Scilab Textbook Companion for Applied Thermodynamics by O. Singh [1]

Created by
Bhavin Shashikant Dedhia
B.Tech (Pursuing)
Mechanical Engineering
National Institute Of Technology, Surathkal
College Teacher
Ganesh Viswanathan
Cross-Checked by
Santosh Kumar, IIT Bombay

July 30, 2019

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

Book Description

Title: Applied Thermodynamics

Author: O. Singh

Publisher: New Age International Pvt. Limited Publishers

Edition: 3

Year: 2009

ISBN: 978-81-224-29

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 4

1 Fundamental concepts and definitions 5

2 Zeroth law of thermodynamics 29

3 First law of thermodynamics 33

4 Second law of thermodynamics 51

5 Entropy 63

6 Thermodynamic Properties of Pure Substance 79

7 Ratio of lost available exhaust gas energy to engine work 100

8 Vapour power cycles 118

9 Gas power cycles 156

11 Boilers and boiler calculations 176

12 Steam engine 200

13 Nozzles 223

15 Steam condenser **242**

16 Reciprocating and Rotary Compressor **256**

17 Introduction to Internal Combustion Engines **277**

18 Introduction to Refrigeration and Airconditioning **288**

19 Jet Propulsion and Rocket Engines **304**

List of Scilab Codes

Exa 1.1	To find out the pressure	5
Exa 1.02	Effort required	5
Exa 1.03	To find out the actual pressure of air	6
Exa 1.04	To find out the guage pressure	7
Exa 1.05	To find out the pressure of the gas	7
Exa 1.06	To find out the change in temperature	8
Exa 1.07	To find out the spring balance reading	8
Exa 1.08	To determine the mass of the piston	9
Exa 1.09	To determine the pressure of the steam	10
Exa 1.10	To determine the absolute pressure in A and B	10
Exa 1.11	To determine the air pressure	11
Exa 1.12	To determine the kinetic energy	12
Exa 1.13	To determine the molecular weight of the gas	13
Exa 1.14	To determine the final temperature	13
Exa 1.15	To find out mass of air removed and volume at initial states	14
Exa 1.16	To determine heat to be supplied	15
Exa 1.17	To determine the final pressure	16
Exa 1.18	To determine the pressure of carbon di oxide gas	17
Exa 1.19	To find out the specific volume	18
Exa 1.20	To find out load lifting capacity	19
Exa 1.21	To find out the time required	20
Exa 1.22	To determine the specific heats	20
Exa 1.23	To determine partial pressure of gases	22
Exa 1.24	To find out the equilibrium pressure and temperature	24

Exa 1.25	To find out specific heat of the mixture . . .	25
Exa 1.26	To determine capacity of the vessel	26
Exa 1.27	To determine the ratio of exit to inlet diameter	27
Exa 1.28	To determine the mass pumped out	27
Exa 2.01	To find temperature in degree celcius	29
Exa 2.02	To find final pressure and temperature . . .	29
Exa 2.03	To find out the temperature	30
Exa 2.04	To find out variation in temperature	30
Exa 2.05	To find out absolute zero temperature on new scale	31
Exa 3.01	To find out work done on the system	33
Exa 3.02	To find out the amount of heat required . .	34
Exa 3.03	To find out the amount of heat to be removed	34
Exa 3.04	To determine the work done	35
Exa 3.05	To determine the heat interaction	35
Exa 3.06	To determine the work done	36
Exa 3.07	To determine the heat transfer	37
Exa 3.08	To determine the exit velocity	37
Exa 3.09	To determine the heat to be transferred to the atmosphere	38
Exa 3.10	To determine the water circulation rate . . .	38
Exa 3.11	To determine the steam supply rate	39
Exa 3.12	To determine the work done	40
Exa 3.13	To determine capacity of the generator . . .	41
Exa 3.14	To determine the exit velocity	41
Exa 3.15	To determine the work done	42
Exa 3.16	To determine the work done	43
Exa 3.17	To determine the work done	44
Exa 3.18	To determine the work available	45
Exa 3.19	To determine the final pressure and temperature	46
Exa 3.20	To determine the heat to be transferred . .	47
Exa 3.21	To determine the heat to be transferred . .	47
Exa 3.22	To determine the duration	48
Exa 3.23	To determine the work available from the turbine	50
Exa 4.02	To determine heat to be supplied	51
Exa 4.03	To determine the power required	51

Exa 4.04	To determine the heat transferred	52
Exa 4.05	To determine the minimum power required .	53
Exa 4.06	To determine the power required	54
Exa 4.07	To determine the efficiency	54
Exa 4.08	To determine the power required	55
Exa 4.10	To determine the efficiency of the engine and COP of refrigerator	55
Exa 4.11	To determine the maximum and minimum temperature in the cycle	56
Exa 4.12	To determine the heat transferred	58
Exa 4.13	To determine the energy taken from the reservoir	58
Exa 4.14	To determine temperature of the sink	59
Exa 4.15	To determine the ratio of heat rejected to body to the heat supplied by the reservoir .	60
Exa 4.18	To determine the heat received from the highest temperature reservoir	60
Exa 4.19	To determine the change in enthalpy and Work done	61
Exa 5.01	To determine the change in entropy	63
Exa 5.02	To determine the change in entropy	64
Exa 5.03	To determine the change in entropy	65
Exa 5.04	To determine the entropy change in universe	65
Exa 5.05	To determine the entropy change in universe	66
Exa 5.06	To determine the entropy change in universe	67
Exa 5.08	To determine the work lost	68
Exa 5.09	To determine the maximum work done . . .	68
Exa 5.10	To determine the change in entropy and enthalpy	69
Exa 5.11	To determine the entropy change in universe	70
Exa 5.12	To determine the change in entropy	70
Exa 5.15	To determine the direction of flow	71
Exa 5.17	To determine the work done and thermal efficiency	72
Exa 5.18	To determine the heat supplied	73
Exa 5.19	To check if process is reversible or not . . .	74
Exa 5.20	To determine the entropy produced	75
Exa 5.21	To determine the change in entropy	76

Exa 6.02	To determine the dryness fraction	79
Exa 6.03	To determine the internal energy	80
Exa 6.04	To find out the entropy of steam	80
Exa 6.05	To find out the boiling point	81
Exa 6.06	To determine mass and volume of water . .	81
Exa 6.07	To determine the slope	82
Exa 6.08	To determine enthalpy entropy and specific volume	83
Exa 6.09	To determine amount of heat added	83
Exa 6.10	To determine pressure and temperature at condensation	85
Exa 6.11	To determine enthalpy change	85
Exa 6.12	To determine the mass and quality of steam	86
Exa 6.13	To determine the turbine output	87
Exa 6.14	To determine the mass and quality of steam	87
Exa 6.15	To determine the dryness fraction of the steam entering	89
Exa 6.16	To determine the work done	90
Exa 6.17	To determine the dryness fraction	91
Exa 6.18	To determine the amount of heat added and initial quality	92
Exa 6.19	To determine heat and work transfer	93
Exa 6.20	To determine the percentage of vessel initial occupied by steam	94
Exa 6.21	To determine the irresversibilty	95
Exa 6.22	To determine the change in availability . . .	97
Exa 6.23	To determine the amount of exergy destruction	98
Exa 7.01	To determine the maximum possible work .	100
Exa 7.02	To determine the availability in the tanks .	101
Exa 7.03	To determine the power output	102
Exa 7.04	To determine the availability	103
Exa 7.06	To determine ratio of lost available exhaust gas energy to engine work	104
Exa 7.07	To determine the availability	105
Exa 7.08	To determine the irresversibilty	107
Exa 7.11	To determine loss of available energy	108
Exa 7.12	To determine the maximum possible work .	108
Exa 7.13	To determine second law efficiency	109

