*(T)*10^-3 //Brake power in kW
eta_m=bp/ip //Mechanical efficiency (Error in book)
eta_bt=bp*3600/(m_f*CV) //Brake thermal efficiency
bsfc=m_f/bp //Brake specific fuel consumption in kg/kWh (Error in book)
//Energy balance
Power_f=m_f/3600*CV //Power in fuel in kW
Power_w=m_w*cp*deltaT_w //Power to cooling water in kW
Power_e=Power_f-bp-Power_w //Power to exhaust, radiation in kW
//Results:
printf("\n The mechanical efficiency, eta_m = %d percent",eta_m*100)
printf("\n The brake thermal efficiency, eta_bt = %.1f percent",eta_bt*100)
printf("\n The specific fuel consumption, bsfc = %.3f kg/kWh",bsfc)
printf("\n\n   Energy balance\n\t Power in fuel = %.1f kW, %d percent",Power_f,Power_f/Power_f*100)
printf("\n\t Brake power = %.2f kW, %.1f percent",bp,bp/Power_f*100)
printf("\n\t Power to cooling water = %.1f kW, %.1f percent",Power_w,Power_w/Power_f*100)
printf("\n\t Power to exhaust, radiation = %.1f kW, %.1f percent",Power_e,Power_e/Power_f*100)
//Answers in the book are wrong
```

Scilab code Exa 18.14 Calculations on petrol engine

```
//Calculations on petrol engine
clc,clear
//Given:
n=6 //Number of cylinders
d=70,l=100 //Bore and stroke in mm
V_c=67 //Clearance volume in cm^2
N=3960 //Engine speed in rpm
m_f=19.5 //Fuel consumption in kg/hr
T=140 //Brake torque delivered in Nm
CV=44000 //Calorific value in kJ/kg
g=1.4 //Specific heat ratio for air (gamma)
//Solution:
bp=2*%pi*N/60*T*10^-3 //Brake power in kW
A=%pi/4*d^2*10^-6 //Area of cylinder in m^2
bmep=bp*1000/(n*l/1000*A*N/(2*60)) //Brake mean
    effective pressure in Pascal
eta_bt=bp*3600/(m_f*CV) //Brake thermal efficiency
V_s=(%pi/4)*d^2*l/1000 //Swept volume of one
    cylinder in cm^3
r=(V_s+V_c)/V_c //Compression ratio
eta=1-1/r^(g-1) //Air standard efficiency
eta_r=eta_bt/eta //Relative efficiency
//Results:
printf("\n (a)The brake power, bp = %d kW",bp)
printf("\n (b)The brake mean effective pressure,
    bmep = %.2f bar",bmep*10^-5)
printf("\n (c)The brake thermal efficiency, eta_bt =
    %.1f percent",eta_bt*100)
printf("\n (d)The relative efficiency, eta_r = %.1f
    percent\n\n",eta_r*100)
```

Scilab code Exa 18.15 Hit and miss governing

```
//Hit and miss governing
clc,clear
//Given:
d=178,l=330 //Bore and stroke in mm
N=400 //Engine speed at full load in rpm
wmep=6.2 //Working loop mep in bar
pmep=0.35 //Pumping loop mep in bar
mep_dc=0.62 //Mean effective pressure from the dead cycles in bar
N_f=47 //Number of firing strokes at no load in rpm
//Solution:
imep=wmep-pmep //Net indicated mean effective pressure per cycle in bar
N_d=N/2-N_f //Number of dead cycles at no load in rpm
ip1=imep*100*l*%pi/4*d^2*N_f/60*10^-9 //Indicated power at no load in kW
pp_dc=mep_dc*100*l*%pi/4*d^2*N_d/60*10^-9 //Pumping power of dead cycles when no load in kW
fp=ip1-pp_dc //Friction power in kW
ip=imep*100*l*%pi/4*d^2*N/(2*60)*10^-9 //Indicated power at full load in kW
bp=ip-fp //Brake power at full load in kW
eta_m=bp/ip //Mechanical efficiency at full load
//Results:
printf("\n The brake power at full load, b.p. = %.2f kW",bp)
printf("\n The mechanical efficiency at full load, eta_m = %.1f percent\n\n",eta_m*100)
```

Scilab code Exa 18.16 Calculations on two stroke engine

```
//Calculations on two stroke engine
clc,clear
//Given:
d=200,l=250 //Bore and stroke in mm
imep=4.5*10^5 //Indicated mean effective pressure in N/m^2
m_f=7 //Fuel consumption in kg/hr
CV=43500 //Calorific value in kJ/kg
N=180 //Engine speed in rpm
//Solution:
//(a)
ip=imep*l*%pi/4*d^2*N/60*10^-9*10^-3 //Indicated power in kW
//(b)
eta_it=ip*3600/(m_f*CV) //Indicated thermal efficiency
//Results:
printf("\n (a)The indicated power, ip = %.1f kW",ip)
printf("\n (b)The indicated thermal efficiency, eta_it = %.1f percent\n\n",eta_it*100)
```

Chapter 26

Gas Turbines

Scilab code Exa 26.1 Calculations on Brayton cycle

