Scilab Textbook Companion for Elements of Mechanical Engineering by R. K. Rajput[1]

Created by
Vatsal Shah
B.TECH
Mechanical Engineering
Institute of Technology,Nirma University
College Teacher
None
Cross-Checked by
Bhavani Jalkrish

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 2

Fuels and Combustion

Scilab code Exa 2.1 Example 1

```
clc
clear
//DATA GIVEN
c=88;                        //% of carbon in coal
h=4.2;                       //% of hydrogen in coal
Wf=0.848;                    //weight of coal in g
Wfw=0.027;                   //weight of fuse wire in
    calorimeter in g
W=1950;                      //weight of water in
    calorimeter in g
We=380;                      //water equivalent of
    calorimeter
Dt=3.06;                     //observed temperature rise
    (t2-t1) in deg celsius
tc=0.017;                    //cooling correction in deg
    celsius
cfw=6700;                    //calorific value of fuse
    wire in J/g

//CALCULATIONS
ctr=(Dt)+tc;                 //corrected temp. rise
```

```
Hw=(W+We)*4.18*[ctr];     //heat recieved by water in
    J
Hfw=Wfw*cfw;              //heat given out by fuse
    wire in J
Hcf=Hw-Hfw;               //heat produced due to
    combustion of fuel in J
HCV=Hcf/Wf;               //higher calorific value of
    fuel in kJ/kg
Ms=9*h/100;               //steam produced per kg of
    coal
LCV=HCV-2465*Ms;          //lower calorific value of
    fuel in kJ/kg

printf('The Higher calorific value of fuel, H.C.V.
    is: %5.1f kJ/kg. \n',HCV);
printf(' The Lower calorific value of fuel, L.C.V.
    is: %5.1f kJ/kg. \n',LCV);
```

Scilab code Exa 2.2 Example 2

```
clc
clear
//DATA GIVEN
V1=0.08;                  //gas burnt in calorimeter
    in m^3
Pg=5.2;                   //pressure of gas supply in
     cm of water
Pb=75.5;                  //barometer reading in cm
    of Hg
Ww=28;                    //weight of water heated by
     gas in kg
Tg=13;                    //temperature of gas in deg
     celsius
Twi=10;                   //temperature of water at
    inlet in deg celsius
```

```
Two=23.5;                      //temperature of water at outlet in deg celsius
Ms=0.06;                       //steam condensed in kg

//CALCULATIONS
//by using general gas equation, reducing the volume to S.T.P.
//p1*V1/T1=p2*V2/T2
p1=Pb+(Pg/13.6);               //in cm of Hg
T1=Tg+273;                     //in K
p2=76;                         //in cm of Hg
T2=15+273;                     //in K
V2=p1*V1*T2/T1/p2;             //in m^3
Hw=Ww*4.18*(Two-Twi);          //heat recieved by water in kJ
HCV=Hw/V1;                     //higher calorific value of fuel in kJ/m^3
LCV=HCV-2465*Ms/V1;            //lower calorific value of fuel in kJ/m^3

printf(' The Calorific values of fuel per m^3 of gas at 15 deg celsius and 76 cm of Hg pressure are: \n');
printf('  The Higher calorific value of fuel, H.C.V. is: %5.1f kJ/m^3. \n',HCV);
printf('  The Lower calorific value of fuel, L.C.V. is: %5.1f kJ/m^3. \n',LCV);
```

Chapter 3

Properties of Gases

Scilab code Exa 3.1 Example 1

```
clc
clear
//DATA GIVEN
Q=-50;                              //heat rejected to
   cooling water in kJ/kg
W=-100;                             //work input in kJ/
   kg

//using First Law of Thermodynamics, Q=(u2-u1)+W
Du=Q-W;                             //(u2-u1) change in
   internal energy in kJ/kg
//since Du is +ve, there is gain in internal energy

printf('The GAIN in internal energy is: %2.0f kJ/kg.
    \n',Du);
```

Scilab code Exa 3.2 Example 2

```
clc
clear
//DATA GIVEN
u1=450;                                 //internal energy at
     beginning of the expansion in kJ/kg
u2=220;                                 //internal energy
    after expansion in kJ/kg
W=120;                                  //work done by the
    air during expansion in kJ/kg

//using First Law of Thermodynamics, Q=(u2-u1)+W
Q=(u2-u1)+W;                            //heat flow in kJ/kg
//since Q is -ve, there is rejection of heat

printf('The heat REJECTED by air is: %3.0f kJ/kg. \n
    ',(-Q));
```

Scilab code Exa 3.3 Example 3

```
clc
clear
//DATA GIVEN
m=0.3;                                  //mass of nitrogen
    in kg
p1=0.1;                                 //pressure in MPa
T1=40+273;                              //temperature before
     compression in K
p2=1;                                   //pressure in MPa
T2=160+273;                             //temperature after
    compression in K
W=-30;                                  //work done during
    the compression in kJ/kg
Cv=0.75                                 //in kJ/kgK

//using First Law of Thermodynamics, Q=(u2-u1)+W
```

```
//(u2-u1)=m*Cv*(T2-T1)
Du=m*Cv*(T2-T1);
Q=Du+W;                                //heat flow in kJ/kg
//since Q is -ve, there is rejection of heat

printf('The heat REJECTED by air is: %1.0f kJ. \n',(-Q));
```

Scilab code Exa 3.4 Example 4

```
clc
clear
//DATA GIVEN
//initial state
p1=0.105;                              //pressure of gas in MPa
V1=0.4;                                //volume of gas in m^3
//final state
p2=0.105;                              //pressure of gas in MPa
V2=0.20;                               //volume of gas in m^3

Q=-42.5;                               //heat transferred in kJ
p=p1;

//process used- ISOBARIC (Constant pressure)
W12=p*(V2-V1)*1000;                    //work in kJ
//using First Law of Thermodynamics, Q=(u2-u1)+W
Du=Q-W12;                              //(u2-u1) change in internal energy in kJ
//since Du is -ve, there is decrease in internal energy
```

```

printf('The DECREASE in internal energy is: %2.1f kJ. \n',(-Du));
```

Scilab code Exa 3.5 Example 5

```
clc
clear
//DATA GIVEN
//part-1
//pressure=p1,temperature=T1
//part-2
//pressure=p2,temperature=T2

//Acc. First Law of Thermodynamics, Q=(u2-u1)+W
//when partition moved
DQ=0;
DW=0;
DU=DQ-DW;
//DU=0

printf('      CONCLUSION: \n');
printf('        Acc. to First Law of Thermodynamics, \n');
printf('        When partion moved, there is conservation of internal energy. \n');
```

Scilab code Exa 3.6 Example 6

```
clc
clear
//DATA GIVEN
//initial state
```

```
p1=10^5;                            //initial pressure of air in Pa
v1=1.8;                             //volume of air in m^3/kg
T1=25+273;                          //initial temperature of air in K
//final state
p2=5*10^5;                          //final pressure of air in Pa
T2=25+273;                          //final temperature of air in K

//process used- ISOTHERMAL (Constant temperature)
W12=[p1*v1*log(p1/p2)]/1000;     //work in kJ/kg
//since W is -ve, work is supplied to the air

//since temperature is constant
Du=0;                               //(u2-u1) change in internal energy in kJ/kg

//using First Law of Thermodynamics, Q=(u2-u1)+W
Q=Du+W12;
//since Q is -ve, there is rejection of heat from system to surroundings

printf(' (i) The Work done on the air is: %3.1f kJ/kg. \n',(-W12));
printf(' (ii) The change in internal energy is: %1.0f kJ/kg. \n',(Du));
printf('(iii) The Heat REJECTED is: %3.1f kJ/kg. \n',(-Q));
```

Scilab code Exa 3.8 Example 8

```
clc
```

```
clear
//DATA GIVEN
p1=4*10^5;                          //initial pressure in N/m^2
V1=0.2;                             //initial volume in m^3
T1=130+273;                         //initial temperature in K
p2=1.02*10^5;                       //final pressure after adiabatic expansion in N/m^2
Q23=72.5;                           //increase in enthalpy during constant pressure process in kJ
Cp=1;                               //in kJ/kgK
Cv=0.714;                           //in kJ/khK

//gamma for air , g
g=Cp/Cv;
R=(Cp-Cv)*1000;

//for reversible adiabatic process 1-2
//p1*(V1^g)=p2*(V2^g)
V2=V1*(p1/p2)^(1/g);                //final volume in m^3
//(T2/T1)=(p2/p1)^((g-1)/g);
T2=T1*(p2/p1)^((g-1)/g);;           //final temp. T2 in K

m=p1*V1/R/T1;                       //mass in kg

//for constant pressure process 2-3
//Q23=m*Cp*(T3-T2);
T3=Q23/m/Cp+T2;
//V2/T2=V3/T3
V3=V2/T2*T3;

//Work done by the path 1-2-3, W123=W12+W23
W12=(p1*V1-p2*V2)/(g-1);
W23=p2*(V3-V2);
```

```
W123=W12+W23;

//if the above processes are replaced by a single reversible polytropic process giving the same work between initial and final states,
//W13=W123=(p1V1-p3V3)/(n-1)
p3=p2;
n=1+(p1*V1-p3*V3)/W123;           //index of expansion, n

printf('(i) The Total Work done is: %5.0f Nm or J.\n',W123);
printf('(ii) The value of index of expansion, n is: %1.3f.\n',n);

//NOTE:
//there is slight variation in answers of the book due to rounding off of the values
```

Scilab code Exa 3.10 Example 10

```
clc
clear
//DATA GIVEN
//initial state
p1=10^5;                          //initial pressure of gas in Pa
V1=0.45;                          //initial volume of gas in m^3
T1=80+273;                        //initial temperature of gas in K
//final state
p2=5*10^5;                        //final pressure of gas in Pa
V2=0.13;                          //final volume of
```

```
gas in m^3

//gamma for air, g
g=1.4;
R=294.2                         //J/kgK

m=p1*V1/R/T1;                   //mass in kg

//p1*(V1^n)=p2*(V2^n)
n=log(p1/p2)/log(V2/V1);        //index n

//In a polytropic process
//(T2/T1)=(V1/V2)^(n-1);
T2=T1*(V1/V2)^(n-1);            //temp. T2 in K

Cv=R/(g-1);
Du=m*Cv*(T2-T1)/1000;           //increase in internal energy in kJ

//using First Law of Thermodynamics, Q=(u2-u1)+W
//W12=(p1*V1-p2*V2)/(n-1)=mR(T2-T1)/(n-1)
W12=m*R*(T1-T2)/(n-1)/1000;
Q=Du+W12;
//since Q is -ve, there is rejection of heat from system to surroundings

printf(' (i) The Mass of the gas is: %1.3f kg. \n',(m));
printf(' (ii) The index n is: %1.3f. \n',(n));
printf('(iii) The change in internal energy is: %2.1f kJ. \n',(Du));
printf(' (iv) The Heat REJECTED is: %2.2f kJ. \n',(-Q));
```

Scilab code Exa 3.11 Example 11

```
clc
clear
//DATA GIVEN
//initial state
p1=1.02;                          //initial pressure of air in bar
V1=0.015;                         //initial volume of air in m^3
T1=22+273;                        //initial temperature of air in K
//final state
p2=6.8;                           //final pressure of air in bar
//Law of adiabatic compression, pV^g=C

//gamma for air, g
g=1.4
R=0.287;

//In a adiabatic process
//(T2/T1)=(p2/p1)^((g-1)/g);
T2=T1*(p2/p1)^((g-1)/g);;         //final temp. T2 in K

//p1*(V1^g)=p2*(V2^g)
V2=V1*(p1/p2)^(1/g);              //final volume in m^3

m=p1*10^5*V1/10^3/R/T1;           //mass in kg

//W=(p1*V1-p2*V2)/(g-1)=mR(T2-T1)/(g-1)
W=m*R*(T1-T2)/(g-1);
//since W is -ve, the work is done on the air

printf(' (i) The Final temperature is: %3.2f deg. celsius. \n',(T2-273));
printf(' (ii) The Final Volume is: %1.5f m^3. \n',V2);
```

```
printf('(iii) The Work done on the air is: %1.3f kJ.\n',(-W));
```

Scilab code Exa 3.12 Example 12

```
clc
clear
//DATA GIVEN
m=0.44;                         //mass of air in kg
T1=180+273;                     //initial temperature of air in K
T2=15+273;                      //final temperature of air in K
W12=52.5;                       //work done during the process in kJ
//V2/V1=3
Vr=3;                           //volume ratio, Vr=V2/V1

//Law of adiabatic expansion, pV^g=C

//In an adiabatic process
//(T2/T1)=(V1/V2)^(g-1);
g=1+[(log(T2/T1)/log(1/Vr))];          //gamma for air, g=Cp/Cv

//W12=(p1*V1-p2*V2)/(n-1)=mR(T2-T1)/(g-1)
R=W12/m/(T1-T2)*(g-1);
//R=Cp-Cv

Cv=R/(g-1);
Cp=g*Cv;

printf(' (i) The value of Cv is: %1.3f kJ/kgK. \n',Cv);
```

```
printf(' (ii) The value of Cp is: %1.3f kJ/kgK. \n', Cp);

//NOTE:
//there is slight variation in answers of the book due to rounding off of the values
```

Scilab code Exa 3.13 Example 13

```
clc
clear
//DATA GIVEN
m=1;                                //mass of etahne gas in kg
M=30;                               //molecular weight of ethane
p1=1.1;                             //initial pressure in bar
T1=27+273;                          //initial temperature in K
p2=6.6;                             //final pressure in bar
Cp=1.75;                            //in kJ/kgK

//Law of compression, pV^1.3=C
n=1.3;

//Characteristic gas constant, R = Universal gas constant (Ro)/Molecular weight(M)
Ro=8314;
R=Ro/M/1000;                        //kJ/kgK

//R=Cp-Cv
Cv=Cp-R;
g=Cp/Cv;                            //gamma g
```

```
//In a polytropic process
//(T2/T1)=(p2/p1)^((n-1)/n);
T2=T1*(p2/p1)^((n-1)/n);;        //final temp. T2 in
    K

//W=(p1*V1-p2*V2)/(n-1)=mR(T2-T1)/(g-1)
W=m*R*(T1-T2)/(n-1);

Q=[(g-n)/(g-1)]*W;               //heat flow in kJ/kg

printf(' The Heat SUPPLIED is: %2.1f kJ/kg. \n',(Q))
    ;
```

Chapter 4

Properties of Steam

Scilab code Exa 4.1 Example 1

```
clc
clear
//DATA GIVEN
Ms=50;                              //mass of dry steam
   in kg
Mw=1.5;                             //mass of water in
   suspension in kg

//dryness fraction , x=(mass of dry steam)/(mass of
   dry steam +mass of water in suspension)
x=Ms/(Ms+Mw);

printf('The Dryness fraction (Quality) of steam is:
   %1.3f.',x);
```

Scilab code Exa 4.2 Example 2

```
clc
```

```
clear
//DATA GIVEN
V=0.6;                              //volume of the vessel in m^3
p=0.5;                              //pressure in bar
M=3;                                //mass of liquid and water vapour in kg

v=V/M;                              //specific volume in m^3/kg
//At 5 bar, from steam tables
vg=0.375;                           //m^3/kg
vf=0.00109;                         //m^3/kg
vfg=vg-vf;
//v=vg-(1-x)vfg
x=(v-vg)/vfg+1;                     //quality of the vapour

//mass and volume of liquid
Mliq=M*(1-x);
Vliq=Mliq*vf;

//mass and volume of vapour
Mvap=M*x;
Vvap=Mvap*vg;

printf('(i) The Mass and Volume of liquid is: \n');
printf('     Mliq. is: %1.3f kg. \n',Mliq);
printf('     Vliq. is: %1.4f m^3. \n',Vliq);
printf('(ii) The Mass and Volume of vapour is: \n');
printf('     Mvap. is: %1.3f kg. \n',Mvap);
printf('     Vvap. is: %1.4f m^3. \n',Vvap);
```

Scilab code Exa 4.3 Example 3

```
clc
clear
//DATA GIVEN
V=0.05;                          //volume of vessel in m^3
Mf=10;                           //mass of liquid in kg
T=245;                           //temp. in deg celsius

//from steam tables, corresponding to 245 deg celsius
Psat=36.5;                       //bar
vf=0.001239;                     //m^3/kg
vg=0.0546;                       //m^3/kg
hf=1061.4;                       //kJ/kg
hfg=1740.2;                      //kJ/kg
sf=2.7474;                       //kJ/kgK
sfg=3.3585;                      //kJ/kgK

Vf=Mf*vf;                        //volume of liquid
Vg=V-Vf;                         //volume of vapour
Mg=Vg/vg;                        //mass of vapour
m=Mf+Mg;                         //total mass of mixture

x=Mg/(Mg+Mf);                    //quality of the mixture
vfg=vg-vf;
v=vf+x*vfg;                      //specific volume

h=hf+x*hfg;                      //specific enthalpy

s=sf+x*sfg;                      //specific entropy

u=h-Psat*10^5*v/10^3;            //specific internal energy

```

```

printf(' (i) The Pressure is: %2.1f bar. \n',Psat);
printf(' (ii) The mass m is: %2.3f kg. \n',m);
printf('(iii) The Specific volume v is: %1.6f m^3/kg. \n',v);
printf(' (iv) The Specific enthalpy h is: %4.2f kJ/kg. \n',h);
printf('  (v) The Specific entropy s is: %1.4f kJ/kgK. \n',s);
printf(' (vi) The Specific internal energy u is: %4.2f kJ/kg. \n',u);

//NOTE:
//there is slight variation in answers of book due to rounding off of the values in the book
```