Exa 7.14	To determine loss of available energy	110
Exa 7.16	To determine the availability and change in irreversibility	111
Exa 7.17	To determine loss of available energy	111
Exa 7.19	To calculate enthalpy of vaporisation	112
Exa 7.20	To determine enthalpy	113
Exa 7.21	To determine isothermal compressibility . .	114
Exa 7.22	To determine the irresversibilty	115
Exa 7.23	To determine the maximum work	115
Exa 7.24	To determine the irresversibilty	116
Exa 8.01	To determine the work done and thermal efficiency	118
Exa 8.02	To determine the efficiency of rankine cycle	119
Exa 8.03	To determine cycle efficiency and pump work	121
Exa 8.04	To determine pressure of steam leaving and thermal efficiency	123
Exa 8.05	To determine the work done and thermal efficiency and ratio of heat supplied to rejected	124
Exa 8.06	To determine cycle efficiency	126
Exa 8.07	To determine cycle efficiency and specific steam consumption and work ratio	128
Exa 8.08	To determine efficiency of the boiler	130
Exa 8.09	To determine capacity of the drain pump . .	132
Exa 8.10	To determine the thermal efficiency	134
Exa 8.11	To determine cycle thermal efficiency and net power developed	135
Exa 8.12	To determine thermal efficiency and steam generation rate	137
Exa 8.13	To determine the thermal efficiency	139
Exa 8.15	To determine the thermal efficiency	141
Exa 8.16	To determine cycle thermal efficiency and net power developed	142
Exa 8.17	To determine the amount of heat added . .	143
Exa 8.18	To determine the thermal efficiency and amount of steam bled	144
Exa 8.19	To determine mass of steam bled	146
Exa 8.20	To determine power available to the generator	148
Exa 8.21	To determine heat consumption in the boiler	149

Exa 8.22 To determine total power produced 150
Exa 8.23 To determine heat available for heating process 151
Exa 8.24 To determine steam consumption 152
Exa 8.25 To the determine the power generated . . . 154
Exa 9.01 To determine the mep 156
Exa 9.02 To determine the compression ratio 157
Exa 9.03 To find out the efficiencies 158
Exa 9.04 To determine the compressor efficiency . . . 160
Exa 9.05 To determine the thermal efficiency 161
Exa 9.06 To determine optimum pressure ratio 162
Exa 9.07 To determine the power required 163
Exa 9.09 To determine specific work output 165
Exa 9.10 To determine isentropic efficiency 166
Exa 9.11 To determine the thermal efficiency and air fuel ratio 167
Exa 9.12 To determine the thermal efficiency 169
Exa 9.13 To determine the brake output and stroke volume 171
Exa 9.15 To determine the overall efficiency 172
Exa 9.16 To determine air standard fuel efficiency . . 174
Exa 11.01 To determine temperature of burnt gases . . 176
Exa 11.02 To determine height of the chimney 176
Exa 11.03 To determine the air supplied and draught . 177
Exa 11.04 To determine the draught and chimney efficiency 178
Exa 11.05 To determine the draught and chimney efficiency 179
Exa 11.06 To determine height and diamter of the chimney 179
Exa 11.07 To determine power of the fan 180
Exa 11.08 To determine the ratio of power required . . 181
Exa 11.09 To determine amount of evaporation 182
Exa 11.10 To determine amount of evaporation 183
Exa 11.11 To determine boiler efficiency 184
Exa 11.12 Boiler efficiency 186
Exa 11.13 Boiler efficiency 187
Exa 11.14 Air leakage 188
Exa 11.15 Boiler efficiency 190

Exa 11.17 Saving of coal 191
Exa 11.18 Temperature of flue gases 192
Exa 11.19 FD fan power 194
Exa 11.20 EXtra heat carried in natural draught . . . 195
Exa 11.21 Height of chimney 196
Exa 11.22 Power consumption of induced draught . . . 197
Exa 11.23 Energy consumed in superheater 198
Exa 12.01 Rankine and carnot efficiency 200
Exa 12.02 Carnot efficiency and stroke length 201
Exa 12.03 Indicated power 202
Exa 12.04 Specific steam consumption 203
Exa 12.05 Diagram factor and indicated thermal efficiency 204
Exa 12.06 Thermal efficiency 206
Exa 12.07 Bore diameter 207
Exa 12.08 Heat leakage 208
Exa 12.09 Percentage re evaporation 210
Exa 12.10 Indicated power 212
Exa 12.11 Indicated power 213
Exa 12.12 Speed of engine and diameter of cylinder . . 214
Exa 12.13 Overall diagram factor 216
Exa 12.14 Total output 217
Exa 12.15 Steam used per hp 219
Exa 12.16 Brake specific steam consumption 220
Exa 12.17 Indicated steam consumption 221
Exa 13.01 Dryness fraction 223
Exa 13.02 Mass flow rate 224
Exa 13.03 Coefficient of velocity 225
Exa 13.04 Area at exit 226
Exa 13.05 Area at exit 228
Exa 13.06 Velocity at throat and cone angle 229
Exa 13.07 Length and radial height of nozzle 230
Exa 13.08 Exit velocity 231
Exa 13.09 Nozzle efficiency 232
Exa 13.10 Degree of supersaturaion and amount of undercooling 233
Exa 13.11 Degree of undercooling 234
Exa 13.12 Percentage increase in discharge 235
Exa 13.13 Entropy change 236

Exa 13.14	Temperature of water coming out of injector	238
Exa 13.15	Mass flow rate	240
Exa 15.01	Mass flow rate and vacuum efficiency	242
Exa 15.02	Mass of water vapour accompanying steam .	243
Exa 15.03	Mass of uncondensed steam	244
Exa 15.04	Mass of water vapour extracted with air . .	246
Exa 15.05	Water circulation rate	247
Exa 15.06	Heat required	248
Exa 15.07	Capacity of air pump	250
Exa 15.08	Mass of air entering	251
Exa 15.09	Volume of air and mixture handled	253
Exa 15.10	Degree of undercooling	254
Exa 16.01	Isothermal efficiency	256
Exa 16.02	Rating of drive	257
Exa 16.03	Isothermal efficiency	259
Exa 16.04	Volumetric efficiency	260
Exa 16.05	Percentage excess work	261
Exa 16.06	Work input	262
Exa 16.07	Work output	263
Exa 16.08	Isothermal efficiency	264
Exa 16.09	Heat rejected in intercooler	266
Exa 16.10	Free air delivery	267
Exa 16.11	Shaft output	268
Exa 16.12	Number of stages	269
Exa 16.13	Work done	270
Exa 16.14	Total work required	271
Exa 16.15	Isentropic efficiency	273
Exa 16.16	Indicated power required and isentropic efficiency	273
Exa 16.17	Brake power required	274
Exa 16.18	Volumetric efficiency and heat rejected . . .	275
Exa 17.01	Indicated power and mechanical efficiency .	277
Exa 17.02	Power required to drive	278
Exa 17.03	Indicated power	279
Exa 17.04	Brake power and fuel consumption	279
Exa 17.05	Volumetric efficiency	280
Exa 17.06	Brake power required	281
Exa 17.07	Brake power and indicated power	282

Exa 17.08	Indicated power and volumetric efficiency	284
Exa 17.09	Brake power and indicated power	285
Exa 17.10	Indicated thermal efficiency	286
Exa 18.01	Work input	288
Exa 18.02	HP required	288
Exa 18.03	Temperature of surroundings	289
Exa 18.04	Refrigeration capacity and COP	290
Exa 18.05	COP	291
Exa 18.06	Refrigeration capacity and COP	292
Exa 18.07	Mass flow rate and COP	293
Exa 18.08	COP and HP required	294
Exa 18.09	COP	295
Exa 18.10	COP and piston displacement	296
Exa 18.11	Mass flow rate and COP	298
Exa 18.12	Partial pressure of vapour and relative humidity	298
Exa 18.13	Enthalpy of mixture	299
Exa 18.14	Mass of water added and heat transferred	300
Exa 18.15	Specific humidity of mixture	301
Exa 18.16	Heat added	302
Exa 19.01	Thrust	304
Exa 19.02	Thrust	306
Exa 19.03	Specific fuel consumption	307
Exa 19.04	Specific fuel consumption	309
Exa 19.05	Velocity at exit of nozzle	310
Exa 19.06	Total thrust	312
Exa 19.07	Jet exit area	313
Exa 19.08	Jet diameter	315
Exa 19.09	Specific thrust	316
Exa 19.10	Overall efficiency	317

Chapter 1

Fundamental concepts and definitions

Scilab code Exa 1.1 `To find out the pressure`

```
//pathname=get_absolute_file_path('1.01.sce')
//filename=pathname+filesep()+'1.01-data.sci'
//exec(filename)
//Manometer deflection of Mercury(in m):
h=30*10^-2
//Density of mercury(in kg/m^3)
d=13550
//Acceleration due to gravity(in m/s^2):
g=9.8
//Pressure difference(in Pa):
p=d*g*h*10^-2
printf("\n\n RESULT \n\n")
printf("\n\n Pressure Difference= %f Pa \n\n",p)
```

