Scilab Textbook Companion for
Thermal Engineering
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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Fuels and Combustion

Scilab code Exa 1.1 Minimum mass of air required

```
//Chapter-1, Illustration 1, Page 15
//Title: Fuels and Combustion
//==========================================================================

clc
clear

//INPUT DATA
C=0.91;//Percentage composition of Carbon
H=0.03;//Percentage composition of Hydrogen
O=0.02;//Percentage composition of Oxygen
N=0.008;//Percentage composition of Nitrogen
S=0.008;//Percentage composition of Sulphur

//CALCULATIONS
m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Mass of air per kg of coal in kg

//OUTPUT
mprintf('Minimum mass of air per kg of coal is %3.2f
```

```
kg',m)





//==================================END OF PROGRAM======================================
```

Scilab code Exa 1.2 Theoretical volume of air required

```
//Chapter-1, Illustration 2, Page 16
//Title: Fuels and Combustion
//==========================================================================================

clc
clear

//INPUT DATA
C=0.86;//Percentage composition of Carbon
H=0.12;//Percentage composition of Hydrogen
O=0.01;//Percentage composition of Oxygen
S=0.01;//Percentage composition of Sulphur
v=0.773;//Specific volume of air at N.T.P in (m^3)/kg

//CALCULATIONS
m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Theoretical mass of air per kg of coal in kg
vth=m*v;//Theoretical volume of air at N.T.P per kg fuel in (m^3)/kg of fuel

//OUTPUT
mprintf('Theoretical volume of air at N.T.P per kg
```

```
fuel is %3.2f (m^3)/kg of fuel',vth)





//==========================================END OF PROGRAM==============================================
```

Scilab code Exa 1.3 Minimum quantity of air and Total mass of products of combustion

```
//Chapter-1, Illustration 3, Page 16
//Title: Fuels and Combustion
//=============================================================================================

clc
clear

//INPUT DATA
C=0.78;//Percentage composition of Carbon
H=0.06;//Percentage composition of Hydrogen
O=0.078;//Percentage composition of Oxygen
N=0.012;//Percentage composition of Nitrogen
S=0.03;//Percentage composition of Sulphur

//CALCULATIONS
m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Minimum quantity of air required in kg
mt=((11*C)/3)+(9*H)+(2*S)+(8.32+N);//Total mass of products of combustion in kg

//OUTPUT
mprintf('Minimum quantity of air required for
```

```
complete combustion is %3.2f kg \n Total mass of products of combustion is %3.3f kg',m,mt)





//============================================END OF PROGRAM================================================
```

Scilab code Exa 1.4 Mass of dry flue gas

```
//Chapter-1, Illustration 4, Page 17
//Title: Fuels and Combustion
//==============================================================================================

clc
clear

//INPUT DATA
C=0.84;//Percentage composition of Carbon
H=0.09;//Percentage composition of Hydrogen
CO2=0.0875;//Volumetric composition of CO2
CO=0.0225;//Volumetric composition of CO
O2=0.08;//Volumetric composition of Oxygen
N2=0.81;//Volumetric composition of Nitrogen
M1=44;//Molecular mass of CO2
M2=28;//Molecular mass of CO
M3=32;//Molecular mass of O2
M4=28;//Molecular mass of N2

//CALCULATIONS
c1=CO2*M1;//Proportional mass of CO2
c2=CO*M2;//Proportional mass of CO
```

```
c3=O2*M3;//Proportional mass of O2
c4=N2*M4;//Proportional mass of N2
c=c1+c2+c3+c4;//Total proportional mass of constituents
m1=c1/c;//Mass of CO2 per kg of flue gas in kg
m2=c2/c;//Mass of CO per kg of flue gas in kg
m3=c3/c;//Mass of O2 per kg of flue gas in kg
m4=c4/c;//Mass of N2 per kg of flue gas in kg
d1=m1*100;//Mass analysis of CO2
d2=m2*100;//Mass analysis of CO
d3=m3*100;//Mass analysis of O2
d4=m4*100;//Mass analysis of N2
m=((3*m1)/11)+((3*m2)/7);//Mass of carbon in kg
md=C/m;//Mass of dry flue gas in kg

//OUTPUT
mprintf('Mass of dry flue gases per kg of coal burnt is %3.1f kg',md)





//==============================END OF PROGRAM==============================
```

Scilab code Exa 1.5 Minimum air required and Mass of air actually supplied and Amount of excess air supplied

```
//Chapter-1, Illustration 5, Page 17
//Title: Fuels and Combustion
//==============================================================================
clc
```

```
clear

//INPUT DATA
C=0.624;//Percentage composition of Carbon
H=0.042;//Percentage composition of Hydrogen
O=0.045;//Percentage composition of Oxygen
CO2=0.13;//Volumetric composition of CO2
CO=0.003;//Volumetric composition of CO
O2=0.06;//Volumetric composition of Oxygen
N2=0.807;//Volumetric composition of Nitrogen
M1=44;//Molecular mass of CO2
M2=28;//Molecular mass of CO
M3=32;//Molecular mass of O2
M4=28;//Molecular mass of N2
mw=0.378;//Mass of H2O in kg

//CALCULATIONS
m=(11.5*C)+(34.5*(H-(O/8)));//Minimum air required in kg
c1=CO2*M1;//Proportional mass of CO2
c2=CO*M2;//Proportional mass of CO
c3=O2*M3;//Proportional mass of O2
c4=N2*M4;//Proportional mass of N2
c=c1+c2+c3+c4;//Total proportional mass of constituents
m1=c1/c;//Mass of CO2 per kg of flue gas in kg
m2=c2/c;//Mass of CO per kg of flue gas in kg
m3=c3/c;//Mass of O2 per kg of flue gas in kg
m4=c4/c;//Mass of N2 per kg of flue gas in kg
d1=m1*100;//Mass analysis of CO2
d2=m2*100;//Mass analysis of CO
d3=m3*100;//Mass analysis of O2
d4=m4*100;//Mass analysis of N2
mC=((3*m1)/11)+((3*m2)/7);//Mass of carbon in kg
md=C/mC;//Mass of dry flue gas in kg
mact=(md+mw)-(C+H+O);//Actual air supplied per kg of fuel in kg
me=mact-m;//Mass of excess air per kg of fuel in kg
```

```

//OUTPUT
mprintf('Minimum air required to burn 1 kg of coal is %3.2f kg \n Mass of air actually supplied per kg of coal is %3.3f kg \n Amount of excess air supplied per kg of coal burnt is %3.3f kg',m,mact,me)





//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 1.6 Mass of air to be supplied and Mass of gaseous products

```
//Chapter-1, Illustration 6, Page 19
//Title: Fuels and Combustion
//=============================================================================================================

clc
clear

//INPUT DATA
C=0.78;//Percentage composition of Carbon
H=0.03;//Percentage composition of Hydrogen
O=0.03;//Percentage composition of Oxygen
S=0.01;//Percentage composition of Sulphur
me=0.3;//Mass of excess air supplied

//CALCULATIONS
m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Mass of air
```

```
per kg of coal in kg
mec=me*m;//Excess air supplied per kg of coal in kg
mact=m+mec;//Actual mass of air supplied per kg of coal in kg
mCO2=(11*C)/3;//Mass of CO2 produced per kg of coal in kg
mHw=9*H;//Mass of H2O produced per kg of coal in kg
mSO2=2*S;//Mass of SO2 produced per kg of coal in kg
mO2=0.232*mec;//Mass of excess O2 produced per kg of coal in kg
mN2=0.768*mact;//Mass of N2 produced per kg of coal in kg

//OUTPUT
mprintf('Mass of air to be supplied is %3.2f kg \n Mass of CO2 produced per kg of coal is %3.2f kg \n Mass of H2O produced per kg of coal is %3.2f kg \n Mass of SO2 produced per kg of coal is %3.2f kg \n Mass of excess O2 produced per kg of coal is %3.2f kg \n Mass of N2 produced per kg of coal is %3.2f kg \n',m,mCO2,mHw,mSO2,mO2,mN2)




//==============================END OF PROGRAM==============================
```

Scilab code Exa 1.7 Total mass of dry flue gases and Percentage composition of dry flue gases by volume

```
//Chapter-1, Illustration 7, Page 20
//Title: Fuels and Combustion
//=============================================================================
```

```
clc
clear

//INPUT DATA
C=0.9;//Percentage composition of Carbon
H=0.033;//Percentage composition of Hydrogen
O=0.03;//Percentage composition of Oxygen
N=0.008;//Percentage composition of Nitrogen
S=0.009;//Percentage composition of Sulphur
M1=44;//Molecular mass of CO2
M2=64;//Molecular mass of SO2
M3=32;//Molecular mass of O2
M4=28;//Molecular mass of N2

//CALCULATIONS
m=(11.5*C)+(34.5*(H-(O/8)))+(4.3*S);//Minimum mass of air per kg of coal in kg
mCO2=(11*C)/3;//Mass of CO2 produced per kg of coal in kg
mHw=9*H;//Mass of H2O produced per kg of coal in kg
mSO2=2*S;//Mass of SO2 produced per kg of coal in kg
mt=11.5*1.5;//Total mass of air supplied per kg of coal in kg
me=mt-m;//Excess air supplied in kg
mO2=0.232*me;//Mass of excess O2 produced per kg of coal in kg
mN2=0.768*mt;//Mass of N2 produced per kg of coal in kg
mtN2=mN2+N;//Total mass of Nitrogen in exhaust in kg
md=mCO2+mSO2+mO2+mtN2;//Total mass of dry flue gases per kg of fuel in kg
CO2=(mCO2/md)*100;//Percentage composition of CO2 by mass in percent
SO2=(mSO2/md)*100;//Percentage composition of SO2 by mass in percent
O2=(mO2/md)*100;//Percentage composition of O2 by mass in percent
```

```
N2=(mN2/md)*100;//Percentage composition of N2 by mass in percent
c1=CO2/M1;//Proportional volume of CO2
c2=SO2/M2;//Proportional volume of SO2
c3=O2/M3;//Proportional volume of O2
c4=N2/M4;//Proportional volume of N2
c=c1+c2+c3+c4;//Total proportional volume of constituents
m1=c1/c;//Volume of CO2 in 1 (m^3) of flue gas
m2=c2/c;//Volume of SO2 in 1 (m^3) of flue gas
m3=c3/c;//Volume of O2 in 1 (m^3) of flue gas
m4=c4/c;//Volume of N2 in 1 (m^3) of flue gas
d1=m1*100;//Volume analysis of CO2
d2=m2*100;//Volume analysis of SO2
d3=m3*100;//Volume analysis of O2
d4=m4*100;//Volume analysis of N2

//OUTPUT
mprintf('Minimum mass of air required is %3.1f kg \n Total mass of dry flue gases per kg of fuel is %3.2f kg \n Percentage composition of CO2 by volume is %3.2f percent \n Percentage composition of SO2 by volume is %3.3f percent \n Percentage composition of O2 by volume is %3.1f percent \n Percentage composition of N2 by volume is %3.2f percent',m,md,d1,d2,d3,d4)






//=================================END OF PROGRAM=====================================
```

Scilab code Exa 1.8 Mass of air actually supplied and Percentage of excess air supplied

```
//Chapter-1, Illustration 8, Page 21
//Title: Fuels and Combustion
//

clc
clear

//INPUT DATA
C=0.88;//Percentage composition of Carbon
H=0.036;//Percentage composition of Hydrogen
O=0.048;//Percentage composition of oxygen
CO2=0.109;//Volumetric composition of CO2
CO=0.01;//Volumetric composition of CO
O2=0.071;//Volumetric composition of Oxygen
N2=0.81;//Volumetric composition of Nitrogen
M1=44;//Molecular mass of CO2
M2=28;//Molecular mass of CO
M3=32;//Molecular mass of O2
M4=28;//Molecular mass of N2

//CALCULATIONS
m=(11.5*C)+(34.5*(H-(O/8)));//Theoretical air required in kg
c1=CO2*M1;//Proportional mass of CO2
c2=CO*M2;//Proportional mass of CO
c3=O2*M3;//Proportional mass of O2
c4=N2*M4;//Proportional mass of N2
c=c1+c2+c3+c4;//Total proportional mass of constituents
m1=c1/c;//Mass of CO2 per kg of flue gas in kg
m2=c2/c;//Mass of CO per kg of flue gas in kg
m3=c3/c;//Mass of O2 per kg of flue gas in kg
m4=c4/c;//Mass of N2 per kg of flue gas in kg
mC=((3*m1)/11)+((3*m2)/7);//Mass of carbon in kg
```

```
md=C/mC;//Mass of dry flue gas in kg
hc=H*9;//Hydrogen combustion in kg of H2O
mair=(md+hc)-(C+H+O);//Mass of air supplied per kg of coal in kg
me=mair-m;//Excess air per kg of coal in kg
mN2=m4*md;//Mass of nitrogen per kg of coal in kg
mact=mN2/0.768;//Actual mass of air per kg of coal in kg
pe=(me/m)*100;//Perccentage excess air in percent

//OUTPUT
mprintf('Mass of air actually supplied per kg of coal is %3.2f kg \n Percentage of excess air is %3.2f percent',mact,pe)








//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 1.9 Mass of excess air supplied and air fuel ratio

```
//Chapter-1, Illustration 9, Page 22
//Title: Fuels and Combustion
//==============================================================================================================

clc
clear

//INPUT DATA
```

```
C=0.84;//Percentage composition of Carbon
H=0.14;//Percentage composition of Hydrogen
O=0.02;//Percentage composition of oxygen
CO2=8.85;//Volumetric composition of CO2
CO=1.2;//Volumetric composition of CO
O2=6.8;//Volumetric composition of Oxygen
N2=83.15;//Volumetric composition of Nitrogen
M1=44;//Molecular mass of CO2
M2=28;//Molecular mass of CO
M3=32;//Molecular mass of O2
M4=28;//Molecular mass of N2
a=8/3;//O2 required per kg C
b=8;//O2 required per kg H2
mair=0.23;//Mass of air

//CALCULATIONS
c=C*a;//O2 required per kg of fuel for C
d=H*b;//O2 required per kg of fuel for H2
tO2=c+d+O;//Theoreticcal O2 required in kg/kg of fuel
tm=tO2/mair;//Theoretical mass of air in kg/kg of fuel
c1=CO2*M1;//Proportional mass of CO2 by Volume
c2=CO*M2;//Proportional mass of CO by Volume
c3=O2*M3;//Proportional mass of O2 by Volume
c4=N2*M4;//Proportional mass of N2 by Volume
c=c1+c2+c3+c4;//Total proportional mass of constituents
m1=c1/c;//Mass of CO2 per kg of flue gas in kg
m2=c2/c;//Mass of CO per kg of flue gas in kg
m3=c3/c;//Mass of O2 per kg of flue gas in kg
m4=c4/c;//Mass of N2 per kg of flue gas in kg
mC=((m1*12)/M1)+((m2*12)/M2);//Mass of carbon per kg of dry flue gas in kg
md=C/mC;//Mass of dry flue per kg of fuel in kg
p=(4*m2)/7;//Oxygen required to burn CO in kg
meO2=md*(m3-p);//Mass of excess O2 per kg of fuel in kg
```

```
me=meO2/mair;//Mass of excess air in kg/kg fuel
mt=tm+me;//Total air required per kg fuel

//OUTPUT
mprintf('Mass of excess air supplied per kg of fuel burnt is %3.1f kg/kg of fuel \n Air-fuel ratio is %3.1f:1',me,mt)





//==================================================END OF PROGRAM======================================================
```

Scilab code Exa 1.10 Volume of air required

```
//Chapter-1, Illustration 10, Page 23
//Title: Fuels and Combustion
//=============================================================================================================

clc
clear

//INPUT DATA
H2=0.27;//Percentage composition of H2 by volume
CO2=0.18;//Percentage composition of CO2 by volume
CO=0.125;//Percentage composition of CO by volume
CH4=0.025;//Percentage composition of CH4 by volume
N2=0.4;//Percentage composition of N2 by volume

//CALCULATIONS
v=(2.38*(H2+CO))+(9.52*CH4);//Volume of air required for complete combustion in (m^3)
```

```

//OUTPUT
mprintf('Volume of air required for complete combustion is %3.3f (m^3)',v)






//==============================END OF PROGRAM==============================
```

Scilab code Exa 1.11 Air fuel ratio

```
//Chapter-1, Illustration 11, Page 24
//Title: Fuels and Combustion
//==========================================================================================

clc
clear

//INPUT DATA
H2=0.5;//Percentage composition of H2 by volume
CO2=0.1;//Percentage composition of CO2 by volume
CO=0.05;//Percentage composition of CO by volume
CH4=0.25;//Percentage composition of CH4 by volume
N2=0.1;//Percentage composition of N2 by volume
pCO2=8;//Percentage volumetric analysis of CO2
pO2=6;//Percentage volumetric analysis of O2
pN2=86;//Percentage volumetric analysis of N2


//CALCULATIONS
```

```
v=(2.38*(H2+CO))+(9.52*CH4);//Volume of air required for complete combustion in (m^3)
vN2=v*0.79;//Volume of nitrogen in the air in m^3
a=CO+CH4+CO2;//CO2 formed per m^3 of fuel gas burnt
b=vN2+N2;//N2 formed per m^3 of fuel gas burnt
vt=a+b;//Total volume of dry flue gas formed in m^3
ve=(pO2*vt)/(21-pO2);//Excess air supplied in m^3
V=v+ve;//Total quantity of air supplied in m^3

//OUTPUT
mprintf('Air-fuel ratio by volume is %3.3f:1',V)




//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 1.12 Volume and analysis of products of combustion

```
//Chapter-1, Illustration 12, Page 24
//Title: Fuels and Combustion
//=============================================================================================================

clc
clear

//INPUT DATA
H2=0.14;//Percentage composition of H2 by volume
CO2=0.05;//Percentage composition of CO2 by volume
CO=0.22;//Percentage composition of CO by volume
CH4=0.02;//Percentage composition of CH4 by volume
O2=0.02;//Percentage composition of O2 by volume
N2=0.55;//Percentage composition of N2 by volume
```

```
e=0.4;//Excess air supplied
//CALCULATIONS
v=(2.38*(H2+CO))+(9.52*CH4)-(4.76*O2);//Volume of air required for complete combustion in (m^3)
ve=v*e;//Volume of excess air supplied in m^3
vtN2=v-(v*0.21);//Volume of N2 in theoretical air in m^3
veN2=ve-(ve*0.21);//Volume of N2 in excess air in m^3
vt=vtN2+veN2;//Total volume of N2 in air supplied in m^3
vCO2=CO+CH4+CO2;//CO2 formed per m^3 of fuel gas
vN2=vt+N2;//N2 formed per m^3 of fuel gas
veO2=ve*0.21;//Volume of excess O2 per m^3 of fuel gas
vT=vCO2+vN2+veO2;//Total volume of dry combustion products
pCO2=(vCO2*100)/vT;//Percentage volume of CO2
pN2=(vN2*100)/vT;//Percentage volume of N2
pO2=(veO2*100)/vT;//Percentage volume of O2

//OUTPUT
mprintf('Volume of air required for complete combustion is %3.3f (m^3) \n Volume of CO2 per m^3 of gas fuel is %3.2f m^3/m^3 of gas fuel \n Volume of N2 per m^3 of gas fuel is %3.3f m^3/m^3 of gas fuel \n Volume of excess O2 per m^3 of gas fuel is %3.2f m^3/m^3 of gas fuel \n Total volume of dry combustion products is %3.3f m^3/m^3 of gas fuel \n Percentage volume of CO2 is %3.1f percent \n Percentage volume of N2 is %3.2f percent \n Percentage volume of O2 is %3.2f percent',v,vCO2,vN2,veO2,vT,pCO2,pN2,pO2)





```

```




//======================================================END OF PROGRAM
   ============================================================
```

Chapter 2

Gas Power Cycles

Scilab code Exa 2.1 Maximum pressure and temperature of cycle and Cycle efficiency and Mean effective pressure