Scilab code Exa 4.4 Example 4

```
clc
clear
//DATA GIVEN
Mw=2;                          //mass of water to be converted to steam in kg
Tw=25;                         //temp. of water in deg celsius
p=5;                           //pressure
x=0.9;                         //dryness fraction

//At 5 bar, from steam tables
hf=640.1;                      //kJ/kg
hfg=2107.4;                    //kJ/kg

h=hf+x*hfg;                    //specific enthalpy (above 0 deg celsius)
hs=1*4.18*(Tw-0);              //sensible heat
```

```
    associated with i kg of water
hnet=h-hs;                          //net quantity of heat to be supplied per kg of water
Htotal=Mw*hnet;                     //total amount of heat to be supplied

printf('The Total amount of heat to be supplied is: %4.2f kJ.',Htotal);
```

Scilab code Exa 4.5 Example 5

```
clc
clear
//DATA GIVEN
m=4.4;                              //mass of steam to be produced in kg
p=6;                                //pressure of steam
Tsup=250;                           //temp. of steam in deg. celsius
Tw=30;                              //temp. of water in deg celsius
Cps=2.2;                            //specific heat of steam in kJ/kg

//At 6 bar, from steam tables
Ts=158.8;                           //deg. celsius
hf=670.4;                           //kJ/kg
hfg=2085;                           //kJ/kg
//since the given temp. 250 deg celsius is greater than 158.8 deg celsius, steam is superheated

hsup=hf+hfg+Cps*(Tsup-Ts);          //enthalpy of 1 kg supergeated steam reckoned from 0 deg. celsius
hs=1*4.18*(Tw-0);                   //sensible heat associated with i kg of water
```

```
hnet=hsup-hs;                         //net quantity of
   heat to be supplied per kg of water
Htotal=m*hnet;                        //total amount of
   heat to be supplied

printf('The Total amount of heat to be supplied is:
   %4.1f kJ.',Htotal);
```

Scilab code Exa 4.6 Example 6

```
clc
clear
//DATA GIVEN
V=0.15;                               //volume of wet steam
    in m^3
p=4;                                  //pressure of wet
   steam in bar
x=0.8;                                //dryness fraction

//At 4 bar, from steam tables
vg=0.462;                             //m^3/kg
hf=604.7;                             //kJ/kg
hfg=2133;                             //kJ/kg

rho=1/(x*vg);                         //density in kg/m^3
m=rho*V;                              //mass of 0.15 m^3 of
    steam

Htotal=(rho*1)*(hf+x*hfg);            //total heat of 1 m^3
    of steam which has a mass of rho(2.7056) kg

printf('(i)The Mass of 0.15 m^3 of steam is: %1.4f
   kg. \n',m);
printf('(ii)The Total heat of 1 m^3 of steam which
   has a mass of 2.7056 kg is: %4.2f kJ. \n',Htotal)
```

```
;
```

Scilab code Exa 4.7 Example 7

```
clc
clear
//DATA GIVEN
m=1000;                               //mass of steam generated in kg/hr
p=16;                                 //pressure of steam in bar
x=0.9;                                //dryness fraction
Tsup=380+273;                         //temp. of superheated steam in K
Tfw=30;                               //temp. of feed water in deg. celsius
Cps=2.2;                              //specific heat of steam in kJ/kg

//At 16 bar, from steam tables
Ts=201.4+273;                         //in K
hf=858.6;                             //kJ/kg
hfg=1933.2;                           //kJ/kg

Hs=m*[(hf+x*hfg)-1*4.187*(Tfw-0)];        //heat supplied to feed water per hr to produce wet steam
Ha=m*[(1-x)*hfg+Cps*(Tsup-Ts)];           //heat absorbed by superheater per hour

printf('(i) The Heat supplied to feed water per hour to produce wet steam is: %4.2f*10^3 kJ. \n',(Hs/1000));
printf('(ii) The Heat absorbed by superheater per hour is: %3.2f*10^3 kJ. \n',(Ha/1000));
```

Scilab code Exa 4.8 Example 8

```
clc
clear

//At 0.75 bar. From steam tables,
//At 100 deg celsius
T1=100;                          //deg celsius
hsup1=2679.4;                    //kJ/kg
//At 150 deg celsius
T2=150;                          //deg celsius
hsup2=2778.2;                    //kJ/kg
Cps1=(hsup2-hsup1)/(T2-T1);

//At 0.5 bar. From steam tables,
//At 300 deg celsius
T3=300;                          //deg celsius
hsup3=3075.5;                    //kJ/kg
//At 400 deg celsius
T4=400;                          //deg celsius
hsup4=3278.9;                    //kJ/kg
Cps2=(hsup4-hsup3)/(T4-T3);

printf('(i) The mean specific heat for superheated
   steam \n       (At 0.75 bar, between 100 and 150
   deg celsius) is: %1.3f. \n',Cps1);
printf('(ii) The mean specific heat for superheated
    steam \n       (At 0.5 bar, between 300 and 400
   deg celsius) is: %1.3f. \n',Cps2);
```

Scilab code Exa 4.9 Example 9

```
clc
clear
//DATA GIVEN
m=1.5;                              //mass of steam in cooker in kg
p1=5;                               //pressure of steam in bar
x1=1;                               //initial dryness fraction of steam
x2=0.6;                             //final dryness fraction of steam

//At 5 bar, from steam tables
Ts1=151.8+273;                       //in K
hf1=640.1;                           //kJ/kg
hfg1=2107.4;                         //kJ/kg
vg1=0.375;                           //m^3/kg

V1=m*vg1;                                              //volume of pressure cooker in m^3
u1=(hf1+hfg1)-(p1*10^5)*(vg1*10^-3);                   //internal energy of steam per kg at initial point 1
//V1=V2
//V1=m*[(1-x2)*vf2+x2*vg2]                             //vf2 is negligible
vg2=V1/x2/1.5;

//from steam tables coreesponding to vg2=0.625 m^3/kg
p2=2.9;
Ts2=132.4+273;                       //in K
hf2=556.5;                           //kJ/kg
hfg2=2166.6;                         //kJ/kg

u2=(hf2+x2*hfg2)-(p2*10^5)*x2*(vg2*10^-3);       //internal energy of steam per kg at final point 2

```

```
hnet=u2-u1;                                    //heat transferred at constant volume per kg
Htotal=m*hnet;                                 //total heat transferred
//-ve sign indicates that heat has been rejected
Hrej=-1*Htotal;

printf(' (i) The Pressure at new state is: %1.1f bar. \n',p2);
printf('      The Temperature at new state is: %3.1f deg. celsius or %3.1f K. \n',(Ts2-273),Ts2);
printf(' (ii) The Total heat to be REJECTED is: %4.2f kJ.',Hrej);
```

Scilab code Exa 4.10 Example 10

```
clc
clear
//DATA GIVEN
V=0.9;                          //capacity of spherical vessel in m^3
p1=8;                           //pressure of steam in bar
x1=0.9;                         //dryness fraction of steam
p2=4;                           //pressure of steam after blow off in bar
p3=3;                           //final pressure of steam in bar

//At 8 bar, from steam tables
hf1=720.9;                      //kJ/kg
hfg1=2046.5;                    //kJ/kg
vg1=0.240;                      //m^3/kg

```

```
m1=V/(x1*vg1);                    //mass of steam in the vessel in kg

h1=hf1+x1*hfg1;                   //enthalpy of steam before blowing off (per kg)
//enthalpy of steam before blowing off (per kg) = enthalpy of steam after blowing off (per kg)
h2=h1;
//h2=hf2+x2*hfg2
//At 4 bar, from steam tables
hf2=604.7;                        //kJ/kg
hfg2=2133;                        //kJ/kg
vg2=0.462;                        //m^3/kg
x2=(h2-hf2)/hfg2;                 //dryness fraction at 2

m2=V/(x2*vg2);                    //mass of steam in the vessel in kg
m=m1-m2;                          //mass of steam blown off in kg

//As it is constant volume cooling, x2*vg2(at 4 bar)=x3*vg3(at 3 bar)
//At 3 bar, from steam tables
hf3=561.4;                        //kJ/kg
hfg3=2163.2;                      //kJ/kg
vg3=0.606;                        //m^3/kg

x3=x2*vg2/vg3;
h3=hf3+x3*hfg3;

//heat lost during cooling, Qlost=m(u3-u2)
u2=h2-p2*10^5*x2*vg2*10^-3;
u3=h3-p3*10^5*x3*vg3*10^-3;
Qlost=m*(u3-u2);

printf('(i) The Mass of of steam blown off is: %1.3f kg. \n',m);
```

```
printf(' (ii) The Dryness fraction of steam in the
    vessel after cooling is: %1.4f. \n',x3);
printf('(iii) The Heat lost during cooling is: %3.2f
     kJ. \n',(-Qlost));

//NOTE:
//The answers of m1,x3 are INCORRECT in the book,
//thus, the answers of m, x3 and Qlost are INCORRECT
     in the book
//while, the values obtained her (in scilab) are
    CORRECT.
```

Scilab code Exa 4.11 Example 11

```
clc
clear
//DATA GIVEN
p=8;                              //pressure of steam
    in bar
x=0.8;                            //dryness fraction

//At 8 bar, from steam tables
vg=0.240;                         //m^3/kg
hfg=2046.5;                       //kJ/kg

We=p*10^5*x*vg/1000;              //external work done
    during evaporation in kJ
LHi=x*hfg-We;                     //Internal latent
    heat in kJ

printf(' (i) The External work done during
    evaporation is: %3.1f kJ. \n',We);
printf(' (ii) The Internal latent heat is: %4.1f kJ.
     \n',LHi);
```

Scilab code Exa 4.12 Example 12

```
clc
clear
//DATA GIVEN
p=10;                          //pressure of steam, p1=p2 in bar
x1=0.85;                       //dryness fraction
V1=0.15;                       //volume of steam in m^3
Tsup2=300+273;                 //temp. of steam in K
Cps=2.2;                       //specific heat of steam in kJ/kgK

//At 10 bar, from steam tables
vg1=0.194;                           //m^3/kg
hfg1=2013.6;                         //kJ/kg
Ts1=179.9+273;                       //in K
m=V1/(x1*vg1);                       //mass of steam in kg
hnet=(1-x1)*hfg1+Cps*(Tsup2-Ts1);    //heat supplied per kg of steam
Htotal=m*hnet;                       //total heat supplied

//External work done during the process We=p*(vsup2-x*vg1)
//since p1=p2=p,
//vg1/Ts1=vsup2/Tsup2
vsup2=vg1*Tsup2/Ts1;
We=p*10^5*(vsup2-x1*vg1)*10^-3;
hp=We/hnet;                          //% of total heat supplied (per kg) which appears as external work
```

```
printf(' (i) The Total heat supplied is: %3.1f kJ. \n',Htotal);
printf(' (ii) The Percentage of total heat supplied (per kg) which appears as external work is: %2.1f percent. \n',(hp*100));
```

Scilab code Exa 4.13 Example 13

```
clc
clear
//DATA GIVEN
p=18;                              //pressure of steam
x=0.85;                            //dryness fraction

//At 18 bar, from steam tables
hf=884.6;                          //kJ/kg
hfg=1910.3;                        //kJ/kg
vg=0.110;                          //m^3/kg
uf=883;                            //kJ/kg
ug=2598;                           //kJ/kg

v=x*vg;                            //specific volume of wet steam
h=hf+x*hfg;                        //specific enthalpy of wet steam
u=(1-x)*uf+x*ug;                   //specific internal energy of wet steam

printf(' (i) The Specific volume v is: %1.4f m^3/kg. \n',v);
printf(' (ii) The Specific enthalpy h is: %4.2f kJ/kg. \n',h);
printf('(iii) The Specific internal energy u is: %4.2f kJ/kg. \n',u);
```

Scilab code Exa 4.14 Example 14

```
clc
clear
//DATA GIVEN
p=7;                          //pressure of steam
h=2550;                       //enthalpy of steam

//At 7 bar, from steam tables
hf=697.1;                     //kJ/kg
hfg=2064.9;                   //kJ/kg
vg=0.273;                     //m^3/kg
uf=696;                       //kJ/kg
ug=2573;                      //kJ/kg

hg=hf+hfg;
//At 7 bar, hg=2762 kJ/kg, hence since actual
   enthalpy is given as 2550 kJ/kg, the steam must
   be in wet vapour state
//specific enthalpy of wet steam, h=hf+x*hfg
x=(h-hf)/hfg;                 //dryness fraction
v=x*vg;                       //specific volume of
   wet steam
u=(1-x)*uf+x*ug;              //specific internal
   energy of wet steam

printf(' (i) The Dryness fraction x is: %1.3f. \n',x
   );
printf(' (ii) The Specific volume v is: %1.4f m^3/kg
   . \n',v);
printf('(iii) The Specific internal energy u is: %4
   .2f kJ/kg. \n',u);
```

Scilab code Exa 4.15 Example 15

```
clc
clear
//DATA GIVEN
p=120;                              //pressure of steam
v=0.01721;                          //specific volume of
    steam

//At 120 bar, from steam tables
vg=0.0143;                          //m^3/kg
//since vg<v, the steam is superheated
//so from superheat tables at 120 bar and v=0.01721
   m^3/kg
T=350;                              //deg. celsius
h=2847.7;                           //specific enthalpy
    of steam
u=h-p*10^5*v/10^3;                  //specific internal
    energy of steam

printf(' (i) The Temperature is: %3.0f deg celsius.
    \n',T);
printf(' (ii) The Specific enthalpy h is: %4.1f kJ/
    kg. \n',h);
printf('(iii) The Specific internal energy u is: %4
    .2f kJ/kg. \n',u);
```

Scilab code Exa 4.16 Example 16

```
clc
clear
//DATA GIVEN
```

```
p=140;                          //pressure of steam
h=3001.9;                       //specific enthalpy
   of steam

//At 140 bar, from steam tables
hg=2642.4;
//since hg<h, the steam is superheated
//so from superheat tables at 140 bar and h=3001.9
   kJ/kg
T=400;                          //deg. celsius
v=0.01722;                      //specific volume of
   steam
u=h-p*10^5*v/10^3;              //specific internal
   energy of steam

printf(' (i) The Temperature is: %3.0f deg celsius.
   \n',T);
printf(' (ii) The Specific volume v is: %1.5f m^3/kg
   . \n',v);
printf('(iii) The Specific internal energy u is: %4
   .2f kJ/kg. \n',u);
```

Scilab code Exa 4.17 Example 17

```
clc
clear

p1=10;                               //pressure in
   bar
//At 10 bar and 300 deg celsius, from steam tables
   of superheated steam
hsup=3051.2                          //kJ/kg
Tsup=300+273;                        //temp. of steam
    in K
//At 10 bar and 300 deg celsius, from steam tables
```

```
of dry saturated steam
Ts=179.9+273                         //temp. of steam in K
vg=0.194;                            //m^3/kg

//By vg/Ts = vsup/Tsup
vsup=vg*Tsup/Ts;
u1=hsup-p1*10^5*vsup/10^3;

p2=1.4;                              //new pressure in bar
x2=0.8;                              //dryness fraction
//At 1.4 bar, from steam tables
hf2=458.4;                           //kJ/kg
hfg2=2231.9;                         //kJ/kg
vg2=1.236;                           //m^3/kg
h2=hf2+x2*hfg2;                      //enthalpy of wet steam (after expansion)
u2=h2-p2*10^5*x2*vg2/10^3;           //internal energy of this steam
Du=u2-u1;                            //change in internal energy per kg

printf(' (i) The Internal energy of superheated steam at 10 bar is: %4.1f kJ/kg. \n',u1);
printf(' (ii) The Change in internal energy per kg is: %2.1f kJ. \n',Du);
printf('      (Negative sign indicates DECREASE in internal energy.)' );
```

Scilab code Exa 4.18 Example 18

```
clc
clear
```

```
//DATA GIVEN
m=1;                              //mass of steam in kg
p=20;                             //pressure of steam in bar
Tsup=400+273;                     //temp. of steam in K
x=0.9;                            //dryness fraction
Cps=2.3;                          //specific heat of steam in kJ/kgK

//At 20 bar, from steam tables
Ts=212.4+273;                          //in K
hf=908.6;                              //kJ/kg
hfg=1888.6;                            //kJ/kg
vg=0.0995;                             //m^3/kg
hsup=hf+hfg+Cps*(Tsup-Ts);             //kJ/kg

//Assume superheated steam to behave as a perfect gas from the commencement of superheating and thus obey Charle's Law
//By vg/Ts=vsup/Tsup
vsup=vg*Tsup/Ts;
usup=hsup-p*10^5*vsup*10^-3;           //internal energy of 1 kg of superheated steam in kJ/kg

h=hf+x*hfg;
u=h-p*10^5*x*vg*10^-3;                 //internal energy of 1 kg of wet steam in kJ/kg

printf('(i) The Internal energy of 1 kg of superheated steam at 400 deg celsius is: %4.2f kJ/kg. \n',usup);
printf('(ii) The Internal energy of 1 kg of wet steam with dryness fraction 0.9 is: %4.2f kJ/kg. \n',u);
```