Scilab code Exa 1.02 `Effort required`

```
//pathname=get_absolute_file_path('1.02.sce')
//filename=pathname+filesep()+'1.02-data.sci'
//exec(filename)
//Diameter of the vessel(in m):
d=30*10^-2
//Accelertion due to gravity(in m/s^2):
g=9.78
//Atmospheric pressure(in Pa):
p=76*(10^-2)*13550*g
//Area:
a=(%pi*d^2)/4
//Effort required:
F=p*a
printf("\n\n RESULT \n\n")
printf("\n\n Effort required= %f N",F)
```

Scilab code Exa 1.03 To find out the actual pressure of air

```
//pathname=get_absolute_file_path('1.03.sce')
//filename=pathname+filesep()+'1.03-data.sci'
//exec(filename)
//Difference in mercury column(in m):
h=30*10^-2
//Atmospheric Pressure(in kPa):
pa=101
//Acceleration due to gravity(in m/s^2):
g=9.78
//Guage pressure(in kPa):
gp=13550*g*h*10^-3
//Actual pressure:
ap=gp+pa
printf("\n\n RESULT \n\n")
printf("\n\n Actual pressure of air= %f kPa",ap)
```

Scilab code Exa 1.04 To find out the guage pressure

```
//pathname=get_absolute_file_path('1.04.sce')
//filename=pathname+filesep()+'1.04-data.sci'
//exec(filename)
//Depth of tank(in m):
h=1
//Specific gravity:
s=0.8
//Density of water(in kg/m^3):
d=1000
//Acceleration due to gravity(in m/s^2):
g=9.81
//Density of oil(in kg/m3):
d0=s*d
//Gauge pressure(in kPa):
gp=d0*g*h*10^-3
printf("\n\n RESULT \n\n")
printf("\n\n Gauge pressure=%f kPa\n\n",gp)
```

Scilab code Exa 1.05 To find out the pressure of the gas

```
//pathname=get_absolute_file_path('1.05.sce')
//filename=pathname+filesep()+'1.05-data.sci'
//exec(filename)
//Barometer Reading(in m):
h=76*10^-2
//Density of mercury(in kg/m^3):
d=13.6*10^3
//Acceleration due to gravity(in m/s^2):
g=9.8
//Difference of heights in gas barometer(in m):
```

```
h1=40*10^-2
//Pressure of gas(in kPa):
pg=(d*g*h1+d*g*h)*10^-3
printf("\n\n RESULT \n\n")
printf("\n\n Pressure of gas=%f kPa\n\n",pg)
```

Scilab code Exa 1.06 To find out the change in temperature

```
//pathname=get_absolute_file_path('1.06.sce')
//filename=pathname+filesep()+'1.06-data.sci'
//exec(filename)
//Mass of water(in kg):
m=1
//Altitude(in m):
h=1000
//Specific heat of water(in J/kg-K):
c=4.18*10^3
//Acceleration due to gravity(in m/s^2):
g=9.81
//Heat required for heating = Potential energy
Q=m*g*h
dT=Q/c
printf("\n\n RESULT \n\n")
printf("\n\n The change in temperature =%f degree
    celcius ",dT)
```

Scilab code Exa 1.07 To find out the spring balance reading

```
//pathname=get_absolute_file_path('1.07.sce')
//filename=pathname+filesep()+'1.07-data.sci'
//exec(filename)
//Weight of object at standard gravitational
    acceleration(in N):
```

```
w=100
//Standard acceleration due to gravity(in m/s^2):
g=9.81
//Gravitation acceleration at given location(in m/s
    ^2):
g1=8.5
//Mass of object(in kg):
m=w/g
//Spring balance reading(in N):
s=m*g1
printf("\n\n RESULT \n\n")
printf("\n\n The spring balance reading = %f N \n\n"
    ,s)
```

Scilab code Exa 1.08 To determine the mass of the piston

```
//pathname=get_absolute_file_path('1.08.sce')
//filename=pathname+filesep()+'1.08-data.sci'
//exec(filename)
//Diameter of cylinder(in m):
dia=15*10^-2
//Manometer difference in Hg column(in m):
h=12*10^-2
//Density of mercury(in kg/m^3):
d=13.6*10^3
//Acceleration due to gravity(in m/s^2):
g=9.81
//Weight of piston(in N): pressure*area
w=h*d*g*%pi*dia^2/4
//Mass of the piston(in kg):
m=w/g
printf("\n\n RESULT \n\n")
printf("\n\n Mass of the piston= %f kg",m)
```

Scilab code Exa 1.09 To determine the pressure of the steam

```
//pathname=get_absolute_file_path('1.09.sce')
//filename=pathname+filesep()+'1.09-data.sci'
//exec(filename)
//Height of water column in limb AB(in m):
Hab=2*10^-2
//Height of mercury column in limb CD(in m):
Hcd=10*10^-2
//Barometer reading for atmospheric pressure(in m):
h=76*10^-2
//Density of mercury(in kg/m^3):
dm=13.6*10^3
//Density of water(in kg/m^3):
dw=1000
//Acceleration due to gravity(in m/s^2):
g=9.81
//Atmospheric pressure(in kPa):
Patm=dm*h*g*10^-3
//Pressure of water in column AB(in kPa):
Pab=dw*Hab*g*10^-3
//Pressure of mercury in column CD(in kPa):
Pcd=dm*Hcd*g*10^-3
//Pressure of steam(in kPa):
Ps=Patm+Pcd-Pab
printf("\n\n RESULT \n\n")
printf("\n\n Pressure of steam = %f kPa",Ps)
```

Scilab code Exa 1.10 To determine the absolute pressure in A and B

```
//pathname=get_absolute_file_path('1.10.sce')
//filename=pathname+filesep()+'1.10-data.sci'
```

```
//exec(filename)
//Pressure in compartment A(in kPa):
Pa=400
//Pressure in compartment B(in kPa):
Pb=150
//Reading of barometer(in m):
h=720*10^-3
//Density of mercury(in kg/m^3):
d=13.6*10^3
//Acceleration due to gravity(in m/s^2):
g=9.81
//Atmospheric pressure from barometer reading(in kPa
    ):
Patm=d*g*h*10^-3
//Absolute pressure in compartment A(in kPa):
PaA=Pa+Patm
//Absolute pressure in compartment B(in kPa):
PaB=Pb+Patm
printf("\n\n RESULT \n\n")
printf("\n\n Absolute pressure in compartment A=%f
    kPa",PaA)
printf("\n Absolute pressure in compartment B=%f kPa
    \n\n",PaB)
```

Scilab code Exa 1.11 To determine the air pressure

```
//pathname=get_absolute_file_path('1.11.sce')
//filename=pathname+filesep()+'1.11-data.sci'
//exec(filename)
//Atmospheric pressure(in kPa):
Patm=90
//Density of water(in kg/m^3):
dw=1000
//Density of oil(in kg/m^3):
doil=850
```

```
//Density of mercury(in kg/m^3):
dm=13600
//Height of water column(in m):
h1=0.15
//Height of oil column(in m):
h2=0.25
//Height of mercury column(in m):
h3=0.40
//Acceleration due to gravity(in m/s^2):
g=9.81
//Pressure due to water column at reference line(in
    kPa):
Pw=dw*g*h1*10^-3
//Pressure due to oil column at reference line(in
    kPa):
Po=doil*g*h2*10^-3
//Pressure due to mercury column at reference line(
    in kPa):
Pm=dm*g*h3*10^-3
//Pressure due to air(in kPa):
Pa=Patm+Pm-Pw-Po
printf("\n\n RESULT \n\n")
printf("\n\n Air pressure=%f kPa \n\n",Pa)
```

Scilab code Exa 1.12 To determine the kinetic energy

```
//pathname=get_absolute_file_path('1.12.sce')
//filename=pathname+filesep()+'1.12-data.sci'
//exec(filename)
//Velocity of the object(in m/s):
v=750
//Gravitational force acting on the body(in N):
F=4000
//Acceleration due to gravity(in m/s^2):
g=8
```

```
//Mass of the object(in kg):
m=F/g
//Kinetic energy of the body(in J):
KE=1/2*m*v^2
printf("\n\n RESULT \n\n")
printf("\n\n Kinetic energy = %f J \n\n",KE)
```