```
//Chapter-2, Illustration 1, Page 55
//Title: Gas Power Cycles
//==============================================================================

clc
clear

//INPUT DATA
P1=0.1;//Pressure of air supplied in MPa
T1=308;//Temperature of air supplied in K
rv=8;//Compression ratio
q1=2100;//Heat supplied in kJ/kg
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K
Cv=0.718;//Specific heat at constant volume in kJ/kg-K
R=0.287;//Universal gas constant in kJ/kg-K

//CALCULATIONS
```

```
y=Cp/Cv;//Ratio of specific heats
n=(1-(1/(rv^(y-1))))*100;//Cycle efficiency
v1=(R*T1)/(P1*1000);//Specific volume at point 1 in (m^3)/kg
v2=v1/rv;//Specific volume at point 2 in (m^3)/kg
T2=T1*(rv^(y-1));//Temperature at point 2 in K
T3=(q1/Cv)+T2;//Temperature at point 3 in K
P2=P1*(rv^y);//Pressure at point 2 in MPa
P3=P2*(T3/T2);//Pressure at point 3 in MPa
wnet=(q1*n)/100;//Net workdone in J/kg
MEP=(wnet/(v1-v2))/1000;//Mean effective pressure in MPa

//OUTPUT
mprintf('Maximum pressure of the cycle is %3.3f MPa \n Maximum temperature of the cycle is %3.0f K \n Cycle efficiency is %3.1f percent \n Mean effective pressure is %3.3f MPa',P3,T3,n,MEP)





//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 2.2 Relative efficiency of engine

```
//Chapter-2, Illustration 2, Page 57
//Title: Gas Power Cycles
//==============================================================================================================

clc
clear
```

```

//INPUT DATA
d=80;//Bore in mm
L=85;//Stroke in mm
Vc=0.06;//Clearance volume in litre
n=0.22;//Actual thermal efficiency
y=1.4;//Ratio of specific heats

//CALCULATIONS
Vs=(3.147/4)*(d^2)*L;//Stroke volume in mm^3
Vt=Vs+(Vc*(10^6));//Total volume in mm^3
rv=Vt/(Vc*(10^6));//Compression ratio
ni=(1-(1/(rv^(y-1))));//Ideal thermal efficiency
nr=(n/ni)*100;//Relative efficiency

//OUTPUT
mprintf('Relative efficiency of the engine is %3.1f
   percent',nr)







//==============================END OF PROGRAM
   =================================
```

Scilab code Exa 2.3 Air standard efficiency

```
//Chapter-2, Illustration 3, Page 57
//Title: Gas Power Cycles
//
   ================================================================
```

```
clc
clear

//INPUT DATA
d=0.137;//Bore in m
L=0.13;//Stroke in m
Vc=280*(10^-6);//Clearance volume in m^3
y=1.4;//Ratio of specific heats

//CALCULATIONS
Vs=(3.147/4)*(d^2)*L;//Stroke volume in m^3
rv=(Vc/Vs)*100;//Compression ratio
rvf=(Vs+Vc)/Vc;//final compression ratio
n=(1-(1/rvf^(y-1)))*100;//Cycle efficiency

//OUTPUT
mprintf('Clearance volume is %3.1f percent of swept
   volume \n Otto cycle efficiency is %3.2f percent'
   ,rv,n)






//==================================END OF PROGRAM
   ======================================
```

Scilab code Exa 2.4 Highest temperature and pressure in cycle and Amount of heat transferred and Thermal efficiency and Mean effective pressure

```
//Chapter-2, Illustration 4, Page 58
//Title: Gas Power Cycles
//
   ========================================================================
```

```
clc
clear

//INPUT DATA
rv=9.5;//Compression ratio
P1=100;//Air pressure in kPa
T1=290;//Air temperature in K
V1=600*(10^-6);//Volume of air in m^3
T4=800;//Final temperature in K
R=287;//Universal gas constan in J/kg.K
Cv=0.718;//Specific heat at constant volume in kJ/kg.K
y=1.4;//Ratio of specific heats

//CALCULATIONS
T3=T4*(rv^(y-1));//Temperature at the end of constant volume heat addition in K
P2=P1*(rv^y);//Pressure at point 2 in kPa
T2=T1*(rv^(y-1));//Temperature at point 2 in K
P3=P2*(T3/T2);//Pressure at point 3 in kPa
m=(P1*1000*V1)/(R*T1);//Specific mass in kg/s
Q=m*Cv*(T3-T2);//Heat transferred in kJ
n=(1-(1/rv^(y-1)))*100;//Thermal efficiency
Wnet=(n*Q)/100;//Net workdone in kJ
MEP=Wnet/(V1*(1-(1/rv)));//Mean effective pressure in kPa

//OUTPUT
mprintf('Maximum pressure of the cycle is %3.2f kPa \n Maximum temperature of the cycle is %3.1f K \n Amount of heat transferred is %3.2f kJ \n Thermal efficiency is %3.1f percent \n Mean effective pressure is %3.1f kPa',P3,T3,Q,n,MEP)
```

```



//==================================================END OF PROGRAM
    =======================================================
```

Scilab code Exa 2.5 Pressure and Temperature at the end of heat addition process and Net work output and Thermal efficiency and Mean effective pressure

```
//Chapter-2, Illustration 5, Page 60
//Title: Gas Power Cycles
//
    ==========================================================================================================

clc
clear

//INPUT DATA
rv=8;//Compression ratio
P1=95;//Pressure at point 1 in kPa
T1=300;//Temperature at point 1 in K
q23=750;//Heat transferred during constant volume
    heat addition process in kJ/kg
y=1.4;//Ratio of specific heats
Cv=0.718;//Specific heat at constant volume in kJ/kg
   -K
R=287;//Universal gas constant in J/kg-K

//CALCULATIONS
T2=T1*(rv^(y-1));//Temperature at point 2 in K
P2=P1*(rv^y);//Pressure at point 2 in kPa
T3=(q23/Cv)+T2;//Temperature at point 3 in K
P3=P2*(T3/T2);//Pressure at point 3 in kPa
nth=(1-(1/(rv^(y-1))))*100;//Thermal efficiency
```

```
Wnet=(nth*q23)/100;//Net work output in kJ/kg
v1=(R*T1)/(P1*1000);//Speific volume at point 1 in (m^3)/kg
MEP=Wnet/(v1*(1-(1/rv)));//Mean effective pressure in kPa

//OUTPUT
mprintf('Pressure at the end of heat addition process is %3.1f kPa \n Temperature at the end of heat addition process is %3.1f K \n Net work output is %3.2f kJ/kg \n Thermal efficiency is %3.2f percent \n Mean effective pressure is %3.0f kPa',P3,T3,Wnet,nth,MEP)








//==============================END OF PROGRAM==================================
```

Scilab code Exa 2.6 Air standard efficiency

```
//Chapter-2, Illustration 6, Page 61
//Title: Gas Power Cycles
//==========================================================================

clc
clear

//INPUT DATA
rv=14;//Compression ratio
```

```
c=0.06;//Cut-off percentage
y=1.4;//Ratio of specific heats

//CALCULATIONS
rc=1.78;//Cut-off ratio
nth=(1-(((rc^y)-1)/((rv^(y-1))*y*(rc-1))))*100;//Thermal efficiency

//OUTPUT
mprintf('Air standard efficiency is %3.1f percent',nth)







//==================================END OF PROGRAM====================================
```

Scilab code Exa 2.7 Cutoff ratio and Heat supplied and Cycle efficiency and MEP

```
//Chapter-2, Illustration 7, Page 62
//Title: Gas Power Cycles
//=============================================================================

clc
clear

//INPUT DATA
rv=16;//Compression ratio
P1=0.1;//Pressure at point 1 in MPa
```

```
T1=288;//Temperature at point 1 in K
T3=1753;//Temperature at point 3 in K
y=1.4;//Ratio of specific heats
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K
R=0.287;//Universal gas constant in kJ/kg-K

//CALCULATIONS
T2=T1*(rv^(y-1));//Temperature at point 2 in K
rc=T3/T2;//Cut-off ratio
q1=Cp*(T3-T2);//Heat supplied in kJ/kg
nth=(1-((((rc^y)-1)/((rv^(y-1))*y*(rc-1)))))*100;//Cycle efficiency
wnet=(q1*nth)/100;//Net work done in kJ/kg
v1=(R*T1)/(P1*1000);//Speific volume at point 1 in (m^3)/kg
v2=v1/rv;//Speific volume at point 2 in (m^3)/kg
MEP=wnet/(v1-v2);//Mean effective pressure in kPa

//OUTPUT
mprintf('Cut-off ratio is %3.2f \n Heat supplied is %3.1f kJ/kg \n Cycle efficiency is %3.1f percent \n Mean effective pressure is %3.2f kPa',rc,q1,nth,MEP)




//==================================END OF PROGRAM==================================
```

Scilab code Exa 2.8 Air standard efficiency and percentage loss in efficiency

```
//Chapter-2, Illustration 8, Page 64
```

```
//Title: Gas Power Cycles
//

clc
clear

//INPUT DATA
d=0.15;//Bore in m
L=0.25;//Stroke in m
Vc=400*(10^-6);//Clearance volume in m^3
V2=Vc;//Clearance volume in m^3
c1=0.05;//Cut-off percentage 1
c2=0.08;//Cut-off percentage 2
y=1.4;//Ratio of specific heats

//CALCULATIONS
Vs=(3.147/4)*(d^2)*L;//Stroke volume in m^3
V31=V2+(c1*Vs);//Volume at the point of cut-off in m^3
rc1=V31/V2;//Cut-off ratio 1
rv=(Vc+Vs)/Vc;//Compression ratio
nth1=(1-(((rc1^y)-1)/((rv^(y-1))*y*(rc1-1))))*100;//Air standard efficiency 1
V32=V2+(c2*Vs);//Volume at the point of cut-off in m^3
rc2=V32/V2;//Cut-off ratio 2
nth2=(1-(((rc2^y)-1)/((rv^(y-1))*y*(rc2-1))))*100;//Air standard efficiency 2
pl=nth1-nth2;//Percentage loss in efficiency

//OUTPUT
mprintf('Air standard efficiency at 5 percent cut-off is %3.2f percent \n Air standard efficiency at 8 percent cut-off is %3.2f percent \n Percentage loss in efficiency is %3.2f percent',nth1,nth2,pl)

```

```
//====================================================END OF PROGRAM
    ================================================
```

Scilab code Exa 2.9 Maximum temperature and Thermal efficiency of cycle

```
//Chapter-2, Illustration 9, Page 65
//Title: Gas Power Cycles
//
    ====================================================================================================

clc
clear

//INPUT DATA
e=7.5;//Expansion ratio
c=15;//Compression ratio
P1=98;//Pressure at point 1 in kN/(m^2)
P4=258;//Pressure at point 4 in kN/(m^2)
T1=317;//Temperature at point 1 in K
y=1.4;//Ratio of specific heats

//CALCULATIONS
T4=T1*(P4/P1);//Temperature at point 4 in K
T3=T4*(e^(y-1));//Temperature at point 3 in K
t3=T3-273;//Temperature at point 3 in oC
T2=T1*(c^(y-1));//Temperature at point 2 in K
n=(1-((T4-T1)/(y*(T3-T2))))*100;//Thermal efficiency

//OUTPUT
mprintf('Maximum temperature attained during the
```

```
cycle is %3.1f oC \n Thermal efficiency of the cycle is %3.1f percent',t3,n)






//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 2.10 Thermal efficiency and MEP

```
//Chapter-2, Illustration 10, Page 66
//Title: Gas Power Cycles
//==================================================================================================================

clc
clear

//INPUT DATA
rv=20;//Compression ratio
P1=95;//Pressure at point 1 in kPa
T1=293;//Temperature at point 1 in K
T3=2200;//Temperature at point 3 in K
y=1.4;//Ratio of specific heats
R=287;//Universal gas constant in J/kg-K
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K

//CALCULATIONS
P2=P1*(rv^y);//Pressure at point 2 in kPa
T2=T1*(rv^(y-1));//Temperature at point 2 in K
v2=(R*T2)/(P2*1000);//Specific volume at point 2 in
```

```
(m^3)/kg
v3=v2*(T3/T2);//Specific volume at point 3 in (m^3)/kg
rc=v3/v2;//Cut-off ratio
nth=(1-(((rc^y)-1)/((rv^(y-1))*y*(rc-1))))*100;//Thermal efficiency
q23=Cp*(T3-T2);//Heat flow between points 2 and 3 in kJ/kg
wnet=(nth*q23)/100;//Net workdone in kJ/kg
MEP=wnet/(v2*(rv-1));//Mean effective pressure in kPa

//OUTPUT
mprintf('Thermal efficiency is %3.1f percent \n Mean effective pressure is %3.2f kPa',nth,MEP)






//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 2.11 Cutoff ratio and air standard efficiency

```
//Chapter-2, Illustration 11, Page 68
//Title: Gas Power Cycles
//==============================================================================================================

clc
clear

//INPUT DATA
```

```
rv=21;//Compression ratio
re=10.5;//Expansion ratio
y=1.4;//Ratio of specific heats

//CALCULATIONS
rc=rv/re;//Cut-off ratio
nth=(1-(((rc^y)-1)/((rv^(y-1))*y*(rc-1))))*100;//Air standard efficiency

//OUTPUT
mprintf('Cut-off ratio is %3.0f \n Air standard efficiency is %3.2f percent',rc,nth)









//==============================END OF PROGRAM==============================
```

Scilab code Exa 2.12 Ideal efficiency of cycle

```
//Chapter-2, Illustration 12, Page 69
//Title: Gas Power Cycles
//==============================================================================

clc
clear

//INPUT DATA
rv=16;//Compression ratio
```

```
rp=1.5;//Pressure ratio
y=1.4;//Ratio of specific heats
cp=8;//Cut-off percentage

//CALCULATIONS
rc=2.2;//Cut-off ratio
ntd=(1-((rp*(rc^y)-1)/((rv^(y-1)*((rp-1)+(y*rp*(rc-1)))))))*100;//Dual cycle efficiency

//OUTPUT
mprintf('Ideal efficiency of engine is %3.1f percent',ntd)






//==============================END OF PROGRAM==================================
```

Scilab code Exa 2.13 Ideal efficiency of engine

```
//Chapter-2, Illustration 13, Page 69
//Title: Gas Power Cycles
//=============================================================================

clc
clear

//INPUT DATA
d=0.2;//Bore in m
L=0.5;//Stroke in m
c=0.06;//Cut-off percentage
```

```
y=1.4;//Ratio of specific heats
rv=15;//Compression ratio
rp=1.4;//Pressure ratio

//CALCULATIONS
Vs=(3.147/4)*(d^2)*L;//Stroke volume in m^3
DV=c*Vs;//Difference in volumes at points 4 and 3
V3=Vs/(rv-1);//Specific volume at point 3 in m^3
V4=V3+DV;//Specific volume at point 4 in m^3
rc=V4/V3;//Cut-off ratio
ntd=(1-((rp*(rc^y)-1)/((rv^(y-1)*((rp-1)+(y*rp*(rc-1)))))))*100;//Ideal efficiency

//OUTPUT
mprintf('Ideal efficiency of the engine is %3.1f percent',ntd)






//==============================END OF PROGRAM==============================
```

Scilab code Exa 2.14 Amount of heat added and rejected and Work done and Thermal efficiency

```
//Chapter-2, Illustration 14, Page 70
//Title: Gas Power Cycles
//==============================================================================
clc
clear

```

```
//INPUT DATA
d=0.2;//Bore in m
L=0.3;//Stroke in m
c=0.04;//Cut-off percentage
y=1.4;//Ratio of specific heats
rv=8;//Compression ratio
P1=1;//Pressure at point 1 in bar
P3=60;//Pressure at point 3 in bar
T1=298;//Temperature at point 1 in K
R=287;//Universal gas constant in J/kg
Cv=0.718;//Speific heat at constant volume in kJ/kg-K
Cp=1.005;//Speific heat at constant pressure in kJ/kg-K

//CALCULATIONS
Vs=(3.147/4)*(d^2)*L;//Stroke volume in m^3
V2=Vs/(rv-1);//Specific volume at point 2 in m^3
V3=V2;//Specific volume at point 3 in m^3
V1=V2+Vs;//Specific volume at pont 1 in m^3
V5=V1;//Specific volume at pont 5 in m^3
P2=P1*(rv^y);//Pressure at point 2 in bar
T2=T1*(rv^(y-1));//Temperature at point 2 in K
T3=T2*(P3/P2);//Temperature at point 3 in K
V4=V3+(c*(V1-V2));//Specific volume at point 4 in m^3
T4=T3*(V4/V3);//Temperature at point 4 in K
T5=T4*((V4/V5)^(y-1));//Temperature at point 5 in K
q1=(Cv*(T3-T2))+(Cp*(T4-T3));//Heat added in kJ/kg
q2=Cv*(T5-T1);//Heat rejected in kJ/kg
nth=(1-(q2/q1))*100;//Thermal efficiency
m=(P1*V1*(10^5))/(R*T1);//Mass of air supplied in kg
W=m*(q1-q2);//Workdone in kJ/cycle

//OUTPUT
mprintf('Amount of heat added is %3.1f kJ/kg \n Amount of heat rejected is %3.2f kJ/kg \n Workdone per cycle is %3.2f kJ/cycle \n Thermal
```

```
     efficiency is %3.2f percent',q1,q2,W,nth)







//=========================================END OF PROGRAM
    =============================================
```

Scilab code Exa 2.15 MEP and Thermal efficiency

```
//Chapter-2, Illustration 15, Page 72
//Title: Gas Power Cycles
//
    ==========================================================================================

clc
clear

//INPUT DATA
P1=1;//Pressure at point 1 in bar
P3=70;//Pressure at point 3 in bar
T1=310;//Temperature at point 1 in K
rv=10;//Compression ratio
y=1.4;//Ratio of specific heats
qin=2805;//Heat added in kJ/kg
m=1;//Mass of air in kg
R=287;//Universal gas constant in J/kg
Cv=0.718;//Speific heat at constant volume in kJ/kg-
    K
Cp=1.005;//Speific heat at constant pressure in kJ/
    kg-K

```

```
//CALCULATIONS
V1=(m*R*T1)/(P1*(10^5));//Volume at point 1 in m^3
T2=T1*(rv^(y-1));//Temperature at point 2 in K
P2=P1*(rv^y);//Pressure at point 2 in K
T3=T2*(P3/P2);//Temperature at point 3 in K
q23=Cv*(T3-T2);//Heat supplied at constant volume in kJ/kg
q34=qin-q23;//Heat supplied at constant pressure in kJ/kg
T4=(q34/Cp)+T3;//Temperature at point 4 in K
V2=V1/rv;//Volume at point 2 in m^3
V4=V2*(T4/T3);//Volume at point 4 in m^3
V5=V1;//Volume at point 5 in m^3
T5=T4*((V4/V5)^(y-1));//Temperature at point 5 in K
qout=Cv*(T5-T1);//Heat rejected in kJ/kg
nth=(1-(qout/qin))*100;//Thermal efficiency
W=qin-qout;//Workdone in kJ/kg
Vs=V1*(1-(1/rv));//Swept volume in (m^3)/kg
MEP=(W/Vs)/100;//Mean effective pressure in bar

//OUTPUT
mprintf('Mean effective pressure is %3.2f bar \n Thermal efficiency is %3.2f percent',MEP,nth)






//============================================================END OF PROGRAM==================================================================
```

Scilab code Exa 2.16 Cycle efficiency and Heat supplied and rejected and Work output and Turbine exit temperature

```
//Chapter-2, Illustration 16, Page 74
//Title: Gas Power Cycles
//

clc
clear

//INPUT DATA
P1=1;//Pressure at point 1 in bar
T1=298;//Temperature at point 1 in K
P2=3;//Pressure at point 2 in bar
T3=923;//Temperature at point 3 in K
y=1.4;//Ratio of specific heats
Cp=1.005;//Speific heat at constant pressure in kJ/kg-K

//CALCULATIONS
x=(y-1)/y;//Ratio
rp=P2/P1;//Pressure ratio
nth=(1-(1/(rp^x)))*100;//Cycle efficiency
T2=T1*(rp^x);//Temperature at point 2 in K
q1=Cp*(T3-T2);//Heat supplied in kJ/kg
Wout=(nth*q1)/100;//Work output in kJ/kg
q2=q1-Wout;//Heat rejected in kJ/kg
T4=T3*((1/rp)^x);//Temperature at point 4 in K

//OUTPUT
mprintf('Cycle efficiency is %3.2f percent \n Heat supplied to air is %3.1f kJ/kg \n Work available at the shaft is %3.2f kJ/kg \n Heat rejected in the cooler is %3.2f kJ/kg \n Turbine exit temperature is %3.2f K',nth,q1,Wout,q2,T4)
```

```

//==========================================================END OF PROGRAM==============================================================
```