Scilab code Exa 4.19 Example 19

```
clc
clear
//DATA GIVEN
p=20;                              //pressure in the
   boilers and main is 20 bar
Tbs=350;                           //temperature of steam
   in boiler with superheater in deg. celsius
Tm=250;                            //temperature of steam
   in the main in deg. celsius
Cps=2.25;                          //specific heat of
   steam in kJ/kg

//At 20 bar, from steam tables
Ts=212.4;                                  //deg. celsius
hf=908.6;                                  //kJ/kg
hg=2797.2;                                 //kJ/kg
hfg=1888.6;                                //kJ/kg

//Boiler B1−20 bar, 350 deg. celsius
h1=hg+Cps*(Tbs-Ts);

//Main−20 bar, 250deg celsius
hm=2*[hg+Cps*(Tm-Ts)];                     //total heat of
    2 kg of steam in the steam main

//Boiler B2−20 bar,
//h2=hf+x2*hfg
//h2=hm−h1
x2=((hm-h1)-hf)/hfg;

printf('The Quality of steam in the Boiler without
   superheater is: %1.3f. \n',x2);
```

Scilab code Exa 4.20 Example 20

```
clc
clear
//DATA GIVEN
m=1;                                      //mass of wet steam in kg
p=6;                                      //pressure of steam in bar
x=0.8;                                    //dryness fraction

//At 6 bar, from steam tables
Ts=158.8+273;                             //in K
hfg=2085;                                 //kJ/kg
swet=4.18*log(Ts/273)+x*hfg/Ts;           //entropy of wet steam in kJ/kgK

printf('The Entropy of wet steam is: %1.4f kJ/kgK.',swet);

//NOTE;
//the exact ans is 5.7794, while in TB it is given as 5.7865 kJ/kgK
```

Scilab code Exa 4.21 Example 21

```
clc
clear
//DATA GIVEN
p1=10;                          //initial pressure of steam in bar
Tsup=250;                       //initial temperature of steam in deg celsius
p2=0.2;                         //final pressure of
```

```
    steam in bar
x2=0.9;                          //final dryness
    fraction of steam

//At 10 bar, from steam tables
hsup=3263.9;                     //kJ/kg
ssup=7.465;                      //kJ/kgK
h1=hsup;
s1=ssup;

//At 0.2 bar, from steam tables
hf2=251.5;                        //kJ/kh
hfg2=2358.4;                      //kJ/kg
sf2=0.8321;                       //kJ/kgK
sg2=7.9094;                       //kJ/kgK
h2=hf2+x2*hfg2;
sfg2=(sg2-sf2);
s2=sf2+x2*sfg2;

Dh=h1-h2;                        //drop in enthalpy
Ds=s1-s2;                        //change in entropy

printf('(i) The Drop in enthalpy is: %3.1f kJ/kg. \
    n',Dh);
printf('(ii) The change (DECREASE) in entropy is:
    %1.4f kJ/kgK.',Ds);
```

Scilab code Exa 4.22 Example 22

```
clc
clear
//DATA GIVEN
m=1;                             //mass of steam in kg
p=12;                            //pressure of steam
    in bar
```

```
Tsup=250+273;                    //temp. of steam in K
Cps=2.1;                         //specific heat of steam in kJ/kg

//At 12 bar, from steam tables
Ts=188+273;                      //in K
hfg=1984.3;                      //kJ/kg
ssup=4.18*log(Ts/273)+hfg/Ts+Cps*log(Tsup/Ts);           //entropy of wet steam in kJ/kgK

printf('The Entropy of 1 kg of superheated steam at 12 bar and 250 deg celsius is: %1.3f kJ/kg. \n',ssup);
```

Scilab code Exa 4.23 Example 23

```
clc
clear
//DATA GIVEN
p=5;                             //pressure of steam in bar
Mwt=50;                          //mass of water in the tank in kg
t1=20;                           //initial temp. in deg. celsius
Ms=3;                            //amount of steam condensed in kg
t2=40;                           //final temp. in deg. celsius
We=1.5;                          //water equivalent of tank in kg

//At 5 bar, from steam tables
hf=640.1;                        //in kJ/kg
hfg=2107.4;                      //in kJ/kg
```

```
Mw=Mwt+We;                          //total mass of water in kg
//heat lost by steam = heat gained by water
//Ms[(hf+xhfg)-1*4.18*(t2-0)]=Mw[1*4.18*(t2-t1)]
x=[Mw*[1*4.18*(t2-t1)]/Ms+1*4.18*(t2-0)-hf]/hfg;            //dryness fraction

printf('The Dryness fraction of steam, x is: %1.4f.',x);
```

Scilab code Exa 4.24 Example 24

```
clc
clear
//DATA GIVEN
p=1.1;                              //pressure of steam in bar
x=0.95;                             //dryness fraction
Mwt=90;                             //mass of water in the tank in kg
t1=25;                              //initial temp. in deg. celsius
Mt=12.5;                            //mass of tank in kg
c=0.42;                             //specific heat of metal in kJ/kgK
t2=40;                              //final temp. in deg. celsius

m1=Mwt;
m2=Mt*c;                            //water equivalent of vessel
M=m1+m2;                            //total mass of water in kg
//At 1.1 bar, from steam tables
```

```
hf=428.8;                                //in kJ/kg
hfg=2250.8;                              //in kJ/kg
//heat lost by steam = heat gained by water
//Ms[(hf+xhfg)-1*4.18*(t2-0)]=M[1*4.18*(t2-t1)]
Ms=M*[1*4.18*(t2-t1)]/[(hf+x*hfg)-1*4.18*(t2-0)];        //mass of steam condensed in kg

printf(' The Mass of steam condensed, Ms is: %1.3f kg.',Ms);
```

Scilab code Exa 4.25 Example 25

```
clc
clear
//DATA GIVEN
//condition of steam before throttling
p1=8;                            //pressure in bar
//condition of steam after throttling
p2=1;                            //pressure in bar
T2=115+273;                      //temp. in deg. celsius
Tsup2=T2;
//At 1 bar,
Ts2=99.6+273;
Cps=2.1;                         //kJ/kgK

//As throttling is a constant enthalpy process,
//h1=h2.....hf1+x1*hgf1=hf2+hfg2+Cps(Tsup2-Ts2)

//At 8 bar, from steam tables,
hf1=720.9;
hfg1=2046.5;
//At 1 bar, from steam tables,
hf2=417.5;
hfg2=2257.9;

```

```
x1=[hf2+hfg2+Cps*(Tsup2-Ts2)-hf1]/hfg1;          //
    dryness fraction

printf('The Dryness fraction of steam in the main,
    x1 is: %1.2f.',x1);
```

Scilab code Exa 4.26 Example 26

```
clc
clear
//DATA GIVEN
Mw=2;                                   //mass of water
    separated out in kg
Ms=20.5;                                //amount of steam (
    condensate) discharged from throttling
    calorimeter in kg
Tsup3=110+273;                          //temp. of steam
    afetr throttling in K
p1=12;                                  //initial pressure
    of steam in bar
p3=(760+5)/1000*1.3366;                 //final pressure of
    steam in bar  (1 mm of Hg=1.3366 bar)
Cps=2.1;                                //kJ/kgK

p2=p1;
//At p1=p2=12 bar, from steam tables
hf2=798.4;                              //in kJ/kg
hfg2=1984.3;                            //in kJ/kg

//At p3=1 bar, from steam tables
Ts3=99.6+273;                           //in K
Tsup3=110+273;                          //in K
hf3=417.5;                              //in kJ/kg
hfg3=2257.9;                            //in kJ/kg

```

```
//h2=h3 ..... hf2+x2*hgf2=hf3+hfg3+Cps(Tsup3-Ts3)
x2=[hf3+hfg3+Cps*(Tsup3-Ts3)-hf2]/hfg2;          //
    dryness fraction x2

x1=(x2*Ms)/(Mw+Ms);                              //
    dryness fraction of steam supplied, x1

printf('The Quality of steam supplied, x1 is: %1.2f.
    ',x1);
```

Scilab code Exa 4.27 Example 27

```
clc
clear
//DATA GIVEN
p1=15;                          //pressure of steam
    sample in bar
p3=1;                           //pressure of steam
    at exit in bar
Tsup3=150+273;                  //temperature os
    steam at the exit in K
Mw=0.5;                         //discharge from
    separating calorimeter in kg/min
Ms=10;                          //discharge from
    throttling calorimeter in kg/min

p2=p1;
//At p1=p2=15 bar, from steam tables
hf2=844.7;                      //in kJ/kg
hfg2=1945.2;                    //in kJ/kg

//At p3=1 bar and 150 deg. celsius, from steam
    tables
hsup3=2776.4;                   //in kJ/kg

```

```
//h2=h3.....hf2+x2*hgf2=hsup3
x2=[hsup3-hf2]/hfg2;                  //dryness fraction x2

x1=(x2*Ms)/(Mw+Ms);                   //quality of steam supplied , x1

printf('The Quality of steam supplied , x1 is: %1.3f.',x1);
```

Chapter 5

Heat Engines

Scilab code Exa 5.1 Example 1

```
clc
clear
//DATA GIVEN
Ms=10000/3600;      //rate of steam flow in kg/s
//inlet to turbine
p1=60;              //pressue in bar
T1=380;             //temp. in deg.celsius

//exit from turbine, inlet to condenser
p2=0.1;             //pressue in bar
x2=0.9;             //quality
v2=200;             //velocity in m/s

//exit from condenser, inlet to pump
p3=0.09;            //pressue in bar
//it is saturated

//exit from pump, inlet to boiler
p4=70;              //pressue in bar

//exit from boiler,
```

```
p5=65;              //pressue in bar
T5=400;             //temp. in deg.celsius

//for condenser,
t1=20;              //inlet temp. in deg. celsius
t2=30;              //exit temp. in deg. celsius

//At 60 bar and 380deg. celsius, from steam tables
h1=3043.0+(3177.2-3043.0)/(400-350)*30;    //By
   interpolation

//At 0.1 bar, from steam tables
hf2=191.8;                               //in kJ/kg
hfg2=2392.8;                             //in kJ/kg
h2=hf2+x2*hfg2;
Pt=Ms*(h1-h2)                            //power output of
   the turbine in kW

//At 70 bar, from steam tables
hf4=1267.4;                              //in kJ/kg
//At 60 bar and 380deg. celsius, from steam tables
ha=(3177.2+3158.1)/2;                    //By interpolation
    between 60 and 70 deg celsius
Q1=Ms*3600*(ha-hf4);                     //heat transfer
   per hour in the boiler
//At 0.09 bar, from steam tables
hf3=183.3;                               //in kJ/kg
Q2=Ms*3600*(h2-hf3);                     //heat transfer
   per hour in the condenser

//heat lost by steam=heat gained by the cooling
   water
//Q2=Mw*4.18*(t2-t1)
Mw=Q2/4.18/10;                           //mass of cooling
   water circuleted per hour in condenser

//(pi)/4*d^2=Ms*x2*vg2
//d=diameter of the pipe connecting turbine with
```

```
condenser
C=200;                              //velocity of steam in m/s
vg2=14.67;                          //specific volume at 0.1 bar
d=(Ms*x2*vg2/(%pi/4)/C)^0.5;

printf(' (i) The Power output of turbine is: %4.0f kW. \n',Pt);
printf(' (ii) The Heat transfer per hour in the Boiler is: %3.2e kJ/h. \n',Q1);
printf('      The Heat transfer per hour in the Condenser is: %3.2e kJ/h. \n',Q2);
printf('(iii) The Mass of cooling water circulated per hour in the condenser is: %3.2e kg/hr. \n',Mw);
printf(' (iv) The Diameter of the pipe connecting turbine with condenser is: %1.3f m or %3.0f mm. \n',d,(d*1000));

//NOTE:
//ans of Mw(1.116*10^7) is given incorrect in the book.
//the correct ans of Mw is = 5.17*10^5 kg/h.
```

Scilab code Exa 5.2 Example 2

```
clc
clear
//DATA GIVEN
p1=15;                  //steam supply pressure in bar
x1=1;                   //quality of steam
p2=0.4;                 //condenser pressure

```

```
//At 0.15 bar, from steam tables
T1=198.3+273;          //in K
hg1=2789.9;            //in kJ/kg
sg1=6.4406;            //in kJ/kgK
//At 0.4 bar, from steam tables
T2=75.9+273;           //in K
hf2=317.7;             //in kJ/kg
hfg2=2319.2;           //in kJ/kg
sf2=1.0261;            //in kJ/kgK
sfg2=6.6448;           //in kJ/kgK

ETAcarnot=(T1-T2)/T1;  //Carnot efficiency
//ETArankine=Adiabatic or isentropic heat drop/heat supplied
//ETArankine=(hg1-h2)/(hg1-hf2)
//as the steam expands isentropically, s1=s2
//sg1=sf2+x2*sfg2
x2=(sg1-sf2)/sfg2;
h2=hf2+x2*hfg2;
ETArankine=(hg1-h2)/(hg1-hf2);          //Rankine efficiency

printf('(i) The Carnot efficiency is: %1.4f or %2.2f percent. \n',ETAcarnot,(ETAcarnot*100));
printf('(ii) The Rankine efficiency is: %1.4f or %2.2f percent. \n',ETArankine,(ETArankine*100));
```

Scilab code Exa 5.3 Example 3

```
clc
clear
//DATA GIVEN
p1=20;                 //boiler pressure in bar
T1=360+273;            //temp. in K
p2=0.08;               //boiler pressure in bar
```

```
//At 20 bar and 360 deg.celsius , from steam tables
h1=3159.3;                  //in kJ/kg
sg1=6.9917;                 //in kJ/kgK

//At 0.08 bar , from steam tables
hf2=173.88;                 //in kJ/kg
hf3=hf2;
sf2=0.5926;                 //in kJ/kgK
s3=sf2;
hfg2=2403.1;                //in kJ/kg
sg2=8.2287;                 //in kJ/kgK
vf2=0.001008;               //m^3/kg
sfg2=7.6361;                //in kJ/kgK

//as the steam expands isentropically , s1=s2
//sg1=sf2+x2*sfg2
x2=(sg1-sf2)/sfg2;
h2=hf2+x2*hfg2;

//Wnet=Wturbine-Wpump
//Wpump=hf4-hf3=vf3(p1-p2)
Wp=vf2*(p1-p2)*100;
hf4=Wp+hf3;
Wt=h1-h2;
Wnet=Wt-Wp;
Q1=h1-hf4;                  //in kJ/kg
ETAcycle=Wnet/Q1;           //cycle efficiency

printf(' (i) The Net work  per kg of steam is: %3.2f kJ/kg. \n',Wnet);
printf(' (ii) The Cycle efficiency is: %1.3f or %2.1f percent. \n',ETAcycle,(ETAcycle*100));
```

Scilab code Exa 5.4 Example 4

```
clc
clear
//given steam table extract
p1=80;                        //in bar
t1=295.1;                     //in deg. celsius
vf1=0.001385;                 //m^3/kg
vg1=0.0235;                   //m^3/kg
hf1=1317;                     //in kJ/kg
hfg1=1440.5;                  //in kJ/kg
hg1=2757.5;                   //in kJ/kg
sf1=3.2073;                   //in kJ/kgK
sfg1=2.5351;                  //in kJ/kgK
sg1=5.7424;                   //in kJ/kgK

p2=0.1;                       //in bar
t2=45.84;                     //in deg. celsius
vf2=0.0010103;                //m^3/kg
vg2=14.68                     //m^3/kg
hf2=191.9;                    //in kJ/kg
hf3=hf2;
hfg2=2392.3;                  //in kJ/kg
hg2=2584.2;                   //in kJ/kg
sf2=0.6488;                   //in kJ/kgK
sfg2=7.5006;                  //in kJ/kgK
sg2=8.1494;                   //in kJ/kgK

ETAt=0.9;                     //steam turbine efficiency
ETAp=0.8;                     //condensate pump
   efficiency

P1=80;                        //in bar
T1=600;                       //in deg celsius
//At 80 bar and 600 deg celsius
v1=0.486;                     //m^3/kg
h1=3642;                      //kJ/kg
s1=7.0206;                    //kJ/kg/K

//as the steam expands isentropically , s1=s2
```

```
//sg1=sf2+x2*sfg2
x2=(s1-sf2)/sfg2;
h2=hf2+x2*hfg2;
Wta=ETAt*(h1-h2);          //actual turbine work in kJ
   /kg
Wp=vf2*(p1-p2)*10^5/10^3;//pump work in kJ/kg
Wpa=Wp/ETAp;               //actual pump work in kJ/kg
Wnet=Wta-Wpa;              //specific work in kJ/kg
//ETAthermal=Wnet/Q1
//Q1=h1-hf4
hf4=hf3+Wpa;
Q1=h1-hf4;
ETAth=Wnet/Q1;

printf(' (i) The Specific work (Wnet) is: %4.2f kJ/
   kg. \n',Wnet);
printf(' (ii) The Thermal efficiency is: %1.3f or %2
   .1f percent. \n',ETAth,(ETAth*100));
```