Scilab code Exa 1.13 To determine the molecular weight of the gas

```
//pathname=get_absolute_file_path('1.13.sce')
//filename=pathname+filesep()+'1.13-data.sci'
//exec(filename)
//Specific heat at constant pressure(in kJ/kg-K):
Cp=2.286
//Specific heat at constant volume(in kJ/kg-K):
Cv=1.768
//Universal gas constant(in kJ/kg-K):
Ru=8.314
//Gas constant(in kJ/kg-K):
R=Cp-Cv
//Molecular weight of gas(in kg/K mol):
m=Ru/R
printf("\n\n RESULT \n\n")
printf("\n\n Molecular weight of gas = %f kg/K mol",
    m)
```

Scilab code Exa 1.14 To determine the final temperature

```
//pathname=get_absolute_file_path('1.14.sce')
//filename=pathname+filesep()+'1.14-data.sci'
//exec(filename)
//Initial pressure(in Pa):
p1=750*10^3
```

```
//Initial temperature(in K):
t1=600
//Initial volume(in m^3):
v1=0.2
//Final pressure(in Pa):
p2=2*10^5
//Final volume(in m^3):
v2=0.5
//Final temperature(in K):
t2=p2*v2*t1/(p1*v1)
printf("\n\n RESULT \n\n")
printf("\n\n Final temperature = %f K \n\n",t2)
```

Scilab code Exa 1.15 `To find out mass of air removed and volume at initial states`

```
//pathname=get_absolute_file_path('1.15.sce')
//filename=pathname+filesep()+'1.15-data.sci'
//exec(filename)
//Initial pressure(in kPa):
p1=100
//Initial temperature(in K):
t1=300
//Initial volume(in m^3):
v1=5
//Final pressure(in kPa):
p2=50
//Final temperature(in K):
t2=280
//Final volume(in m^3):
v2=5
//Gas constant for air(in J/kg-K):
R=287//Initial pressure(in kPa):
p1=100
//Initial temperature(in K):
t1=300
```

```
//Initial volume(in m^3):
v1=5
//Final pressure(in kPa):
p2=50
//Final temperature(in K):
t2=280
//Final volume(in m^3):
v2=5
//Gas constant for air(in J/kg-K):
R=287
//Initial mass(in kg):
m1=p1*v1/(R*t1)*10^3
//Final mass(in kg):
m2=p2*v2/(R*t2)*10^3
//Mass removed(in kg):
dm=m1-m2
//Volume of this mass of air at initial states(in m
    ^3):
V=dm*R*t1/p1
printf("\n\n RESULT \n\n")
printf("\n\n Mass of air removed = %f kg",dm)
printf("\n Volume of air at initial states = %f m^3\
    n\n",V)
```

Scilab code Exa 1.16 To determine heat to be supplied

```
//pathname=get_absolute_file_path('1.16.sce')
//filename=pathname+filesep()+'1.16-data.sci'
//exec(filename)
//Diameter of the vessel(in m):
d=1
//Height of the vessel(in m):
h=4
//Volume of the vessel(in m^3):
v=%pi*d^2*h/4
```

```
//Initial pressure(in kPa):
p1=100
//Initial temperature(in K):
t1=300
//Final pressure(in kPa):
p2=125
//Cp of hydrogen(in kJ/kg-K):
Cp=14.307
//Cv of volume(in kJ/kg-K):
Cv=10.183
//Final temperature(in K):
t2=p2*t1/p1
//Gas constant for hydrogen:
R=Cp-Cv
//Mass of hydrogen(in kg):
m=p1*v/(R*t1)
//Heat supplied at const. volume(in kJ):
Q=m*Cv*(t2-t1)
printf("\n\n RESULT \n\n")
printf("\n\n Heat to be supplied = %f kJ",Q)
```

Scilab code Exa 1.17 To determine the final pressure

```
//pathname=get_absolute_file_path('1.17.sce')
//filename=pathname+filesep()+'1.17-data.sci'
//exec(filename)
//Total volume(in m^3):
v=2+2
//Mass of air in container 1(in kg):
m1=20
//Mass of air in container 2(in kg):
m2=4
//Temperature of the system(in K):
t=300
//Gas constant for air(in J/kg-K):
```

```
R=287
//Total mass after the valve is opened(in kg):
m=m1+m2
//Final pressure(in kPa):
p=m*R*t/v*10^-3
printf("\n\n RESULT \n\n")
printf("\n\n Final pressure = %f kPa",p)
```

Scilab code Exa 1.18 To determine the pressure of carbon di oxide gas

```
//pathname=get_absolute_file_path('1.18.sce')
//filename=pathname+filesep()+'1.18-data.sci'
//exec(filename)
//Mass of gas(in kg):
m=5
//Volume of the container(in m^3):
v=2
//Temperature in the container(in K):
t=300
//Universal gas constant(in kJ/kg-K):
R=8.314
//Vander-Waals Constant(from table):
a=3628.5*10^2
b=3.14*10^-2
//Molecular weight of CO2:
mw=44.01
//Considering it as a perfect gas
//Gas constant for CO2(in j/kg-K):
Rp=R*10^3/mw
//Pressure of the gas(in N/m^2):
pp=m*Rp*t/v
//Considering it as a real gas:
//Molar specific volume(in m^3/kg.mol):
v1=v*mw/m
//Vanderwall eqn:
```

```
pr=R*10^3*t/(v1-b)-a/(v1^2)
printf("\n\n RESULT \n\n")
printf("\n\n Pressure if considered perfect gas = %f N/m^2",pp)
printf("\n\n Pressure if considered real gas = %f N/m^2",pr)
```

Scilab code Exa 1.19 `To find out the specific volume`

```
//pathname=get_absolute_file_path('1.19.sce')
//filename=pathname+filesep()+'1.19-data.sci'
//exec(filename)
//Pressure of steam(in kPa):
p=17672
//Temperature of steam(in K):
t=712
//Critical pressure(in kPa):
Pc=22.09*10^3
//Critical temperature(in K):
Tc=647.3
//Gas constant for steam(in kJ/kg-K):
Rs=0.4615
//Considering perfect gas:
//Specific volume(in m^3/kg)
vp=Rs*t/p
//Considering real gas:
//Reduced pressure:
Rp=p/Pc
//Reduced temperature:
Rt=t/Tc
//Value of compressibility factor(from chart for Rp & Rt):
Z=0.785
//Specific volume(in m^3/kg):
vr=Z*vp
```

```
printf("\n\n RESULT \n\n")
printf("\n\n Specific volume considering perfect gas
    = %f m^3/kg",vp)
printf("\n Specific volume considering real gas =%f
   m^3/kg \n\n",vr)
```

Scilab code Exa 1.20 To find out load lifting capacity

```
//pathname=get_absolute_file_path('1.20.sce')
//filename=pathname+filesep()+'1.20-data.sci'
//exec(filename)
//Diameter of the balloon(in m):
d=5
//Atmospheric pressure(in N/m^2):
p=1.013*10^5
//Temperature of the surroundings(in K):
t=17+273
//Universal gas constant(in J/kg-K):
R=8.314*10^3
//Molecular weight of hydrogen:
mw=2
//Gas constant for air(in J/kg-K):
Ra=287
//Volume of the balloon(in m^3):
v=4/3*%pi*(5/2)^3
//Gas constant for H2(in kJ/kg-K):
Rh=R/mw
//Mass of H2 in balloon(in kg):
mh=p*v/(Rh*t)
//Volume of air displaced(in m^3):
vd=v
//Mass of air displaced(in kg):
ma=p*vd/(Ra*t)
//Load lifting capacity due to buoyant force(in kg):
L=ma-mh
```

```
printf("\n\n RESULT \n\n")
printf("\n\n Load lifting capacity = %f \n\n",L)
```

Scilab code Exa 1.21 To find out the time required

```
//pathname=get_absolute_file_path('1.21.sce')
//filename=pathname+filesep()+'1.21-data.sci'
//exec(filename)
//Volume of vessel(in m^3):
v=20
//Rate at which air is drawn(in m^3/min):
q=0.25
//Initial pressure/final pressure (ratio):
Pr=4
//Time required(in min):
t=v/q*log(Pr)
printf("\n\n RESULT \n\n")
printf("\n\n Time required = %f mins \n\n",t)
```