Scilab code Exa 2.17 Pressure ratio and Maximum net specific work output and Thermal efficiency and Work ratio and Carnot efficiency

```
//Chapter-2, Illustration 17, Page 75
//Title: Gas Power Cycles
//=============================================================================================================================

clc
clear

//INPUT DATA
T1=283;//Temperature at point 1 in K
T3=1353;//Temperature at point 3 in K
y=1.41;//Ratio of specific heats
Cp=1.007;//Specific heat constant pressure in kJ/kg-K

//CALCULATIONS
x=(y-1)/y;//Ratio
rpmax=((T3/T1)^(1/x));//Maximum pressure ratio
rpopt=sqrt(rpmax);//Optimum pressure ratio
T2=T1*(rpopt^x);//Temperature at point 2 in K
T4=T2;//Maximum temperature at point 4 in K
Wmax=Cp*((T3-T4)-(T2-T1));//Maximum net specific work output in kJ/kg
nth=(Wmax/(Cp*(T3-T2)))*100;//Thermal efficiency
WR=nth/100;//Work ratio
nc=((T3-T1)/T3)*100;//Carnot efficiency

//OUTPUT
```

```
mprintf('Optimum pressure ratio is %3.2f \n Maximum net specific work output %3.0f kJ/kg \n Thermal efficiency %3.0f percent \n Work ratio is %3.2f \n Carnot efficiency is %3.0f percent',rpopt,Wmax,nth,WR,nc)






//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 2.18 Maximum work output and Cycle efficiency and Comparison with carnot efficiency

```
//Chapter-2, Illustration 18, Page 76
//Title: Gas Power Cycles
//=============================================================================================================

clc
clear

//INPUT DATA
Tmin=300;//Minimum temperature in K
Tmax=1073;//Maximum temperature in K
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K

//CALCULATIONS
Wmax=Cp*((sqrt(Tmax)-sqrt(Tmin))^2);//Maximum work output in kJ/kg
nB=(1-sqrt(Tmin/Tmax))*100;//Brayton cycle
```

```
efficiency
nC=(1-(Tmin/Tmax))*100;//Carnot efficiency
r=nB/nC;//Ratio of brayton cycle efficiency to carnot efficieny

//OUTPUT
mprintf('Maximum work per kg of air is %3.2f kJ/kg \n Cycle efficiency is %3.0f percent \n Ratio of brayton cycle efficiency to carnot efficieny is %3.3f',Wmax,nB,r)






//==================================END OF PROGRAM======================================
```

Scilab code Exa 2.19 Net power output and Thermal efficiency and Work ratio

```
//Chapter-2, Illustration 19, Page 77
//Title: Gas Power Cycles
//=============================================================================================

clc
clear

//INPUT DATA
T1=291;//Temperature at point 1 in K
P1=100;//Pressure at point 1 in kN/(m^2)
nC=0.85;//Isentropic efficiency of compressor
nT=0.88;//Isentropic effficiency of turbine
```

```
rp=8;//Pressure ratio
T3=1273;//Temperature at point 3 in K
m=4.5;//Mass flow rate of air in kg/s
y=1.4;//Ratio of speciifc heats
Cp=1.006;//Specific heat at constant pressure in kJ/kg-K

//CALCULATIONS
x=(y-1)/y;//Ratio
T2s=T1*(rp^x);//Temperature at point 2s in K
T2=T1+((T2s-T1)/nC);//Temperature at point 2 in K
t2=T2-273;//Temperature at point 2 in oC
T4s=T3*((1/rp)^x);//Temperature at point 4s in K
T4=T3-((T3-T4s)*nT);//Temperature at point 4 in K
t4=T4-273;//Temperature at point 4 in oC
W=m*Cp*((T3-T4)-(T2-T1));//Net power output in kW
nth=(((T3-T4)-(T2-T1))/(T3-T2))*100;//Thermal efficiency
WR=W/(m*Cp*(T3-T4));//Work ratio

//OUTPUT
mprintf('Net power output of the turbine is %3.0f kW \n Thermal efficiency of the plant is %3.0f percent \n Work ratio is %3.3f',W,nth,WR)







//==============================END OF PROGRAM==============================
```

Scilab code Exa 2.20 Percentage increase in cycle efficiency

```
//Chapter-2, Illustration 20, Page 79
//Title: Gas Power Cycles
//
    ============================================================================

clc
clear

//INPUT DATA
P1=0.1;//Pressure at point 1 in MPa
T1=303;//Temperature at point 1 in K
T3=1173;//Temperature at point 3 in K
rp=6;//Pressure ratio
nC=0.8;//Compressor efficiency
nT=nC;//Turbine efficiency
e=0.75;//Regenerator effectiveness
y=1.4;//Ratio of specific heats
Cp=1.005;//Specific heat at constant pressure in kJ/
    kg-K

//CALCULATIONS
x=(y-1)/y;//Ratio
T2s=T1*(rp^x);//Temperature at point 2s in K
T4s=T3/(rp^x);//Temperature at point 4s in K
DTa=(T2s-T1)/nC;//Difference in temperatures at
    point 2 and 1 in K
DTb=(T3-T4s)*nT;//Difference in temperatures at
    point 3 and 4 in K
wT=Cp*DTb;//Turbine work in kJ/kg
wC=Cp*DTa;//Compressor work in kJ/kg
T2=DTa+T1;//Temperature at point 2 in K
q1=Cp*(T3-T2);//Heat supplied in kJ/kg
nth1=((wT-wC)/q1)*100;//Cycle efficiency without
    regenerator
T4=T3-DTb;//Temperature at point 4 in K
T5=T2+(e*(T4-T2));//Temperature at point 5 in K
q2=Cp*(T3-T5);//Heat supplied with regenerator in kJ
    /kg
```

```
nth2=((wT-wC)/q2)*100;//Cycle efficiency with regenerator
p=((nth2-nth1)/nth1)*100;//Percentage increase due to regeneration

//OUTPUT
mprintf('Percentage increase in the cycle efficiency due to regeneration is %3.2f percent',p)








//==================================END OF PROGRAM======================================
```

Scilab code Exa 2.21 Velocity of air leaving nozzle

```
//Chapter-2, Illustration 21, Page 80
//Title: Gas Power Cycles
//==============================================================================

clc
clear

//INPUT DATA
P1=1;//Pressure at point 1 in atm
P3=5;//Pressure at point 3 in atm
T1=288;//Temperature at point 1 in K
T4=1143;//Temperature at point 4 in K
y=1.4;//Ratio of specific heats
```

```
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K

//CALCULATIONS
rp=P3/P1;//Pressure ratio
x=(y-1)/y;//Ratio
T3=T1*(rp^x);//Temperature at point 3 in K
T5=T4-(T3-T1);//Temperature at point 5 in K
T6=T4/(rp^x);//Temperature at point 6 in K
C6=sqrt(2000*Cp*(T5-T6));//Velocity of air leaving the nozzle in m/s

//OUTPUT
mprintf('Velocity of air leaving the nozzle is %3.1f m/s',C6)






//==================================END OF PROGRAM=====================================
```

Scilab code Exa 2.22 Turbine exit pressure and Velocity of exhaust gases and Propulsive efficiency

```
//Chapter-2, Illustration 22, Page 81
//Title: Gas Power Cycles
//==========================================================================

clc
clear

```

```
//INPUT DATA
C1=280;//Velocity of aircraft in m/s
P1=48;//Pressure at point 1 kPa
T1=260;//Temperature at point 1 in K
rp=13;//Pressure ratio
T4=1300;//Temperature at point 4 in K
Cp=1005;//Specific heat at constant pressure in J/kg
y=1.4;//Ratio of specific heats

//CALCULATIONS
x=(y-1)/y;//Ratio
T2=T1+((C1^2)/(2*Cp));//Temperature at point 2 in K
P2=P1*((T2/T1)^(1/x));//Pressure at point 2 in kPa
P3=rp*P2;//Pressure at point 3 in kPa
P4=P3;//Pressure at point 4 in kPa
T3=T2*(rp^x);//Temperature at point 3 in K
T5=T4-T3+T2;//Temperature at point 5 in K
P5=P4*((T5/T4)^(1/x));//Pressure at point 5 in kPa
P6=P1;//Pressure at point 6 in kPa
T6=T5*((P6/P5)^x);//Temperature at point 6 in K
C6=sqrt(2*Cp*(T5-T6));//Velocity of air at nozzle exit in m/s
W=(C6-C1)*C1;//Propulsive power in J/kg
Q=Cp*(T4-T3);//Total heat transfer rate in J/kg
nP=(W/Q)*100;//Propulsive efficiency

//OUTPUT
mprintf('Pressure at the turbine exit is %3.1f kPa \n Velocity of exhaust gases are %3.1f m/s \n Propulsive efficiency is %3.1f percent',P5,C6,nP)
```

```



//========================================END OF PROGRAM
    ============================================
```

Chapter 3

Internal Combustion Engines

Scilab code Exa 3.1 Air standard efficiency and Indicated Power and Indicated thermal efficiency

```
//Chapter-3, Illustration 1, Page 139
//Title: Internal Combustion Engines
//=============================================================================

clc
clear

//INPUT DATA
d=200;//diameter of cylinder in mm
L=300;//stroke of cylinder in mm
Vc=1.73;//Clearance volume in litres
imep=650;//indicated mean effective pressure in kN/(m^2)
g=6.2;//gas consumption in (m^3)/h
CV=38.5;//Calorific value in MJ/(m^3)
y=1.4;//Ratio of specific heats
N=150;//No. of firing cycles per minute

//CALCULATIONS
```

```
Vs=((3.1415/4)*(d^2)*L)*(10^-6);//Stroke volume in litres
Vt=Vs+Vc;//Total volume in litres
rv=(Vt/Vc);//Compression ratio
n=(1-(1/rv^(y-1)))*100;//Air standard efficiency
IP=imep*(Vs*10^-3)*(N/60);//Indicated power in kW
F=(g*CV*1000)/3600;//Fuel energy input in kW
nT=(IP/F)*100;//Indicated thermal efficiency

//OUTPUT
mprintf('Air Standard Efficiency is %3.1f percent \n Indicated Power is %3.1f kW \n Indicated thermal efficiency is %3.0f percent',n,IP,nT)




//===================================END OF PROGRAM=======================================
```

Scilab code Exa 3.2 Relative efficiency of engine

```
//Chapter-3, Illustration 2, Page 140
//Title: Internal Combustion Engines
//=====================================================================================================

clc
clear

//INPUT DATA
Vs=0.0008;//Swept volume in m^3
Vc=0.00015;//Clearance volume in m^3
CV=38;//Calorific value in MJ/(m^3)
v=0.45;//volume in m^3
```

```
IP=81.5;//Indicated power in kW
y=1.4;//Ratio of specific heats

//CALCULATIONS
rv=(Vs+Vc)/Vc;//Compression ratio
n=(1-(1/rv^(y-1)));//Air standard efficiency
Ps=(v*CV*1000)/60;//Power supplied in kW
nact=IP/Ps;//Actual efficiency
nr=(nact/n)*100;//Relative efficiency

//OUTPUT
mprintf('Relative Efficiency is %3.2f percent',nr)



//==============================END OF PROGRAM==================================
```

Scilab code Exa 3.3 Indicated power and Brake power and and Brake thermal efficiency and Brake mean effective pressure and Mechanical efficiency and Brake specific fuel consumption

```
//Chapter-3, Illustration 3, Page 141
//Title: Internal Combustion Engines
//==========================================================================================

clc
clear

//INPUT DATA
n=6;//No. of cylinders
d=0.61;//Diameter in m
L=1.25;//Stroke in m
N=2;//No.of revolutions per second
```

```
m=340;//mass of fuel oil in kg
CV=44200;//Calorific value in kJ/kg
T=108;//Torque in kN-m
imep=775;//Indicated mean efective pressure in kN/(m^2)

//CALCULATIONS
IP=(imep*L*3.1415*(d^2)*N)/(8);//Indicated power in kW
TotalIP=(n*IP);//Total indicated power in kW
BP=(2*3.1415*N*T);//Brake power in kW
PI=(m*CV)/3600;//Power input in kW
nB=(BP/PI)*100;//Brake thermal efficiency
bmep=(BP*8)/(n*L*3.1415*(d^2)*2);//Brake mean effective pressure in kN/(m^2)
nM=(BP/TotalIP)*100;//Mechanical efficiency
bsfc=m/BP;//Brake specific fuel consumption in kg/kWh

//OUTPUT
mprintf('Total Indicated Power is %3.1f kW \n Brake Power is %3.1f kW \n Brake thermal efficiency is %3.1f percent \n Brake mean effective pressure is %3.1f kN/(m^2) \n Mechanical efficiency is %3.1f percent \n Brake specific fuel consumption is %3.3f kg/kW.h',TotalIP,BP,nB,bmep,nM,bsfc)



//===================================END OF PROGRAM=======================================
```

Scilab code Exa 3.4 Indicated power and Brake output and Mechanical efficiency and Overall energy balance

```
//Chapter-3, Illustration 4, Page 142
//Title: Internal Combustion Engines
//
==================================================================

clc
clear

//INPUT DATA
Hm=21;//Mean height of indicator diagram in mm
isn=27;//indicator spring number in kN/(m^2)/mm
Vs=14;//Swept volume in litres
N=6.6;//Speed of engine in rev/s
Pe=77;//Effective brake load in kg
Re=0.7;//Effective vrake radius in m
mf=0.002;//fuel consumed in kg/s
CV=44000;//Calorific value of fuel in kJ/kg
mc=0.15;//cooling water circulation in kg/s
Ti=311;//cooling water inlet temperature in K
To=344;//cooling water outlet temperature in K
C=4.18;//specific heat capacity of water in kJ/kg-K
Ee=33.6;//Energy to exhaust gases in kJ/s
g=9.81;//Acceleration due to geravity in m/(s^2)

//CALCULATIONS
imep=isn*Hm;//Indicated mean efective pressure in kN
   /(m^2)
IP=(imep*Vs*N)/(2000);//Indicated Power in kW
BP=(2*3.1415*N*g*Pe*Re)/1000;//Brake Power in kW
nM=(BP/IP)*100;//Mechanical efficiency
Ef=mf*CV;//Eneergy from fuel in kJ/s
Ec=mc*C*(To-Ti);//Energy to cooling water in kJ/s
Es=Ef-(BP+Ec+Ee);//Energy to surroundings in kJ/s
p=(BP*100)/Ef;//Energy to BP in %
q=(Ec*100)/Ef;//Energy to coolant in %
r=(Ee*100)/Ef;//Energy to exhaust in %
w=(Es*100)/Ef;//Energy to surroundings in %

```

```
//OUTPUT
mprintf('Indicated Power is %3.1f kW \n Brake Power is %3.0f kW \n Mechanical Efficiency is %3.0f percent \n \nENERGY BALANCE                    kJ/s      Percentage \nEnergy from fuel              %3.0f          100\nEnergy to BP              %3.0f          %3.0f\nEnergy to coolant              %3.01f          %3.1f\nEnergy to exhaust              %3.1f          %3.1f\nEnergy to surroundings, etc        %3.1f          %3.1f',IP,BP,nM,Ef,BP,p,Ec,q,Ee,r,Es,w)




//================================END OF PROGRAM====================================
```

Scilab code Exa 3.5 Brake power and Brake specific fuel consumption and Indicated thermal efficiency and Energy balance

```
//Chapter-3, Illustration 5, Page 143
//Title: Internal Combustion Engines
//=============================================================================

clc
clear

//INPUT DATA
t=30;//duration of trial in minutes
N=1750;//speed in rpm
T=330;//brake torque in Nm
m=9.35;//mass of fuel in kg
CV=42300;//Calorific value in kJ/kg
```

```
mj=483;//jacket cooling water circulation in kg
Ti=290;//inlet temperature in K
TO=350;//outlet temperature in K
ma=182;//air consumption in kg
Te=759;//exhaust temperature in K
Ta=256;//atmospheric temperature in K
nM=0.83;//Mechanical efficiency
ms=1.25;//mean specific heat capacity of exhaust gas in kJ/kg-K
Cw=4.18;//specific heat capacity of water in kJ/kg-K

//CALCULATIONS
BP=(2*3.1415*T*N)/(60*1000);//Brake power in kW
sfc=(m*2)/BP;//specific fuel consumption in kg/kWh
IP=BP/nM;//Indicated power in kW
nIT=((IP*3600)/(m*CV*2))*100;//Indicated thermal efficiency
Ef=(m*CV)/t;//Eneergy from fuel in kJ/min
EBP=BP*60;//Energy to BP in kJ/min
Ec=(mj*Cw*(TO-Ti))/t;//Energy to cooling water in kJ/min
Ee=((ma+m)*ms*(Te-Ti))/30;//Energy to exhaust in kJ/min
Es=Ef-(EBP+Ec+Ee);//Energy to surroundings in kJ/min

//OUTPUT
mprintf('Brake power is %3.1f kW \n Specific fuel consumption is %3.3f kg/kWh \n Indicated thermal efficiency is %3.1f percent \n Energy from fuel is %3.0f kJ/min \n Energy to BP is %3.0f kJ/min \n Energy to cooling water is %3.0f kJ/min \n Energy to exhaust is %3.0f kJ/min \n Energy to surroundings is %3.0f kJ/min',BP,sfc,nIT,Ef,EBP,Ec,Ee,Es)




```

```


//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 3.6 Indicated power and Mechanical efficiency of engine

```
//Chapter-3, Illustration 6, Page 144
//Title: Internal Combustion Engines
//==============================================================================

clc
clear

//INPUT DATA
BP0=12;//Brake Power output in kW
BP1=40.5;//Brake Power in trial 1 in kW
BP2=40.2;//Brake Power in trial 2 in kW
BP3=40.1;//Brake Power in trial 3 in kW
BP4=40.6;//Brake Power in trial 4 in kW
BP5=40.7;//Brake Power in trial 5 in kW
BP6=40.0;//Brake Power in trial 6 in kW

//CALCULATIONS
BPALL=BP0+BP6;//Total Brake Power in kW
IP1=BPALL-BP1;//Indicated Power in trial 1 in kW
IP2=BPALL-BP2;//Indicated Power in trial 2 in kW
IP3=BPALL-BP3;//Indicated Power in trial 3 in kW
IP4=BPALL-BP4;//Indicated Power in trial 4 in kW
IP5=BPALL-BP5;//Indicated Power in trial 5 in kW
IP6=BPALL-BP6;//Indicated Power in trial 6 in kW
IPALL=IP1+IP2+IP3+IP4+IP5+IP6;//Total Indicated Power in kW
nM=(BPALL/IPALL)*100;//Mechanical efficiency
```

```

//OUTPUT
mprintf('Indicated Power of the engine is %3.1f kW \n Mechanical efficiency of the engine is %3.1f percent',IPALL,nM)



//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 3.7 Engine dimensions and Brake power

```
//Chapter-3, Illustration 7, Page 145
//Title: Internal Combustion Engines
//==============================================================================================================

clc
clear

//INPUT DATA
n=2;//No. of cylinders
N=4000;//speed of engine in rpm
nV=0.77;//Volumetric efficiency
nM=0.75;//Mechanical efficiency
m=10;//fuel consumed in lit/h
g=0.73;//spcific gravity of fuel
Raf=18;//air-fuel ratio
Np=600;//piston speed in m/min
imep=5;//Indicated mean efective pressure in bar
R=281;//Universal gas constant in J/kg-K
T=288;//Standard temperature in K
P=1.013;//Standard pressure in bar

```