Scilab code Exa 5.5 Example 5

```
clc
clear
//DATA GIVEN
p1=28;                    //pressure at 1 in bar
p2=0.06;                  //pressure at 2 in bar

//At 28 bar, from steam tables
h1=2802;                  //in kJ/kg
s1=6.2104;                //in kJ/kgK

//At 0.06 bar, from steam tables
hf2=151.5;                //in kJ/kg
hf3=hf2;
hfg2=2415.9;              //in kJ/kg
```

```
sf2=0.521;                    //in kJ/kgK
sf3=sf2;
sfg2=7.809;                   //in kJ/kgK
vf2=0.001;                    //m^3/kg


//as the steam expands isentropically , s1=s2
//sg1=sf2+x2*sfg2
x2=(s1-sf2)/sfg2;
h2=hf2+x2*hfg2;

//Wnet=Wturbine-Wpump
//Wpump=hf4-hf3=vf3(p1-p2)
Wp=vf2*(p1-p2)*10^5/10^3;
hf4=Wp+hf2;
Wt=h1-h2;
Wnet=Wt-Wp;
Q1=h1-hf4;                    //in kJ/kg
ETAcycle=Wnet/Q1;             //cycle efficiency
wr=Wnet/Wt;                   //work ratio
ssc=3600/Wnet;                //specific steam consumption in kg/kWh

printf(' (i) The Cycle efficiency is: %1.4f or %2.2f percent. \n',ETAcycle,(ETAcycle*100));
printf(' (ii) The Work ratio is: %1.3f kJ/kg. \n',wr);
printf('(iii) The Specific steam consumption in kg/kWh is: %1.3f kg/kWh. \n',ssc);
```

Scilab code Exa 5.6 Example 6

```
clc
clear
//DATA GIVEN
```

```
p1=35;                    //pressure at inlet to
   turbine in bar
x1=1;
p2=0.2;                   //pressure at exhaust in bar
m=9.5;                    //flow rate in kg/s

//At 35 bar, from steam tables
hg1=2802;                 //in kJ/kg
h1=hg1;
sg1=6.1228;               //in kJ/kgK

//At 0.2 bar, from steam tables
hf2=251.5;                //in kJ/kg
hf3=hf2;
hfg2=2358.4;              //in kJ/kg
vf2=0.001017;             //m^3/kg
sf2=0.8321;               //in kJ/kgK
sfg2=7.0773;              //in kJ/kgK

//Wnet=Wturbine-Wpump
//Wpump=hf4-hf3=vf3(p1-p2)
Wp=vf2*(p1-p2)*10^5/10^3;
Wpnet=m*Wp;
hf4=Wp+hf3;

//as the steam expands isentropically, s1=s2
//sg1=sf2+x2*sfg2
x2=(sg1-sf2)/sfg2;                       //dryness
   fraction
h2=hf2+x2*hfg2;
Wt=h1-h2;
Wtnet=m*Wt;
ETArankine=(h1-h2)/(h1-hf2);             //Rankine
   efficiency
chf=m*(h2-hf3);                          //condenser
   heat flow

printf('(i) The Pump Work is: %2.2f kW. \n',Wpnet);
```

```
printf(' (ii) The Turbine Work is: %2.2f kW. \n',
    Wtnet);
printf('(iii) The Rankine efficiency is: %1.4f or %2
    .2f percent. \n',ETArankine,(ETArankine*100));
printf(' (iv) The Condenser heat flow is: %1.3f kW.
    \n',chf);
printf('  (v) The dryness at the end of expansion,
    x2 is: %1.3f or %2.1f percent. \n',x2,(x2*100));

//NOTE:
//The value of x2 in the book is given as 0.7470
//while the exact ans is 0.74755
//and so the values of other answers are varying by
    some units
```

Scilab code Exa 5.7 Example 7

```
clc
clear
//DATA GIVEN
h12=840;                    //Adiabatic enthalpy drop, (
    h1-h2) in kJ/kg
h1=2940;                    //enthalpy of steam supplied
     in kJ/kg
p2=0.1;                     //back pressure in bar

//At 0.1 bar, from steam tables
hf=191.8;                   //in kJ/kg
//ETArankine=(hg1-h2)/(hg1-hf2)
ETArankine=(h12)/(h1-hf);
Wuse=h12;                   //useful work done per kg of
     steam in kJ/kg
ssc=1/Wuse*3600;            //specific steam consumption

printf('(i) The Rankine efficiency is: %1.4f or %2.2
```

```
f percent. \n',ETArankine,(ETArankine*100));
printf('(ii) The Specific steam consumption is: %1.3f kg/kWh. \n',ssc);
```

Scilab code Exa 5.8 Example 8

```
clc
clear
//DATA GIVEN
IP=35;                        //power developed by the engine in kW
m=284;                        //flow rate in kg/h
p1=15;                        //steam inlet pressure in bar
p2=0.14;                      //condenser pressure in bar

//At 35 bar and 25 deg celsius from steam tables
h1=2923.3;                     //in kJ/kg
s1=6.709;                      //in kJ/kgK

//At 0.14 bar, from steam tables
hf2=220;                      //in kJ/kg
hf3=hf2;
hfg2=2376.6;                  //in kJ/kg
sf2=0.737;                    //in kJ/kgK
sfg2=7.296;                   //in kJ/kgK

//as the steam expands isentropically, s1=s2
//sg1=sf2+x2*sfg2
x2=(s1-sf2)/sfg2;                         //dryness fraction
h2=hf2+x2*hfg2;

ETArankine=(h1-h2)/(h1-hf2);              //Rankine efficiency
```

```
ETAthermal=IP/(m/3600*(h1-hf2));      //Thermal
    efficiency
ETArel=ETAthermal/ETArankine;         //Relative
    efficiency

printf(' (i) The Final condition of steam is: %1.2f.
    \n',x2);
printf(' (ii) The Rankine efficiency is: %1.4f or %2
    .2f percent. \n',ETArankine,(ETArankine*100));
printf('(iii) The Relative efficiency is: %1.3f or
    %2.1f percent. \n',ETArel,(ETArel*100));
```

Scilab code Exa 5.9 Example 9

```
clc
clear
//DATA GIVEN
T1=400+273;                   //temp. in K
T2=T1;
T3=40+273;                    //temp. in K
T4=T3;
W=130;                        //work produced in kJ

ETAth=(T1-T3)/T1;             //Engine thermal
    efficiency

//ETAth=Work done/Heat added
Ha=W/ETAth;                   //Heat added in kJ
Hr=Ha-W;                      //Heat rejected in kJ
//Heat rejected=T3(S3-S4)
S34=Hr/T3;                    //Entropy change during
    the heat rejection process

printf(' (i) The Engine thermal efficiency is: %1.3f
```

```
or %2.1f percent. \n',ETAth,(ETAth*100));
printf(' (ii) The Heat added is: %3.0f kJ. \n',Ha);
printf('(iii) The Entropy change during the heat rejection process is: %1.3f kJ/K. \n',S34);
```

Scilab code Exa 5.10 Example 10

```
clc
clear
//DATA GIVEN
p1=18;                              //maximum pressure in bar
T1=410+273;                         //maximum temperature in K
T2=T1;
Rac=6;                              //ratio of isentropic or adiabatic compression, V4/V1=6
Rie=1.5;                            //ratio of isothermal expansion, V2/V1=1.5
V1=0.18;                            //volume of air at beginning of isothermal expansion in m^3
wc=210;                             //no. of cycles per s

//gamma for air=1.4
g=1.4;

//for isentropic process 4-1
//Also (T1/T4)=(V4/V1)^(g-1)
//(V4/V1)=Rac
T4=T1/Rac^(g-1);
T3=T4;
//p1(V1^gamma)=p4(V4^gamma)
//p4=p1*(V1/V4)^g
//where, (V4/V1)=Rac
```

```
p4=p1/(Rac^g);

//for isothermal process 1-2
//p1V1=p2V2
//V1/V2=1/Rie
p2=p1*(1/Rie);

//for isentropic process 2-3
//p2(V2^gamma)=p3(V3^gamma)
//V2/V3=V1/V4=1/Rac
p3=p2*(1/Rac)^g;

//change in entropy, DS=S2-S1=mRlog(V2/V1)=p1V1/T1*log(V2/V1)
DS=p1*10^5*V1/10^3/T1*log(Rie);

//Heat supplied, Qs=p1*V1*log(V2/V1)
//Qs=T1(S2-S1)
Qs=T1*DS;
//Qr=p4*V4*log(V3/V4)                    //heat rejected in kJ
//Qr=T4(S3-S4), bcs increase in entropy during heat addition is equal to decrease in entropy during heat rejection
Qr=T4*DS;

ETA=(Qs-Qr)/Qs;                          //mean thermal efficiency of the cycle

//mean effective pressure of the cycle, Pm = work done per cycle/stroke volume
Rv31=Rac*Rie;                            //ratio of volumes at 3 and 1, V3/V1=V3/V2*V2/V1
//stroke volume, Vs=V3-V1
Vs=V1*(Rv31-1);
J=1;
Pm=(Qs-Qr)*10^3/10^5*J/Vs;

```

```
P=(Qs-Qr)*wc/60;                              //power of the engine in kW

printf(' (i) The Pressure and Temperature at point 1 are:\n');
printf('                    p1:%2.0f bar.\n',p1);
printf('                    T1:%3.0f K.\n',T1);
printf('      The Pressure and Temperature at point 2 are:\n');
printf('                    p2:%2.0f bar.\n',p2);
printf('                    T2:%3.0f K.\n',T2);
printf('      The Pressure and Temperature at point 3 are:\n');
printf('                    p3:%1.2f bar.\n',p3);
printf('                    T3:%3.1f K.\n',T3);
printf('      The Pressure and Temperature at point 4 are:\n');
printf('                    p4:%1.2f bar.\n',p4);
printf('                    T4:%3.1f K.\n',T4);
printf(' (ii) The Change in entropy during isothermal expansion is: %1.3f kJ/K. \n',DS);
printf('(iii) The Mean thermal efficiency of the cycle is: %1.3f or %2.1f percent. \n',ETA,(ETA*100));
printf(' (iv) The Mean effective pressure is: %1.3f bar. \n',Pm);
printf('  (v) The Power of the engine working on this cycle is given by: %3.1f kW. ',P);

//NOTE:
//there is slight variation in answers of book due to rounding off of the values
```

Scilab code Exa 5.11 Example 11

```
clc
clear
//DATA GIVEN
//CASE-1
//(T1-T2)/T1=1/6
//SO, T1=1.2(T2).........                    Eqn(1)

//CASE-2
//T2 REDUCED BY 70 DEG. CELSIUS
//{T1-[T2-(70+273)]}/T1 = 1/3..............Eqn(2)
//2T1=3T2-1029

//By Eqn (1) and (2)
T2=(70+273)*3/(3-2*1.2);
T1=1.2*T2;

printf('(i) The Temperature of the Source, T1 is: %4
    .0f K or %4.0f deg. celsius. \n',T1,(T1-273));
printf('(ii) The Temperature of the Sink, T2 is: %4
    .0f K or %4.0f deg. celsius. \n',T2,(T2-273));
```

Scilab code Exa 5.12 Example 12

```
clc
clear
//DATA GIVEN
T1=1990;                    //Temperature of the
    heat Source in K
T2=850;                     //Temperature of the
    heat Sink in K
Qs=32.5;                    //heat supplied in kJ/
    min
P=0.4;                      //power developed by the
     engine in kW

```

```
ETAcarnot=(T1-T2)/T1;
//Also ETAth=work done/Heat supplied
ETAth=P/Qs;

printf('The Efficiency of carnot cycle is: %1.3f or %2.1f percent. \n',ETAcarnot,(ETAcarnot*100));
printf(' The Thermal efficiency of engine claimed by inventor is: %1.3f or %2.1f percent. \n\n',ETAth,(ETAth*100));

if(ETAth>ETAcarnot)
    printf(' Thus, The claim of the inventor is possible.');
else
    printf(' Thus, The claim of the inventor is NOT feasible, \n as no engine can be more efficient than that working on carnot cycle.');
```

Scilab code Exa 5.13 Example 13

```
clc
clear
//DATA GIVEN
ETAotto=60;                    //Efficiency of otto cycle in %
shr=1.5;                       //ratio of specific heats

//ETAotto=1-1/(r)^(shr-1)
r=(1/(1-ETAotto/100))^(1/(shr-1)); //compression ratio

printf('The compression ratio is: %1.2f.',r);
```

Scilab code Exa 5.14 Example 14

```
clc
clear
//DATA GIVEN
D=0.25;                                  //bore of the engine in m
L=0.375;                                 //stroke of the engine in m
Vc=0.00263;                              //clearance volume in m^3
p1=1;                                    //initial pressure in bar
T1=50+273;                               //initial temperature in K
p3=25;                                   //maximum pressure in bar

Vs=(%pi/4)*D^2*L;                        //swept volume
r=(Vs+Vc)/Vc;                            //compression ratio

//for air, gamma=1.4
g=1.4;
//Air standard efficiency of otto cycle ETAotto=1-1/(r)^(g-1)
ETAotto=1-1/(r)^(g-1);

//for adiabatic process 1-2
//p1(V1^gamma)=p2(V2^gamma)
//p2=p1*(V1/V2)^g
//where, (V1/V2)=r
p2=p1*(r^g);                                      //pressure at 2 in bar
```

```
rp=p3/p2;                                    //pressure ratio
Pm=p1*r*[(r^(g-1)-1)*(rp-1)]/[(g-1)*(r-1)]; //mean effective pressure in bar

printf('(i) The Air standard efficiency of otto cycle is: %1.3f or %2.1f percent. \n',ETAotto,(ETAotto*100));
printf('(ii) The Mean effective pressure is: %1.3f bar. \n',Pm);
```

Scilab code Exa 5.15 Example 15

```
clc
clear
//DATA GIVEN
T1=38+273;                        //initial temperature in K
T3=1950+273;                      //maximum temperature K
rp=15;                            //pressure ratio
//for air, gamma=1.4
g=1.4;

//for adiabatic compression 1-2
//p1(V1^gamma)=p2(V2^gamma)
//(V1/V2)=r
r=(rp)^(1/g);

//Thermal efficiency ETAth=1-1/(r)^(g-1)
ETAth=1-1/(r)^(g-1);

//for adiabatic compression 1-2
//(T2/T1)=(V1/V2)^(g-1)
//(V1/V2)=r
```

```
T2=T1*r^(g-1);

//for adiabatic expansion 3-4
//(T3/T4)=(V4/V3)^(g-1)
//(V4/V3)=r
T4=T3/r^(g-1);

//heat supplied per kg of air, Qs=m*Cv*(T3-T2)
R=0.287;
Cv=R/(g-1);
Qs=Cv*(T3-T2);

//heat rejected per kg of air, Qr=m*Cv*(T4-T1)
Qr=Cv*(T4-T1);

W=Qs-Qr;                                //work done per kg of air

printf(' (i) The compression ratio is: %1.1f.\n',r);
printf(' (ii) The Thermal efficiency is: %1.3f or %2.1f percent. \n',ETAth,(ETAth*100));
printf('(iii) The Work done is: %3.1f kJ or %6.0f Nm.',W,(W*1000));

//NOTE:
//there is slight variation in answers in the book because of rounding off of the values
```

Scilab code Exa 5.16 Example 16

```
clc
clear
//DATA GIVEN
V1=0.45;                                //volume in m^3
p1=1;                                   //initial pressure
```

```
in bar
T1=30+273;                          //initial temperature in K
p2=11;                              //pressure at the end of compression stroke in bar
Qs=210;                             //heat addaed at constant volume in kJ
wc=210;                             //no. of working cycles/min

//for air , gamma=1.4
g=1.4;

//for adiabatic compression 1-2
//p1(V1^gamma)=p2(V2^gamma)
//(V1/V2)=r
r=(p2/p1)^(1/g);
//Also (T2/T1)=(V1/V2)^(g-1)
//(V1/V2)=r
T2=T1*r^(g-1);

//Applying gas laws to points 1 and 2
//p1V1/T1=p2V2/T2
V2=T2/T1*p1/p2*V1;

//heat supplied during process 2-3, Qs=mCv(T3-T2)
R=287;
m=p1*10^5*V1/R/T1;
Cv=R/1000/(g-1);
T3=Qs/m/Cv+T2;

//for constant volume process 2-3
//p3/T3=p2/T2
p3=p2/T2*T3;
V3=V2;

//for adiabatic expansion 3-4
//p3(V3^gamma)=p4(V4^gamma)
```

```
//(V4/V3)=r
p4=p3*(1/r)^(g);
//Also T3/T4)=(V4/V3)^(g-1)
//(V4/V3)=r
T4=T3/r^(g-1);
V4=V1;

//percentage clearance , pc=Vc/Vs=V2/(V1-V2)
pc=V2/(V1-V2)*100;

//heat rejected per cycle , Qr=Cv*(T4-T1)
Qr=m*Cv*(T4-T1);

//Air standard efficiency of otto cycle ETAotto=(Qs-
    Qr)/Qs
ETAotto=(Qs-Qr)/Qs;
//Alternatively
//ETAotto=1-1/(r)^(g-1)
ETAotto=1-1/(r)^(g-1);

//mean effective pressure , Pm=W/Vs
W=Qs-Qr;                            //work done per kg
    of air
Vs=V1-V2;
Pm=W*10^3/10^5/Vs;

//power developed , P=work done per cycle*no. of
    cycles per s
P=W*(wc/60);

printf(' (i) The Pressure , Temperature and Volumes
    at salient points in the cycle are:\n');
printf('      At point 1 are:\n');
printf('                  p1:%1.1f bar.\n',p1);
printf('                  V1:%1.2f m^3.\n',V1);
printf('                  T1:%3.0f K.\n',T1);
printf('      At point 2 are:\n');
printf('                  p2:%2.2f bar.\n',p2);
```

```
printf('                    V2:%1.3f m^3.\n',V2);
printf('                    T2:%3.0f K.\n',T2);
printf('        At point 3 are:\n');
printf('                    p3:%2.2f bar.\n',p3);
printf('                    V3:%1.3f m^3.\n',V3);
printf('                    T3:%4.0f K.\n',T3);
printf('        At point 4 are:\n');
printf('                    p4:%1.2f bar.\n',p4);
printf('                    V4:%1.2f m^3.\n',V4);
printf('                    T4:%3.1f K.\n',T4);
printf(' (ii) The Percentage clearance is: %2.2f
    percent. \n',pc);
printf('(iii) The Air standard efficiency of the
    cycle is: %1.3f or %2.1f percent. \n',ETAotto,(
    ETAotto*100));
printf(' (iv) The Mean effective pressure is: %1.3f
    bar. \n',Pm);
printf('  (v) The Power developed is: %3.1f kW.',P);

//NOTE:
//there is slight variation in answers in the book
    because of rounding off of the values
```