Scilab code Exa 1.22 To determine the specific heats

```
//pathname=get_absolute_file_path('1.22.sce')
//filename=pathname+filesep()+'1.22-data.sci'
//exec(filename)
//Total mass of system of gas(in kg):
M=5
//Compostion of Nitrogen:
n=0.80
//Compostion of Oxygen:
o=0.18
//Composition of Carbon dioxide:
c=0.02
//Compression ratio for Oxygen:
```

```
ro=1.4
//Compression ratio for Nitrogen:
rn=1.4
//Compression ratio for Carbon dioxide:
rc=1.3
//Universal gas constant(in J/kg-K):
R=8314
//Molecular weight of Nitrogen:
mwn=28
//Molecular weight of Oxygen:
mwo=32
//Molecular weight of Carbon dioxide:
mwc=44
//Gas constant for Nitrogen(in J/kg-K):
Rn=R/mwn
//Gas constant for Oxygen(in J/kg-K):
Ro=R/mwo
//Gas constant for Carbon dioxide(in J/kg-K):
Rc=R/mwc
//Gas constant for mixture(in J/kg-K):
Rm=n*Rn+o*Ro+c*Rc
//Specific heat at constant pressure for Nitrogen(in
    kJ/kg-K):
Cpn=(rn/(rn-1))*Rn
//Specific heat at constant pressure for Oxygen(in
    kJ/kg-K):
Cpo=(ro/(ro-1))*Ro
//Specific heat at constant pressure for Carbon
    dioxide(in kJ/kg-K):
Cpc=rc/(rc-1)*Rc
//Specific heat at constant pressure for the mixture
    (in kJ/kg-K):
Cpm=n*Cpn+o*Cpo+c*Cpc
//Number of moles of Nitrogen:
nn=n*M/mwn
//Number of moles of Oxygen:
no=o*M/mwo
//Number of moles of Carbon dioxide:
```

```
nc=c*M/mwc
//Total number of moles:
nt=nn+no+nc
//Mole fraction of Nitrogen:
xn=nn/nt
//Mole fraction of Oxygen:
xo=no/nt
//Mole fraction of Carbon dioxide:
xc=nc/nt
//Molecular weight of the mixture
mwm=xn*mwn+xo*mwo+xc*mwc
printf("\n\n RESULT \n\n")
printf("\n\n The molecular weight of the mixture =
    %f kg/kmol \n\n",mwm)
```

Scilab code Exa 1.23 To determine partial pressure of gases

```
//pathname=get_absolute_file_path('1.23.sce')
//filename=pathname+filesep()+'1.23-data.sci'
//exec(filename)
//Composition of Oxygen:
o=0.18
//Composition of Nitrogen:
n=0.75
//Composition of Carbon dioxide:
c=0.07
//Pressure of mixture(in MPa):
p=0.5
//Temperature of the mixture(in K):
t=107+273
//Total mass of the mixture(in kg):
m=5
//Molecular weight of Nitrogen:
mwn=28
//Molecular weight of Oxygen:
```

```
mwo=32
//Molecular weight of Carbon dioxide:
mwc=44
//Total values of mixture(assume):
v=1
//Mole fraction of Oxygen(by volume):
xvo=o/v
//Mole fraction of Nitrogen(by volume):
xvn=n/v
//Mole fraction of Carbon dioxide(by volume):
xvc=c/v
//Molecular weight of the mixture(in kg/kmol):
mwm=xo*mwo+xn*mwn+xc*mwc
//Mole fraction of Nitrogen(by mass):
xmn=n*mwn/mwm
//Mole fraction of Oxygen(by mass):
xmo=o*mwo/mwm
//Mole fraction of Carbon dioxide(by mass):
xmc=c*mwc/mwm
//Partial pressure of Oxygen:
po=o*p
//Partial pressure of Nitrogen:
pn=n*p
//Partial pressure of Carbon dioxide:
pc=c*p
printf("\n\n RESULT \n\n")
printf("\n\n Mole fraction of Oxygen by mass = %f ",
   xmo)
printf("\n Mole fraction of Nitrogen by mass = %f ",
   xmn)
printf("\n Mole fraction of Carbon dioxide by mass =
    %f ",xmc)
printf("\n\n Partial pressure of Oxygen = %f MPa",po
   )
printf("\n Partial pressure of Nitrogen = %f MPa",pn
   )
printf("\n Partial pressure of Carbon dioxide = %f
   MPa",pc)
```

Scilab code Exa 1.24 `To find out the equilibrium pressure and temperature`

```
//pathname=get_absolute_file_path('1.24.sce')
//filename=pathname+filesep()+'1.24-data.sci'
//exec(filename)
//Volume of gas in 1 chamber(in m^3):
V=3
//Partial pressure of Nitrogen(in kPa):
pn=800
//Partial pressure of Carbon dioxide(in kPa):
pc=400
//Temperature of Nitrogen(in K):
tn=480
//Temperature of Carbon dioxide(in K):
tc=390
//Compression ratio for Nitrogen:
rn=1.4
//Compression ratio for Carbon dioxide:
rc=1.3
//Universal gas constant(in J/kg-K):
R=8314
//Molecular weight of Nitrogen:
mwn=28
//Molecular weight of Carbon dioxide:
mwc=44
//Moles of Nitrogen:
nn=pn*V/(R*tn)
//Moles of Carbon dioxide:
nc=pc*V/(R*tc)
//Total no of moles:
nt=nn+nc
//Specific heat for Nitrogen at constant volume(in J
    /kg-K):
cvn=(R/mwn)/(rn-1)
```

```
//Specific heat for Carbon dioxide at constant
   volume(in J/kg-K):
cvc=(R/mwc)/(rc-1)
//Mass of Nitrogen(in kg):
mn=nn*mwn
//Mass of Carbon dioxide(in kg):
mc=nc*mwc
//Equilibrium temperature of the mixture(in K):
t=(mn*cvn*tn+mc*cvc*tc)/(mn*cvn+mc*cvc)
//Equilibrium pressure of the mixture(kPa):
p=nt*R*t/(V+V)
printf("\n\n RESULT \n\n")
printf("\n\n Equilibrium temperature = %f K ",t)
printf("\n Equilibrium pressure = %f kPa",p)
```

Scilab code Exa 1.25 To find out specific heat of the mixture

```
//pathname=get_absolute_file_path('1.25.sce')
//filename=pathname+filesep()+'1.25-data.sci'
//exec(filename)
//Mass of hydrogen taken(in kg):
mh=2
//Mass of helium taken(in kg):
mhe=3
//Specific heat at constant pressure for hydrogen(in
   kJ/kg-K):
Ch=11.23
//Specific heat at constant pressure for helium(in
   kJ/kg-K):
Che=5.193
//Total mass of the mixture(in kg):
mt=mh+mhe
//Specific heat at constant pressure for the mixture
   (in kJ/kg-K):
Cm=(Ch*mh+Che*mhe)/mt
```

```
printf("\n\n RESULT \n\n")
printf("\n\n Specific heat at constant pressure for
    the mixture = %f kJ/kg-K \n\n",Cm)
```

Scilab code Exa 1.26 To determine capacity of the vessel

```
//pathname=get_absolute_file_path('1.26.sce')
//filename=pathname+filesep()+'1.26-data.sci'
//exec(filename)
//Mass of Hydrogen(in kg):
mh=18
//Mass of Nitrogen(in kg):
mn=10
//Mass of Carbon dioxide(in kg):
mc=2
//Initial temperature(in K):
t1=27+273.15
//Final temperature(in K):
t2=2*t1
//Universal gas constant(in kJ/kg-K):
R=8.314
//Molecular weight of Hydrogen:
mwh=2
//Molecular weight of Nitrogen:
mwn=28
//Molecular weight of Carbon dioxide:
mwc=44
//Initial pressure of the gases(in kPa)
p1=101.325
//Gas constant for Hydrogen(in kJ/kg-K):
Rh=R/mwh
//Gas constant for Nitrogen(in kJ/kg-K):
Rn=R/mwn
//Gas constant for Carbon dioxide(in kJ/kg-K):
Rc=R/mwc
```

```
//Gas constant for the mixture(in kJ/kg-K):
Rm=(mh*Rh+mn*Rn+mc*Rc)/(mh+mn+mc)
//Capacity of the vessel(in m^3):
V=(mh+mn+mc)*Rm*t1/p1
//Final pressure of the mixture(in kPa):
p2=p1*t2/t1
printf("\n\n RESULT \n\n")
printf("\n\n Volume of the vessel = %f m^3",V)
printf("\n Final pressure of the mixture =%f kPa",p2
    )
```