```
//CALCULATIONS
L=Np/(2*N);//Piston stroke in m
mf=m*g;//mass of fuel in kg/h
ma=mf*Raf;//mass of air required in kg/h
Va=(ma*R*T)/(P*60*(10^5));//volume of air required in (m^3)/min
D=sqrt((2*Va)/(nV*L*N*3.1415));//Diameter in m
IP=(2*imep*100*L*3.1415*(D^2)*N)/(4*60);//Indicated Power in kW
BP=nV*IP;//Brake Power in kW

//OUTPUT
mprintf('Piston Stroke is %3.3f m \n Bore diameter is %3.4f m \n Brake power is %3.1f kW',L,D,BP)



//==================================END OF PROGRAM======================================
```

Chapter 4

Steam nozzles and Steam turbines

Scilab code Exa 4.1 Throat area and Exit area and Mach number at exit

```
//Chapter-4, Illustration 1, Page 161
//Title: Steam Nozzles and Steam Turbines
//
    ================================================================================

clc
clear

//INPUT DATA
P1=3.5;//Pressure at entry in MN/(m^2)
T1=773;//Temperature at entry in K
P2=0.7;//Pressure at exit in MN/(m^2)
ma=1.3;//mass flow rate of air in kg/s
y=1.4;//Ratio of specific heats
R=0.287;//Universal gas constant in KJ/Kg-K

//CALCULATIONS
c=y/(y-1);//Ratio
Pt=((2/(y+1))^c)*P1;//Throat pressure in MN/(m^2)
```

```
v1=(R*T1)/(P1*1000);//Specific volume at entry in (m^3)/kg
Ct=((2*c*P1*v1*(1-((Pt/P1)^(1/c))))^0.5)*1000;//Velocity at throat in m/s
vt=v1*((P1/Pt)^(1/y));//Specific volume at throat in (m^3)/kg
At=((ma*vt)/Ct)*(10^6);//Area of throat in (mm^2)
C2=((2*c*P1*v1*(1-((P2/P1)^(1/c))))^0.5)*1000;//Velocity at exit in m/s
v2=v1*((P1/P2)^(1/y));//Specific volume at exit in (m^3)/kg
A2=((ma*v2)/C2)*(10^6);//Area of exit in (mm^2)
M=C2/Ct;//Mach number at exit

//OUTPUT
mprintf('Throat area is %3.0f (mm^2) \n Exit area is %3.0f (mm^2) \n Mach number at exit is %3.2f',At,A2,M)






//==============================END OF PROGRAM==============================
```

Scilab code Exa 4.2 Increase in pressure and temperature and internal energy

```
//Chapter-4, Illustration 2, Page 163
//Title: Steam Nozzles and Steam Turbines
//==================================================================
```

```
clc
clear

//INPUT DATA
T1=273;//Temperature at section 1 in K
P1=140;//Pressure at section 1 in KN/(m^2)
v1=900;//Velocity at section 1 in m/s
v2=300;//Velocity at section 2 in m/s
Cp=1.006;//Specific heat at constant pressure in kJ/kg-K
Cv=0.717;//Specific heat at constant volume in kJ/kg-K
y=1.4;//Ratio of specific heats

//CALCULATIONS
c=y/(y-1);//Ratio
R=Cp-Cv;//Universal gas constant in KJ/Kg-K
T2=T1-(((v2)^2-(v1)^2)/(2000*c*R));//Temperature at section 2 in K
DT=T2-T1;//Increase in temperature in K
P2=P1*((T2/T1)^c);//Pressure at section 2 in KN/(m^2)
DP=(P2-P1)/1000;//Increase in pressure in MN/(m^2)
IE=Cv*(T2-T1);//Increase in internal energy in kJ/kg

//OUTPUT
mprintf('Increase in temperature is %3.0f K \n Increase in pressure is %3.2f MN/(m^2) \n Increase in internal energy is %3.0f kJ/kg',DT,DP,IE)






//==================================================END OF PROGRAM========================================================
```

Scilab code Exa 4.3 Throat area and exit area and Degree of undercooling at exit

```
//Chapter-4, Illustration 3, Page 163
//Title: Steam Nozzles and Steam Turbines
//

clc
clear

//INPUT DATA
P1=2;//Pressure at entry in MN/(m^2)
T1=598;//Temperature at entry in K
P2=0.36;//Pressure at exit in MN/(m^2)
m=7.5;//mass flow rate of steam in kg/s
n=1.3;//Adiabatic gas constant
v1=0.132;//Volume at entry in (m^3)/kg from steam table
Ts=412.9;//Saturation temperature in K

//CALCULATIONS
c=n/(n-1);//Ratio
Pt=((2/(n+1))^c)*P1;//Throat pressure in MN/(m^2)
Ct=((2*c*P1*v1*(1-((Pt/P1)^(1/c))))^0.5)*1000;//Velocity at throat in m/s
vt=v1*((P1/Pt)^(1/n));//Specific volume at throat in (m^3)/kg
At=((m*vt)/Ct)*(10^6);//Area of throat in (mm^2)
C2=((2*c*P1*v1*(1-((P2/P1)^(1/c))))^0.5)*1000;//Velocity at exit in m/s
v2=v1*((P1/P2)^(1/n));//Specific volume at exit in (m^3)/kg
A2=((m*v2)/C2)*(10^6);//Area of exit in (mm^2)
```

```
T2=T1*((P2/P1)^(1/c));//Temperature at exit in K
D=Ts-T2;//Degree of undercooling at exit in K

//OUTPUT
mprintf('Throat area is %3.0f (mm^2) \n Exit area is %3.0f (mm^2) \n Degree of undercooling at exit is %3.1f K',At,A2,D)




//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 4.4 Throat and exit velocities and Throat and exit areas

```
//Chapter-4, Illustration 4, Page 165
//Title: Steam Nozzles and Steam Turbines
//====================================================================================================

clc
clear

//INPUT DATA
P1=2.2;//Pressure at entry in MN/(m^2)
T1=533;//Temperature at entry in K
P2=0.4;//Pressure at exit in MN/(m^2)
m=11;//mass flow rate of steam in kg/s
n=0.85;//Efficiency of expansion
h1=2940;//Enthalpy at entrance in kJ/kg from Moiller chart
ht=2790;//Enthalpy at throat in kJ/kg from Moiller chart
h2s=2590;//Enthalpy below exit level in kJ/kg from
```

```
Moiller chart
vt=0.16;//Throat volume in (m^3)/kg
v2=0.44;//Volume at exit in (m^3)/kg

//CALCULATIONS
Ct=(2000*(h1-ht))^0.5;//Throat velocity in m/s
h2=ht-(0.85*(ht-h2s));//Enthalpy at exit in kJ/kg
C2=(2000*(h1-h2))^0.5;//Exit velocity in m/s
At=((m*vt)/Ct)*(10^6);//Area of throat in (mm^2)
A2=((m*v2)/C2)*(10^6);//Area of exit in (mm^2)

//OUTPUT
mprintf('Throat velocity is %3.0f m/s \n Exit velocity is %3.0f m/s \n Throat area is %3.0f (mm^2) \n Exit area is %3.0f (mm^2) \n',Ct,C2,At,A2)




//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 4.5 Nozzle dimensions and Degree of undercooling and supersaturation and Loss in available heat and Increase in entropy and Ratio of mass flow rate

```
//Chapter-4, Illustration 5, Page 166
//Title: Steam Nozzles and Steam Turbines
//=============================================================================================================

clc
clear

//INPUT DATA
```

```
P1=35;//Pressure at entry in bar
T1=573;//Temperature at entry in K
P2=8;//Pressure at exit in bar
Ts=443.4;//Saturation temperature in K
Ps=3.1;//Saturation pressure in bar
m=5.2;//mass flow rate of steam in kg/s
n=1.3;//Adiabatic gas constant
v1=0.06842;//Specific volume at entry in (m^3)/kg
    from steam table
v3=0.2292;//Specific volume at exit in (m^3)/kg from
     steam table
h1=2979;//Enthalpy in kJ/kg from Moiller chart
h3=2673.3;//Enthalpy in kJ/kg from Moiller chart

//CALCULATIONS
c=n/(n-1);//Ratio
C2=((2*c*P1*(10^5)*v1*(1-((P2/P1)^(1/c))))^0.5);//
    Velocity at exit in m/s
v2=v1*((P1/P2)^(1/n));//Specific volume at exit in (
    m^3)/kg
A2=((m*v2)/C2)*(10^4);//Area of exit in (cm^2)
a=((A2/18)^0.5)*10;//Length in mm
b=3*a;//Breadth in mm
T2=T1*((P2/P1)^(1/c));//Temperature at exit in K
D=Ts-T2;//Degree of undercooling in K
Ds=P2/Ps;//Degree of supersaturation
hI=h1-h3;//Isentropic enthalpy drop in kJ/kg
ha=(C2^2)/2000;//Actual enthalpy drop in kJ/kg
QL=hI-ha;//Loss in available heat in kJ/kg
DS=QL/Ts;//Increase in entropy in kJ/kg-K
C3=(2000*(h1-h3))^0.5;//Exit velocity from nozzle
mf=((A2*C3*(10^-4))/v3);//Mass flow rate in kg/s
Rm=m/mf;//Ratio of mass rate

//OUTPUT
mprintf('Cross section of nozzle is %3.1f mm * %3.1f
     mm \n Degree of undercooling is %3.1f K and
    Degree of supersaturation is %3.2f \n Loss in
```

```
available heat drop due to irreversibility is %3.2f kJ/kg \n Increase in entropy is %3.5f kJ/kg-K \n Ratio of mass flow rate with metastable expansion to the thermal expansion is %3.3f',b,a,D,Ds,QL,DS,Rm)





//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 4.6 Nozzle efficiency and Exit area and Throat velocity

```
//Chapter-4, Illustration 6, Page 169
//Title: Steam Nozzles and Steam Turbines
//=============================================================================================================

clc
clear

//INPUT DATA
m=14;//Mass flow rate of steam in kg/s
P1=3;//Pressure of Steam in MN/(m^2)
T1=300;//Steam temperature in oC
h1=2990;//Enthalpy at point 1 in kJ/kg
h2s=2630;//Enthalpy at point 2s in kJ/kg
ht=2850;//Enthalpy at point t in kJ/kg
n=1.3;//Adiabatic gas constant
C2=800;//Exit velocity in m/s
v2=0.4;//Specific volume at exit in (m^3)/kg

//CALCULATIONS
```

```
x=n/(n-1);//Ratio
Pt=((2/(n+1))^x)*P1;//Temperature at point t in MN/(m^2)
h2=h1-((C2^2)/2000);//Exit enthalpy in kJ/kg
nN=((h1-h2)/(h1-h2s))*100;//Nozzle efficiency
A2=((m*v2)/C2)*(10^6);//Exit area in (mm^2)
Ct=sqrt(2000*(h1-ht));//Throat velocity in m/s

//OUTPUT
mprintf('Nozzle efficiency is %3.1f percent \n Exit area is %3.0f (mm^2) \n Throat velocity is %3.0f m/s',nN,A2,Ct)




//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 4.7 Areas at throat and exit and Steam quality at exit

```
//Chapter-4, Illustration 7, Page 170
//Title: Steam Nozzles and Steam Turbines
//=============================================================================

clc
clear

//INPUT DATA
P1=10;//Pressure at point 1 in bar
P2=0.5;//Pressure at point 2 in bar
h1=3050;//Enthalpy at point 1 in kJ/kg
h2s=2480;//Enthalpy at point 2s in kJ/kg
ht=2910;//Enthalpy at throat in kJ/kg
```

```
n=1.3;//Adiabatic gas constant
r=0.1;//Total available heat drop
v1=0.258;//Specific volume at point 1 in (m^3)/kg
h2f=340.6;//Enthalpy for exit pressure from steam tables in kJ/kg
hfg=2305.4;//Enthalpy for exit pressure from steam tables in kJ/kg
m=0.5;//Mass flow rate in kg/s

//CALCULATIONS
x=n/(n-1);//Ratio
Pt=((2/(n+1))^x)*P1;//Temperature at throat in bar
h2=h2s+(r*(h1-h2s));//Enthalpy at point 2 in kJ/kg
vt=((P1/Pt)^(1/n))*v1;//Specific volume at throat in (m^3)/kg
v2=((P1/P2)^(1/n))*v1;//Specific volume at point 2 in (m^3)/kg
Ct=sqrt(2000*(h1-ht));//Throat velocity in m/s
At=((m*vt)/Ct)*(10^6);//Throat area in (mm^2)
C2=sqrt(2000*(h1-h2));//Exit velocity in m/s
A2=((m*v2)/C2)*(10^6);//Exit area in (mm^2)
x2=((h2-h2f)/hfg)*100;//Steam quality at exit

//OUTPUT
mprintf('Throat area is %3.0f (mm^2) \n Exit area is %3.0f (mm^2) \n Steam quality at exit is %3.0f percent',At,A2,x2)






//==================================END OF PROGRAM==================================
```

Scilab code Exa 4.8 Maximum discharge and Area of nozzle at exit

```
//Chapter-4, Illustration 8, Page 171
//Title: Steam Nozzles and Steam Turbines
//

clc
clear

//INPUT DATA
P1=3.5;//Dry saturated steam in bar
P2=1.1;//Exit pressure in bar
At=4.4;//Throat area in cm^2
h1=2731.6;//Enthalpy at P1 in kJ/kg
v1=0.52397;//Specific volume at P1 in m^3/kg
n=1.135;//Adiabatic gas constant
ht=2640;//Enthalpy at Pt in kJ/kg
vt=0.85;//Specific volume at throat in m^3/kg
h2=2520;//Enthalpy at P2 in kJ/kg
v2=1.45;//Specific volume at P2 in m^3/kg

//CALCULATIONS
x=n/(n-1);//Ratio
Pt=((2/(n+1))^x)*P1;//Throat pressure in bar
Ct=sqrt(2000*(h1-ht));//Throat velocity in m/s
mmax=((At*Ct*(10^-4))/vt)*60;//Maximum discharge in kg/min
C2=sqrt(2000*(h1-h2));//Exit velocity in m/s
A2=((mmax*v2)/(C2*60))*(10^6);//Exit area in mm^2

//OUTPUT
mprintf('Maximum discharge is %3.3f kg/min \n Exit area is %3.2f mm^2',mmax,A2)
```

```
//==================================================END OF PROGRAM
    =======================================================
```

Scilab code Exa 4.9 Type of nozzle and Minimum area of nozzle

```
//Chapter-4, Illustration 9, Page 172
//Title: Steam Nozzles and Steam Turbines
//
    ==============================================================================================================

clc
clear

//INPUT DATA
P1=10;//Pressure at point 1 in bar
T1=200;//Temperature at point 1 in oC
P2=5;//Pressure at point 2 in bar
n=1.3;//Adiabatic gas constant
h1=2830;//Enthalpy at P1 in kJ/kg
ht=2710;//Enthalpy at point Pt in kJ/kg
vt=0.35;//Specific volume at Pt in m^3/kg
m=3;//Nozzle flow in kg/s

//CALCULATIONS
x=n/(n-1);//Ratio
Pt=((2/(n+1))^x)*P1;//Throat pressure in bar
Ct=sqrt(2000*(h1-ht));//Throat velocity in m/s
At=(m*vt)/Ct;//Throat area in m^2

//OUTPUT
mprintf('Since throat pressure is greater than exit
```

```
    pressure, nozzle used is convergent-divergent
    nozzle \n Minimum area of nozzle required is %3.5
    f m^2',At)





//==================================================END OF PROGRAM
    ======================================================
```

Scilab code Exa 4.10 Throat velocity and Mass flow rate of steam

```
//Chapter-4, Illustration 10, Page 173
//Title: Steam Nozzles and Steam Turbines
//
    ====================================================================================================

clc
clear

//INPUT DATA
P1=10.5;//Pressure at point 1 in bar
x1=0.95;//Dryness fraction
n=1.135;//Adiabatic gas constant
P2=0.85;//Pressure at point 2 in bar
vg=0.185;//Specific volume in m^3/kg


//CALCULATIONS
c=n/(n-1);//Ratio
Pt=((2/(n+1))^c)*P1;//Throat pressure in MN/(m^2)
v1=x1*vg;//Specific volume at point 1 in m^3/kg
Ct=sqrt((2*n*P1*v1*(10^5)/(n+1)));//Velocity at
    throat in m/s
```

```
vt=((P1/Pt)*(v1^n))^(1/1.135);//Specific volume at throat in m^3/kg
m=Ct/vt;//Mass flow rate per unit throat area in kg/(m^2)

//OUTPUT
mprintf('Throat velocity is %3.2f m/s \n Mass flow rate of steam is %3.2f kg/(m^2)',Ct,m)





//==================================================END OF PROGRAM=======================================================
```

Scilab code Exa 4.11 Degree of undercooling and supersaturation

```
//Chapter-4, Illustration 11, Page 174
//Title: Steam Nozzles and Steam Turbines
//=============================================================================================================

clc
clear

//INPUT DATA
P1=10;//Pressure at point 1 in bar
T1=452.9;//Temperature at point 1 in K
P2=4;//Pressure at point 2 in bar
n=1.3;//Adiabatic gas constant
Ps=0.803;//Saturation pressure at T2 in bar
Ts=143.6;//Saturation temperature at P2 in oC
//CALCULATIONS
x=(n-1)/n;//Ratio
```

```
T2=((P2/P1)^x)*T1;//Temperature at point 2 in K
Ds=P2/Ps;//Degree of supersaturation
Du=Ts-(T2-273);//Degree of undercooling

//OUTPUT
mprintf('Degree of supersaturation is %3.2f \n Degree of undercooling %3.0f oC',Ds,Du)







//==============================END OF PROGRAM==================================
```

Scilab code Exa 4.12 Quantity of steam used and Exit velocity of steam

```
//Chapter-4, Illustration 12, Page 174
//Title: Steam Nozzles and Steam Turbines
//=============================================================================

clc
clear

//INPUT DATA
P1=9;//Pressure at point 1 in bar
P2=1;//Pressure at point 2 in bar
Dt=0.0025;//Throat diameter in m
nN=0.9;//Nozzle efficiency
n=1.135;//Adiabatic gas consstant
h1=2770;//Enthalpy at point 1 in kJ/kg
ht=2670;//Throat enthlapy in kJ/kg
```

```
h3=2400;//Enthlapy at point 2 in kJ/kg
x2=0.96;//Dryness fraction 2
vg2=0.361;//Specific volume in m^3/kg

//CALCULATIONS
x=n/(n-1);//Ratio
Pt=((2/(n+1))^x)*P1;//Throat pressure in bar
Ct=sqrt(2000*(h1-ht)*nN);//Throat velocity in m/s
At=(3.147*2*(Dt^2))/4;//Throat area in m^2
vt=x2*vg2;//Specific volume at throat in m^3/kg
m=(At*Ct)/vt;//Mass flow rate of steam in kg/s
hact=nN*(h1-h3);//Actual enthalpy drop in kJ/kg
C2=sqrt(2000*hact);//Exit velocity of steam in m/s

//OUTPUT
mprintf('Quantity of steam used per second is %3.3f kg/s \n Exit velocity of steam is %3.2f m/s',m,C2)




//=====================================END OF PROGRAM=========================================
```

Scilab code Exa 4.13 Blade angles and Tangential force and Axial thrust and Diagram power and Diagram efficiency

```
//Chapter-4, Illustration 13, Page 202
//Title: Steam Nozzles and Steam Turbines
//==========================================================================================

clc
clear
```

```

//INPUT DATA
C1=1000;//Steam velocity in m/s
a1=20;//Nozzle angle in degrees
U=400;//Mean blade speed in m/s
m=0.75;//Mass flow rate of steam in kg/s
b1=33;//Blade angle at inlet from the velocity triangle in degrees
b2=b1;//Blade angle at exit from the velocity triangle in degrees
Cx=1120;//Change in whirl velocity from the velocity triangle in m/s
Ca=0;//Change in axial velocity from the velocity triangle in m/s

//CALCULATIONS
Fx=m*Cx;//Tangential force on blades in N
Fy=m*Ca;//Axial thrust in N
W=(m*Cx*U)/1000;//Diagram power in kW
ndia=((2*U*Cx)/(C1^2))*100;//Diagram efficiency