Scilab code Exa 5.17 Example 17

```
clc
clear
//DATA GIVEN
r=15;                           //compression ratio
//V3-V2=a/100*Vs............Vs=stroke volume=V1-V2
//V3=1.84V2
c=6;                            //heat addition takes
    place at 'a' percent of stroke
//for air, gamma=1.4
g=1.4;
```

```

//Air standard efficiency of diesel cycle ETAdiesel =1-[1/(r)^(g-1)][(rho^g-1)/(rho-1)]
//rho=cut off ratio=V3/V2
rho=c/100*(r-1)+1;
ETAdiesel=1-[1/g/(r)^(g-1)]*[(rho^g-1)/(rho-1)];

printf('The Air standard efficiency of diesel cycle is: %1.3f or %2.1f percent. \n',ETAdiesel,(ETAdiesel*100));
```

Scilab code Exa 5.18 Example 18

```
clc
clear
//DATA GIVEN
L=0.25;                                    //stroke of the engine in m
D=0.15;                                    //diameter of cylinder in m
V2=0.0004;                                 //clearance volume in m^3
Vs=(%pi/4)*D^2*L;                          //swept volume in m^3
Vt=Vs+V2;                                  //total cylinder volume in m^3
c=5;                                       //fuel injection takes place at 'c' percent of stroke
V3=V2+c/100*Vs;                            //volume at point of cut-off in m^3
rho=V3/V2;                                 //cut-off ratio
r=(Vs+V2)/V2;                              //compression ratio

//for air, gamma=1.4
```

```
g=1.4;

//Air standard efficiency of diesel cycle ETAdiesel
    =1-[1/(r)^(g-1)][(rho^g-1)/(rho-1)]
ETAdiesel=1-[1/g/(r)^(g-1)]*[(rho^g-1)/(rho-1)];

printf(' The Efficiency of diesel engine is: %1.3f
    or %2.1f percent. \n',ETAdiesel,(ETAdiesel*100));
```

Scilab code Exa 5.19 Example 19

```
clc
clear
//DATA GIVEN
r=14;                          //compression ratio
//fuel cut-off is delayed from 5-8%
//for air, gamma=1.4
g=1.4;

//when fuel is cut-off at 5%
c1=5;
rho1=c1/100*(r-1)+1;
//Efficiency of diesel engine ETAdiesel=1-[1/(r)^(g
    -1)][(rho^g-1)/(rho-1)]
ETAdiesel1=1-[1/g/(r)^(g-1)]*[(rho1^g-1)/(rho1-1)];

//when fuel is cut-off at 8%
c2=8;
rho2=c2/100*(r-1)+1;
//Efficiency of diesel engine ETAdiesel=1-[1/(r)^(g
    -1)][(rho^g-1)/(rho-1)]
ETAdiesel2=1-[1/g/(r)^(g-1)]*[(rho2^g-1)/(rho2-1)];

ETAloss=(ETAdiesel1-ETAdiesel2)*100;

```

```
printf(' The Percentage loss in efficiency due to delay in fuel cut-off is: %1.1f percent. \n',ETAloss);
```

Scilab code Exa 5.20 Example 20

```
clc
clear
//DATA GIVEN
Pm=7.5;                          //mean effective pressure in bar
r=12.5;                          //compression ratio
p1=1;                            //initial pressure in bar

//for air, gamma=1.4
g=1.4;

//mean effective pressure, Pm=p1*r^g*[g*(rho-1)-r^(1-g)*(rho^g-1)]/[(g-1)*(r-1)]
//we get, 0.346(rho)^1.4-1.4(rho)+2.04
//By trial and error method, we get
rho=2.24;

co=(rho-1)/(r-1)*100;            //% cut-off

printf(' The Percentage cut-off of the cycle is: %2.2f percent. \n',co);
```

Scilab code Exa 5.21 Example 21

```
clc
clear
```

```
//DATA GIVEN
D=0.2;                              //bore of the engine in m
L=0.3;                              //stroke of the engine in m
p1=1;                               //initial pressure in bar
T1=27+273;                          //initial temperature in K
c=8;                                //cut-off % of stroke volume
r=15;                               //compression ratio
wc=380;                             //no. of cycles per s

Vs=(%pi/4)*D^2*L;                   //swept volume in m^3
V1=Vs*(1+1/(r-1));                  //in m^3
//for air, gamma=1.4
g=1.4;

R=287;
m=p1*10^5*V1/R/T1;                  //mass of air  in the cylinder in kg/cycle

//for adiabatic process 1-2
//p1(V1^gamma)=p2(V2^gamma)
//p2=p1*(V1/V2)^g
//where, (V1/V2)=r
p2=p1*(r^g);                                    //pressure at 2 in bar
//Also (T2/T1)=(V1/V2)^(g-1)
//(V1/V2)=r
T2=T1*r^(g-1);
V2=Vs/(r-1);
Vc=V2;
p3=p2;
```

```

//cut-off ratio, c=(rho-1)/(r-1)
rho=c/100*(r-1)+1;
V3=rho*V2;
//alternatively
V3=c/100*Vs+Vc;

//for constant pressure process 2-3
//V3/T3=V2/T2
T3=T2/V2*V3;

//for isentropic process 3-4
//p3(V3^gamma)=p4(V4^gamma)
//(V4/V)=V4/V2*V2/V3=V1/V2*V2/V3=r/rho
p4=p3*((rho/r)^g);
//Also (T4/T3)=(V3/V4)^(g-1)
//(V4/V)=V4/V2*V2/V3=V1/V2*V2/V3=r/rho
T4=T3*((rho/r)^(g-1));
V4=V1;

//Air standard efficiency of diesel cycle ETAdiesel=1-[1/(r)^(g-1)][(rho^g-1)/(rho-1)]
ETAdiesel=1-[1/g/(r)^(g-1)]*[(rho^g-1)/(rho-1)];

//mean effective pressure, Pm=p1*r^g*[g*(rho-1)-r^(1-g)*(rho^g-1)]/[(g-1)*(r-1)];
Pm=p1*r^g*[g*(rho-1)-r^(1-g)*(rho^g-1)]/[(g-1)*(r-1)];

P=Pm*10^5*Vs/10^3*(wc/60);               //Power of the engine in kW

printf(' (i) The Pressure, Temperature and Volumes at salient points in the cycle are:\n');
printf('       At point 1 are:\n');
printf('                    p1:%1.1f bar.\n',p1);
printf('                    V1:%1.4f m^3.\n',V1);
printf('                    T1:%3.0f K.\n',T1);
```

```
printf('        At point 2 are:\n');
printf('                  p2:%2.2f bar.\n',p2);
printf('                  V2:%1.7f m^3.\n',V2);
printf('                  T2:%3.1f K.\n',T2);
printf('        At point 3 are:\n');
printf('                  p3:%2.2f bar.\n',p3);
printf('                  V3:%1.6f m^3.\n',V3);
printf('                  T3:%4.1f K.\n',T3);
printf('        At point 4 are:\n');
printf('                  p4:%1.3f bar.\n',p4);
printf('                  V4:%1.4f m^3.\n',V4);
printf('                  T4:%3.2f K.\n',T4);
printf(' (ii) The Theoritical air standard
   efficiency of diesel cycle is: %1.3f or %2.1f
   percent. \n',ETAdiesel,(ETAdiesel*100));
printf('(iii) The Mean effective pressure is: %1.3f
   bar. \n',Pm);
printf(' (iv) The Power developed is: %2.2f kW.',P);
```

Chapter 6

Steam Boilers

Scilab code Exa 6.1 Example 1

```
clc
clear
//DATA GIVEN
LCV=44700;                    //LCV of fuel in kJ
afrn=20;                       //air parts=20 in air fuel
    mixture
afrd=1;                        //fuel parts=1 in air fuel
    mixture
Cpg=1.08;                     //avg specific heat in kJ/
    kgK
T1=38+273;                    //boiler room temp. in K

//heat of combustion=heat of gases
//1*44700=Mg*Cpg*(T2-T1)
T2=afrd*LCV/(afrn+afrd)/Cpg+T1;

printf(' The Maximum temp. T2 attained in the
    furnace of the boiler is:\n %5.0f Kelvin ',T2);
printf('or %5.0f degree celsius.\n',(T2-273));
```

Scilab code Exa 6.2 Example 2

```
clc
clear
//DATA GIVEN
Ms=5.4;                    //mass of steam used in kg/kWh
p=50;                      //pressure of steam in bar
Tsup=350;                  //temp. of steam in deg celsius
eta=82;                    //boiler efficiency in %
Tfw=150;                   //feed water temp. in deg cel;sius
C=28100;                   //calorific value of coal in kJ
rate=500;                  //cost of coal/tonne in Rs

//boiler efficiency is given by, eta=Ms*(hsup-hf1)/(Mf*C)
//from steam table, at 45 bar and 350deg celsius, hsup=3068.4 kJ/kg
h=3068.4;                              //enthalpy at 45 bar and 350 deg celsius
hf1=4.18*(Tfw-0);                      //hf1 at 150 deg celsius in kJ/kg

//subs. these in eq. of boiler efficiency
Mf=Ms*(h-hf1)/((eta/100)*C);           //mass of coal required in kg/kWh
cost=(Mf/1000)*rate*100;               //cost of coal in paisa/kWh

printf('  (i) The mass of coal required is: %5.3f kg/kWh. \n',Mf);
```

```
printf('  (ii) The Total cost of fuel(coal) is: %2.1
    f paisa/kWh. \n',cost);

//NOTE:in text book
//in question pressure is given as =50 bar
//but from steam table enthalpy is found at 45 bar
```

Scilab code Exa 6.3 Example 3

```
clc
clear
//DATA GIVEN
Mc=1250;                        //quantity of coal in kg
    consumed in 24 hours
Mw=13000;                       //mass of water
    evaporated in kg
MEPs=7;                         //mean effective pressure
     of steam in bar
Tfw=40;                         //feed water temp. in deg
     celsius
h=2570.7;                       //enthalpy of steam at 7
    bar in kJ/kg
C=30000;                        //calorific value of coal
     in kJ/kg

Ma=Mw/Mc;                       //mass of water actually
    evaporated per kg of fuel
hf1=4.18*(Tfw-0);
hfg=2257;                       //in kJ/kg
Me=Ma*(h-hf1)/hfg;              //in kg
eta=Ma*(h-hf1)/C;               //boiler efficiency

printf(' (i)  The equivalent evaporation per kg of
    coal, Me is: %5.3f kg. \n',Me);
printf(' (ii)  The efficiency of boiler, eta is: %1
```

```
.3f or %2.1f percent. ',eta,eta*100);
```

Scilab code Exa 6.4 Example 4

```
clc
clear
//DATA GIVEN
p=12;                    //mean steam pressure in bar
Ms=40000;                //mass of steam generated in kg
x=0.85;                  //mean dryness fraction
Tfw=30;                  //mean feed  water temp. in deg celsius
Mc=4000;                 //mass of coal used in kg
C=33400;                 //calorific value of coal in kJ/kg

//from steam table, corresponding to 12 bar,
hf=798.4;                //in kJ/kg
hfg=1984.3;              //in kJ/kh
h=hf+x*hfg;              //in kj/kg
hf1=4.18*(Tfw-0);        //heat of feed water in kJ/kg

Fe=(h-hf1)/2257;         //factor of equivalent evaporation,Fe
Ma=Ms/Mc;                //per kg of fuel
Me=Ma*(h-hf1)/2257;      //(kg of steam)/(kg of fuel)
eta=Ma*(h-hf1)/C;        //efficiency of boiler

printf(' (i) The Factor of equivalent temerature,Fe is: %5.3f\n',Fe);
printf(' (ii) The Equivalent evaporation from and
```

```
    at 100 deg celsius , Me is: %5.2f (kg of steam)/(
    kg of coal).\n',Me);
printf(' (iii) The Efficiency of boiler is: %5.4f ',
    eta);
printf('or %5.2f percent. \n',eta*100);
```

Scilab code Exa 6.5 Example 5

```
clc
clear
//DATA GIVEN
M=18000;                    //mass of steam generated in
     kg/hr
p=12.5;                     //steam pressure in bar
x=0.97;                     //quality of steam
Tfw=105;                    //feed  water temp. in deg
    celsius
Mf=2040;                    //rate of coal firing in kg/
    hr
C=27400;                    //highrer calorific value (
    HCV) of coal in kJ/kg

//from steam table, corresponding to 12.5 bar,
hf=806.7;                   //in kJ/kg
hfg=1977.4;                 //in kJ/kg
h=hf+x*hfg;                 //in kJ/kg
hf1=4.18*(Tfw-0);           //heat of feed water in kJ/
    kg

//heat rate of the boiler = heat supplied per hour
heatrate=M*(h-hf1)          //heat rate of boiler
Ma=M/Mf;                    //in kg per kg of fuel
Me=Ma*(h-hf1)/2257;         //(kg of steam)/(kg of fuel)
eta=Ma*(h-hf1)/C;           //thermal efficiency

```

```
printf(' (i) The Heat rate of boiler is: %1.4e kJ/h.\n',heatrate);
printf(' (ii) The Equivalent evaporation, Me is: %5.3f (kg of steam)/(kg of fuel). \n',Me);
printf('(iii) The Thermal efficiency is: %5.4f ',eta);
printf('or %5.2f percent. \n',eta*100);
```

Scilab code Exa 6.6 Example 6

```
clc
clear
//DATA GIVEN
Mw=5940;            //mass of water evaporated kg/hr
Mc=675;             //mass of coal burnt in kg/hr
C=31600;            //lower calorific value(LCV) of coal in kJ/kg
p1=14;              //pressure of steam at boiler stop valve in bar
Te1=32;             //temp. of feed water entering economiser in deg celsius
Te2=115;            //temp. of feed water leaving economiser in deg celsius
x=0.96;             //dryness fraction of steam entering superheater
Tsup=260;           //temp. of steam leaving superheater in deg celsius
Cp=2.3              //specific heat of superheated steam

hf1=4.18*(Te2-Te1);                         //heat utilised by 1 kg of feed water in economiser
//from steam table, corresponding to 14 bar,
Ts=195;
hf=830.1;
```

```
hfg=1957.7;
hboiler=(hf+x*hfg)-hf1;                    //heat utilised by 1 kg of feed water in boiler
hsuperheater=(1-x)*hfg+Cp*(Tsup-Ts);       //heat utilised by 1 kg of feed water in superheater
Ma=Mw/Mc;                                  //in kg per kg of fuel
Pe=hf1/C*Ma*100;                           //% of heat utilised in economiser
Pb=hboiler/C*Ma*100;                       //% of heat utilised in boiler
Ps=hsuperheater/C*Ma*100;                  //% of heat utilised in superheater
htotal=hf1+hboiler+hsuperheater;           //total heat absorbed in kg of water
eta=Ma*htotal/C;                           //overall efficiency of boiler plant

printf(' (i) The Percentage of heat utilised in Economiser is: %5.2f percent.\n',Pe);
printf('     The Percentage of heat utilised in Boiler is: %5.2f percent.\n',Pb);
printf('     The Percentage of heat utilised in Superheater is: %5.2f percent.\n',Ps);
printf(' (ii) The Overall Efficiency of boiler plant is: %5.4f ',eta);
printf('or %5.2f percent. \n',eta*100);
```

Scilab code Exa 6.7 Example 7

```
clc
clear
//DATA GIVEN
C=29915;              //calorific value of coal in kJ/kg
```

```
Mw=9.1;              //mass of feed water per kg of dry coal in kg
Me=9.6;              //equivalent evaporation fraom and at 100 deg celsius per kg of dry coal in kg
Te=12;               //temp. of feed water to economiser in deg celsius
Tb=105;              //temp. of feed water to boiler in deg celsius
Ta=13;               //temp. of air
Tfg=370;             //temp. of flue gases entering economiser
Mfg=18.2;            //mass of flue gases entering economiser per kg of coal
Cp=1.046;            //mean specific heat of flue gases

hb=Me*2257;                   //heat supplied for steam generation in kJ
ETAb=hb/C;                    //boiler efficiency
hflue=Mfg*Cp*(Tfg-Ta);        //heat in the flue gase per kg of dry coal entering economiser
he=Mw*4.184*(Tb-Te);          //heat utilised in economiser
ETAe=he/hflue;                //economiser efficiency
htotal=hb+he;                 //total heat absorbed in kg of water
ETA=htotal/C;                 //boiler plant efficiency

printf(' (i) The Boiler efficiency is: %5.3f ',ETAb);
printf('or %2.1f percent. \n',ETAb*100);
printf(' (ii) The Economiser efficiency is: %5.3f ',ETAe);
printf('or %2.2f percent. \n',ETAe*100);
printf('(iii) The Overall Efficiency of boiler plant is: %5.3f ',ETA);
printf('or %2.1f percent. \n',ETA*100);
```