```
//Calculations on Brayton cycle
clc,clear
//Given:
P1=101.325 //Pressure at the beginning(1) in kPa
T1=27+273 //Temperature at the beginning(1) in K
r_p=6 //pressure ratio
g=1.4 //Specific heat ratio(gamma)
cp=1.005 //Specific heat in kJ/kgK
W_TC=2.5 //Ratio of Turbine work and compressor work
m=1 //Assume mass in kg
//Solution:
//Refer fig 26.22
T2=T1*r_p^((g-1)/g) //Temperature at 2 in K
T3=poly(0,'T3') //Defining temperature at 3 as a
    unknown in K
T4=T3/r_p^((g-1)/g) //Defining temperature at 4 in
    terms of T3 in K
W_C=m*cp*(T2-T1) //Compressor work in kJ
W_T=m*cp*(T3-T4) //Turbine work in kJ
T3=roots(W_T-W_TC*W_C) //Temperature at 3 in K
T4=horner(T4,T3) //Temperature at 4 in K
```

```
eta=((T3-T4)-(T2-T1))/(T3-T2) //Cycle efficiency
//Results:
printf("\n The maximum temperature in the cycle, T3 = %.1f K",T3)
printf("\n The cycle efficiency, eta = %.2f percent\n\n",eta*100)
```

Scilab code Exa 26.2 Calculations on Joule cycle

```
//Calculations on Joule cycle
clc,clear
//Given:
T1=25+273,T3=825+273 //Minimum and maximum temperature in K
r_p=4.5 //pressure ratio
eta_C=85,eta_T=90 //Isentropic efficiencies of compressor and turbine in percent
P=1300 //Power rating of the turbine in kW
cp=1.005 //Specific heat in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 26.23
T2!=T1*r_p^((g-1)/g) //Isentropic temperature at 2 in K
T2=(T2!-T1)/(eta_C/100)+T1 //Temperature at 2 in K
T4!=T3/r_p^((g-1)/g) //Isentropic temperature at 4 in K
T4=T3-eta_T/100*(T3-T4!) //Temperature at 4 in K
W_C=cp*(T2-T1) //Compressor work in kJ/kg
W_T=cp*(T3-T4) //Turbine work in kJ/kg
Q1=cp*(T3-T2) //Heat added in kJ/kg
W=W_T-W_C //Work output in kJ/kg (Round off error)
eta=W/Q1 //Cycle efficiency
r_w=W/W_T //Work ratio
HR=3600/(eta) //Heat rate in kJ/kWh (Round off error
```

```
)
m=P/W //Mass flow rate in kg/s
//Results:
printf("\n The specific work output, W = %d kJ/kg",W)
printf("\n The cycle efficiency, eta = %.1f percent",eta*100)
printf("\n The work ratio, rw = %.3f",r_w)
printf("\n The heat rate = %d kJ/kWh",HR)
printf("\n The mass flow rate for 1300 kW, m = %.2f kg/s\n\n",m)
//Round off error in the values of 'W' and 'HR'
```

Scilab code Exa 26.3 Calculations for zero efficiency

```
//Calculations for zero efficiency
clc,clear
//Given:
T1=25+273,T3=750+273 //Minimum and maximum temperature in K
r_p=4 //pressure ratio
eta_C=75 //Isentropic efficiency of compressor in percent
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 26.24
T2!=T1*r_p^((g-1)/g) //Isentropic temperature at 2 in K
T2=(T2!-T1)/(eta_C/100)+T1 //Temperature at 2 in K
T4!=T3/r_p^((g-1)/g) //Isentropic temperature at 4 in K
//For zero efficiency of the cycle (T3-T4) = (T2-T1)
eta_T=(T2-T1)/(T3-T4!) //Turbine efficiency
//Results:
printf("\n The turbine efficiency for zero cycle
```

```
efficiency, eta_T = %.1f percent\n\n",eta_T*100)
```

Scilab code Exa 26.4 Calculations on gas turbine