Scilab code Exa 1.27 To determine the ratio of exit to inlet diameter

```
//pathname=get_absolute_file_path('1.27.sce')
//filename=pathname+filesep()+'1.27-data.sci'
//exec(filename)
//Temperature of entering air(in K):
t1=27+273.15
//Temperature to which it gets heated up to(in K):
t2=500
//Ratio of exit to inlet diameter:
R=sqrt(t2/t1)
printf("\n\n RESULT \n\n")
printf("\n\n Ratio of exit to inlet diameter = %f \n
    \n",R)
```

Scilab code Exa 1.28 To determine the mass pumped out

```
//pathname=get_absolute_file_path('1.28.sce')
//filename=pathname+filesep()+'1.28-data.sci'
//exec(filename)
//Volume of vessel(in m^3):
v=2
```

```
//Atmospheric pressure(in kPa):
p1=76/76*101.325
//Temperature of gas(in K):
t1=27+273.15
//Pressure difference(in kPa):
dp=70/76*101.325
//Univeresal gas constant(in kJ/kg-K):
R=8.314
//Molecular weight of hydrogen:
mwh=2
//Temperature after cooling(in case 2)(in K):
t2=10+273.15
//Case 1:
//Gas constant of hydrogen(in kJ/kg-K):
Rh=R/mwh
//Final pressure of hydrogen(in kPa):
p2=p1-dp
//Mass pumped out(in kg):
m=(p1-p2)*v/(Rh*t1)
//Case 2:(temperature reduces till 10 degrees
    isochorically)
//Pressure after cooling(in kPa):
p3=t2/t1*p2
printf("\n\n RESULT \n\n")
printf("\n\n Mass pumped out = %f kg",m)
printf("\n Final pressure if the temperature is
    reduced = %f kPa",p2)
```

Chapter 2

Zeroth law of thermodynamics

Scilab code Exa 2.01 To find temperature in degree celcius

```
//pathname=get_absolute_file_path('2.01.sce')
//filename=pathname+filesep()+'2.01-data.sci'
//exec(filename)
//Temperature of human body in degree Fahrenheit:
Tf=98.6;
//Temperature of the body in degree Celcius:
Tc=(Tf-32)/1.8
printf("\n\nRESULTS\n\n")
printf("\n\nTemperature of the human body in degree
    Celcius= %f \n\n",Tc)
```

Scilab code Exa 2.02 To find final pressure and temperature

```
//pathname=get_absolute_file_path('2.02.sce')
//filename=pathname+filesep()+'2.02-data.sci'
//exec(filename)
//Thermodynamic property at T=0:
p0=3;
```

```
//Thermodynamic property at T=100:
p100=8;

//Value of a:
a=(100-0)/(log(8)-log(3))
//Value of b:
b=0-a*log(3)
//At thermodynamic property p=6.5:
t=a*log(6.5)+b/2
printf("\n\nRESULTS\n\n")
printf("\n\nTemperature at the value of
    thermodynamic property (p=6.5)= %f \n\n",t)
```

Scilab code Exa 2.03 To find out the temperature

```
//pathname=get_absolute_file_path('2.03.sce')
//filename=pathname+filesep()+'2.03-data.sci'
//exec(filename)
//EMF at temperature T=0
E0=0.003*0-5*(10^-7)*(0^2)+0.5*10^-3
//EMF at temperature T=100
E100=0.003*100-5*(10^-7)*(100^2)+0.5*10^-3
//EMF at temperature T=30
E30=0.003*30-5*(10^-7)*(30^2)+0.5*10^-3
//Temperature shown by the thermometer at T=30:
t=(E30-E0)/(E100-E0)*(100-0)
printf("\n\nRESULT \n\n")
printf("\n\n The temperature shown by thermometer=
    %f \n\n",t)
```

Scilab code Exa 2.04 To find out variation in temperature

```
//pathname=get_absolute_file_path('2.04.sce')
```

```
//filename=pathname+filesep()+'2.04-data.sci'
//exec(filename)
//Temperature of gas using gas thermometer:
T1=50
//EMF at T=0:
E0=0.18*0-5.2*10^-4*(0^2)
//EMF at T=100:
E100=0.18*100-5.2*10^-4*(100^2)
//EMF at T=50:
E50=0.18*50-5.2*10^-4*(50^2)
//Temperature at EMF=E50:
t=(100-0)*E50/(E100-E0)
p=(t-50)/50*100
printf("\n\n RESULT \n\n")
printf("\n\n percentage variation= %f \n\n",p)
```

Scilab code Exa 2.05 To find out absolute zero temperature on new scale

```
//pathname=get_absolute_file_path('2.05.sce')
//filename=pathname+filesep()+'2.05-data.sci'
//exec(filename)
//Freezing point of water in unknown temperature scale:
X0=0
//Boiling point of water in unknown temperature scale:
X100=1000
//Conversion Relation : X=aC+b
//Value of a:
a=(X100-X0)/(100-0)
b=0
//Absolute temperature in new temperature scale:
X=a*-273.15+b
printf("\n\n RESULT \n\n")
printf("\n\n Conversion Relation: X=%f*C+%f",a,b)
```

```
printf("\n\n Absolute temperature in new scale= %f",
    X)
```

Chapter 3

First law of thermodynamics

Scilab code Exa 3.01 To find out work done on the system

```
//pathname=get_absolute_file_path('3.01.sce')
//filename=pathname+filesep()+'3.01-data.sci'
//exec(filename)
//Pressure in the gas cylinder(in kPa):
p=689
//Final volume(in m^3):
v2=0.045
//Initial volume(in m^3):
v1=0.04
//Work done by the paddle(in kJ):
Pw=-4.88
//Work done by the system on the piston(in kJ):
w=p*(v2-v1)
//Net Work of the system(in kJ):
wn=w+Pw
printf("\nRESULTS\n")
printf("\nWork done on the piston=%f kJ",w)
printf("\nWork done on the system=%f kJ",-wn)
```

Scilab code Exa 3.02 To find out the amount of heat required

```
//pathname=get_absolute_file_path('3.02.sce')
//filename=pathname+filesep()+'3.02-data.sci'
//exec(filename)
//Mass of the gas(in kg):
m=0.5
//Initial internal energy(in kJ/kg):
u1=26.6
//Final internal energy(in kJ/kg):
u2=37.8
//Heat required(in kJ):
Q=(u2-u1)*m
printf("\nRESULT\n")
printf("Heat required= %f kJ",Q)
```

Scilab code Exa 3.03 To find out the amount of heat to be removed

```
//pathname=get_absolute_file_path('3.03.sce')
//filename=pathname+filesep()+'3.03-data.sci'
//exec(filename)
//Mass flow rate(in kg/hr):
m=50
//Initial temp(in C):
t1=800
//Final temp(in C):
t2=50
//Heat capacity at const pressure(in kJ/kg.K):
Cp=1.08
//Heat to be removed(in kJ/hr):
Q=m*Cp*(t2-t1)
printf("\nRESULT\n")
printf("Heat should be removed at %d kJ/hr",-Q)
```

Scilab code Exa 3.04 To determine the work done

```
//pathname=get_absolute_file_path('3.04.sce')
//filename=pathname+filesep()+'3.04-data.sci'
//exec(filename)
//Volume of the cylinnder(in m^3):
v=0.78
//Atmospheric pressure(in kPa):
p=101.325
//Work done(in kJ):
w=p*v
printf("\nRESULT\n")
printf("\nWork done by air= %f",-w)
printf("\nWork done by surroundings= %f",w)
```

Scilab code Exa 3.05 To determine the heat interaction

```
//pathname=get_absolute_file_path('3.05.sce')
//filename=pathname+filesep()+'3.05-data.sci'
//exec(filename)
//Mass of the gas(in kg):
m=5
//Value of n in P*(V^n)=const:
n=1.3
//Initial pressure(in MPa):
p1=1
//Initial volume(in m^3):
v1=0.5
//Final pressure(in MPa):
p2=0.5
//Final volume(in m^3):
v2=v1*((p1/p2)^(1/n))
```

```
//Work done(in kJ):
w=(p2*v2-p1*v1)*10^3/(1-n)
//Change in internal energy(in kJ/kg):
du=1.8*(p2*v2-p1*v1)*10^3
//Heat interaction(in kJ):
Q=du+w
printf("\nRESULT\n")
printf("\nHeat interaction = %f kJ",Q)
printf("\nWork interaction = %f kJ",w)
printf("\nChange in internal energy = %f kJ",du)
```