//OUTPUT
mprintf('Blade angles are %3.0f degrees,%3.0f degrees \n Tangential force on blades is %3.0f N \n Axial thrust is %3.0f \n Diagram power is %3.0f kW \n Diagram efficiency %3.1f percent',b1,b2,Fx,Fy,W,ndia)





//==============================END OF PROGRAM==================================
```

Scilab code Exa 4.14 Power developed and Blade efficiency and Steam consumption

```
//Chapter-4, Illustration 14, Page 203
//Title: Steam Nozzles and Steam Turbines
//

clc
clear

//INPUT DATA
D=2.5;//Mean diameter of blade ring in m
N=3000;//Speed in rpm
a1=20;//Nozzle angle in degrees
r=0.4;//Ratio blade velocity to steam velocity
Wr=0.8;//Blade friction factor
m=10;//Steam flow in kg/s
x=3;//Sum in blade angles in degrees
b1=32.5;//Blade angle at inlet from the velocity triangle in degrees
W1=626.7;//Relative velocity at inlet from the velocity triangle in m/s
Cx=967;//Change in whirl velocity from the velocity triangle in m/s

//CALCULATIONS
U=(3.147*D*N)/60;//Blade velocity in m/s
C1=U/r;//Steam velocity in m/s
b2=b1-x;//Blade angle at exit in degrees
W2=Wr*W1;//Relative velocity at outlet from the velocity triangle in m/s
W=(m*Cx*U)/1000;//Power developed in kW
ndia=((2*U*Cx)/(C1^2))*100;//Blade efficiency
sc=(m*3600)/W;//Steam consumption in kg/kWh

//OUTPUT
mprintf('Power developed is %3.0f kW \n Blade
```

```
efficiency is %3.1f percent \n Steam consumed is %3.2f kg/kWh',W,ndia,sc)




//==============================END OF PROGRAM==============================
```

Scilab code Exa 4.15 Blading efficiency and Blade velocity coefficient

```
//Chapter-4, Illustration 15, Page 204
//Title: Steam Nozzles and Steam Turbines
//==========================================================================

clc
clear

//INPUT DATA
m=3;//Mass flow rate of steam in kg/s
C1=425;//Steam velocity in m/s
r=0.4;//Ratio of blade speed to jet speed
W=170;//Stage output in kW
IL=15;//Internal losses in kW
a1=16;//Nozzle angle in degrees
b2=17;//Blade angle at exit in degrees
W1=265;//Relative velocity at inlet from the velocity triangle in m/s
W2=130;//Relative velocity at outlet from the velocity triangle in m/s

//CALCULATIONS
U=C1*r;//Blade speed in m/s
P=(W+IL)*1000;//Total power developed in W
```

```
Cx=P/(m*W);//Change in whirl velocity in m/s
ndia=((2*U*Cx)/(C1^2))*100;//Blading efficiency
Wr=W2/W1;//Blade velocity co-efficient

//OUTPUT
mprintf('Blading efficiency is %3.1f percent \n Blade velocity co-efficient is %3.2f',ndia,Wr)




//==============================END OF PROGRAM==============================
```

Scilab code Exa 4.16 Blade angles and Turbine power

```
//Chapter-4, Illustration 16, Page 205
//Title: Steam Nozzles and Steam Turbines
//=============================================================================

clc
clear

//INPUT DATA
C1=375;//Steam velocity in m/s
a1=20;//Nozzle angle
U=165;//Blade speed in m/s
m=1;//Mass flow rate of steam in kg/s
Wr=0.85;//Blade friction factor
Ca1=130;//Axial velocity at inlet from the velocity triangle in m/s
Ca2=Ca1;//Axial velocity at outlet in m/s
W1=230;//Relative velocity at inlet from the velocity triangle in m/s
```

```
Cx=320;//Change in whirl velocity from the velocity triangle in m/s

//CALCULATIONS
b2=41;//Blade angle at exit from the velocity triangle in degrees
b1=34;//Blade angle at exit from the velocity triangle in degrees
W=(m*Cx*U)/1000;//Power developed by turbine in kW

//OUTPUT
mprintf('Blade angles assumed are %3.0f degrees,%3.0f degrees \n Power developed by turbine is %3.1f kW',b1,b2,W)




//==============================END OF PROGRAM==============================
```

Scilab code Exa 4.17 Nozzle angle and Blade angle at entry and exit

```
//Chapter-4, Illustration 17, Page 206
//Title: Steam Nozzles and Steam Turbines
//==============================================================================

clc
clear

//INPUT DATA
m=2;//Mass flow rate of steam in kg/s
W=130;//Turbine power in kW
U=175;//Blade velocity in m/s
```

```
C1=400;//Steam velocity in m/s
Wr=0.9;//Blade friction factor
W1=240;//Realtive velocity at inlet from the velocity triangle in m/s

//CALCULATIONS
Cx1=(W*1000)/(m*U);//Whirl velocity at inlet in m/s
W2=Wr*W1;//Realtive velocity at outlet from the velocity triangle in m/s
a1=19;//Nozzle angle from the velocity triangle in degrees
b1=33;//Blade angle at inlet from the velocity triangle in degrees
b2=36;//Blade angle at outlet from the velocity triangle in degrees

//OUTPUT
mprintf('Nozzle angle is %3.0f degrees \n Blade angles are %3.0f degrees,%3.0f degrees',a1,b1,b2)






//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 4.18 Diagram efficiency

```
//Chapter-4, Illustration 18, Page 207
//Title: Steam Nozzles and Steam Turbines
//==============================================================================================================

clc
```

```
clear

//INPUT DATA
U=150;//Blade speed in m/s
m=3;//Mass flow rate of steam in kg/s
P=10.5;//Pressure in bar
r=0.21;//Ratio blade velocity to steam velocity
a1=16;//Nozzle angle in first stage in degrees
b2=20;//Blade angle at exit in first stage in degrees
a3=24;//Nozzle angle in second stage in degrees
b4=32;//Blade angle at exit in second stage in degrees
Wr=0.79;//Blade friction factor for first stage
Wr2=0.88;//Blade friction factor for second stage
Cr=0.83;//Blade velocity coefficient
W1=570;//Relative velocity at inlet from the velocity triangle for first stage in m/s
C2=375;//Velocity in m/s
W3=185;//Relative velocity at inlet from the velocity triangle for second stage in m/s

//CALCULATIONS
C1=U/r;//Steam speed at exit in m/s
W2=Wr*W1;//Relative velocity at outlet for first stage in m/s
C3=Cr*C2;//Steam velocity at inlet for second stage in m/s
W4=Wr2*W3;//Relative velocity at exit for second stage in m/s
DW1=W1+W2;//Change in relative velocity for first stage in m/s
DW2=275;//Change in relative velocity from the velocity triangle for second stage in m/s
ndia=((2*U*(DW1+DW2))/(C1^2))*100;//Diagram efficiency

//OUTPUT
```

```
mprintf('Diagram efficiency is %3.1f percent',ndia)




//==================================END OF PROGRAM=====================================
```

Scilab code Exa 4.19 Blade speed and Blade tip angles and Diagram efficiency

```
//Chapter-4, Illustration 19, Page 208
//Title: Steam Nozzles and Steam Turbines
//==========================================================================================

clc
clear

//INPUT DATA
b1=30;//Blade angle at inlet in first stage in degrees
b2=30;//Blade angle at exit in first stage in degrees
b3=30;//Blade angle at inlet in second stage in degrees
b4=30;//Blade angle at exit in second stage in degrees
t1=240;//Temperature at entry in oC
P1=11.5;//Pressure at entry in bar
P2=5;//Pressure in wheel chamber in bar
vl=10;//Loss in velocity in percent
h=155;//Enthalpy at P2 in kJ/kg
W4=17.3;//Relative velocity at exit from the velocity triangle for second stage in m/s
```

```
a4=90;//Nozzle angle in second stage in degrees
C3=33;//Steam velocity at inlet from the velocity triangle for second stage in m/s
W2=49;//Relative velocity at outlet from the velocity triangle for first stage in m/s
x=15;//Length of AB assumed for drawing velocity triangle in mm
y=67;//Length of BC from the velocity triangle in mm

//CALCULATIONS
C1=sqrt(2000*h);//Velocity of steam in m/s
W3=W4/0.9;//Relative velocity at inlet for second stage in m/s
C2=C3/0.9;//Velocity in m/s
W1=W2/0.9;//Relative velocity at inlet for first stage in m/s
C1n=C1/y;//Velocity of steam in m/s
U=x*C1n;//Blade speed in m/s
a3=17;//Nozzle angle in second stage from the velocity triangle in degrees
a2=43;//Nozzle angle from the velocity triangle in degrees
DW1=731.5;//Change in relative velocity from the velocity triangle for first stage in m/s
DW2=257.5;//Change in relative velocity from the velocity triangle for second stage in m/s
ndia=((2*U*(DW1+DW2))/(C1^2))*100;//Diagram efficiency

//OUTPUT
mprintf('Blade speed is %3.1f m/s \n Blade tip angles of the fixed blade are %3.0f degrees and %3.0f degrees \n Diagram efficiency is %3.1f percent',U,a3,a2,ndia)




```

```



//==========================================END OF PROGRAM==============================================
```

Scilab code Exa 4.20 Blade speed and Turbine power

```
//Chapter-4, Illustration 20, Page 210
//Title: Steam Nozzles and Steam Turbines
//=============================================================================

clc
clear

//INPUT DATA
C1=600;//Steam velocity in m/s
b1=30;//Blade angle at inlet in first stage in degrees
b2=30;//Blade angle at exit in first stage in degrees
b3=30;//Blade angle at inlet in second stage in degrees
b4=30;//Blade angle at exit in second stage in degrees
a4=90;//Nozzle angle in second stage in degrees
m=3;//Mass of steam in kg/s
x=15;//Length for drawing velocity triangle in mm
y=56;//Length of BC from the velocity triangle in mm

//CALCUALTIONS
C1n=C1/y;//Velocity of steam in m/s
U=x*C1n;//Blade speed in m/s
l=103;//Length from velocity triangle in mm
```

```
P=(m*l*C1n*U)/1000;//Power developed in kW

//OUTPUT
mprintf('Blade speed is %3.1f m/s \n Power developed by the turbine is %3.2f kW',U,P)






//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 4.21 Mean diameter of drum and Volume of steam

```
//Chapter-4, Illustration 21, Page 211
//Title: Steam Nozzles and Steam Turbines
//=============================================================================================================

clc
clear

//INPUT DATA
N=400;//Speed in rpm
m=8.33;//Mass of steam in kg/s
P=1.6;//Pressure of steam in bar
x=0.9;//Dryness fraction
W=10;//Stage power in kW
r=0.75;//Ratio of axial flow velocity to blade velocity
a1=20;//Nozzle angle at inlet in degrees
a2=35;//Nozzle angle at exit in degrees
b1=a2;//Blade tip angle at exit in degrees
```

```
b2=a1;//Blade tip angle at inlet in degrees
a=25;//Length of AB from velocity triangle in mm
vg=1.091;//Specific volume of steam from steam tables in (m^3)/kg

//CALCULATIONS
Cx=73.5;//Change in whirl velocity from the velocity triangle by measurement in mm
y=Cx/a;//Ratio of change in whirl velocity to blade speed
U=sqrt((W*1000)/(m*y));//Blade speed in m/s
D=((U*60)/(3.147*N))*1000;//Mean diameter of drum in mm
v=m*x*vg;//Volume flow rate of steam in (m^3)/s

//OUTPUT
mprintf('Mean diameter of drum is %3.0f mm \n Volume of steam flowing per second is %3.2f m^3/s',D,v)











//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 4.22 Drum diameter and Blade height

```
//Chapter-4, Illustration 22, Page 212
//Title: Steam Nozzles and Steam Turbines
```

```
//===============================================================
clc
clear

//INPUT DATA
N=300;//Speed in rpm
m=4.28;//Mass of steam in kg/s
P=1.9;//Pressure of steam in bar
x=0.93;//Dryness fraction
W=3.5;//Stage power in kW
r=0.72;//Ratio of axial flow velocity to blade velocity
a1=20;//Nozzle angle at inlet in degrees
b2=a1;//Blade tip angle at inlet in degrees
l=0.08;//Tip leakage steam
vg=0.929;//Specific volume of steam from steam tables in (m^3)/kg

//CALCULATIONS
mact=m-(m*l);//Actual mass of steam in kg/s
a=(3.147*N)/60;//Ratio of blade velocity to mean dia
b=r*a;//Ratio of axial velocity to mean dia
c=46;//Ratio of change in whirl velocity to mean dia
D=sqrt((W*1000)/(mact*c*a));//Mean dia in m
Ca=b*D;//Axial velocity in m/s
h=((mact*x*vg)/(3.147*D*Ca))*1000;//Blade height in mm
D1=D-(h/1000);//Drum dia in m

//OUTPUT
mprintf('Drum diameter is %3.3f m \n Blade height is %3.0f mm',D1,h)




```

```






//==========================================END OF PROGRAM==============================================
```

Scilab code Exa 4.23 Rotor blade angles and Flow coefficient and Blade loading coefficient and Power developed

```
//Chapter-4, Illustration 23, Page 214
//Title: Steam Nozzles and Steam Turbines
//=============================================================================================================

clc
clear

//INPUT DATA
P0=800;//Steam pressure in kPa
P2=100;//Pressure at point 2 in kPa
T0=973;//Steam temperature in K
a1=73;//Nozzle angle in degrees
ns=0.9;//Steam efficiency
m=35;//Mass flow rate in kg/s
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K
y=1.4;//Ratio of specific heats

//CALCULATIONS
b1=atand(tand(a1)/2);//Blade angle at inlet in degrees
b2=b1;//Blade angle at exit in degrees
p=2/tand(a1);//Flow coefficient
```

```
s=p*(tand(b1)+tand(b2));//Blade loading coefficient
Dh=ns*Cp*T0*(1-((P2/P0)^((y-1)/y)));//Difference in enthalpies in kJ/kg
W=(m*Dh)/1000;//Power developed in MW

//OUTPUT
mprintf('Rotor blade angles are %3.2f degrees and %3.2f degrees \n Flow coefficient is %3.3f \n Blade loading coefficient is %3.0f \n Power developed is %3.1f MW',b1,b2,p,s,W)














//==================================================END OF PROGRAM========================================================
```

Scilab code Exa 4.24 Rotor blade angles and Power developed and Final state of steam and Blade height

```
//Chapter-4, Illustration 24, Page 215
//Title: Steam Nozzles and Steam Turbines
//=============================================================================================================
clc
```

```
clear

//INPUT DATA
P0=100;//Steam pressure in bar
T0=773;//Steam temperature in K
a1=70;//Nozzle angle in degrees
ns=0.78;//Steam efficiency
m=100;//Mass flow rate of steam in kg/s
D=1;//Turbine diameter in m
N=3000;//Turbine speed in rpm
h0=3370;//Steam enthalpy from Moiller chart in kJ/kg
v2=0.041;//Specific volume at P2 from steam tables in (m^3)/kg
v4=0.05;//Specific volume at P4 from steam tables in (m^3)/kg

//CALCULATIONS
U=(3.147*D*N)/60;//Blade speed in m/s
C1=(2*U)/sind(a1);//Steam speed in m/s
b1=atand(tand(a1)/2);//Blade angle at inlet for first stage in degrees
b2=b1;//Blade angle at exit for first stage in degrees
b3=b1;//Blade angle at inlet for second stage in degrees
b4=b2;//Blade angle at exit for second stage in degrees
Wt=(4*m*(U^2))/(10^6);//Total workdone in MW
Dh=(2*(U^2))/1000;//Difference in enthalpies in kJ/kg
Dhs=Dh/ns;//Difference in enthalpies in kJ/kg
h2=h0-Dh;//Enthalpy at point 2 in kJ/kg
h2s=h0-Dhs;//Enthalpy at point 2s in kJ/kg
Dh2=(2*(U^2))/1000;//Difference in enthalpies in kJ/kg
Dh2s=Dh2/ns;//Difference in enthalpies in kJ/kg
h4=h2-Dh2;//Enthalpy at point 4 in kJ/kg
h4s=h2-Dh2s;//Enthalpy at point 4s in kJ/kg
```

```
Ca=C1*cosd(a1);//Axial velocity in m/s
hI=(m*v2)/(3.147*D*Ca);//Blade height at first stage in m/s
hII=(m*v4)/(3.147*D*Ca);//Blade height at second stage in m/s

//OUTPUT
mprintf('Rotor blade angles for first stage are %3.2f degrees and %3.2f degrees \n Rotor blade angles for second stage are %3.2f degrees and %3.2f degrees \n Power developed is %3.2f MW \n Final state of steam at first stage is %3.2f kJ/kg \n Final state of steam at second stage is %3.2f kJ/kg \n Blade height at first stage is %3.4f m \n Blade height at second stage is %3.4f m',b1,b2,b3,b4,Wt,h2s,h4s,hI,hII)















//==================================END OF PROGRAM=====================================
```

Scilab code Exa 4.25 Rotor blade angles and Power developed and Final state of steam and Blade height

```
//Chapter-4, Illustration 25, Page 218
//Title: Steam Nozzles and Steam Turbines
//

clc
clear

//INPUT DATA
P0=100;//Steam pressure in bar
T0=773;//Steam temperature in K
a1=70;//Nozzle angle in degrees
ns=0.78;//Steam efficiency
m=100;//Mass flow rate of steam in kg/s
D=1;//Turbine diameter in m
N=3000;//Turbine speed in rpm
h0=3370;//Steam enthalpy from Moiller chart in kJ/kg
P4=27;//Pressure at point 4 in bar
T4=638;//Temperature at point 4 in K
v4=0.105;//Specific volume at P4 from mollier chart in (m^3)/kg
ns=0.65;//Stages efficiency

//CALCULATIONS
U=(3.147*D*N)/60;//Blade speed in m/s
C1=(4*U)/sind(a1);//Steam speed in m/s
Ca=C1*cosd(a1);//Axial velocity in m/s
b1=atand((3*U)/Ca);//Blade angle at inlet for first stage in degrees
b2=b1;//Blade angle at exit for first stage in degrees
b4=atand(U/Ca);//Blade angle at exit for second stage in degrees
b3=b4;//Blade angle at inlet for second stage in degrees
WI=m*6*(U^2);//Power developed in first stage in MW
WII=m*2*(U^2);//Power developed in second stage in MW
```

```
W=(WI+WII)/(10^6);//Total power developed in MW
Dh=(W*1000)/100;//Difference in enthalpies in kJ/kg
Dhs=(W*1000)/(ns*100);//Difference in enthalpies in kJ/kg
h4=h0-Dh;//Enthalpy at point 4 in kJ/kg
h4s=h0-Dhs;//Enthalpy at point 4s in kJ/kg
h=(m*v4)/(3.147*D*Ca);//Rotor blade height in m

//OUTPUT
mprintf('Rotor blade angles for first stage are %3.2f degrees and %3.2f degrees \n Rotor blade angles for second stage are %3.2f degrees and %3.2f degrees \n Power developed is %3.2f MW \n Final state of steam at first stage is %3.1f kJ/kg \n Final state of steam at second stage is %3.2f kJ/kg \n Rotor blade height is %3.4f m',b1,b2,b3,b4,W,h4,h4s,h)











//==============================END OF PROGRAM==================================
```

Scilab code Exa 4.26 Rotor blade angles

```
//Chapter-4, Illustration 26, Page 221
//Title: Steam Nozzles and Steam Turbines
//
```

```
clc
clear

//INPUT DATA
a1=30;//Nozzle angle in degrees
Ca=180;//Axial velocity in m/s
U=280;//Rotor blade speed in m/s
R=0.5;//Degree of reaction

//CALCULATIONS
a1n=90-a1;//Nozzle angle measured from axial
    direction in degrees
Cx1=Ca*tand(a1n);//Whirl velocity in m/s
b1=atand((Cx1-U)/Ca);//Blade angle at inlet in
    degrees
b2=a1n;//Blade angle at exit in degrees

//OUTPUT
mprintf('Blade angle at inlet is %3.0f degrees \n
    Blade angle at exit is %3.0f degrees',b1,b2)










//==================================END OF PROGRAM
    ====================================
```