```
//Calculations on gas turbine
clc,clear
//Given:
P1=1,P2=6 //Pressure at entering and leaving of compressor in bar
T1=27+273 //Temperature at entering in K
T3=700+273 //Maximum temperature in K
eta_C=0.80,eta_T=0.85 //Isentropic efficiencies of compressor and turbine in percent
eta_c=0.98 //Combustion efficiency in percent
P3=P2-0.1 //Pressure at 3 after falling 0.1 bar in bar
cp_a=1.005 //Specific heat of air in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
cp_g=1.147 //Specific heat of gas in kJ/kgK
g1=1.333 //Specific heat ratio(gamma) of gas
CV=42700 //Calorific value of fuel in kJ/kg
//Solution:
//Refer fig 26.25
T2!=T1*(P2/P1)^((g-1)/g) //Isentropic temperature at 2 in K
T2=(T2!-T1)/(eta_C)+T1 //Temperature at 2 in K
T4!=T3/(P3/P1)^((g1-1)/g1) //Isentropic temperature at 4 in K
T4=T3-eta_T*(T3-T4!) //Temperature at 4 in K
W_C=cp_a*(T2-T1) //Compressor work in kJ/kg
W_T=cp_g*(T3-T4) //Turbine work in kJ/kg
W=W_T-W_C //Work output in kJ/kg
Q1=cp_g*(T3-T2)/eta_c //Heat added in kJ/kg
eta=W/Q1 //Cycle efficiency
r_w=W/W_T //Work ratio
```

```
AR=round(3600/W) //Air rate in kg/kWh
sfc=Q1*AR/CV //Specific fuel consumption in kg/kWh
A_F=AR/sfc //Air fuel ratio
//Results:
printf("\n (a)The thermal efficiency, eta = %.1f percent",eta*100)
printf("\n (b)The work ratio, rw = %.3f",r_w)
printf("\n (e)The air rate = %d kg/kWh",AR)
printf("\n (d)The specific fuel consumption, sfc = %.3f kg/kWh",sfc)
printf("\n (c)The air fuel ratio = %.1f\n\n",A_F)
```

Scilab code Exa 26.5 Calculations on gas turbine

```
//Calculations on gas turbine
clc,clear
//Given:
P1=1,P2=6.20 //Pressure at entering and leaving of compressor in bar
T1=300 //Temperature at entering in K
eta_C=88,eta_T=90 //Isentropic efficiencies of compressor and turbine in percent
CV=44186 //Calorific value of fuel in kJ/kg
F_A=0.017 //Fuel air ratio
cp_a=1.005 //Specific heat of air in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
cp_g=1.147 //Specific heat of gas in kJ/kgK
g1=1.333 //Specific heat ratio(gamma) of gas
//Solution:
//Refer fig 26.26
T2!=T1*(P2/P1)^((g-1)/g) //Isentropic temperature at 2 in K
T2=(T2!-T1)/(eta_C/100)+T1 //Temperature at 2 in K
m_a=1 //Assume mass of air in kg
m_f=F_A*m_a //Mass of fuel in kg
```

```
T3=(cp_a*m_a*T2+m_f*CV)/(cp_g*(m_a+m_f)) //Temperature at 3 in K
r_p=P2/P1 //pressure ratio
T4!=T3/r_p^((g1-1)/g1) //Isentropic temperature at 4 in K
T4=T3-eta_T/100*(T3-T4!) //Temperature at 4 in K
W_C=m_a*cp_a*(T2-T1) //Compressor work in kJ/kg
W_T=(m_a+m_f)*cp_g*(T3-T4) //Turbine work in kJ/kg
W=W_T-W_C //Work output in kJ/kg
Q1=m_f*CV //Heat added in kJ/kg
eta=W/Q1 //Cycle efficiency
//Results:
printf("\n The turbine work, W_T = %.2f kJ/kg",W_T)
printf("\n The compressor work, W_C = %.2f kJ/kg",W_C)
printf("\n The thermal efficiency , eta = %.2f percent\n\n",eta*100)
```

Scilab code Exa 26.6 Calculations on gas turbine with heat exchanger

```
//Calculations on gas turbine with heat exchanger
clc,clear
//Given:
T1=17+273 //Temperature at entering in K
P1=1 //Pressure at entering of compressor in bar
r_p=4.5 //pressure ratio
W=4000 //Work output in kW
m=40 //Mass flow rate in kg/s
e=0.6 //Thermal ratio or effectiveness of heat exchanger
eta_C=84 //Isentropic efficiency of compressor in percent
eta=0.29 //Thermal efficiency
cp_a=1.005 //Specific heat of air in kJ/kgK
g=1.4 //Specific heat ratio(gamma) of air
```