Scilab code Exa 6.8 Example 8

```
clc
clear
//DATA GIVEN
Ms=2000;                //rate of steam production in kg/hr
x=1;                    //quality of steam
p=10;                   //steam pressure in bar
Tfw=110;                //feed  water temp. in deg celsius
Mf=225;                 //rate of coal firing in kg/hr
C=30100;                //calorific value of coal in kJ/kg
Puc=10;                 //% of unburnt coal

//from steam table, corresponding to 10 bar,
h=2776.2;                       //in kJ/kg
hf1=4.18*(Tfw-0);               //heat contained in 1kg of feed water before entering boiler in kJ/kg
htotal=h-hf1                    //total heat given to produce 1 kg of steam in boiler in kJ/kg
Mc=Mf*(100-Puc)/100;            //mass of coal actually burnt in kg
Ma=Ms/Mc;                       //(kg of steam)/(kg of fuel)
ETAb=Ma*(h-hf1)/C;              //thermal efficiency of boiler
ETAc=(Ms/Mf)*(h-hf1)/C;         //thermal efficiency of boiler and grate combined

printf(' (i) The Thermal efficiency of the boiler is : %5.3f ',ETAb);
printf('or %5.2f percent. \n',ETAb*100);
```

```
printf(' (ii) The Thermal efficiency of the boiler and grate combined is: %5.3f ',ETAc);
printf('or %5.2f percent. \n',ETAc*100);
```

Scilab code Exa 6.9 Example 9

```
clc
clear
//DATA GIVEN
Ma=7.5;                 //mass of steam generated per kg of coal
p=11;                   //steam pressure in bar
Tfw=70;                 //temp. of feed water temp. in deg celsius
eta=75;                 //efficiency of boiler in %
Fe=1.15;                //factor of evaporation
Cps=2.3;                //specific heat of steam in kJ/kgK

//from steam table, corresponding to 11 bar,
hf=781.4;               //in kJ/kg
hfg=1998.5;             //in kJ/kg
Ts=184.1+273;           //in K
hf1=4.18*(Tfw-0);

//Factor of evaporation,Fe=[{hf+hfg+Cps*(Tsup-Ts)}-hf1]/2257
Tsup=[Fe*2257+hf1-hf-hfg]/Cps+Ts;          //Tsup in K
x=(Tsup-Ts);                               //degree of superheat in deg. celsius

//Boiler efficiency eta=Ma*(h-hf1)/C;
h=[hf+hfg+Cps*(Tsup-Ts)];
C=Ma*(h-hf1)/(eta/100);                    //calorific value of coal in kJ/kg
```

```
Me=Ma*(h-hf1)/2257;                         //
    Equivalent evaporation im kg

printf(' (i) The Temperature of steam generation,
    Tsup is: %5.1f K\n',Tsup);
printf('      The Degree of superheat is: %5.1f deg
    celsius.\n',x);
printf(' (ii) The calorific value of coal, C is: %5
    .0f kJ/kg. \n',C);
printf('(iii) The Equivalent evaporation, Me is: %5
    .3f kg. \n',Me);
```

Scilab code Exa 6.10 Example 10

```
clc
clear
//DATA GIVEN
p=13;                          //steam pressure in bar
ds=77;                         //degree of superheat in
     deg. celsius
Tfw=85;                        //temp. of feed water in
     deg. celsius
Mw=3000;                       //mass of water
    evaporated in kg/hr
Mc=410;                        //coal fired
Mash=40;                       //mass of ash in kg/hr
Pca=9.6;                       //% of combustible in
    ash
Pm=4.5;                        //% of moisture in coal
C=30500;                       //calorific vaalue of
    dry coal per kg
Cps=2.1;                       //specific heat of
    superheated steam in kJ/kgK


```

```
//from steam table, corresponding to 13 bar,
hf=814.7;                   //in kJ/kg
hfg=1970.7;                 //in kJ/kg
Ts=191.6;                   //in deg. selsius
h=hf+hfg+Cps*(ds);
hf1=4.18*(Tfw-0);
htotal=h-hf1;               //total heat supplied to produce 1 kg of steam

Mc1=Mc*(1-Pm/100);          //mass of dry coal in kg
Ma=Mw/Mc1;
ETAb=Ma*(h-hf1)/C;          //efficiency of boiler plant including superheater

Mcom=Mash*Pca/100;          //Mass of combustible in ash per hr
//the combustible present in ash is practically carbon and its value may be taken as 338/60 kJ/kg
//heat actually supplied pr hr=heat of dry coal-heat of combustible in ash
Hsupp=Mc1*C-Mcom*33860;     //heat actually supplied pr hr
Huse=Mw*(h-hf1);            //heat usefully utilised in boiler pr hr

ETAc=Huse/Hsupp;            //efficiency of boiler and furnace combined

printf('(i) The Efficiency of boiler plant including superheater is: %5.3f or %2.1f percent. \n',ETAb,(ETAb*100));
printf('(ii) The Efficiency of the boiler and furnace combined is: %5.3f or %2.1f percent. \n',ETAc,(ETAc*100));
```

Scilab code Exa 6.11 Example 11

```
clc
clear
//DATA GIVEN
Ms=5000;                  //mass of steam generated in kg/hr
Mf=700;                   //rate of coal firing in kg/hr
C=31402;                  //higher calorific value(HCV) of coal in kJ/kg
x=0.92;                   //quality of steam
p=12;                     //steam pressure in bar
Tfw=45;                   //feed  water temp. in deg celsius

//from steam table, corresponding to 12 bar,
hf=798.4;                 //in kJ/kg
hfg=1984.3;               //in kJ/kg
h=hf+x*hfg;               //in kJ/kg
hf1=4.18*(Tfw-0);         //heat of feed water in kJ/kg
Ma=Ms/Mf;                 //in kg per kg of fuel
Me=Ma*(h-hf1)/2257;       //(kg of steam)/(kg of fuel)
eta=Ma*(h-hf1)/C;         //thermal efficiency

printf(' (i) The Equivalent evaporation, Me is: %5.3f (kg of steam)/(kg of coal). \n',Me);
printf(' (ii) The Boiler efficiency is: %5.3f or %2.1f percent. \n',eta,eta*100);
```

Scilab code Exa 6.12 Example 12

```
clc
clear
```

```
//DATA GIVEN
hsup=3373.7;                    //enthalpy of steam (at
    100 bar,500 deg. celsius) in kJ/kg
hf1=677;                        //enthalpy of feed water
    (at inlet temp. 160 deg. celsius) in kJ/kg
hf=1407.65;                     //ennthalpy of saturated
    liquid at 100 bar in kJ/kg
hg=2724.7;                      //ennthalpy of saturated
    vapout at 100 bar in kJ/kg
Ms=100000;                      //rate of steam
    generation in kg/hr
eta=88;                         //efficiency of steam
    generation
C=21000;                        //calorific value of fuel
     in kJ/kg

//eta=(heat absorbed by steam per hr)/(heat added by
     fuel per hour)
m=Ms*(hsup-hf1)/(C*(eta/100));        //fuel burning
    rate in kg/hr
htotal=hsup-hf1;                      //total heat
    supplied to steam formation
Pec=(hf-hf1)/htotal;                  //% of heat
    absorbed in economiser
Pev=(hg-hf)/htotal;                   //% of heat
    absorbed in evaporator
Ps=(hsup-hg)/htotal;                  //% of heat
    absorbed in superheater

printf(' (i) The Fuel burning rate, m is: %5.1f kJ/h
    . \n',m);
printf(' (ii) The Percentage of heat absorbed in
    economiser is: %5.4f or %5.2f percent.\n',Pec,(
    Pec*100));
printf('      The Percentage of heat absorbed in
    evaporator is: %5.4f or %5.2f percent.\n',Pev,(
    Pev*100));
printf('      The Percentage of heat absorbed in
```

```
superheater is: %5.4f or %5.2f percent.\n',Ps,(Ps
    *100));
```

Scilab code Exa 6.13 Example 13

```
clc
clear
//DATA GIVEN
//BOILER
Mw=2060;                //mass of feed water
Mc=227;                 //mass of coal supplied in kg/hr
C=30000;                //calorific value of coal in kJ/
    kg
hs=2750;                //enthalpy of steam produced in
    kJ/kg
hfw=398;                //enthalpy of feed water
//ECONOMISER
Twin=15;                //temp. of feed water entering
    economiser in deg celsius
Twout=95;               //temp. of feed water leaving
    economiser in deg celsius
Tgout=18;               //atmospheric temp.
Tgin=370;               //temp. of entering flue gases
Mfg=4075;               //mass of flue gases
//assuming Cpw and Cpg,
Cpw=4.187;
Cpg=1.01;

ETAb=Mw*(hs-hfw)/(Mc*C);
                                    //efficiency of
    boiler
ETAe=Mw*Cpw*(Twout-Twin)/(Mfg*Cpg*(Tgin-Tgout));
        //efficiency of economiser

printf('(i) The Boiler efficiency is: %5.4f or %2.2
```

```
    f percent. \n',ETAb,(ETAb*100));
printf(' (ii) The Economiser efficiency is: %5.3f or
    %2.1f percent. \n',ETAe,(ETAe*100));
```

Scilab code Exa 6.14 Example 14

```
clc
clear
//DATA GIVEN
Tfw=50;               //mean feed  water temp. in deg
    celsius
p=5;                  //mean steam pressure in bar
x=0.95;               //dryness fraction of steam
Mc=600;               //coal consumption kg/hr
C=30400;              //calorific value of coal in kJ/
    kg
Ms=4800;              //feed water supplied to boiler
    in kg/hr

//from steam table, corresponding to 12 bar,
hf=640.1;             //in kJ/kg
hfg=2107.4;           //in kJ/kh
h=hf+x*hfg;           //in kj/kg
hf1=4.18*(Tfw-0);

Ma=Ms/Mc;             //in kg per kg of fuel
Me=Ma*(h-hf1)/2257;   //(kg of steam)/(kg of fuel)

printf(' The Equivalent evaporation from and at 100
    deg celsius, Me is: %5.3f (kg of steam)/(kg of
    coal).\n',Me);
```

Chapter 7

Internal Combustion Engines

Scilab code Exa 7.1 Example 1

```
clc
clear
//DATA GIVEN
Pmi=6;                          //mean effective pressure in bar
N=1000;                         //engine speed in R.P.M.
D=0.11;                         //diameter of piston in m
L=0.14;                         //stroke length in m
n=1;                            //no. of cylinders
k=1;                            //for 2-stroke cylinder

//INDICTED POWER ,I.P.=(n*PMI*l*A*N*k*10)/6 kW
A=(%pi/4)*(D^2);
IP=(n*Pmi*L*A*N*k*10)/6;

printf('The Indicted Power developed is: %2.1f kW.', IP);
```

Scilab code Exa 7.2 Example 2

```
clc
clear
//DATA GIVEN
//L=1.5D
n=4;                          //no. of cylinders
P=14.7;                       //power developed in kW
N=1000;                       //engine speed in R.P.M.
Pmi=5.5;                      //mean effective pressure in bar
k=0.5;                        //for 4-stroke cylinder

//INDICTED POWER, I.P.=(n*PMI*l*A*N*k*10)/6 kW
//A=(pi/4)*D^2,
//L=1.5D,
D=((6*P)/(10*k*N*n*Pmi*1.5*(%pi/4)))^(1/3);      //bore diameter in m
L=1.5*D;                                          //length of stroke in m

printf('The Bore diameter is: %5.2f mm.\n',(D*1000));
printf(' The Stoke length is: %5.2f mm.\n',(L*1000));
```

Scilab code Exa 7.3 Example 3

```
clc
```

```
clear
//DATA GIVEN
Db=0.6;                              //diameter of brake
    wheel in m
d=0.026;                             //diameter of rope in
    m
W=200;                               //dead load on the
    brake in N
S=30;                                //spring balance
    reading in N
N=450;                               //engine speed in R.P.
    M.

//Brake Power, B.P.=(W-S)(pi)(Db+d)N/(60*1000) kW
BP=(W-S)*(%pi)*(Db+d)*N/(60*1000);

printf('The Brake Power, B.P. is: %2.1f kW.\n',BP);
```

Scilab code Exa 7.4 Example 4

```
clc
clear
//DATA GIVEN
T=175;                          //torque due to brake load
    in Nm
N=500;                          //engine speed in R.P.M.

//Brake Power, BP = (2*pi)NT/(60*1000) kW
BP = (2*%pi)*N*T/(60*1000);

printf('The Brake Power, B.P. is: %4.2f kW.\n',BP);
```

Scilab code Exa 7.5 Example 5

```
clc
clear
//DATA GIVEN
D=0.3;                              //bore of engine cylinder in m
L=0.45;                             //stroke length in m
N=300;                              //engine speed in R.P.M.
Pmi=6;                              //mean effective pressure in bar
NBL=1.5;                            //Net brake load (W-S) in kN
Db=1.8;                             //diameter of brake drum
d=0.02;                             //brake rope diameter
n=1;                                //no. of cylinders
k=0.5;                              //for 4-stroke cylinder

//INDICTED POWER ,I.P.=(n*PMI*l*A*N*k*10)/6 kW
A=(%pi/4)*(D^2);
IP=(n*Pmi*L*A*N*k*10)/6;
BP=NBL*(%pi)*(Db+d)*N/(60);
eta=BP/IP;                          //mechanical efficiency

printf(' (i) The Indicted Power, I.P. is: %5.2f kW. \n',IP);
printf(' (ii) The Brake Power, B.P. is: %5.2f kW. \n',BP);
printf('(iii) Mechanical efficiency is: %5.4f or %5.2f percent.\n',eta,(eta*100));
```

Scilab code Exa 7.6 Example 6

```
clc
clear
//DATA GIVEN
D=0.2;                              //diameter of engine cylinder in m
L=0.350;                            //length of stroke in m
Pmico=6.5;                          //mean effective pressure on cover side in bar
Pmicr=7;                            //mean effective pressure on crank side in bar
N=420;                              //engine speed in R.P.M.
Drod=0.02;                          //diameter of piston rod in m
W=1370;                             //dead load on the brake in N
S=145;                              //spring balance reading in N
Db=1.2;                             //diameter of brake wheel in m
d=0.02;                             //diameter of rope in m
n=1;                                //no. of cylinders
k=0.5;                              //for 4-stroke cylinder

//INDICTED POWER ,I.P.=(n*Pmi*l*A*N*k*10)/6 kW
Aco=(%pi/4)*(D^2);                       //area of cylinder om cover end in m^2
Acr=(%pi/4)*(D^2-Drod^2);                //area of cylinder om crank end in m^2
IPco=(n*Pmico*L*Aco*N*k*10)/6;           //IP on cover end side in kW
IPcr=(n*Pmicr*L*Acr*N*k*10)/6;           //IP on crank end side in kW
IPtotal=IPco+IPcr;                       //IP total in kW

```

```
//Brake Power, B.P.=(W-S)(pi)(Db+d)N/(60*1000) kW
BP=(W-S)*(%pi)*(Db+d)*N/(60*1000);

eta=BP/IPtotal;                          //mechanical efficiency

printf('Mechanical efficiency is: %5.4f or %5.2f percent.\n',eta,(eta*100));
```

Scilab code Exa 7.7 Example 7

```
clc
clear
//DATA GIVEN
IP=30;                                 //indicted power in kW
BP=26;                                 //Brake Power in kW
N=1000;                                //engine speed in R.P.M.
F=0.35;                                //fuel per brake power hour in kg/BP/h
C=43900;                               //calorific value of fuel used in kJ/kg

Fc=F*BP;                               //fuel consumption per hour
Mf=Fc/3600;
ETAti=IP/(Mf*C);                      //Indicted thermal eficiency
ETAtb=BP/(Mf*C);                      //Brake thermal efficiency
ETAm=BP/IP;                           //Mechanical efficiency

printf(' (i) The Indicted thermal eficiency is: %5.3f or %2.1f percent. \n',ETAti,(ETAti*100));
printf(' (ii) The Brake thermal efficiency is: %5.3f
```

```
 or %2.1f percent. \n',ETAtb,(ETAtb*100));
printf('(iii) Mechanical efficiency is: %5.3f or %2.1f percent. \n',ETAm,(ETAm*100));
```

Scilab code Exa 7.8 Example 8

```
clc
clear
//DATA GIVEN
Db=0.75;                              //diameter of brake pulley in m
d=0.05;                               //diameter of rope in m
W=400;                                //dead load on the brake in N
S=50;                                 //spring balance reading in N
Fc=4.2;                               //fuel consumption in kg/hr
N=1000;                               //rated engine speed in R.P.M.
C=43900;                              //calorific value of fuel used in kJ/kg
n=1;                                  //no. of cylinders
k=0.5;                                //for 4-stroke cylinder


//Brake Power, B.P.=(W-S)(pi)(Db+d)N/(60*1000) kW
BP=(W-S)*(%pi)*(Db+d)*N/(60*1000);
sfc=Fc/BP;                                      //brake specific fuel consumption in kg/kWhr
Mf=Fc/3600;
ETAtb=BP/(Mf*C);                                //Brake thermal efficiency
```

```
printf(' (i) The Brake specific fuel consumption, s.
   f.c (brake) is: %5.3f kg/kWh. \n',sfc);
printf(' (ii) The Brake thermal efficiency is: %5.3f
    or %2.1f percent. \n',ETAtb,(ETAtb*100));
```