Scilab code Exa 4.27 Rotor blade angles and Power developed and Isentropic enthalpy drop

```
//Chapter-4, Illustration 27, Page 222
//Title: Steam Nozzles and Steam Turbines
//=================================================================

clc
clear

//INPUT DATA
P0=800;//Steam pressure in kPa
T0=900;//Steam temperature in K
a1=70;//Nozzle angle in degrees
ns=0.85;//Steam efficiency
m=75;//Mass flow rate of steam in kg/s
R=0.5;//Degree of reaction
U=160;//Blade speed in m/s

//CALCULATIONS
C1=U/sind(a1);//Steam speed in m/s
Ca=C1*cosd(a1);//Axial velocity in m/s
b1=0;//Blade angle at inlet from velocity triangle in degrees
b2=a1;//Blade angle at exit in degrees
a2=b1;//Nozzle angle in degrees
W=(m*(U^2))/(10^6);//Power developed in MW
Dhs=(W*1000)/(ns*m);//Isentropic enthalpy drop in kJ/kg

//OUTPUT
mprintf('Rotor blade angles are %3.0f degrees and %3.0f degrees \n Power developed is %3.2f MW \n Isentropic enthalpy drop is %3.2f kJ/kg',b1,b2,W,Dhs)


```

```






//========================================END OF PROGRAM
    ============================================
```

Chapter 5

Air Compressors

Scilab code Exa 5.1 Indicated power and Mass of air and Temperature delivered by compressor

```
//Chapter-5, Illustration 1, Page 250
//Title: Air Compressors
//=============================================================================
clc
clear

//INPUT DATA
D=0.2;//Cylinder diameter in m
L=0.3;//Cylinder Stroke in m
P1=1;//Pressure at entry in bar
T1=300;//Temperature at entry in K
P2=8;//Pressure at exit in bar
n=1.25;//Adiabatic gas constant
N=100;//Speed in rpm
R=287;//Universal gas constant in J/kg-K

//CALCULATIONS
x=(n-1)/n;//Ratio
```

```
V1=(3.147*L*(D^2))/4;//Volume of cylinder in m^3/cycle
W=(P1*(10^5)*V1*(((P2/P1)^x)-1))/x;//Work done in J/cycle
Pc=(W*100)/(60*1000);//Indicated power of compressor in kW
m=(P1*(10^5)*V1)/(R*T1);//Mass of air delivered in kg/cycle
md=m*N;//Mass delivered per minute in kg
T2=T1*((P2/P1)^x);//Temperature of air delivered in K

//OUTPUT
mprintf('Indicated power of compressor is %3.2f kW \n Mass of air delivered by compressor per minute is %3.2f kg \n Temperature of air delivered is %3.1fK',Pc,md,T2)




//==================================END OF PROGRAM======================================
```

Scilab code Exa 5.2 Size of cylinder

```
//Chapter-5, Illustration 2, Page 251
//Title: Air Compressors
//=============================================================================

clc
clear

//INPUT DATA
```

```
IP=37;//Indicated power in kW
P1=0.98;//Pressure at entry in bar
T1=288;//Temperature at entry in K
P2=5.8;//Pressure at exit in bar
n=1.2;//Adiabatic gas constant
N=100;//Speed in rpm
Ps=151.5;//Piston speed in m/min
a=2;//For double acting compressor

//CALCULATIONS
L=Ps/(2*N);//Stroke length in m
x=(n-1)/n;//Ratio
r=(3.147*L)/4;//Ratio of volume to bore
D=sqrt((IP*1000*60*x)/(N*a*r*P1*(10^5)*(((P2/P1)^x)
   -1)));//Cylinder diameter in m

//OUTPUT
mprintf('Stroke length of cylinder is %3.4f m \n
   Cylinder diameter is %3.4f m',L,D)






//==================================END OF PROGRAM
   ==================================
```

Scilab code Exa 5.3 Cylinder dimensions

```
//Chapter-5, Illustration 3, Page 251
//Title: Air Compressors
//
   ==========================================================================
```

```
clc
clear

//INPUT DATA
IP=11;//Indicated power in kW
P1=1;//Pressure at entry in bar
P2=7;//Pressure at exit in bar
n=1.2;//Adiabatic gas constant
Ps=150;//Piston speed in m/s
a=2;//For double acting compressor
r=1.5;//Storke to bore ratio

//CALCULATIONS
x=(n-1)/n;//Ratio
y=3.147/(4*(r^2));//Ratio of volume to the cube of stroke
z=(P1*(10^2)*y*(((P2/P1)^x)-1))/x;//Ratio of workdone to the cube of stroke
L=(sqrt(IP/(z*Ps)))*1000;//Stroke in mm
D=(L/r);//Bore in mm

//OUTPUT
mprintf('Stroke length of cylinder is %3.0f mm \n Bore diameter of cylinder is %3.0f mm',L,D)






//==================================================END OF PROGRAM=======================================================
```

Scilab code Exa 5.4 Volumetric efficiency and Volumetric efficiency referred to atmospheric conditions and Work required

```
//Chapter-5, Illustration 4, Page 252
//Title: Air Compressors
//
=================================================================

clc
clear

//INPUT DATA
x=0.05;//Ratio of clearance volume to swept volume
P1=1;//Pressure at point 1 in bar
T1=310;//Temperature at point 1 in K
n=1.2;//Adiabatic gas constant
P2=7;//Pressure at point 2 in bar
Pa=1.01325;//Atmospheric pressure in bar
Ta=288;//Atmospheric temperature in K

//CALCULATIONS
V1=1+x;//Ratio of volume of air sucked to stroke volume
V4=((P2/P1)^(1/n))/20;//Ratio of volume delivered to stroke volume
DV=V1-V4;//Difference in volumes
nv1=DV*100;//Volumetric efficiency
V=(P1*DV*Ta)/(T1*Pa);//Ratio of volumes referred to atmospheric conditions
nv2=V*100;//Volumetric efficiency referred to atmospheric conditions
W=(n*0.287*T1*((P2/P1)^((n-1)/n)-1))/(n-1);//Work required in kJ/kg

//OUTPUT
mprintf('Volumetric efficiency is %3.1f percent \n Volumetric efficiency referred to atmospheric conditions is %3.1f percent \n Work required is %3.1f kJ/kg',nv1,nv2,W)


```

```







//==========================================END OF PROGRAM==============================================
```

Scilab code Exa 5.5 Theoretical volume of air taken

```
//Chapter-5, Illustration 5, Page 253
//Title: Air Compressors
//=============================================================================================================

clc
clear

//INPUT DATA
D=0.2;//Bore in m
L=0.3;//Stroke in m
lc=0.015;//Linear clearance in m
P1=1;//Pressure at point 1 in bar
P2=7;//Pressure at point 2 in bar
n=1.25;//Adiabatic gas constant

//CALCULATIONS
V3=(3.147*(D^2)*lc)/4;//Clearance volume in m^3
Vs=(3.147*(D^2)*L)/4;//Stoke volume in m^3
C=V3/Vs;//Clearance ratio
nv=(1+C-(C*((P2/P1)^(1/n))))*100;//Volumetric efficiency
DV=(nv*Vs)/100;//Volume of air taken in (m^3)/stroke

```

```
//OUTPUT
mprintf('Theoretical volume of air taken in per stroke is %3.6f (m^3)/stroke',DV)








//=============================================END OF PROGRAM==================================================
```

Scilab code Exa 5.6 Mean effective pressure and Power required

```
//Chapter-5, Illustration 6, Page 254
//Title: Air Compressors
//=====================================================================================================================

clc
clear

//INPUT DATA
D=0.2;//Bore in m
L=0.3;//Stroke in m
r=0.05;//Ratio of clearance volume to stroke volume
P1=1;//Pressure at point 1 in bar
T1=293;//Temperature at point 1 in K
P2=5.5;//Pressure at point 2 in bar
n=1.3;//Adiabatic gas constant
N=500;//Speed of compressor in rpm

//CALCULATIONS
```

```
x=(n-1)/n;//Ratio
Vs=(3.147*L*(D^2))/4;//Stroke volume in m^3
Vc=r*Vs;//Clearance volume in m^3
V1=Vc+Vs;//Volume at point 1 in m^3
V4=Vc*((P2/P1)^(1/n));//Volume at point 4 in m^3
EVs=V1-V4;//Effective swept volume in m^3
W=(P1*(10^5)*EVs*(((P2/P1)^x)-1))/x;//Work done in J/cycle
MEP=(W/Vs)/(10^5);//Mean effective pressure in bar
P=(W*N)/(60*1000);//Power required in kW

//OUTPUT
mprintf('Mean effective pressure is %3.2f bar \n Power required is %3.2f kW',MEP,P)







//==============================END OF PROGRAM==============================
```

Scilab code Exa 5.7 Free air delivered and Volumetric efficiency and Delivery temperature and Cycle power and Isothermal efficiency

```
//Chapter-5, Illustration 7, Page 255
//Title: Air Compressors
//==========================================================================

clc
clear

//INPUT DATA
```

```
D=0.2;//Bore in m
L=0.3;//Stroke in m
r=0.05;//Ratio of clearance volume to stroke volume
P1=97;//Pressure at entry in kN/(m^2)
P4=P1;//Pressure at point 4 in kN/(m^2)
T1=293;//Temperature at point 1 in K
P2=550;//Compression Pressure in kN/(m^2)
P3=P2;//Pressure at point 3 in kN/(m^2)
n=1.3;//Adiabatic gas constant
N=500;//Speed of compressor in rpm
Pa=101.325;//Air pressure in kN/(m^2)
Ta=288;//Air temperature in K

//CALCULATIONS
x=(n-1)/n;//Ratio
DV=(3.147*L*(D^2))/4;//Difference in volumes in m^3
V3=r*DV;//Clearance volume in m^3
V1=V3+DV;//Volume at point 1 in m^3
V4=V3*((P3/P4)^(1/n));//Volume at point 4 in m^3
Vs=V1-V4;//Effective swept volume in m^3
EVs=Vs*N;//Effective swept volume per min
Va=(P1*EVs*Ta)/(Pa*T1);//Free air delivered in (m^3)/min
nV=((V1-V4)/(V1-V3))*100;//Volumetric effciency
T2=T1*((P2/P1)^x);//Air delivery temperature in K
t2=T2-273;//Air delivery temperature in oC
W=(n*P1*(V1-V4)*(((P2/P1)^x)-1))*N/((n-1)*60);//Cycle power in kW
Wiso=P1*V1*(log(P2/P1));//Isothermal workdone
P=(n*P1*V1*(((P2/P1)^x)-1))/(n-1);//Cycle power neglecting clearance
niso=(Wiso/P)*100;//Isothermal efficiency

//OUTPUT
mprintf('Free air delivered is %3.3f (m^3)/min \n Volumetric efficiency is %3.0f percent \n Air delivery temperature is %3.1f oC \n Cycle power is %3.0f kW \n Isothermal efficiency is %3.1f
```

```
percent',Va,nV,t2,W,niso)










//==========================================END OF PROGRAM==============================================
```

Scilab code Exa 5.8 Mean effective pressure and Brake power

```
//Chapter-5, Illustration 8, Page 257
//Title: Air Compressors
//=============================================================================================
clc
clear

//INPUT DATA
Ve=30;//Volume of air entering compressor per hour in m^3
P1=1;//Presure of air entering compressor in bar
N=450;//Speed in rpm
P2=6.5;//Pressure at point 2 in bar
nm=0.8;//Mechanical efficiency
nv=0.75;//Volumetric efficiency
niso=0.76;//Isothermal efficiency

//CALCULATIONS
```

```
Vs=Ve/(nv*3600);//Swept volume per sec in (m^3)/s
V=(Vs*60)/N;//Swept volume per cycle in m^3
V1=(Ve*60)/(3600*N);//Volume at point 1 in m^3
Wiso=P1*100*V1*log(P2/P1);//Isothermal workdone per cycle
Wact=Wiso/niso;//Actual workdone per cycle on air
MEP=(Wact/V)/100;//Mean effective pressure in bar
IP=(Wact*N)/60;//Indicated power in kW
BP=IP/nm;//Brake power in kW

//OUTPUT
mprintf('Mean effective pressure is %3.3f bar \n Brake power is %3.2f kW',MEP,BP)








//==============================================END OF PROGRAM=================================================
```

Scilab code Exa 5.9 Cylinder dimensions

```
//Chapter-5, Illustration 9, Page 258
//Title: Air Compressors
//=============================================================================================================

clc
clear

//INPUT DATA
Va=15;//Volume of air in (m^3)/min
```

```
Pa=1.01325;//Pressure of air in bar
Ta=302;//Air temperature in K
P1=0.985;//Pressure at point 1 in bar
T1=313;//Temperature at point 1 in K
r=0.04;//Ratio of clearance volume to swept volume
y=1.3;//Ratio of stroke to bore diameter
N=300;//Speed in rpm
n=1.3;//Adiabatic gas constant
P2=7.5;//Pressure at point 2 in bar

//CALCULATIONS
x=((P2/P1)^(1/n))-1;//Ratio of volume at point 4 to clearance volume
a=x*r;//Ratio of volume at point 4 to swept volume
nv=1-a;//Volumetric efficiency
V1=(Pa*Va*T1)/(Ta*P1);//Volume at point 1 in (m^3)/min
Vs=V1/(nv*N*2);//Swept volume in m^3
D=((Vs*4)/(3.147*y))^(1/3);//Bore in m
L=y*D;//Stroke in m

//OUTPUT
mprintf('Cylinder bore in %3.3f m \n Cylinder stroke %3.3f m',D,L)







//==================================END OF PROGRAM======================================
```

Scilab code Exa 5.10 Volumetric efficiency and Indicated power and Isothermal efficiency of compressor

```
//Chapter-5, Illustration 10, Page 259
//Title: Air Compressors
//==================================================================================

clc
clear

//INPUT DATA
P1=0.98;//Pressure at point 1 in bar
P4=P1;//Pressure at point 4 in bar
P2=7;//Pressure at point 2 in bar
P3=P2;//Pressure at point 3 in bar
n=1.3;//Adiabatic gas constant
Ta=300;//Air temperature in K
Pa=1.013;//Air pressure in bar
T1=313;//Temperature at point 1 in K
c=0.04;//Ratio of clearance volume to swept volume
Va=15;//Volume of air delivered in m^3
R=0.287;//Universal gas constant in kJ/kg-K

//CALCULATIONS
x=(n-1)/n;//Ratio
r=(P2/P1)^(1/n);//Ratio of volumes
a=r*c;//Ratio of volume at point 4 to swept volume
DV=1+c-a;//Difference in volumes
V=(P1*DV*Ta)/(T1*Pa);//Volume of air delivered per cycle
nv=V*100;//Volumetric efficiency
DV1=(Pa*Va*T1)/(Ta*P1);//Difference in volumes
T2=T1*((P2/P1)^x);//Temperature at point 2 in K
ma=(Pa*100*Va)/(R*Ta);//Mass of air delivered in kg/min
IP=(ma*R*(T2-T1))/(x*60);//Indicated power in kW
Piso=(ma*R*T1*log(P2/P1))/60;//Isothermal indicated power in kW
niso=(Piso/IP)*100;//Isothermal efficiency

```

```
//OUTPUT
mprintf('Volumetric efficiency is %3.1f percent \n Indicated power is %3.2f kW \n Isothermal efficiency is %3.0f percent',nv,IP,niso)















//=======================================END OF PROGRAM===========================================
```

Scilab code Exa 5.11 Power required

```
//Chapter-5, Illustration 11, Page 261
//Title: Air Compressors
//=============================================================================================================

clc
clear

//INPUT DATA
V1=7*(10^-3);//Volume of air in (m^3)/s
P1=1.013;//Pressure of air in bar
T1=288;//Air temperature in K
```

```
P2=14;//Pressure at point 2 in bar
n=1.3;//Adiabatic gas constant
nm=0.82;//Mechanical efficiency

//CALCULATIONS
x=(n-1)/n;//Ratio
W=(P1*100*V1*(((P2/P1)^x)-1))/x;//Work done by
    compressor in kW
P=W/nm;//Power requred to drive compressor in kW

//OUTPUT
mprintf('Power requred to drive compressor is %3.2f
    kW',P)









//==================================END OF PROGRAM
    =====================================
```

Scilab code Exa 5.12 Theoretical volume efficiency and Volume of air delivered and Power of compressor

```
//Chapter-5, Illustration 12, Page 261
//Title: Air Compressors
//
    ==========================================================================
clc
clear

```

```
//INPUT DATA
L=0.15;//Stroke in mm
D=0.15;//Bore in mm
N=8;//Speed in rps
P1=100;//Pressure at point 1 in kN/(m^2)
P2=550;//Pressure at point 2 in kN/(m^2)
n=1.32;//Adiabatic gas constant
C=0.06;//Ratio of clearance volume to swept volume

//CALCULATIONS
x=(n-1)/n;//Ratio
nv=(1+C-(C*((P2/P1)^(1/n))))*100;//Volumetric efficiency
DV=(3.147*(D^2)*L)/4;//Difference in volumes at points 1 and 3
DV1=(nv*DV)/100;//Difference in volumes at points 1 and 4
V2=DV1*((P1/P2)^(1/n))*N;//Volume of air delivered per second
W=(P1*DV1*(((P2/P1)^x)-1))*N/x;//Power of compressor in kW

//OUTPUT
mprintf('Theoretical volume efficiency is %3.1f percent \n Volume of air delivered is %3.5f (m^3)/s \n Power of compressor is %3.3f kW',nv,V2,W)










//==========================================END OF PROGRAM==============================================
```

Scilab code Exa 5.13 Minimum indicated power and Maximum temperature and Heat to be removed and Mass of cooling water

```
//Chapter-5, Illustration 13, Page 262
//Title: Air Compressors
//=============================================================================
clc
clear

//INPUT DATA
V=16;//Volume of air compresssed in m^3
P1=1;//Pressure at point 1 in bar
P3=10.5;//Pressure at point 3 in bar
T1=294;//Temperature at point 1 in K
Tc=25;//Temperature of cooling water in oC
n=1.35;//Adiabatics gas constant
R=0.287;//Universal gas constant in kJ/kg-K
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K
Cw=4.187;//Specific heat of water in kJ/kg-K

//CALCULATIONS
x=(n-1)/n;//Ratio
P2=sqrt(P1*P3);//Pressure at point 2 in bar
W1=(2*P1*100*V*(((P2/P1)^x)-1))/(x*60);//Indicated power of compressor from P1 to P2 in kW
W2=(P1*100*V*(((P3/P1)^x)-1))/(x*60);//Indicated power of compressor from P1 to P3 in kW
T4=T1*((P2/P1)^x);//Maximum temperature for two stage compression in K
T2=T1*((P3/P1)^x);//Maximum temperature for single stage compression in K
```

```
m=(P1*100*V)/(R*T1);//Mass of air compressed in kg/min
Q=m*Cp*(T4-T1);//Heat rejected by air in kJ/min
mc=Q/(Cw*Tc);//Mass of cooling water in kg/min

//OUTPUT
mprintf('Minimum indicated power required for 2 stage compression is %3.1f kW \n Power required for single stage compression is 18 percent more than that for two stage compression with perfect intercooling \n Maximum temperature for two stage compression is %3.1f K \n Maximum temperature for single stage compression is %3.1f K \n Heat rejected by air is %3.1f kJ/min \n Mass of cooling water required is %3.1f kg/min',W1,T4,T2,Q,mc)















//==============================END OF PROGRAM==============================
```