Scilab code Exa 3.06 To determine the work done

```
//pathname=get_absolute_file_path('3.06.sce')
//filename=pathname+filesep()+'3.06-data.sci'
//exec(filename)
//Initial pressure(in MPa):
p1=1
//Final pressure(in MPa):
p2=2
//Initial volume(in m^3):
v1=0.05
//Value of n:
n=1.4
//Final volume(in m^3):
v2=v1*((p1/p2)^(1/n))
//Change in internal energy(in kJ/kg):
du=7.5*(p2*v2-p1*v1)*10^3
//Work done(in kJ):
w=(p2*v2-p1*v1)*10^3/(1-n)
//Heat interaction(in kJ):
Q=du+w
printf("\nRESULT\n")
printf("\nHeat interaction = %f kJ",Q)
printf("\nWork interaction = %f kJ",w)
```

```
printf("\nChange in internal energy = %f kJ",du)
//If 180 kJ heat transfer takes place:
//Work done(in kJ):
w2=180-du
printf("\nNew work = %f kJ",w2)
```

Scilab code Exa 3.07 To determine the heat transfer

```
//pathname=get_absolute_file_path('3.08.sce')
//filename=pathname+filesep()+'3.08-data.sci'
//exec(filename)
//Initial temperature(in K):
t1=627+273
//Final temperature(in K):
t2=27+273
//Specific heat at const pressure(in kJ/kg.K):
Cp=1.005
//Exit velocity(in m/s):
c2=sqrt(2*Cp*10^3*(t1-t2))
printf("\nRESULT\n")
printf("\nExit Velocity = %f m/s",c2)
```

Scilab code Exa 3.08 To determine the exit velocity

```
//pathname=get_absolute_file_path('3.08.sce')
//filename=pathname+filesep()+'3.08-data.sci'
//exec(filename)
//Initial temperature(in K):
t1=627+273
//Final temperature(in K):
t2=27+273
//Specific heat at const pressure(in kJ/kg.K):
Cp=1.005
```

```
//Exit velocity(in m/s):
c2=sqrt(2*Cp*10^3*(t1-t2))
printf("\nRESULT\n")
printf("\nExit Velocity = %f m/s",c2)
```

Scilab code Exa 3.09 To determine the heat to be transferred to the atmosphere

```
//pathname=get_absolute_file_path('3.09.sce')
//filename=pathname+filesep()+'3.09-data.sci'
//exec(filename)
//Work interaction(in kJ):
w=-200
//Increase in enthalpy(in kJ/kg):
dh=100
//Heat picked up by the cooling water(in kJ/kg):
qc=-90
//Heat flow(in kJ/kg):
Q=dh+w
//Heat transferred to atmosphere(in kJ/kg):
Qa=Q-qc
printf("\nRESULT\n")
printf("\nHeat transferred to atmosphere = %d kJ/kg"
    ,Qa)
```

Scilab code Exa 3.10 To determine the water circulation rate

```
//pathname=get_absolute_file_path('3.10.sce')
//filename=pathname+filesep()+'3.10-data.sci'
//exec(filename)
//Seating capacity:
c=500
//Heat requirement per person(in kcal/hr):
q=50
```

```
//Enthalpy of water entering the pipe(in kcal/kg):
h1=80
//Enthalpy of water leaving the pipe(in kcal/kg):
h2=45
//Difference in elevation of inlet and exit pipe(in
   m):
z=10
//Acceleration due to gravity(in m/s^2):
g=9.81
//Heat to be supplied(in kcal/hr):
Q=c*q
//Heat lost by water(in kcal/kg):
Q1=-Q
//By SFEE:
//Quantity of water circulated(in kg/hr):
m=(Q1*10^3*4.18)/(g*z+(h2-h1)*10^3*4.18)
printf("\nRESULT\n")
printf("\nWater circulation rate = %f kg/min",m/60)
```

Scilab code Exa 3.11 To determine the steam supply rate

```
//pathname=get_absolute_file_path('3.11.sce')
//filename=pathname+filesep()+'3.11-data.sci'
//exec(filename)
//Enthalpy of steam entering the injector(in kcal/kg
   ):
h1=720;
g = 9.81;
//Enthalpy of water entering(in kcal/kg):
h2=24.6
//Enthalpy of water and steam mixture leaving the
   injector(in kcal/kg):
h3=100
//Depth of water injector from steam injector(in m):
z=2
```

```
//Velocity of steam entering the injector(in m/s):
v1=50
//Velocity of mixture leaving the injector(in m/s):
v3=25
//Heat loss from injector to surroundings(in kcal/kg
    ):
q=12
//By applying SFEE:
//Steam supply rate(in kg/s):
m=(((v3^2)/2+h3*10^3*4.18)-(h2*10^3*4.18+g*z))/(((v1
    ^2)/2+h1*10^3*4.18)-((v3^2)/2+h3*10^3*4.18)-(q
    *10^3*4.18))
printf("\nRESULT\n")
printf("\nSteam supply rate = %f kg/s",m)
```

Scilab code Exa 3.12 To determine the work done

```
//pathname=get_absolute_file_path('3.12.sce')
//filename=pathname+filesep()+'3.12-data.sci'
//exec(filename)
//Atmospheric pressure(in bar):
p=1.013
//Volume to which the baloon is inflated(in m^3):
v=0.4
//Work done by cylinder(in kJ):
w1=0
//Work done by the balloon(in kJ):
w2=p*10^5*v
//Total work(in kJ):
w=w1+w2
printf("\nRESULT\n")
printf("\nWork done by the system upon atmoshere =
    %f kJ",w/(10^3))
printf("\nWork done by the atmoshere = %f kJ",-w
    /(10^3))
```

Scilab code Exa 3.13 To determine capacity of the generator

```
//pathname=get_absolute_file_path('3.13.sce')
//filename=pathname+filesep()+'3.13-data.sci'
//exec(filename)
//Heat added(in J/s):
Qa=5000
//Turbine work(in J/s):
Wt=0.25*Qa
//Heat rejected(in J/s):
Qr=0.75*Qa
//Work by feed pump(in J/s):
Wp=0.002*Qa
//Capacity of generator(in W):
C=Wt-Wp
printf("\nRESULT\n")
printf("\nCapacity of generator = %f kW ",C/(10^3))
```

Scilab code Exa 3.14 To determine the exit velocity

```
//pathname=get_absolute_file_path('3.14.sce')
//filename=pathname+filesep()+'3.14-data.sci'
//exec(filename)
//Ambient temperature(in K):
T1=27+273
//Temperature of air inside heat exchanger(in K):
T2=750+273
//Temperature of air leaving turbine(in K):
T3=600+273
//Temperature of air leaving the nozzle(in K):
T4=500+273
```

```
//Velocity of air entering turbine(in m/s):
c2=50
//Velocity of air entering the nozzle(in m/s):
c3=60
//Specific heat at constant pressure(in kj?kg.K):
Cp=1.005
//By applying SFEE between points 1 & 2:
//Heat transfer to air in heat exchanger(in kJ):
Q12=Cp*(T2-T1)
printf("\nRESULT\n")
printf("\nHeat transfer to air in heat exchanger =%f
    kJ",Q12)
//By applying SFEE between points 2 & 3:
//Power output from turbine(in kJ/s):
Wt=Cp*(T2-T3)+(c2^2-c3^2)*10^(-3)/2
printf("\nPower output from turbine = %f kJ/s",Wt)
//By applying SFEE between points 3 & 4:
//Velocity at exit of the nozzle(in m/s):
c4=sqrt(2*(Cp*(T3-T4)+(c3^2)*10^(-3)/2))
printf("\nVelocity at exit of the nozzle = %f m/s",
   c4)
```