```
cp_g=1.07 //Specific heat of gas in kJ/kgK
g1=1.365 //Specific heat ratio(gamma) of gas
//Solution:
//Refer fig 26.27
T2!=T1*r_p^((g-1)/g) //Isentropic temperature at 2 in K
T2=(T2!-T1)/(eta_C/100)+T1 //Temperature at 2 in K
W=W/m //Specific work output in kJ/kg
Q1=W/eta //Heat added in kJ/kg
W_C=cp_a*(T2-T1) //Compressor work in kJ/kg
W_T=W+W_C //Turbine work in kJ/kg
function y=f(T4)
    T3=T4-Q1/cp_g //Defining temperature at 3 in terms of T4 in K
    T5=T4-W_T/cp_g //Defining temperature at 5 in terms of T4 in K
    y=(cp_a*(T3-T2))/(cp_g*(T5-T2))-e
endfunction
//Since effectiveness from the relation must be equal to the given effectiveness
//Thus their difference must be equal to Zero, thus function, f solve for zero to get the value of variable(T4)
T4=fsolve(1000,f) //Temperature at 4 in K
T5=T4-W_T/cp_g //Temperature at 5 in K
T5!=T4/r_p^((g1-1)/g1) //Isentropic temperature at 5 in K
eta_T=(T4-T5)/(T4-T5!) //Isentropic efficiency of turbine
//Results:
printf("\n The isentropic efficiency of the gas turbine, eta_T = %.1f percent\n\n",eta_T*100)
```

Scilab code Exa 26.7 Calculations on compound gas turbine

```
//Calculations on compound gas turbine
clc,clear
//Given:
r_p=4 //pressure ratio
eta_C=0.86,eta_HPT=0.84,eta_LPT=0.80 //Isentropic efficiencies of compressor and high and low pressure turbine in percent
e=70 //Effectiveness of heat exchanger in percent
eta_d=0.92 //Mechanical efficiency of drive to compressor
T4=660+273,T6=625+273 //Temperature of gases entering H.P. turbine and L.P. turbine in K
cp_a=1.005 //Specific heat of air in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
cp_g=1.15 //Specific heat of gas in kJ/kgK
g1=1.333 //Specific heat ratio(gamma) of gas
T1=15+273 //Atmospheric temperature in K
P1=1 //Atmospheric pressure in bar
//Solution:
//Refer fig 26.28, 26.29
P2=r_p*P1,P4=P2 //Pressure at 2, 4 in bar
T2!=T1*r_p^((g-1)/g) //Isentropic temperature at 2 in K
T2=(T2!-T1)/(eta_C)+T1 //Temperature at 2 in K
W_C=cp_a*(T2-T1) //Compressor work in kJ/kg
W_HPT=W_C/eta_d //Work done by H.P. turbine in kJ/kg
T5=T4-W_HPT/cp_g //Temperature at 5 in K
T5!=T4-(T4-T5)/(eta_HPT) //Isentropic temperature at 5 in K
P5=P4/(T4/T5!)^(g1/(g1-1)) //Pressure at 5 in bar
P6=P5,P7=P1 //Pressure at 6, 7 in bar
T7!=T6*(P7/P6)^((g1-1)/g1) //Isentropic temperature at 7 in K
T7=T6-eta_LPT*(T6-T7!) //Temperature at 7 in K
W_LPT=cp_g*(T6-T7) //Work done by L.P. turbine in kJ/kg
T3=poly(0,'T3') //Defining temperature at 3 as a unknown in K
```

```
e1=(cp_a*(T3-T2))/(cp_g*(T7-T2)) //Effectiveness in terms of T3
//Effectiveness from the relation must be equal to the given effectiveness
//Thus their difference must be zero
T3=roots(e1-e/100) //Temperature at 3 in K
W=cp_g*(T6-T7) //Work output in kJ/kg (error in book)
Q1=cp_g*(T4-T3)+cp_g*(T6-T5) //Heat added in kJ/kg
eta=W/Q1 //Cycle efficiency
//Results:
printf("\n The pressure of the gas entering L.P.T., P6 = %.2f bar",P6)
printf("\n The net specific power, W = %.2f kW/kg/s",W)
printf("\n The overall efficiency, eta = %.4f\n\n",eta)
//Answer is wrong in book
```

Scilab code Exa 26.8 Calculations on automotive gas turbine

```
//Calculations on automotive gas turbine
clc,clear
//Given:
r_p=6 //pressure ratio
e=65 //Effectiveness of heat exchanger in percent
T5=800+273,T1=15+273 //Inlet temperature to H.P. turbine and L.P. compressor in K
m=0.7 //Mass flow rate in kg/s
eta_C=0.8,eta_HPT=0.85,eta_LPT=0.85 //Isentropic efficiency of compressor and high and low pressure turbine in percent
eta_d=98 //Mechanical efficiency to drive compressor in percent
eta_c=97 //Combustion efficiency in percent
```