Scilab code Exa 5.14 Intermediate pressure and Total volume of each cylinder and Cycle power

```
//Chapter-5, Illustration 14, Page 264
//Title: Air Compressors
//=============================================================================

clc
clear

//INPUT DATA
V=0.2;//Air flow rate in (m^3)/s
P1=0.1;//Intake pressure in MN/(m^2)
P3=0.7;//Final pressure in MN/(m^2)
T1=289;//Intake temperature in K
n=1.25;//Adiabatic gas constant
N=10;//Compressor speed in rps

//CALCULATIONS
x=(n-1)/n;//Ratio
P2=sqrt(P1*P3);//Intermediate pressure in MN/(m^2)
V1=(V/N)*1000;//Total volume of LP cylinder in litres
V2=((P1*V1)/P2);//Total volume of HP cylinder in litres
W=((2*P1*V*(((P2/P1)^x)-1))/x)*1000;//Cycle power in kW

//OUTPUT
mprintf('Intermediate pressure is %3.3f MN/(m^2) \n Total volume of LP cylinder is %3.0f litres \n Total volume of HP cylinder is %3.1f litres \n Cycle power is %3.0f kW',P2,V1,V2,W)







```

```

//==================================================END OF PROGRAM===============================================================
```

Scilab code Exa 5.15 Power of compressor

```
//Chapter-5, Illustration 15, Page 265
//Title: Air Compressors
//=============================================================================================================

clc
clear

//INPUT DATA
P1=1;//Pressure at point 1 in bar
T1=290;//Temperature at point 1 in K
P3=60;//Pressure at point 3 in bar
P2=8;//Pressure at point 2 in bar
T2=310;//Temperature at point 2 in K
L=0.2;//Stroke in m
D=0.15;//Bore in m
n=1.35;//Adiabatic gas constant
N=200;//Speed in rpm

//CALCULATIONS
x=(n-1)/n;//Ratio
V1=(3.147*(D^2)*L)/4;//Volume at point 1 in m^3
V2=(P1*V1*T2)/(T1*P2);//Volume of air entering LP cylinder in m^3
W=((P1*(10^5)*V1*(((P2/P1)^x)-1))/x)+((P2*(10^5)*V2*(((P3/P2)^x)-1))/x);//Workdone by compressor per cycle in J
P=(W*N)/(60*1000);//Power of compressor in kW

```

```
//OUTPUT
mprintf('Power of compressor is %3.2f kW',P)








//=========================================END OF PROGRAM
   ============================================
```

Scilab code Exa 5.16 Heat rejected and Diameter of HP cylinder and Power required

```
//Chapter-5, Illustration 16, Page 265
//Title: Air Compressors
//
   ==========================================================================================


clc
clear

//INPUT DATA
N=220;//Speed of compressor in rpm
P1=1;//Pressure entering LP cylinder in bar
T1=300;//Temperature at point 1 in K
Dlp=0.36;//Bore of LP cylinder in m
Llp=0.4;//Stroke of LP cylinder in m
Lhp=0.4;//Stoke of HP cylinder in m
C=0.04;//Ratio of clearance volumes of both
    cylinders
P2=4;//Pressure leaving LP cylinder in bar
P5=3.8;//Pressure entering HP cylinder in bar
```

```
T3=300;//Temperature entering HP cylinder in K
P6=15.2;//Dicharge pressure in bar
n=1.3;//Adiabatic gas constant
Cp=1.0035;//Specific heat at constant pressure in kJ
    /kg-K
R=0.287;//Universal gas constant in kJ/kg-K
T5=T1;//Temperature at point 5 in K

//CALCULATIONS
x=(n-1)/n;//Ratio
Vslp=(3.147*(Dlp^2)*Llp*N*2)/4;//Swept volume of LP
    cylinder in m^3/min
nv=1+C-(C*((P2/P1)^(1/n)));//Volumetric efficiency
V1=nv*Vslp;//Volume of air drawn at point 1 in (m^3)
    /min
m=(P1*100*V1)/(R*T1);//Mass of air in kg/min
T2=T1*((P2/P1)^x);//Temperature at point 2 in K
QR=m*Cp*(T2-T5);//Heat rejected in kJ/min
V5=(m*R*T5)/(P5*100);//Volume of air drawn in HP
    cylinder M^3/min
Plp=P2/P1;//Pressure ratio of LP cylinder
Php=P6/P5;//Pressure ratio of HP cylinder
Vshp=V5/nv;//Swept volume of HP cylinder in m^3/min
Dhp=sqrt((Vshp*4)/(3.147*Lhp*N*2));//Bore of HP
    cylinder in m
P=(m*R*(T2-T1))/(x*60);//Power required for HP
    cylinder in kW

//OUTPUT
mprintf('Heat rejected in intercooler is %3.1f kJ/
    min \n Diameter of HP cylinder is %3.4f m \n
    Power required for HP cylinder is %3.0f kW',QR,
    Dhp,P)





```

```
//==================================END OF PROGRAM
   =====================================
```

Scilab code Exa 5.17 Ratio of cylinder diameters

```
//Chapter-5, Illustration 17, Page 267
//Title: Air Compressors
//
   ==========================================================================

clc
clear

//INPUT DATA
P1=1;//Pressure at point 1 in bar
P3=30;//Pressure at point 3 in bar
T1=300;//Temperature at point 1 in K
n=1.3;//Adiabatics gas constant

//CALCULATIONS
P2=sqrt(P1*P3);//Intermediate pressure in bar
rD=sqrt(P2/P1);//Ratio of cylinder diameters

//OUTPUT
mprintf('Ratio of cylinder diameters is %3.2f',rD)
```

```

//==================================================END OF PROGRAM=======================================================
```

Scilab code Exa 5.18 Delivery pressures and Ratio of cylinder volumes and Temperature and Heat rejected in intercooler and Total indicated power

```
//Chapter-5, Illustration 18, Page 268
//Title: Air Compressors
//=============================================================================================================

clc
clear

//INPUT DATA
P1=1.013;//Pressure at point 1 in bar
T1=288;//Temperaturea at point 1 in K
v1=8.4;//free air delivered by compressor in m^3
P4=70;//Pressure at point 4 in bar
n=1.2;//Adiabatic gas constant
Cp=1.0035;//Specific heat at constant pressure in kJ/kg-K

//CALCULATIONS
x=(n-1)/n;//Ratio
P2=P1*((P4/P1)^(1/3));//LP cylinder delivery pressure in bar
P3=P2*((P4/P1)^(1/3));//IP cylinder delivery pressure in bar
r=P2/P1;//Ratio of cylinder volumes
r1=P3/P2;//Ratio of cylinder volumes
r2=r*r1;//Ratio of cylinder volumes
V3=1;//Volume at point 3 in m^3
T4=T1*((P2/P1)^x);//Three stage outlet temperature
```

```
in K
QR=Cp*(T4-T1);//Heat rejected in intercooler in kJ/kg of air
W=((3*P1*100*v1*(((P4/P1)^(x/3))-1))/(x*60));//Total indiacted power in kW

//OUTPUT
mprintf('LP cylinder delivery pressure is %3.3f bar \n IP cylinder delivery pressure is %3.2f bar \n Ratio of cylinder volumes is %3.2f:%3.1f:%3.0f \n Temperature at end of each stage is %3.2f K \n Heat rejected in each intercooler is %3.1f kJ/kg of air \n Total indicated power is %3.2f kW',P2,P3,r2,r1,V3,T4,QR,W)













//========================================END OF PROGRAM============================================
```

Scilab code Exa 5.19 Intermediate pressures and Effective swept volume and Temperature and volume of air delivered and Workdone

```
//Chapter-5, Illustration 19, Page 269
//Title: Air Compressors
//
```

```
clc
clear

//INPUT DATA
D=0.45;//Bore in m
L=0.3;//Stroke in m
C=0.05;//Ratio of clearance volume to swept volume
P1=1;//Pressure at point 1 inn bar
T1=291;//Temperature at point 1 in K
P4=15;//Pressure at point 4 in bar
n=1.3;//Adiabatic gas constant
R=0.29;//Universal gas constant in kJ/kg-K

//CALCULATIONS
x=(n-1)/n;//Ratio
k=(P4/P1)^(1/3);//Pressure ratio
P2=k*P1;//Pressure at point 2 in bar
P3=k*P2;//Pressure at point 1 in bar
Vslp=(3.147*(D^2)*L)/4;//Swept volume of LP cylinder
V7=C*Vslp;//Volume at point 7 in m^3
V1=Vslp+V7;//Volume at point 1 in m^3
V8=V7*(k^(1/n));//Volume at point 8 in m^3
EVs=(V1-V8)*1000;//Effective swept volume in litres
T4=T1*(k^x);//Temperature at point 4 in K
t4=T4-273;//Delivery temperature in oC
DV=((P1*T4*(V1-V8))/(P4*T1))*1000;//Delivery volume per stroke in litres
W=(3*R*T1*((k^x)-1))/x;//Workdone per kg of air in kJ

//OUTPUT
mprintf('Intermediate pressures are %3.3f bar and %3.3f bar \n Effective swept volume of LP cylinder is %3.2f litres \n Temperature of air delivered per stroke is %3.1f oC \n Volume of air delivered per stroke is %3.2f litres \n Work done per kg
```

```
    of air is %3.1f kJ',P2,P3,EVs,t4,DV,W)











//==============================END OF PROGRAM==================================
```

Scilab code Exa 5.20 Number of stages and Exact stage pressure ratio and Intermediate pressures

```
//Chapter-5, Illustration 20, Page 271
//Title: Air Compressors
//==============================================================================

clc
clear

//INPUT DATA
P1=1;//Pressure at point 1 in bar
Pns=100;//Maximum pressure in bar
p=4;//Pressure ratio

//CALCULATIONS
Ns=log(Pns)/log(p);//Number of stages
y=ceil(Ns);//Rounding off to next higher integer
ps=(Pns/P1)^(1/y);//Exact stage pressure ratio
```

```
P2=ps*P1;//Pressure at point 2 in bar
P3=ps*P2;//Pressure at point 3 in bar
P4=ps*P3;//Pressure at point 4 in bar

//OUTPUT
mprintf('Number of stages are %3.0f \n Exact stage pressure ratio is %3.3f \n Intermediate pressures are %3.3f bar,%3.2f bar,%3.2f bar',y,ps,P2,P3,P4)









//==================================END OF PROGRAM==================================
```

Chapter 6

Refrigeration Cycles

Scilab code Exa 6.1 Claim is correct or not

```
//Chapter-6, Illustration 1, Page 308
//Title: Refrigeration cycles
//=============================================================================

clc
clear

//INPUT DATA
COP=8.5;//Co-efficient of performance
T1=300;//Room temperature in K
T2=267;//Refrigeration temperature in K

//CALCULATIONS
COPmax=T2/(T1-T2);//Maximum COP possible

//OUTPUT
mprintf('Maximum COP possible is %3.2f \n Since the COP claimed by the inventor is more than the maximum possible COP his claim is not correct',COPmax)
```

```



//==================================================END OF PROGRAM
    =======================================================
```

Scilab code Exa 6.2 Weight of ice formed and Minimum power required

```
//Chapter-6, Illustration 2, Page 309
//Title: Refrigeration cycles
//
    ==========================================================================================================

clc
clear

//INPUT DATA
TL=268;//Low temperature in K
TH=293;//High temperature in K
t=24;//time in hrs
C=2100;//Capacity of refrigerator in kJ/s
Tw=10;//Water temperature in oC
L=335;//Latent heat of ice in kJ/kg

//CALCULATIONS
COP=TL/(TH-TL);//Co-efficient of performance
Pmin=C/COP;//Minimum power required in kW
Qr=(4.187*(Tw-0))+L;//Heat removed from water in kJ/
    kg
m=C/Qr;//mass of ice formed in kg/s
W=(m*t*3600)/1000;//Weight of ice formed in tons

//OUTPUT
mprintf('Minimum power required is %3.2f kW \n
    Weight of ice formed in 24 hours is %3.2f tons',
```

```
Pmin,W)






//==========================================END OF PROGRAM==========================================
```

Scilab code Exa 6.3 Mass of ice formed

```
//Chapter-6, Illustration 3, Page 309
//Title: Refrigeration cycles
//=============================================================================================

clc
clear

//INPUT DATA
TL=-10;//Temperature of brine in oC
TH=20;//Temperature of water in oC
L=335;//Latent heat of ice in kJ/kg

//CALCULATIONS
Qr=(4.187*(TH-0))+L;//Heat removed from water in kJ/kg
COP=(TL+273)/(TH-TL);//Co-efficient of performance
mi=(COP*3600)/Qr;//mass of ice formed per kWh in kg

//OUTPUT
mprintf('Mass of ice formed per kWh is %3.1f kg',mi)


```

```




//=========================================END OF PROGRAM=============================================
```

Scilab code Exa 6.4 Rate of heat removed and Power input to compreesor and Rate of heat rejection to environment and Coefficient of performance

```
//Chapter-6, Illustration 4, Page 310
//Title: Refrigeration cycles
//=============================================================================================

clc
clear

//INPUT DATA
P1=1.2;//Pressure at point 1 in bar
P2=7;//Pressure at point 2 in bar
m=0.05;//mass flow rate of refrigerant in kg/s
h1=340.1;//Enthalpy at point 1 from refrigerant-12 tables in kJ/kg
s1=1.57135;//Entropy at point 1 from refrigerant-12 tables in kJ/kg-K
s2=1.57135;//Entropy at point 2 from refrigerant-12 tables in kJ/kg-K
h2=372;//Enthalpy at point 2 from refrigerant-12 tables in kJ/kg
h3=226.575;//Enthalpy at point 3 from refrigerant-12 tables in kJ/kg
h4=226.575;//Enthalpy at point 4 from refrigerant-12 tables in kJ/kg

```

```
//CALCULATIONS
Q2=m*(h1-h4);//Rate of heat removed from the refrigerated space in kW
W=m*(h2-h1);//Power input to the compressor in kW
Q1=m*(h2-h3);//Rate of heat rejection to the environment in kW
COP=Q2/W;//Co-efficient of performance

//OUTPUT
mprintf('Rate of heat removed from the refrigerated space is %3.2f kW \n Power input to the compressor is %3.3f kW \n Rate of heat rejection to the environment is %3.2f kW \n Co-efficient of performance is %3.2f',Q2,W,Q1,COP)




//==================================END OF PROGRAM=====================================
```

Scilab code Exa 6.5 COP of system

```
//Chapter-6, Illustration 5, Page 311
//Title: Refrigeration cycles
//=============================================================================

clc
clear

//INPUT DATA
T2=40;//Temperature at point 2 in oC
T1=-10;//Temperature at point 1 in oC
h2=367.155;//Enthalpy at point 2 from refrigerant-12
```

```
tables in kJ/kg
s2=1.54057;//Entropy at point 2 from refrigerant-12 tables in kJ/kg-K
s1=1.54057;//Entropy at point 1 from refrigerant-12 tables in kJ/kg-K
sg=1.56004;//Entropy from refrigerant-12 tables in kJ/kg-K
sf=0.96601;//Entropy from refrigerant-12 tables in kJ/kg-K
hf=190.822;//Enthalpy from refrigerant-12 tables in kJ/kg-K
hfg=156.319;//Enthalpy from refrigerant-12 tables in kJ/kg-K
h3=238.533;//Enthalpy at point 3 from refrigerant-12 tables in kJ/kg-K
h4=h3;//Enthalpy at point 4 from refrigerant-12 tables in kJ/kg-K

//CALCULATIONS
x1=(s1-sf)/(sg-sf);//Quality factor
h1=hf+(x1*hfg);//Enthalpy at point 1 from refrigerant-12 tables in kJ/kg
COP=(h1-h4)/(h2-h1);//Co-efficient of performance

//OUTPUT
mprintf('COP of the system is %3.2f',COP)



//===========================================END OF PROGRAM================================================
```

Scilab code Exa 6.6 Capacity of refrigeration plant and Mass flow rate of refrigerant and Discharge temperature and Cylinder dimensions and Power of compressor and Theoretical and actual COP

```
//Chapter-6, Illustration 6, Page 311
//Title: Refrigeration cycles
//

clc
clear

//INPUT DATA
Tc=35;//Temperature of condenser in oC
Te=-15;//Temperature of evaporator in oC
m=10;//Mass of ice per day in tons
Tw=30;//Temperature of water in oC
Ti=-5;//Temperature of ice in oC
nv=0.65;//Volumetric efficiency
N=1200;//Speed in rpm
x=1.2;//Stroke to bore ratio
na=0.85;//Adiabatic efficiency
nm=0.95;//Mechanical efficiency
S=4.187;//Specific heat of water in kJ/kg
L=335;//Latent heat of ice in kJ/kg
h1=1667.24;//Enthalpy at Te from Ammonia chart in kJ/kg
h2=1925;//Enthalpy at Te from Ammonia chart in kJ/kg
h4=586.41;//Enthalpy at Tc from Ammonia chart in kJ/kg
v1=0.508;//Specific humidity at Te from Ammonia chart in (m^3)/kg

//CALCULATIONS
Qr=(((m*1000)/24)*((S*(Tw-0))+L+(1.94*(0-Ti))))/3600;//Refrigerating capacity in kW
mr=Qr/(h1-h4);//Refrigerant mass flow rate in kg/s
T2=112;//Discharge temperature in oC
D=((mr*v1*4*60)/(nv*3.14*x*N))^(1/3);//Cylinder diameter in m
L=x*D;//Stroke length in m
W=(mr*(h2-h1))/(na*nm);//Compressor motor power in
```

```
kW
COPth=(h1-h4)/(h2-h1);//Theoretical COP
COPact=Qr/W;//Actual COP

//OUTPUT
mprintf('Refrigerating capacity of plant is %3.2f kW \n Refrigerant mass flow rate is %3.4f kg/s \n Discharge temperature is %3.0f oC \n Cylinder diameter is %3.3f m \n Stroke length is %3.3f m \n Compressor motor power is %3.2f kW \n Theoretical COP is %3.2f \n Actual COP is %3.2f',Qr,mr,T2,D,L,W,COPth,COPact)




//==============================END OF PROGRAM==============================
```

Scilab code Exa 6.7 Circulation rate of ammonia and Power required and COP

```
//Chapter-6, Illustration 7, Page 313
//Title: Refrigeration cycles
//=============================================================================

clc
clear

//INPUT DATA
T1=-5;//Temperature at point 1 in oC
T2=30;//Temperature at point 2 in oC
m=13500;//mass of ice per day in kg
Tw=20;//Temperature of water in oC
```

```
COP=0.6;//Co-efficient of performance
h2=1709.33;//Enthalpy at point 2 in kJ/kg
s2=6.16259;//Entropy at point 2 in kJ/kg-K
s1=6.16259;//Entropy at point 1 in kJ/kg-K
sf=1.8182;//Entropy in kJ/kg-K
sg=6.58542;//Entropy in kJ/kg-K
hf=400.98;//Enthalpy in kJ/kg
hfg=1278.35;//Enthalpy in kJ/kg
h4=562.75;//Enthalpy at point 4 in kJ/kg
S=4.187;//Specific heat of water in kJ/kg
L=336;//Latent heat of ice in kJ/kg

//CALCULATIONS
x1=(s1-sf)/(sg-sf);//Quality factor
h1=hf+(x1*hfg);//Enthalpy at point 1 from refrigerant-12 tables in kJ/kg
COPi=(h1-h4)/(h2-h1);//Ideal COP
COPact=COP*COPi;//Actual COP
Qr=((m*S*(Tw-0))+(m*L))/(24*3600);//Total amount of heat removed in kJ/s
mr=Qr/(h1-h4);//Circulation rate of ammonia in kg/s
W=mr*(h2-h1);//Power required in kW

//OUTPUT
mprintf('Circulation rate of ammonia is %3.3f kg/s \n Power required is %3.3f kW \n COP is %3.3f',mr,W,COPact)





//==================================================END OF PROGRAM======================================================
```