Scilab code Exa 7.9 Example 9

```
clc
clear
//DATA GIVEN
n=6;                              //no. of cylinders
D=0.09;                           //bore of each
   cylinder in m
L=0.1;                            //length of stroke in
   m
r=7;                              //compression ratio
ETArel=0.55;                      //relative efficiency
Fsc=0.3;                          //indicated specific
   fuel consumption in kg/kWh
Pmi=8.6;                          //indicated mean
   effective pressure in bar
N=2500;                           //engine speed in R.P.
   M.
k=0.5;                            //for 4-stroke
   cylinder

//Air standard efficiency, ETAair=1-1/(r^(gamma-1))
g=1.4;                            //gamma of air=1.4
ETAair=1-1/(r^(g-1));
//Indicated thermal efficiency, ETArel=ETAthi/ETAair
   ;
ETAthi=ETArel*ETAair;
//Indicted thermal eficiency, ETAthi=IP/(Mf*C)
Mf=Fsc/3600;
```

```
//taking IP=1,
C=1/(ETAthi*Mf);                    //calorific value in kJ/kg
//INDICTED POWER ,I.P.=(n*Pmi*l*A*N*k*10)/6 kW
A=(%pi/4)*(D^2);
IP=(n*Pmi*L*A*N*k*10)/6;
Fc=Fsc*IP;                          //total fuel consumption in kg/hr

printf(' (i) The Calorific value of coal, C is: %5.0f kJ/kg. \n',C);
printf(' (ii) The Fuel consumption is: %5.2f kg/h. \n',Fc);

//NOTE:
//ans of calorific value here is exact, while in TB its rounded off value
```

Scilab code Exa 7.10 Example 10

```
clc
clear
//DATA GIVEN
n=4;                                //no. of cylinders
BP=30;                              //Brake Power in kW
N=2500;                             //engine speed in R.P.M.
Pmi=8;                              //mean effective pressure in bar
ETAm=0.8;                           //mechanical efficiency
ETAthb=0.28;                        //brake thermal efficiency
C=43900;                            //calorific value of fuel used in kJ/kg
```

```
k=1;                              //for 2-stroke
    cylinder

//mechanical efficiency , ETAm=BP/IP
IP=BP/ETAm;
//INDICTED POWER ,I.P.=(n*PMI*l*A*N*k*10)/6 kW
//L=1.5D,
D=((6*IP)/(10*k*N*n*Pmi*1.5*(%pi/4)))^(1/3);      //
    bore diameter in m
L=1.5*D;                                          //
    length of stroke in m
//Brake thermal efficiency , ETAtb=BP/(Mf*C)
Mf=BP/(ETAthb*C);                                 //
    fuel consumption in kg/hr

printf(' (i) The Bore diameter is: %5.3f m or %2.0f
   mm.\n',D,(D*1000));
printf('      The Stoke length is: %2.0f mm.\n',(L
    *1000));
printf(' (ii) The Fuel consumption is: %5.5f kg/s or
     %3.2f kg/hr. \n',Mf,(Mf*3600));
```

Scilab code Exa 7.11 Example 11

```
clc
clear
//DATA GIVEN
n=6;                              //no. of cylinders
Pdisp=700;                        //piston disp per
    cylinder in cm^3
P=78;                             //power developed in
   kW
N=3200;                           //engine speed in R.P.
   M.
Mf=27;                            //mass of fuel used in
```

```
kg/hr
C=44000;                          //calorific value of fuel used in kJ/kg
afr=12;                           //air fuel ratio
Pa=0.9;                           //intake air pressure in bar
Ta=32+273;                        //intake air tempertaure in K
R=0.287;                          //gas constant for air in kJ/kgK
k=0.5;                            //for 4-stroke cylinder

Ma=afr*Mf;                                  //mass of air
//by eq. pa*Va=Ma*R*Ta
Va=Ma*R*Ta/Pa/100;                          //volume of intake air in m^3/hr
Vswept=(Pdisp/10^6)*n*(N/2)*60;             //volume swept in m^3/hr
ETAvol=Va/Vswept;                           //volumetric efficiency

//Brake thermal efficiency , ETAbt=brake work/heat supplied by the fuel
ETAbt=P/(Mf*C/3600);
//Brake Power, BP = (2*pi)N*Tb/(60*1000) kW
Tb=P*60/(2*%pi*N);                          //brake torque in kNm

printf('  (i) The Volumetric efficiency is: %5.3f or %5.1f percent. \n',ETAvol,(ETAvol*100));
printf('  (ii) The Brake thermal efficiency is: %5.4f or %5.2f percent. \n',ETAbt,(ETAbt*100));
printf(' (iii) The Brake Torque is: %5.4f kNm. \n',Tb);
```

Scilab code Exa 7.12 Example 12

```
clc
clear
//DATA GIVEN
//L=1.5D
n=6;                             //no. of cylinders
Vs=1.75;                         //stroke volume in litres
IP=26.3;                         //power developed in kW
Ne=504;                          //engine speed in R.P.M.
Pmi=6;                           //mean effective pressure in bar
k=0.5;                           //for 4-stroke cylinder

//INDICTED POWER ,I.P.=(n*PMI*l*A*N*k*10)/6 kW
//L*A=Vs
Na=IP*6/(n*Pmi*(Vs/10^3)*k*10);        //actual speed in R.P.M
Fa=Na*n*k;                             //actual no. of fires in one minute
Fe=Ne*n/2;                             //expected no. of fires in one minute
Fm=Fe-Fa;                              //misfires per minute
Fmavg=Fm/n;                            //avg. no. of times each cylinder misfires in one minute

printf('The Average no. of times each cylinder misfires in one minute is: %1.0f.\n',Fmavg);
```

Scilab code Exa 7.13 Example 13

```
clc
clear
//DATA GIVEN
D=0.075;                              //bore in m
L=0.09;                               //stroke length in m
n=4;                                  //no. of cylinders
erar=39/8;                            //engine to rear axle
    ratio =39:8
Dw=0.65;                              //wheel diameter with
    tyre fully inflated in m
Fc=0.227;                             //petrol consumption
    for a distance of 3.2 km at a speed of 48 km/hr
Pmi=5.625;                            //mean effective
    pressure in bar
C=43470;                              //calorific value of
    fuel used in kJ/kg
k=0.5;                                //for 4-stroke
    cylinder

s=48*1000/60;                         //speed of car in m/
    min
//if Nt rev are made by tyre per minute, speed=pi*Dw
    *Nt
Nt=s/(%pi*Dw);                        //R.P.M.
//as engine to rear axle ratio is 39:8
Ne=erar*Nt;                           //speed of enfine
    shaft in R.P.M.
//INDICTED POWER ,I.P.=(n*PMI*l*A*N*k*10)/6 kW
A=(%pi/4)*(D^2);
IP=(n*Pmi*L*A*Ne*k*10)/6;

s=s/1000;                             //speed of car in km/
```

```
min
t=3.2/s;                          //time in min for covering 3.2 km
//petrol consumption for a distance of 3.2 km aat a speed of 48 km/hr is 0.227kg
Mf=Fc/(t*60);                     //fuel consumed per sec
ETAthi=IP/(Mf*C);                 //Indicated fuel efficiency

printf('(i) The Indicated Power developed is: %5.2f kW. \n',IP);
printf('(ii) The Indicated thermal efficiency is: %1.3f or %2.1f percent. \n',ETAthi,(ETAthi*100));
```

Scilab code Exa 7.14 Example 14

```
clc
clear
//DATA GIVEN
D=0.25;                           //cylinder diameter in m
L=0.4;                            //stroke length in m
Pmg=7;                            //Gross mean effective pressure in bar
Pmp=0.5;                          //Pumping mean effective pressure in bar
N=250;                            //engine speed in R.P.M.
NBL=1080;                         //net load on the brake (W-S) in N
Db=1.5;                           //effective diameter of the brake in m
Fc=10;                            //fuel used per hr in kg
```

```
C=44300;                          //calorific value of fuel used in kJ/kg
n=1;                              //no. of cylinders
k=0.5;                            //for 4-stroke cylinder

//INDICTED POWER ,I.P.=(n*PMI*l*A*N*k*10)/6 kW
Pm=Pmg-Pmp;
A=(%pi/4)*(D^2);
IP=(n*Pm*L*A*N*k*10)/6;
BP=NBL*(%pi)*(Db)*N/(60*1000);
ETAm=BP/IP;                        //mechanical efficiency
Mf=Fc/3600;
ETAthi=IP/(Mf*C);                  //Indicated thermal efficiency

printf(' (i) The Indicated Power, I.P. is: %5.2f kW.\n',IP);
printf(' (ii) The Brake Power, B.P. is: %2.1f kW. \n',BP);
printf('(iii) Mechanical efficiency is: %5.3f or %2.1f percent.\n',ETAm,(ETAm*100));
printf(' (iv) Indicated thermal efficiency is: %5.3f or %2.1f percent.\n',ETAthi,(ETAthi*100));
```

Scilab code Exa 7.15 Example 15

```
clc
clear
//DATA GIVEN
ETAthb=30;                        //Brake thermal efficiency in %
afr=20;                           //air fuel ratio by weight
```

```
C=41800;                              //calorific value of fuel used in kJ/kg

//Brake thermal efficiency , ETAthb=work produced/heat supplied
work=(ETAthb/100)*C;                  //work produced per kg of fuel
//STP conditions refer to 1.0132 bar and 15 deg celsius
m=afr;                                //mass of air per kg of fuel
R=287;
V=m*R*(15+273)/(1.0132*10^5);  //volume of air used
//Brake mean effective pressure , Pmb=work done/cylinder volume
Pmb=(work*1000)/(V*10^5);

printf('The Brake mean effective pressure , Pmb is: %2.2f bar.\n',Pmb);
```

Scilab code Exa 7.16 Example 16

```
clc
clear
//DATA GIVEN
V1=0.216;                             //gas consumption in m^3/min
P1=75;                                //gas temperature in mm of water
T1=17+273;                            //gas tempertaure in K
m=2.84;                               //air consumption in kg/min
Ta=17+273;                            //air tempertaure in K
br=745;                               //barometer reading in mm of Hg
```

```
D=0.25;                          //bore of engine cylinder in m
L=0.475;                         //stroke length in m
N=240;                           //engine speed in R.P.M.
R=287;                           //gas constant for air in J/kgK
n=1;                             //no. of cylinders
k=1;                             //for 2-stroke cylinder

P1=br+P1/13.6;                   //pressure of the gas
//at NTP
P2=760;                          //mm of Hg
T2=0+273;                        //in K
//P1*V1/T1=P2*V2/T2
V2=P1*V1*T2/(P2*T1);             //volume of gas used at NTP in m^3
Vg=V2/(N/2);                     //gas used per stroke in m^3

//PV=mRT
P2=1.0132*10^5;
V=m*R*T2/P2;                     //volume occupied by air in m^3/min
Va=V/(N/2);                      //air used per stroke in m

Vmix=Vg+Va;                      //mixture of gas and air in m^3

//ETAvol=(actual volume of mixture drawn per stroke at NTP)/(swept volume of system)
ETAvol=Vmix/((%pi/4)*D^2*L);

printf(' The Volumetric efficiency is: %3.3f or %3.1f percent. \n',ETAvol,(ETAvol*100));
```

Scilab code Exa 7.17 Example 17

```
clc
clear
//DATA GIVEN
t=1;                              //duration of trial in hr
N=14000;                          //revolutions
mc=500;                           //no. of missed cycles
NBL=1470;                         //Net brake load (W-S) in N
Pmi=7.5;                          //mean effective pressure in bar
Vg=20000/3600;                    //gas consumption in litres/s
C=21;                             //LCV of gas at sipply conditions in kJ/litre
D=0.25;                           //cylinder diameter in m
L=0.4;                            //stroke length in m
Cb=4;                             //effective brake circumference in m
r=6.5;                            //compression ratio
n=1;                              //no. of cylinders
k=0.5;                            //for 4-stroke cylinder

//gamma for air, g=1.4
g=1.4;

//INDICTED POWER ,I.P.=(n*PMI*l*A*N*k*10)/6 kW
Nk=(N*k-mc)/60;                   //(N*k)-working cycles/min
A=(%pi/4)*(D^2);
```

```
IP=(n*Pmi*L*A*Nk*10)/6;
N=N/60;
BP=NBL*(Cb)*N/(60*1000);
eta=BP/IP;                    //mechanical
    efficiency
ETAthi=IP/(Vg*C);             //Indicated thermal
    efficiency

//relative efficiency , ETArel=ETAthi/ETAas
//ETAas=1-1/(r^(g-1))
ETAas=1-1/(r^(g-1));          //air-standard
    efficiency
ETArel=ETAthi/ETAas;          //relative efficiency

printf('  (i) The Indicated Power, I.P. is: %5.2f kW
    . \n',IP);
printf('  (ii) The Brake Power, B.P. is: %5.2f kW. \
    n',BP);
printf(' (iii) Mechanical efficiency is: %5.3f or %2
    .1f percent.\n',eta,(eta*100));
printf('  (iv) The Indicated thermal efficiency is:
    %2.2f or %2.0f percent. \n',ETAthi,(ETAthi*100));
printf('   (v) The Relative efficiency is: %2.3f or
    %2.1f percent. \n',ETArel,(ETArel*100));
```

Chapter 10

Air Compressors

Scilab code Exa 10.1 Example 1

```
clc
clear
//DATA GIVEN
V1=1;                               //volume of air
   taken in m^3/mim
p1=1.013;                           //intake pressure in
    bar
T1=15+273;                          //intake temperature
    in K
p2=7;                               //delivery pressure
   in bar
t=1*60;                             //time in seconds
//law of compression , pV^1.35=C
n=1.35;
R=287;

m=p1*10^5*V1/R/T1;                  //mass of air
   delivered in kg/min

//(T2/T1)=(p2/p1)^((n-1)/n);
T2=T1*(p2/p1)^((n-1)/n);            //delivery temp. T2
```

```
    in K

W=(n)/(n-1)*m*R*(T2-T1)/1000;     //indicated work in
    kJ/min

IP=W/t;                           //indicated power in
     kW

printf(' The Indicated power, IP is: %1.2f kW. \n',
    IP);
```

Scilab code Exa 10.2 Example 2

```
clc
clear
//continued from Example 1
//DATA GIVEN
V=1;                              //volume dealt with
    per min at inlet in m^3/mim
Vc=1/300;                         //volume drawn in
    per cycle, in m^3/cycle
r=1.5;                            //stroke to bore
    ratio
ETAc=0.85;                        //mechanical
    efficiency of the compressor
ETAmt=0.90;                       //mechanical
    efficiency of the motor transmission

//cylinder volume, Vc=(pi/4)D^2*L
D=[(Vc*4/%pi)/r]^(1/3);           //bore in m

//from example 1
Pi=4.23/ETAc;                     //power input to the
     compressor in kW
MP=Pi/ETAmt;                      //motor power in kW
```

```
printf(' (i) The Cylinder bore,D is: %3.1f mm. \n',(
   D*1000));
printf(' (ii) The Motor power is: %1.2f kW. \n',MP);
```

Scilab code Exa 10.3 Example 3

```
clc
clear
//DATA GIVEN
T1=20+273;                          //temperature in K
p1=1;                               //pressure in bar
p2=10;                              //pressure in bar
Cv=0.718;                           //in kJ/kgK

//law of compression, pV^1.2=C
n=1.2;
R=0.287;                            //in kJ/kgK

//(T2/T1)=(p2/p1)^((n-1)/n);
T2=T1*(p2/p1)^((n-1)/n);           //temp. T2 in K
m=1;
W=(n)/(n-1)*m*R*T1*[(p2/p1)^((n-1)/n)-1];          //
   work done per kg of air (kJ/kg of air)

//By the First Law of Thermodynamics
//heat transferred during compression, Q=W+DU
//Q=(p1V1-p2V2)/(n-1)+Cv(T2-T1)
//Q=(T2-T1)*[Cv-R/(n-1)]
Q=(T2-T1)*[Cv-R/(n-1)];

printf(' (i) The Temperature at the end of
   compression is: %3.0f K or %3.0f deg. celsius. \n
   ',T2,(T2-273));
printf(' (ii) The Work done during compression per
```

```
   kg of air is: %3.2f kJ/kg of air. \n',W);
printf('      The Heat transferred during
   compression per kg of air is: %2.2f kJ/kg of air.
    \n',Q);
printf('      (Negative sign indicates heat
   REJECTION.) \n');
```

Scilab code Exa 10.4 Example 4

```
clc
clear
//DATA GIVEN
p1=1;                                //suction pressure
   in bar
T1=20+273;                           //suction
   temperature in K
p2=6;                                //discharge pressure
    in bar
T2=180+273;                          //discharge
   temperature in K
N=1200;                              //speed of
   compressor in R.P.M.
Pshaft=6.25;                         //shaft power in kW
Ma=1.7;                              //mass of air
   delivered in kg/min
D=0.14;                              //diameter in m
L=0.1;                               //stroke in m
R=287;                               //in kJ/kgK

Vd=(%pi/4)*D^2*L*N;                  //displacement
   volume for single acting compressor in m^3/min
FAD=Ma*R*T1/p1/10^5;                 //m^3/min
ETAvol=FAD/Vd*100;                   //actual volumetric
   efficiency