```
CV=42600 //Calorific value of fuel in kJ/kg
cp=1.005 //Assume specific heat in kJ/kgK
g=1.4 //Specific heat ratio(gamma)
//Solution:
//Refer fig 26.30, 26.31
P1=1 //Atmospheric pressure in bar
P3=r_p*P1,P5=P3,P7=P1 //Pressure at 3, 5, 7 in bar
T3!=T1*r_p^((g-1)/g) //Isentropic temperature at 3
    in K
T3!=round(T3!*10)/10
T3=(T3!-T1)/(eta_C)+T1 //Temperature at 3 in K
W_C=m*cp*(T3-T1) //Compressor work in kW
W_HPT=W_C*100/eta_d //Work done by H.P. turbine in
    kW
T6=T5-W_HPT/(m*cp) //Temperature at 6 in K
T6!=T5-(T5-T6)/(eta_HPT) //Isentropic temperature at
     6 in K
P6=P5/(T5/T6!)^(g/(g-1)) //Pressure at 6 in bar
T7!=T6*(P7/P6)^((g-1)/g) //Isentropic temperature at
     7 in K
T7=T6-eta_LPT*(T6-T7!) //Temperature at 7 in K
W=m*cp*(T6-T7) //Net power developed in kW
T4=e/100*(T7-T3)+T3 //Temperature at 4 in K
Q1=m*cp*(T5-T4)*100/eta_c //Heat supplied in kJ/s
eta=W/Q1 //Overall thermal efficiency
sfc=Q1*3600/(CV*W) //Specific fuel consumption in kg
    /kWh
//Results:
printf("\n (a)The net power developed, W = %.2f kW",
    W)
printf("\n (b)The overall thermal efficiency, eta =
    %.1f percent",eta*100)
printf("\n (c)The specific fuel consumption, sfc = %
    .3f kg/kWh\n\n",sfc)
```

Scilab code Exa 26.9 Calculations on Helium gas turbine

```
//Calculations on Helium gas turbine
clc,clear
//Given:
P1=4,P2=16 //Pressure at entering and leaving of compressor in bar
T1=320,T2=590 //Temperature at entering and leaving of compressor in K
e=70 //Effectiveness of heat exchanger in percent
P3=15.5,P4=4.2 //Pressure at entering and leaving of turbine in bar
T3=1400,T4=860 //Temperature at entering and leaving of turbine in K
P=100 //Net power output in MW
cp_h=5.2 //Specific heat of helium in kJ/kgK
g_h=1.67 //Specific heat ratio(gamma) for helium
//Solution:
//Refer fig 26.32, 26.33
T2!=T1*(P2/P1)^((g_h-1)/g_h) //Isentropic temperature at 2 in K
eta_C=(T2!-T1)/(T2-T1) //Compressor efficiency
T4!=T3/(P3/P4)^((g_h-1)/g_h) //Isentropic temperature at 4 in K
eta_T=(T3-T4)/(T3-T4!) //Turbine efficiency
Tx=T2+(T4-T2)*e/100 //Temperature at leaving of regenerator in K
Q1=cp_h*(T3-Tx) //Heat supplied in kJ/kg
W_T=cp_h*(T3-T4) //Turbine work in kJ/kg
W_C=cp_h*(T2-T1) //Compressor work in kJ/kg
W=W_T-W_C //Work output in kJ/kg
eta=W/Q1 //Cycle efficiency
T5=T4-(Tx-T2) //Temperature at 5 in K
Qout=cp_h*(T5-T1) //Heat rejected in precooler in kJ/kg
m_h=P*1000/W //Helium flow rate in kg/s
//Results:
printf("\n (a)The compressor efficiency, eta_C = %.3
```

```
    f\n\tThe turbine efficiency , eta_T = %.3f",eta_C,
    eta_T)
printf("\n (b)The thermal efficiency of the cycle ,
    eta = %.1f percent",eta*100)
printf("\n (c)The heat rejected in the cooler before
    compressor , Qout = %.1f kJ/kg",Qout)
printf("\n (d)The helium flow rate for the net power
    output of 100 MW, m = %.2f kg/s\n\n",m_h)
```

Scilab code Exa 26.10 Calculations on closed cycle gas turbine

```
//Calculations on closed cycle gas turbine
clc,clear
//Given:
r_p=9 //Overall pressure ratio
eta_LPC=85,eta_HPC=85 //Isentropic efficiency of L.P
    . and H.P. compressors in percent
eta_LPT=90,eta_HPT=90 //Isentropic efficiency of L.P
    . and H.P. turbine in percent
T1=300,T5=1100 //Inlet temperature to turbine and
    compressor in K
cp_ar=0.5207 //Specific heat of Argon in kJ/kgK
g_ar=1.667 //Specific heat ratio(gamma) for Argon
R_ar=0.20813 //Specific gas constant for Argon in kJ
    /kgK
//Solution:
//Refer fig. 26.34, 26.35
m_ar=1 //Assume mass flow rate in kg/s
P1=1 //Assume pressure at entering to L.P.
    compressor in bar
P2=sqrt(r_p)*P1 //Pressure at leaving to L.P.
    compressor in bar
P3=P2 //Pressure at entering to H.P. compressor in
    bar
P4=r_p*P1 //Pressure at leaving to H.P. compressor
```