Scilab code Exa 6.8 Refrigerating effect and Mass flow rate of refrigerant and Theoretical power and COP and Theoretical bore and stroke of compressor

```
//Chapter-6, Illustration 8, Page 314
//Title: Refrigeration cycles
//
clc
clear

//INPUT DATA
Tc=20;//Temperature of condenser in oC
Te=-25;//Temperature of evaporator in oC
m=15;//Mass of ice per day in tons
Ts=5;//Subcooled temperature in oC
Tsh=10;//Superheated temperature in oC
n=6;//No. of cylinders
N=950;//Speed of compressor in rpm
x=1;//Stroke to bore ratio
h1=402;//Enthalpy at point 1 from R-22 tables in kJ/kg
h2=442;//Enthalpy at point 2 from R-22 tables in kJ/kg
h3=216;//Enthalpy at point 3 from R-22 tables in kJ/kg
h4=216;//Enthalpy at point 4 from R-22 tables in kJ/kg
v1=2.258;//Specific volume at point 1 in (m^3)/min

//CALCULATIONS
Re=h1-h4;//Refrigerating effect in kJ/kg
mr=(m*14000)/(Re*60);//Mass flow of refrigerant in kg/min
Pth=(mr*(h2-h1))/60;//Theoretical power in kW
COP=(h1-h4)/(h2-h1);//Co-efficient of performance
Dth=v1/n;//Theoretical displacement per cylinder
```

```
D=(((Dth*4)/(3.147*N))^(1/3))*1000;//Theoretical bore of compressor in mm
L=D;//Theoretical stroke of compressor in mm

//OUTPUT
mprintf('Refrigerating effect is %3.0f kJ/kg \n Mass flow of refrigerant per minute is %3.2f kg/min \n Theoretical input power is %3.2f kW \n COP is %3.2f \n Theoretical bore of compressor is %3.2f mm \n Theoretical stroke of compressor is %3.2f mm',Re,mr,Pth,COP,D,L)







//==================================================END OF PROGRAM ======================================================
```

Scilab code Exa 6.9 COP when there is no subcooling and when there is subcooling

```
//Chapter-6, Illustration 9, Page 316
//Title: Refrigeration cycles
//=============================================================================================================

clc
clear

//INPUT DATA
T2=40;//Temperature at point 2 in oC
T1=-5;//Temperature at point 1 in oC
```

```
h2=367.155;//Enthalpy at point 2 from F-12 tables in kJ/kg
sg=1.55717;//Entropy from F-12 tables in kJ/kg-K
s1=1.54057;//Entropy at point 1 from F-12 tables in kJ/kg-K
sf=0.98311;//Entropy from F-12 tables in kJ/kg-K
hf=195.394;//Enthalpy from F-12 tables in kJ/kg
hfg=153.934;//Enthalpy from F-12 tables in kJ/kg
h4=238.533;//Enthalpy at point 4 from F-12 tables in kJ/kg
h4s=218;//Enthalpy at point 4 with subcooling from F-12 tables in kJ/kg

//CALCULATIONS
x1=(s1-sf)/(sg-sf);//Quality factor
h1=hf+(x1*hfg);//Enthalpy at point 1 from refrigerant-12 tables in kJ/kg
COPns=(h1-h4)/(h2-h1);//Co-efficient of performance with no subcooling
COPs=(h1-h4s)/(h2-h1);//Co-efficient of performance with subcooling

//OUTPUT
mprintf('COP with no subcooling is %3.3f \n COP with subcooling is %3.3f',COPns,COPs)









//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 6.10 Ideal COP of system

```
//Chapter-6, Illustration 10, Page 309
//Title: Refrigeration cycles
//
    ===================================================================================
clc
clear

//INPUT DATA
Tg=470;//Heating temperature in K
T0=290;//Cooling temperature in K
TL=270;//Refrigeration temperature in K

//CALCULATIONS
COP=((Tg-T0)/Tg)*(TL/(T0-TL));//Ideal COP of
    absorption refrigeration system

//OUTPUT
mprintf('Ideal COP of absorption refrigeration
    system is %3.2f',COP)



//================================END OF PROGRAM
    ===================================
```

Scilab code Exa 6.11 Maximum and minimum temperature in cycle and COP and Rate of refrigeration

```
//Chapter-6, Illustration 11, Page 317
```

```
//Title: Refrigeration cycles
//==================================================================================

clc
clear

//INPUT DATA
T1=-18;//Temperature at point 1 in oC
T3=27;//Temperature at point 3 in oC
rp=4;//Pressure ratio
m=0.045;//mass flow rate in kg/s
y=1.4;//Ratio of specific heats
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K

//CALCULATIONS
x=(y-1)/y;//Ratio
T2=(rp^x)*(273+T1);//Temperature at point 2 in K
Tmax=T2-273;//Maximum temperature in oC
T4=((1/rp)^x)*(273+T3);//Temperature at point 4 in K
Tmin=T4-273;//Minimum temperature in oC
qL=Cp*(T1-Tmin);//Heat rejected
Wcin=Cp*(Tmax-T1);//Compressor work
Wtout=Cp*(T3-Tmin);//Turbine work
Wnet=Wcin-Wtout;//Net work done
COP=qL/Wnet;//Co-efficient of performance
Qref=m*qL;//Rate of refrigeration in kW

//OUTPUT
mprintf('Maximum temperature in the cycle is %3.0foC \n Minimum temperature in the cycle is %3.0foC \n COP is %3.2f \n Rate of refrigeration is %3.2f kW',Tmax,Tmin,COP,Qref)
```

```

//==================================END OF PROGRAM======================================
```

Scilab code Exa 6.12 Work developed and Refrigerating effect and COP

```
//Chapter-6, Illustration 12, Page 318
//Title: Refrigeration cycles
//=============================================================================================================

clc
clear

//INPUT DATA
P1=1;//Pressure at point 1 in bar
T1=268;//Temperature at point 1 in K
P2=5;//Pressure at point 2 in bar
T3=288;//Temperature at point 3 in K
n=1.3;//Adiabatic gas constant
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K

//CALCULATIONS
x=(n-1)/n;//Ratio
T2=((P2/P1)^x)*T1;//Temperature at point 2 in K
T4=((P1/P2)^x)*T3;//Temperature at point 4 in K
W=Cp*(T3-T4);//Work developed per kg of air in kJ/kg
Re=Cp*(T1-T4);//Refrigerating effect per kg of air in kJ/kg
Wnet=Cp*((T2-T1)-(T3-T4));//Net work output in kJ/kg
COP=Re/Wnet;//Co-efficient of performance

//OUTPUT
mprintf('Work developed per kg of air is %3.3f kJ/kg
```

```
\n Refrigerating effect per kg of air is %3.3f kJ/kg \n COP of the cycle is %3.2f',W,Re,COP)





//==============================================END OF PROGRAM==================================================
```

Scilab code Exa 6.13 COP of refrigerator and Driving power required and Air mass flow rate

```
//Chapter-6, Illustration 13, Page 319
//Title: Refrigeration cycles
//=============================================================================================================

clc
clear

//INPUT DATA
T1=277;//Temperature at point 1 in K
T3=328;//Temperature at point 3 in K
P1=0.1;//Pressure at point 1 in MPa
P2=0.3;//Pressure at point 2 in MPa
nc=0.72;//Isentropic efficiency of compressor
nt=0.78;//Isentropic efficiency of turbine
y=1.4;//Adiabatic gas constant
Cp=1.005;//Specific heat at constant pressure in kJ/kg-K
m=3;//Cooling load in tonnes

//CALCULATIONS
x=(y-1)/y;//Ratio
```

```
T2s=T1*((P2/P1)^x);//Temperature at point 2s in K
T2=((T2s-T1)/nc)+T1;//Temerature at point 2 in K
T4s=T3*((P1/P2)^x);//Temperature at point 4s in K
T4=T3-((T3-T4s)*nt);//Temperature at point 4 in K
Re=Cp*(T1-T4);//Refrigerating effect in kJ/kg
Wnet=Cp*((T2-T1)-(T3-T4));//Net work output in kJ/kg
COP=Re/Wnet;//Co-efficient of performance
P=(m*3.52)/COP;//Driving power required in kW
ma=(m*3.52)/Re;//Mass flow rate of air in kg/s

//OUTPUT
mprintf('COP of refrigerator is %3.2f \n Driving power required is %3.0f kW \n Mass flow rate of air is %3.3f kg/s',COP,P,ma)




//==============================END OF PROGRAM==================================
```

Scilab code Exa 6.14 Theoretical COP and Net cooling produced

```
//Chapter-6, Illustration 14, Page 321
//Title: Refrigeration cycles
//==================================================================================

clc
clear

//INPUT DATA
P1=2.5;//Pressure at point 1 in bar
P3=9;//Pressure at point 3 in bar
COPr=0.65;//Ratio of actual COP to the theoretical
```

```
   COP
m=5;//Refrigerant flow in kg/min
T1=309;//Temperature at point 1 in K
T2s=300;//Temperature at point 2s in K
h1=570.3;//Enthalpy at P1 from the given tables in
   kJ/kg
h4=456.4;//Enthalpy at P3 from the given tables in
   kJ/kg
h2g=585.3;//Enthalpy at P3 from the given tables in
   kJ/kg
s2=4.76;//Entropy at P1 from the given tables in kJ/
   kg-K
s2g=4.74;//Entropy at P3 from the given tables in kJ
   /kg-K
Cp=0.67;//Specific heat at P3 in kJ/kg-K

//CALCULATIONS
T2=(2.718^((s2-s2g)/Cp))*T2s;//Temperature at point
   2 in K
h2=h2g+(Cp*(T2-T2s));//Enthalpy at point 2 in kJ/kg
COPR=(h1-h4)/(h2-h1);//Refrigerant COP
COPact=COPr*COPR;//Actual COP
qL=COPact*(h2-h1);//Heat rejected in kJ/kg
QL=((m*qL*60)/3600)/3.516;//Cooling produced per kg
   of refrigerant in tonnes of refrigeration

//OUTPUT
mprintf('Theoretical COP is %3.2f \n Net cooling
   produced per hour is %3.2f TR',COPR,QL)




//==================================END OF PROGRAM
   ======================================
```

Scilab code Exa 6.15 Theoretical COP of machine

```
//Chapter-6, Illustration 15, Page 322
//Title: Refrigeration cycles
//
    ==========================================================================

clc
clear

//INPUT DATA
T2=298;//Temperature at point 2 in K
T1=268;//Temperature at point 1 in K
hf1=-7.54;//Liquid Enthalpy at T1 in kJ/kg
x1=0.6;//Quality factor 1
hfg1=245.3;//Latent heat at T1 in kJ/kg
sf1=0.251;//Liquid Entropy at T1 in kJ/kg-K
s1=0.507;//Entropy at point 1 in kJ/kg-K
hfg2=121.4;//Latent heat at T2 in kJ/kg
hf2=81.3;//Liquid Enthalpy at T2 in kJ/kg
h4=hf2;//Enthalpy at point 4 in kJ/kg

//CALCULATIONS
h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
x2=((s1-sf1)*T2)/hfg2;//Quality factor 2
h2=hf2+(x2*hfg2);//Enthalpy at point 2 in kJ/kg
COP=(h1-h4)/(h2-h1);//COP of the machine

//OUTPUT
mprintf('COP of the machine is %3.2f',COP)




```

```
//==========================================END OF PROGRAM==============================================
```

Scilab code Exa 6.16 Theoretical COP of refrigerator and Capacity of refrigerator

```
//Chapter-6, Illustration 16, Page 323
//Title: Refrigeration cycles
//=============================================================================================

clc
clear

//INPUT DATA
P1=25;//Pressure at point 1 in bar
P2=60;//Pressure at point 2 in bar
h2=208.1;//Vapour enthalpy at P2 in kJ/kg
h3=61.9;//Liquid enthalpy at P2 in kJ/kg
h4=h3;//Liquid enthalpy at P2 in kJ/kg
s2=0.703;//Vapour entropy at P2 in kJ/kg-K
sf1=-0.075;//Liquid entropy at P1 in kJ/kg-K
sfg1=0.971;//Entropy in kJ/kg-K
hf1=-18.4;//Liquid Enthalpy at P1 in kJ/kg
hfg1=252.9;//Latent heat at P1 in kJ/kg
m=5;//Refrigerant flow in kg/min

//CALCULATIONS
x1=(s2-sf1)/sfg1;//Quality factor 1
h1=hf1+(x1*hfg1);//Enthalpy at point 1 in kJ/kg
COP=(h1-h4)/(h2-h1);//Co-efficient of performance
QL=(m*(h1-h4))/60;//Capacity of the refrigerator in kW

//OUTPUT
```

```
mprintf('COP of refrigerator is %3.2f \n Capacity of refrigerator is %3.2f kW',COP,QL)



//==================================================END OF PROGRAM======================================================
```

Scilab code Exa 6.17 COP and Theoretical power required

```
//Chapter-6, Illustration 17, Page 324
//Title: Refrigeration cycles
//=============================================================================================================

clc
clear

//INPUT DATA
T1=271;//Temperature at point 1 in K
T=265;//Temperature at point 1' in K
Ta=303;//Temperature at point 2' in K
Cpv=0.733;//Specific heat of vapour in kJ/kg
Cpl=1.235;//Specific heat of liquid in kJ/kg
h=184.07;//Liquid enthalpy at T in kJ/kg
s=0.7;//Entropy at point 1' in kJ/kg-K
sa=0.685;//Vapour entropy at Ta in kJ/kg-K
ha=199.62;//Enthalpy at point 2' in kJ/kg
hfb=64.59;//Liquid enthalpy at Ta in kJ/kg
DT3=5;//Temperature difference in oC
Q=2532;//Refrigeration capacity in kJ/min

//CALCULATIONS
s2=s+(Cpv*((log(T1/T))/(log(2.718))));//Entropy at point 1 in kJ/kg-K
```

```
h1=h+(Cpv*(T1-T));//Enthalpy at point 1 in kJ/kg–K
T2=(2.718^((s2-sa)/Cpv))*Ta;//Temperature at point 2 in K
h2=ha+(Cpv*(T2-Ta));//Enthalpy at point 2 in kJ/kg
h4=hfb-(Cpl*DT3);//Enthalpy at point 4 in kJ/kg
COP=(h1-h4)/(h2-h1);//Co–efficient of performance
m=Q/(h1-h4);//Mass flow rate of refrigerant in kJ/min
P=(m*(h2-h1))/(60*12);//Power required in kW/TR

//OUTPUT
mprintf('COP is %3.2f \n Theoretical power required per tonne of refrigeration is %3.3f kW/TR',COP,P)













//==================================================END OF PROGRAM==================================================
```

Chapter 7

Air Conditioning

Scilab code Exa 7.1 Heating capacity of coil and Surface temperature and Capacity

```
//Chapter-7, Illustration 1, Page 345
//Title: Air Conditioning
//=============================================================================

clc
clear

//INPUT DATA
DBTo=10;//Out door Dry bulb temperature in oC
WBTo=8;//Out door Wet bulb temperature in oC
DBTi=20;//In door Dry bulb temperature in oC
RH=0.6;//Re-Heat factor
a=0.3;//amount of air circulated in (m^3)/min/person
S=50;//Seating capacity of office
BPF=0.32;//ByPass factor
ha=25;//Enthalpy at point a from Psychrometric chart shown in Page 346 in kJ/kg
hb=42.5;//Enthalpy at point b from Psychrometric chart shown in Page 346 in kJ/kg
```

```
hc=42.5;//Enthalpy at point c from Psychrometric chart shown in Page 346 in kJ/kg
Wa=0.006;//Specific humidity at point a from Psychrometric chart shown in Page 346 in kg/kg dry air
Wc=0.009;//Specific humidity at point c from Psychrometric chart shown in Page 346 in kg/kg dry air
Tb=27;//Temperature at point b in oC
na=0.81;//Specific Volume from Psychrometric chart shown in page 346 in (m^3)/kg

//CALCULATIONS
ma=(a*S)/(na*60);//mass of air circulated per second in kg/s
Hc=ma*(hb-ha);//Heating capacity of coil in kW
Ts=(Tb-(BPF*DBTo))/(1-BPF);//Heating coil surface temperature in oC
C=(ma*3600)*(Wc-Wa);//Capacity of humidifier in kg/hr

//OUTPUT
mprintf('Heating capacity of coil is %3.2f kW \n Surface temperature of coil is %3.0f oC \n Capacity of humidifier is %3.2f kg/hr',Hc,Ts,C)
```

Scilab code Exa 7.2 Capacity of coils and Amount of water vapour removed and by pass factor

```
//Chapter-7, Illustration 2, Page 346
//Title: Air Conditioning
//

clc
```

```
clear

//INPUT DATA
S=60;//No. of staff
DBTo=30;//Out door Dry bulb temperature in oC
RHo=0.7;//Re-Heat factor at out-door
a=0.4;//amount of air circulated in (m^3)/min/person
DBTi=20;//In door Dry bulb temperature in oC
RHi=0.6;//Re-Heat factor at indoor
Td=25;//Heating coil surface temperature in oC
ha=82.5;//Enthalpy at point a from Psychrometric chart shown in Page 347 in kJ/kg
hb=34.5;//Enthalpy at point b from Psychrometric chart shown in Page 347 in kJ/kg
hc=42.5;//Enthalpy at point c from Psychrometric chart shown in Page 347 in kJ/kg
Wa=0.020;//Specific humidity at point a from Psychrometric chart shown in Page 347 in kg/kg dry air
Wb=0.009;//Specific humidity at point b from Psychrometric chart shown in Page 347 in kg/kg dry air
Tb=12;//Temperature at point b in oC
na=0.89;//Specific Volume from Psychrometric chart shown in page 346 in (m^3)/kg

//CALCULATIONS
ma=(a*S)/(na*60);//mass of air circulated per second in kg/s
Hc=(ma*(ha-hb))/3.5;//Heating capacity of cooling coil in tonnes
Hh=ma*(hc-hb);//Heating capacity of heating coil in kW
W=(ma*3600)*(Wa-Wb);//Amount of water vapour removed per hour in kg/hr
BPF=(Td-DBTi)/(Td-Tb);//By-Pass factor

//OUTPUT
```

```
mprintf('Capacity of cooling coil is %3.2f tonnes \n Capacity of heating coil is %3.1f kW \n Amount of water vapour removed per hour is %3.2f kg/hr \n Bypass factor is %3.3f',Hc,Hh,W,BPF)
```

Scilab code Exa 7.3 Supply air condition and Refrigeration load and Total refrigeration capacity and Quantity of fresh air supplied

```
//Chapter-7, Illustration 3, Page 347
//Title: Air Conditioning
//

clc
clear

//INPUT DATA
RSH=10;//Room sensible heat in kW
RLH=10;//Room latent heat in kW
td1=25;//Inside temperature in oC
RH1=0.5;//Inside Re-Heat factor
h1=50.4;//Enthalpy at point 1 in kJ/kg
td2=35;//Out door Dry bulb temperature in oC
tw2=28;//Out door Wet bulb temperature in oC
CR=4;//Cooling coil ratio
BPF=0.1;//Cooling coil bypass factor
tADP=10;//Apparatus dew point temperature in oC
RH3=0.55;//Re-Heat factor at point 3
h3=58.2;//Enthalpy at point 3 in kJ/kg
RH4=0.95;//Re-Heat factor at point 4
h4=32.2;//Enthalpy at point 4 in kJ/kg
RH5=0.81;//Re-Heat factor at point 5
h5=36.8;//Enthalpy at point 5 in kJ/kg
RH6=0.54;//Re-Heat factor at point 6
h6=43.1;//Enthalpy at point 5 in kJ/kg
```

```
td6=22;//Temperature at point 6 in oC

//CALCULATIONS
td3=((td2-td1)/5)+td1;//Temperature at point 3 from Psychrometric chart shown in Page 348 in oC
td4=(BPF*(td3-tADP))+tADP;//Temperature at point 4 from Psychrometric chart shown in Page 348 in oC
td5=td4+((td1-td4)/5);//Temperature at point 5 from Psychrometric chart shown in Page 348 in oC
RSHF=RSH/(RSH+RLH);//Room Sensible Heat Factor
QR=h1-h6;//Total heat removed in kJ/kg
S=(RSH+RLH)/QR;//Supply air quantity in kg/s
R=(S*(h6-h5))/3.5;//Refrigeration load due to reheat in ton
D=(S*4)/5;//Dehumidified air quantity in kg/s
T=(D*(h3-h4))/3.5;//Total refrigerating capacity in ton
Q=(D/5)/1.2;//Quantity of fresh air supplied in (m^3)/s

//OUTPUT
mprintf('Supply air condition to the room is %3.2f kg/s \n Refrigeration load due to reheat is %3.2f ton \n Total refrigerating capacity is %3.2f ton \n Quantity of fresh air supplied is %3.3f (m^3)/s',S,R,T,Q)
```