```

```
//(T2/T1)=(p2/p1)^((n-1)/n);
n=1/[1-(log(T2/T1)/log(p2/p1))];          //index of compression ,n

IP=(n)/(n-1)*Ma/60*R/1000*T1*[(p2/p1)^((n-1)/n)-1];          //indicated power in kW

Piso=Ma/60*R/1000*T1*log(p2/p1);                                //isothermal power
ETAiso=Piso/IP*100;                                              //isothermal efficiency

ETAmech=IP/Pshaft*100;                                           //mechanical efficiency

ETAovr_iso=Piso/Pshaft*100;                                      //overall isothermal eddiciency

printf(' (i) The actual Volumetric efficiency is: %2.2f percent. \n',ETAvol);
printf(' (ii) The Indicated Power, IP is: %1.3f KW.\n',IP);
printf('(iii) The Isothermal efficiency is: %2.2f percent.\n',ETAiso);
printf(' (iv) The Mechanical efficiency is: %2.1f percent.\n',ETAmech);
printf('  (v) The Overall isothermal efficiency is: %2.1f percent.\n',ETAovr_iso);
```

Scilab code Exa 10.5 Example 5

```
//5(b) is as follows:
```

```
clc
clear
//DATA GIVEN
m=6.75;                 //mass of air in kg/min
p1=1;                   //pressure in bar
T1=21+273;              //temp. in K
p2=1.35;                //pressure in bar
T2=43+273;              //temp. in K
DTcw=3.3;               //temp. rise of cooling
    water in deg. celsius
Cp=1.003;               //Cp for air in kJ/kgK
//gamma for air=1.4
g=1.4;

W=m*Cp*(T2-T1);         //work in kJ/min
//If the compression would have been isotropic,
//T_2=T1*(rp)^[(g-1)/g]
rp=p2/p1;
T_2=T1*(rp)^[(g-1)/g];
Qr=m*Cp*(T_2-T2);       //heat rejected to cooling
    water

Mw=Qr/[4.18*(DTcw)];    //mass of cooling water in
    kg/min

printf(' (i) The Work is: %3.2f kJ/min. \n',W);
printf(' (ii) The Mass of cooling water is: %1.2f kg
    /min. \n',Mw);

//NOTE:
//in the question compression process is mentioned
    and p2 is given as 0.35 bar (p2<p1)
//which is wrong and further p2 is given as 1.35 bar
     which is allowable
//so here value of p2 is taken as 1.35 bar.
```

Scilab code Exa 10.6 Example 6

```
clc
clear
//DATA GIVEN
V1=14;                              //quantity of air to be delivered , in m^3/mim
p1=1.013;                           //intake pressure in bar
T1=15+273;                          //intake temperature in K
p2=7;                               //delivery pressure in bar
N=300;                              //speed of compressor in R.P.M.
n=1.3;                              //compression and expansion index
R=0.287;

//clearance volume , Vc = 0.05 Vs    ,Vs=swept volume
//swept volume Vs=V1-V3=V1-Vc=V1-0.05Vs
//V1=1.05Vs
Vpc=V1/N/2;                                                  //(V1-V4) volume induced per cycle in m^3
//V4/V3=(p2/p1)^(1/n)
c=(p2/p1)^(1/n);
//V4=c*V3=c*0.05Vs
//V1-V4=1.05Vs-c*0.05Vs
Vs=Vpc/(1.05)/(1.05-c*0.05);                                 //volume swept in m^3

//using relation (T2/T1)=(p2/p1)^((n-1)/n);
T2=T1*(p2/p1)^((n-1)/n);
```

```
                                                    //delivery temp.
   T2 in K

IP=(n)/(n-1)*p1*10^5*Vpc/100*[(p2/p1)^((n-1)/n)-1];
        //indicated power in kW

printf(' (i) The Swept volume of the cylinder, Vs is
   : %1.4f m^3. \n',Vs);
printf(' (ii) The delivery temperature, Ts is: %3.0f
    deg. celsius. \n',(T2-273));
printf('(iii) The Indicated power, IP is: %2.2f kW.
   \n',IP);

//NOTE:
//there is slight variation in answers in textbook
   due to rounding off of values in book
```

Chapter 13

Transmission of Motion and Power

Scilab code Exa 13.1 Example 1

```
clc
clear
//DATA GIVEN
N1=240;                          //speed of the engine
   shaft in R.P.M.
d1=1.5;                          //diameter of pulley on
   engine shaft in m
d2=0.75;                         //diameter of pulley on
   machine shaft in m
t=0.005;                         //thickness of the belt
   in m

//with no slip
//(N2/N1)=(d1+t)/(d2+t)
N2=(d1+t)/(d2+t)*N1;             //speed of the machine
   shaft in R.P.M.

//with slip of 2%
S=2;                             //slip in %
```

```
//(N2/N1)=(d1+t)/(d2+t)*((100-S)/100)
N2s=(d1+t)/(d2+t)*N1*((100-S)/100);

printf(' (i) The Speed of machine shaft, N2 with no slip is: %4.1f R.P.M. \n',N2);
printf(' (ii) The Speed of machine shaft, N2 with slip of 2 percent is: %4.1f R.P.M. \n',N2s);
```

Scilab code Exa 13.2 Example 2

```
clc
clear
//DATA GIVEN
r1=900/2000;                    //radius of larger pulley in m
r2=300/2000;                    //radius of smaller pulley in m
d=6;                            //distance between the centres of pulley in m

//Length of cross belt, Lcross=(pi)(r1+r2)+(r1+r2)^2/d+2d;
Lcross=(%pi)*(r1+r2)+(r1+r2)^2/d+2d;
//Length of open belt, Lopen=(pi)(r1+r2)+(r2-r1)^2/d+2d;
Lopen=(%pi)*(r1+r2)+(r2-r1)^2/d+2d;

Lred=Lcross-Lopen;              //length to be reduced
printf(' The Length of the belt to be reduced, \n (to change the direction of rotation of the follower pulleys)is: %2.0f mm. \n',(Lred*1000));
```

Scilab code Exa 13.3 Example 3

```
clc
clear
//DATA GIVEN
T1=1500;                    //tension on the tight
   side in N
T2=1200;                    //tension on the slack
   side in N
v=80;                       //speed of the belt in m
   /s

P=(T1-T2)*v;                //power transmitted by
   the belt in watts

printf(' The Power transmitted by the belt is: %2.0f
    kW. \n',(P/1000));
```

Scilab code Exa 13.4 Example 4

```
clc
clear
//DATA GIVEN
v=500;                      //speed of the belt in m
   /min
mu=0.3;                     //coefficient of
   friction
theta=160;                  //angle of contact in
   degrees
T1=700;                     //maximum tension in the
    belt in N

//(T1/T2)=e^(mu*theta)
theta=theta*(%pi)/180;      //theta converted into
   radians
T2=T1/(%e^(mu*theta));      //tension on the slack
   side in N
```

```
v=v/60;                          //speed of the belt
   converted into m/s
P=(T1-T2)*v;                     //power transmitted by
   the belt in watts

printf(' The Power transmitted by the belt is: %2.3f
    kW. \n',(P/1000));
```

Scilab code Exa 13.5 Example 5

```
clc
clear
//DATA GIVEN
r1=750/2000;                     //radius of larger
   pulley in m
r2=300/2000;                     //radius of smaller
   pulley in m
d=1.5;                           //distance between the
   centres of pulley in m
Tms=14;                          //maximum safe tension
   in N/mm
b=150;                           //width of the belt in
   mm
v=540;                           //speed of the belt in m
   /min
mu=0.25;                         //coefficient of
   friction

T1=Tms*b;                        //maximum tension in the
    belt in N
v=v/60;                          //speed of the belt
   converted into m/s
//(i) for open belt
ALPHAo=asin ((r1-r2)/d)*180/(%pi);      //alpha in
   degrees
```

```
THETAo=180-2*ALPHAo;                    //angle of lap or contact in deg
T2o=T1/(%e^(mu*(THETAo*%pi/180)));      //tension on the slack side in N
Po=(T1-T2o)*v;                          //power transmitted by the belt in watts

//(ii) for cross belt
ALPHAc=asin ((r1+r2)/d)*180/(%pi);      //alpha in degrees
THETAc=180+2*ALPHAc;                    //angle of lap or contact in deg
T2c=T1/(%e^(mu*(THETAc*%pi/180)));      //tension on the slack side in N
Pc=(T1-T2c)*v;                          //power transmitted by the belt in watts

printf(' (i) The Maximum Power transmitted by the open belt is: %2.3f kW. \n',(Po/1000));
printf(' (ii) The Maximum Power transmitted by the cross belt is: %2.3f kW. \n',(Pc/1000));
```

Scilab code Exa 13.6 Example 6

```
clc
clear
//DATA GIVEN
b=0.25;                     //width of the belt in m
t=0.006;                    //thickness of the belt in m
r=900/2000;                 //radius of the pulley in m
rho=1100;                   //density of the material in kg/m^3
Tp=2;                       //permissible tension of
```

```
the belt in MN/m^2
ratio=2;                       //ratio of T1/T2=2
N=200;                         //speed of the pulley in R.P.M.

Tmax=Tp*10^6*b*t;              //maximum safe tension of the belt
//centrifugal tension , Tc=m*v^2
m=(b*t)*1*rho;                 //mass of the belt per unit metre length
v=2*(%pi)*(r+t/2)*N/60;
Tc=m*v^2;

T1=Tmax-Tc;                    //tension in the tight side in N
T2=T1/ratio;                   //tension in the slack side in N
P=(T1-T2)*v;                   //power transmitted by the belt in watts


printf(' (i) The Centrifugal tension Tc is: %3.1f N. \n',Tc);
printf(' (ii) The Power transmitted by the belt is: %2.1f kW. \n',(P/1000));
```

Scilab code Exa 13.7 Example 7

```
clc
clear
//DATA GIVEN
P=35;                          //power required to be transmitted by the belt in kW
d=1.5;                         //effective diameter of pulley in m
```

```
N=300;                          //speed of the pulley in
    R.P.M.
theta=11/24*2*%pi;              //angle of contact in
    radians
mu=0.3;                         //coefficient of
    friction
t=0.0095;                       //thickness of the belt
    in m
rho=1100;                       //density of the
    material in kg/m^3
sigma=2.5;                      //permissible stress in
    MN/m^2

v=%pi*d*N/60;                   //speed of the belt in m
    /s
//P=(T2-T1)*v, so (T2-T1)=P/v...................(1)
c=%e^(mu*theta);                //so, T2/T1=c........(2)
//By equation (1) and (2),
T2=(P/v*1000)/(c-1);            //tension in the slack
    side in N
T1=c*T2;                        //tension in the tight
    side in N

//maximum tension, Tmax=sigma*b*t=0.2375*b*10^6 N
        (3)
//centrifugal tension, Tc=m*v^2=5800.5*b N
                  (4)
//T1=Tmax-c
                                                      (5)
//By eqn. (3),(4) and (5)
b=T1/((sigma*10^6*t)-(t*1*rho*v^2));        //width of
    the belt in m

printf('The Width of the belt is: %3.0f mm (say 150
    mm). \n',(b*1000));
```

Scilab code Exa 13.8 Example 8

```
clc
clear
//DATA GIVEN
b=0.2;                          //width of the belt in m
t=0.01;                         //thickness of the belt
   in m
Tp=2;                           //permissible tension of
    the belt in MN/m^2
ratio=1.8;                      //ratio of T1/T2=1.8
rho=1100;                       //density of the
   material in kg/m^3

Tmax=Tp*10^6*b*t;               //maximum safe tension
   of the belt
//we know centrifugal tension, Tc=Tmax/3
Tc=Tmax/3;
//centrifugal tension, Tc=m*v^2
m=(b*t)*1*rho;                  //mass of the belt per
   unit metre length
v=(Tc/m)^0.5;

T1=Tmax-Tc;                     //tension in the tight
   side in N
T2=T1/ratio;                    //tension in the slack
   side in N
P=(T1-T2)*v;                    //power transmitted by
   the belt in watts

printf(' (i) The Velocity of the belt is: %3.1f m/s.
    \n',v);
printf(' (ii) The Maximum power transmitted by the
   belt is: %2.2f kW. \n',(P/1000));
```

Scilab code Exa 13.9 Example 9

```
clc
clear
//DATA GIVEN
To=1000;                          //initial tension in the belt in N
theta=150;                        //angle of embrace in degrees
mu=0.25;                          //coefficient of friction
v=500;                            //speed of the belt in m/min

//Initial tension, To=(T1+T2)/2
//so, (T1+T2)=2000............................. (1)
theta=theta*(%pi)/180;            //theta converted into radians
c=%e^(mu*theta);                  //so, T2/T1=c........(2)
//By equation (1) and (2),
T2=(To*2)/(c+1);                  //tension in the slack side in N
T1=c*T2;                          //tension in the tight side in N

v=v/60;                           //speed of the belt converted into m/s
P=(T1-T2)*v;                      //power transmitted by the belt in watts

printf(' (i) The Tension in the tight side T1 is: %4.0f N. \n',T1);
printf('     The Tension in the slack side T2 is: %3.1f N. \n',T2);
```

```
printf(' (ii) The Power transmitted by the belt is: %2.2f kW. \n',(P/1000));
```

Scilab code Exa 13.10 Example 10

```
clc
clear
//DATA GIVEN
P=400;                        //maximum value of force that can be developed in N
mu=0.25;                      //coefficient of friction
d=0.6;                        //diameter of drum in m
//Refer the figure
theta=180+45;                 //angle of contact in degrees
theta=theta*(%pi)/180;        //theta converted into radians

//moments about A, Ma=0,
T1=P*1/0.5;

//(i)Drum is rotating anticlockwise
//T1>T2                       (T1/T2)=e^(mu*theta)
T2=T1/(%e^(mu*theta));
Mcac=(T1-T2)*(d/2);           //maximum braking torquethat can be developed in N

//(i)Drum is rotating clockwise
//T2>T1                       (T2/T1)=e^(mu*theta)
T2=T1*(%e^(mu*theta));
Mcc=(T2-T1)*(d/2);            //maximum braking torquethat can be developed in N

printf(' (i) The Maximum braking torque that can be
```

```
developed in anticlockwise direction is: %3.0f Nm. \n',Mcac);
printf('(ii) The Maximum braking torque that can be developed in clockwise direction is: %3.1f Nm. \n',Mcc);
```

Scilab code Exa 13.11 Example 11

```
clc
clear
//DATA GIVEN
Pt=80;                              //power to be transmitted by the rope in kW
d=1.5;                              //diameter of pulley in m
N=200;                              //speed of the pulley in R.P.M.
alpha=45/2;                         //semi angle of groove in degrees
theta=160;                          //angle of contact in degrees
mu=0.3;                             //coefficient of friction
m=0.6;                              //mass of each rope per unit metre length
Ts=800;                             //safe pull in N

//centrifugal tension, Tc=m*v^2
v=(%pi)*d*N/60;                                  //velocity of the rope in m/s
Tc=m*v^2;

T1=Ts-Tc;                                        //tension in the tight side in N
//(T1/T2)=e^(mu*theta)
```

```
theta=theta*(%pi)/180;                  //theta converted into radians
alpha=alpha*(%pi)/180;                  //alpha converted into radians
T2=T1/(%e^(mu*theta/sin(alpha)));       //tension on the slack side in N
p=(T1-T2)*v;                            //power transmitted by the belt in watts

//no. of ropes required, n=Total power transmitted/Power transmitted by each rope
n=Pt/(p/1000);

//Initial tension in rope, To=(T1+T2+2Tc)/2
To=(T1+T2+2*Tc)/2;

printf(' (i) The Number of ropes required for the drives is: %1.1f say %1.0f. \n',n,n);
printf(' (ii) The Initial tension in the rope, To is: %3.2f N. \n',To);
```

Scilab code Exa 13.12 Example 12

```
clc
clear
//DATA GIVEN
T=72;                       //number of teeth
Pc=26;                      //circular pitch in mm

//circular pitch, Pc=(pi*D)/T
D=Pc*T/(%pi);               //pitch diameter in m
//Pc*Pd=(pi)
Pd=(%pi)/Pc;                //diametral pitch in teeth/mm
// Module, m=D/T
```

```
m=D/T;                      //module in mm/tooth

printf(' (i) The Pitch diameterm, D is: %3.2f mm. \n
   ',D);
printf(' (ii) The Diametral pitch, Pd is: %1.2f
   teeth/mm. \n',Pd);
printf('(iii) The Module,m is: %1.2f mm/tooth. \n',m
   );
```

Scilab code Exa 13.13 Example 13

```
clc
clear
//DATA GIVEN
Ta=40;                      //number of teeth of
   gear A
Tb=100;                     //number of teeth of
   gear B
Tc=50;                      //number of teeth of
   gear C
Td=150;                     //number of teeth of
   gear D
Te=52;                      //number of teeth of
   gear E
Tf=130;                     //number of teeth of
   gear F
Na=1000;                    //speed of the motor
   shaft in R.P.M.

//(Nf/Na)=(Ta/Tb)*(Tc/Td)*(Te/Tf)
Nf=(Ta/Tb)*(Tc/Td)*(Te/Tf)*Na;        //Speed of the
   output shaft in R.P.M.

printf(' The Speed of the output shaft, Nf is: %3.2f
    R.P.M. \n',Nf);
```