```
in bar
T2!=T1*(P2/P1)^((g_ar-1)/g_ar) //Isentropic temperature at 2 in K
T2=(T2!-T1)/(eta_LPC/100)+T1 //Temperature at 2 in K
W_LPC=m_ar*cp_ar*(T2-T1) //Work required by L.P. compressor in kJ/kg/s
T3=T1 //Temperature at 3 in K
T4!=T3*(P4/P3)^((g_ar-1)/g_ar) //Isentropic temperature at 4 in K
T4=(T4!-T3)/(eta_HPC/100)+T3 //Temperature at 4 in K
//Work required is same for both L.P.C. and H.P.C. as pressure ratio is same for both
W_HPC=W_LPC //Work required by H.P. compressor in kJ/kg/s
P5=P4,P6=P2,P7=P6,P8=P1 //Pressure at 5, 6, 7, 8 in bar
T6!=T5/(P5/P6)^((g_ar-1)/g_ar) //Isentropic temperature at 6 in K
T6=T5-eta_HPT/100*(T5-T6!) //Temperature at 6 in K
W_HPT=m_ar*cp_ar*(T5-T6) //Work done by H.P. turbine in kJ/kg/s
//Work done is same for both L.P.T. and H.P.T. as pressure ratio is same for both
W_LPT=W_HPT //Work done by L.P. turbine in kJ/kg/s
T7=T5 //Temperature at 7 in K
//(a)
W=(W_HPT+W_LPT)-(W_HPC+W_LPC) //Net work done in kW/kg
//(b)
r_w=W/(W_HPT+W_LPT) //Work ratio
//(c)
Q1_c=m_ar*cp_ar*(T5-T4) //Heat supplied in combustion chamber in kJ/kg/s
Q1_r=m_ar*cp_ar*(T7-T6) //Heat supplied in reheater in kJ/kg/s
eta=W/(Q1_c+Q1_r) //Overall efficiency
//Results:
printf("\n (a)The work done per kg of fuel flow, W =
```

```
    %.1f kW/kg",W)
printf("\n (b)The work ratio, r_w = %.3f",r_w)
printf("\n (c)The overall efficiency, eta = %.3f\n\n
   ",eta)
```

Chapter 27

Testing of Internal Combustion Engines According to Indian and International Standards

Scilab code Exa 27.1 Calculations on non supercharged CI engine

```
//Calculations on non supercharged CI engine
clc,clear
//Given:
Pr=500 //Standard reference brake power in kW
eta_m=85 //Mechanical efficiency in percent
br=220 //Standard specific fuel consumption in g/kWh
px=87 //Site ambient air pressure in kPa
Tx=45+273 //Site ambient temperature in K
phix=80/100 //Relative humidity at site
//Solution:
//Refer table 27.1, 27.2 and 27.3
a=1 //Factor
m=1,n=0.75,q=0 //Exponents
psx=9.6 //Saturation vapour pressure at site in kPa
psr=3.2 //Standard saturation vapour pressure in kPa
pr=100 //Standard total barometric pressure in kPa
Tr=298 //Standard air temperature in K
```

```
phir=0.3 //Standard relative humidity
k=((px-a*phix*psx)/(pr-a*phir*psr))^m*(Tr/Tx)^n //The ratio of indicated power
alpha=k-0.7*(1-k)*(100/eta_m-1) //Power adjustment factor
Beta=k/alpha //Fuel consumption adjustment factor
Px=alpha*Pr //Brake power at site in kW
bx=Beta*br //Specific fuel consumption at site in g/kWh
//Results:
printf("\n The site continuous net brake power, Px = %.1f kW",Px)
printf("\n The site continuous specific fuel consumption, bx = %.1f g/kWh\n",bx)
```

Scilab code Exa 27.2 Calculations on turbocharged CI engine

```
//Calculations on turbocharged CI engine
clc,clear
//Given:
Pr=1000 //Standard reference brake power in kW
eta_m=90 //Mechanical efficiency in percent
Pir=2 //Boost pressure ratio
Tra=313 //Substitute reference air temperature in K
Pimax=2.36 //Maximum boost pressure ratio
h=4000 //Altitude in m
px=61.5 //Site ambient air pressure in kPa
Tx=323 //Site ambient temperature in K
Tcx=310 //Charge air coolent temperature at site in K
//Solution:
//Refer table 27.1, 27.2 and 27.3
m=0.7,n=1.2,q=1 //Exponents
pr=100 //Standard total barometric pressure in kPa
Tcr=298 //Standard charge air coolent temperature in
```

```
K
Tr=298 //Standard air temperature in K
pra=pr*Pir/Pimax //Standard reference pressure in
   kPa
pra=round(10*pra)/10
k=(px/pra)^m*(Tra/Tx)^n*(Tcr/Tcx)^q //The ratio of
   indicated power
alpha=k-0.7*(1-k)*(100/eta_m-1) //Power adjustment
   factor
Px1=round(alpha*Pr) //Brake power at site in kW
//If reference conditions are not changed
k=(px/pr)^m*(Tr/Tx)^n*(Tcr/Tcx)^q //The ratio of
   indicated power
alpha=k-0.7*(1-k)*(100/eta_m-1) //Power adjustment
   factor
Px2=round(alpha*Pr) //Brake power at site in kW
//Results:
printf("\n Power available at an altitude of 4000m,
   Px = %d kW",Px1)
printf("\n Power available at an altitude of 4000m
   if reference conditions are not changed, Px = %d
   kW\n",Px2)
```

Scilab code Exa 27.3 Calculations on turbocharged CI engine

```
//Calculations on turbocharged CI engine
clc,clear
//Given:
Px=640 //Brake power at site in kW
px=70 //Site ambient air pressure in kPa
Tx=330 //Site ambient temperature in K
Tcx=300 //Charge air coolent temperature at site in
   K
eta_m=85 //Mechanical efficiency in percent
py=100 //Test ambient pressure in kPa
```

```
Tcy=280 //Charge air coolent temperature at test in K
Ty=300 //Test ambient temperature in K
//Solution:
//Refer table 27.1, 27.2 and 27.3
m=0.7,n=1.2,q=1 //Exponents
pr=100 //Standard total barometric pressure in kPa
Tcr=298 //Standard charge air coolent temperature in K
Tr=298 //Standard air temperature in K
kr=(px/pr)^m*(Tr/Tx)^n*(Tcr/Tcx)^q //The ratio of indicated power
kr=floor(1000*kr)/1000
alphar=kr-0.7*(1-kr)*(100/eta_m-1) //Power adjustment factor
Pr=Px/alphar //Standard reference brake power in kW
ky=(py/pr)^m*(Tr/Ty)^n*(Tcr/Tcy)^q //The ratio of indicated power at test
alphay=ky-0.7*(1-ky)*(100/eta_m-1) //Power adjustment factor at test
Py=Pr*alphay //Brake power at test in kW (Round off error)
//Results:
printf("\n Power developed under test ambient conditions, Py = %.0f kW",Py)
//Round off error in the value of 'Py'
```

Scilab code Exa 27.4 Simulating site ambient conditions

```
//Simulating site ambient conditions
clc,clear
//Given:
//Datas are taken from Ex. 27.3
Px=640 //Brake power at site in kW
eta_m=85 //Mechanical efficiency in percent
```

```
px=70 //Site ambient air pressure in kPa
py=100 //Standard total barometric pressure in kPa
Tx=330 //Site ambient temperature in K
Ty=300 //Test ambient temperature in K
p2_py=2.5 //Pressure ratio
by=238 //Specific fuel consumption at test in g/kWh
//Solution:
//Refer table 27.1, 27.2 and 27.3
m=0.7,n=1.2,q=1 //Exponents
ky=(py/px)^m //The ratio of indicated power at test
alphay=ky-0.7*(1-ky)*(100/eta_m-1) //Power adjustment factor at test
Py=round(Px*alphay) //Brake power at test in kW
//From fig 27.1
Tx_Ty=Tx/Ty //Temperature ratio
p1_py=0.925 //Ratio
p1=p1_py*py //Air pressure after throttle in kPa (printing error)
Betay=ky/alphay //Fuel consumption adjustment factor at test
bx=by/Betay //Specific fuel consumption at site in g/kWh
//Results:
printf("\n Power developed on the test bed, Py = %d kW",Py)
printf("\n The pressure behind the throttle plate, p1 = %.1f kPa",p1)
printf("\n The fuel consumption adjusted to site ambient conditions, bx = %d g/kWh",bx)
//Answer in the book is printed wrong
```

Scilab code Exa 27.5 Calculations on unsupercharged SI engine

```
//Calculations on unsupercharged SI engine
clc,clear
```

```
//Given:
Py=640 //Brake power at test in kW
py=98 //Test ambient pressure in kPa
Ty=303 //Test ambient temperature in K
phiy=0.8 //Relative humidity at test
//Solution:
//Refer table 27.1, 27.3
psy=4.2 //Saturation vapour pressure at test in kPa
psr=3.2 //Standard saturation vapour pressure in kPa
pr=100 //Standard total barometric pressure in kPa
Tr=298 //Standard air temperature in K
phir=0.3 //Standard relative humidity
alpha_a=((pr-phir*psr)/(py-phiy*psy))^1.2*(Ty/Tr)^0.6 //Correction factor for CI engine
Pr=round(alpha_a*Py) //Standard reference brake power in kW
//Results:
printf("\n The power at standard reference conditions, Pr = %d kW",Pr)
```

Scilab code Exa 27.6 Calculations on turbocharged CI engine

```
//Calculations on turbocharged CI engine
clc,clear
//Given:
Py=896 //Brake power at test in kW
py=96 //Test ambient pressure in kPa
Ty=302 //Test ambient temperature in K
phiy=0.2 //Relative humidity at test
px=98 //Site ambient air pressure in kPa
Tx=315 //Site ambient temperature in K
phix=0.4 //Relative humidity at site
N=1800 //Engine speed in rpm
V_s=51.8 //Swept volume in litres
m_f=54.5 //Fuel delivery in gm/s
```

```
pi=2.6 //Pressure ratio
//Solution:
//Refer table 27.1, 27.3
psy=4.8 //Saturation vapour pressure at test in kPa
psx=8.2 //Saturation vapour pressure at site in kPa
q=m_f*1000/(N/(2*60)*V_s) //Fuel delivery in mg/
    litrecycle
qc=round(q/pi) //Corrected fuel delivery inmg/
    litrecycle
//Applying condition given in fig 27.2 for value of
    engine factor (fm)
if (qc <= 40) then
    fm=0.3;
elseif (qc >= 65) then
    fm=1.2;
else
    fm=0.036*qc-1.14;
end
fa=((px-phix*psx)/(py-phiy*psy))^0.7*(Ty/Tx)^1.5 //
    Atmospheric factor
alpha_d=fa^fm //Correction factor for CI engine
Px=alpha_d*Py //Brake power at site in kW
//Results:
printf("\n Power at site ambient conditions, Px = %d
    kW",Px)
```

Scilab code Exa 27.7 Calculations on turbocharged CI engine

```
//Calculations on turbocharged CI engine
clc,clear
//Given:
Py=700 //Brake power at test in kW
py=96 //Test ambient pressure in kPa
Ty=302 //Test ambient temperature in K
phiy=0.2 //Relative humidity at test
```

```
px=69 //Site ambient air pressure in kPa
Tx=283 //Site ambient temperature in K
phix=0.4 //Relative humidity at site
N=1200 //Engine speed in rpm
V_s=45 //Swept volume in litres
m_f=51.3 //Fuel delivery in gm/s
pi=2.0 //Pressure ratio
eta_m=85 //Mechanical efficiency in percent
//Solution:
pr=100 //Standard total barometric pressure in kPa
Tr=298 //Standard air temperature in K
phir=0.3 //Standard relative humidity
//Refer table 27.1, 27.3
psy=4.1 //Saturation vapour pressure at test in kPa
psx=1.2 //Saturation vapour pressure at site in kPa
psr=3.2 //Standard saturation vapour pressure in kPa
q=m_f*1000/(N/(2*60)*V_s) //Fuel delivery in mg/
   litrecycle
qc=round(q/pi) //Corrected fuel delivery in mg/
   litrecycle
//Applying condition given in fig 27.2 for value of
   engine factor (fm)
if (qc <= 40) then
    fm=0.3;
elseif (qc >= 65) then
    fm=1.2;
else
    fm=0.036*qc-1.14;
end
fa=((px-phix*psx)/(py-phiy*psy))^0.7*(Ty/Tx)^1.5 //
   Atmospheric factor
alpha_d=fa^fm //Correction factor for CI engine
//Applying condition given in section 27.4.2
if (alpha_d > 0.9) & (alpha_d < 1.1) then
    Px=alpha_d*Py
else
    fa=((pr-phir*psr)/(py-phiy*psy))^0.7*(Ty/Tr)^1.5
        //Atmospheric factor
```

```
    alpha_d=fa^fm //Correction factor for CI engine
    Pr=alpha_d*Py //Standard reference brake power
       in kW
    m=0.7,n=2 //Exponents
    k=(px/pr)^m*(Tr/Tx)^n //The ratio of indicated
       power
    alpha=k-0.7*(1-k)*(100/eta_m-1) //Power
       adjustment factor
    Px=alpha*Pr //Brake power at site in kW
end
//Results:
printf("\n Power at site ambient conditions, Px = %d
   kW",Px)
//Answer in the book is wrong
```