Scilab code Exa 3.15 To determine the work done

```
//pathname=get_absolute_file_path('3.15.sce')
//filename=pathname+filesep()+'3.15-data.sci'
//exec(filename)
//Initial pressure(in MPa):
p1=0.5
//Initial temperature(in K):
T1=400
//Ratio of v2 to v1:
r1=2
//Ratio of v3 to v1:
r2=6
```

```
//Universal gas constant(in kJ/kg):
R=8.314
//Work from state 1 to 2(in kJ):
Wa=R*T1
//Temperature at point 2(in K):
T2=2*T1
//Work done from state 2 to 3(in kJ):
Wb=R*T2*log(r2/r1)
//Total work done by air(in kJ):
W=Wa+Wb
printf("\nRESULT\n")
printf("\nWork done = %f kJ",W)
```

Scilab code Exa 3.16 To determine the work done

```
//pathname=get_absolute_file_path('3.16.sce')
//filename=pathname+filesep()+'3.16-data.sci'
//exec(filename)
//Initial pressure(in MPa):
pi=0.5
//Initial volume(in m^3):
vi=0.5
//Final pressure(in MPa):
pf=1
//Atmospheric pressure(in Pa):
patm=1.013*10^5
//Final volume(in m^3):
vf=3*vi
//Work done(in J):
W=(vf-vi)*(pi+pf)*10^5/2
printf("\nRESULT\n")
printf("\nWork done = %d J",W)
```

Scilab code Exa 3.17 To determine the work done

```
//pathname=get_absolute_file_path('3.17.sce')
//filename=pathname+filesep()+'3.17-data.sci'
//exec(filename)
//Initial pressure(in MPa):
p1=0.5;
CpH2 = 14.307;
CpN2 = 1.039;
RN2 = 0.2968;
RH2 = 4.124;
T1 = 300;
v1=0.5;
vN1 = 0.5;
vN2 = 0.75;
v2 = 0.25;
//Initial volume(in m^3):
vi=0.5
//Final pressure(in MPa):
pf=1
//Atmospheric pressure(in Pa):
patm=1.013*10^5
//Adiabatic index of compression for H2:
rH2=CpH2/(CpH2-RH2)
//Adiabatic index of compression for N2:
rN2=CpN2/(CpN2-RN2)
//Final pressure of hydrogen(in Pa):
p2=p1*(v1/v2)^rH2
printf("\nRESULT\n")
printf("\nFinal pressure of hydrogen = %f MPa",p2
    /(10^6))
//Partition work:
Pw=0
printf("\nPartition work = %d",Pw)
//Work done upon H2(in J):
WH2=(p1*v1-p2*v2)/(rH2-1)
//Work done by nitrogen(in J):
WN2=-WH2
```

```
printf("\nWork done by hyrogen = %d J",WH2)
printf("\nWork done by nitrogen = %d J",WN2)
//Mass of N2(in kg):
mN2=p1*v1/(RN2*10^3*T1)
//Final temperature of N2(in K):
T2=p2*vN2*T1/(p1*v1)
//Cv of N2(in kJ/kg):
CvN2=CpN2-RN2
//Heat added to N2(in kJ):
QN2=mN2*CvN2*10^3*(T2-T1)+WN2
printf("\nHeat added to nitrogen = %f kJ",QN2/(10^3)
    )
```

Scilab code Exa 3.18 To determine the work available

```
//pathname=get_absolute_file_path('3.18.sce')
//filename=pathname+filesep()+'3.18-data.sci'
//exec(filename)
//Volume of the cylinder(in m^3):
v1=2
//Pressure in the cylinder(in Pa):
p1=0.5*10^6
//Temperature of the cylinder(in K):
T1=375
//Specific heat at const pressure(in kJ/kg.K):
Cp=1.003
//Specific heat at const volume(in kJ/kg.K):
Cv=0.716
//Gas constant for air(in kJ/kg.K):
Ra=0.287
//Atmospheric pressure(in Pa):
patm=1.013*10^5
//Compression ratio:
r=1.4
//Initial mass of air(in kg):
```

```
m1=p1*v1/(Ra*T1)
//Final temperature(in K):
T2=T1*(patm/p1)^((r-1)/r)
//Final mass of air left in tank(in kg):
m2=patm*v1/(Ra*T2)
//Kinetic energy available(in kJ):
KE=m1*Cv*T1-m2*Cv*T2-(m1-m2)*Cp*T2
printf("\nRESULT\n")
printf("\nAmount of work available = %f J",KE)
```

Scilab code Exa 3.19 To determine the final pressure and temperature

```
//pathname=get_absolute_file_path('3.19.sce')
//filename=pathname+filesep()+'3.19-data.sci'
//exec(filename)
//Pressure in the vessel(in Pa):
p1=0.5*10^6
//Volume of 1st chamber(in m^3):
v1=0.5
//Temperature in the vessel(in K):
T1=300
//Final pressure(in Pa):
p2=10^6
//Volume of 2nd chamber(in m^3):
v2=0.5
//Final temperature(in K):
T2=500
//Universal gas constant(in J/kg.K):
R=8314
//Moles in chamber 1:
n1=p1*v1/(R*T1)
//Moles in chamber 2:
n2=p2*v2/(R*T2)
//Temperature of the mixture(in K):
T3=(n1*T1+n2*T2)/(n1+n2)
```

```
//Final pressure(in MPa):
p3=(n1+n2)*R*T3/(v1+v2)
printf("\nRESULT\n")
printf("\nFinal pressure = %f MPa",p3/(10^6))
printf("\nFinal temperature = %f K",T3)
```

Scilab code Exa 3.20 To determine the heat to be transferred

```
//pathname=get_absolute_file_path('3.20.sce')
//filename=pathname+filesep()+'3.20-data.sci'
//exec(filename)
//Volume of the bottle(in m^3):
v=0.5
//Pressure in the bottle(in Bar):
p=1.0135
//Displacement work(in N-m):
W=p*10^5*(0-v)
//Heat transfer(in N-m):
Q=-W
printf("\nRESULT\n")
printf("\nHeat transferred = %d N-m",Q)
```

Scilab code Exa 3.21 To determine the heat to be transferred

```
//pathname=get_absolute_file_path('3.21.sce')
//filename=pathname+filesep()+'3.21-data.sci'
//exec(filename)
//Volume of bottle(in m^3):
v1=0.3
//Pressure in the bottle(in bar):
p1=35
//Temperature in the bottle(in K):
T1=40+273
```

```
//Turbo generator's actual output(in kJ/s):
w1=5
//Final prssure(in bar):
p2=1
//Final volume(in m^3):
v2=v1
//Gas constant for air(in kJ/kg.K):
Ra=0.287
//Compression ratio:
r=1.4
//% of output which is consumed= 60%
//Specific heat at const volume(in kJ/kg):
Cv=0.718
//Specific heat at const pressure(in kJ/kg):
Cp=1.005
//Final temperature(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Initial mass in the bottle(in kg):
m1=p1*10^2*v1/(Ra*T1)
//Final mass in the bottle(in kg):
m2=p2*10^2*v2/(Ra*T2)
//Maximum work that can be obtained(in kJ):
W=(m1*Cv*T1-m2*Cv*T2)-(m1-m2)*Cp*T2
//Input to the turbo generator(in kJ/s):
i=w1/0.6
//Time duration(in s):
t=W/i
printf("\nRESULT\n")
printf("\nDuration = %f seconds",t)
```

Scilab code Exa 3.22 To determine the duration

```
//pathname=get_absolute_file_path('3.22.sce')
//filename=pathname+filesep()+'3.22-data.sci'
//exec(filename)
```

```
//Pressure at state 1(in bar):
p1=1.5
//Temperature at state 1(in K):
T1=77+273
//Pressure at state 2(in bar):
p2=7.5
//Mass of the air(in kg):
m=3
//Value of n:
n=1.2
//Gas constant for air(in kJ/kg.K):
Ra=0.287
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((n-1)/n)
//Initial volume(in m^3):
v1=m*Ra*T1/(p1*10^2)
//Volume at state 2(in m^3):
v2=(p1*(v1^n)/p2)^(1/n)
//Temperature at state 3(in K):
T3=T1
//Volume at state 3(in m^3):
v3=v2*T3/T2
//Pressure at state 3(in bar):
p3=7.5
//Compression work during process 1-2(in kJ):
W12=m*Ra*(T2-T1)/(1-n)
//Work during process 2-3(in kJ):
W23=p2*(10^2)*(v3-v2)
//Work during process 3-1(in kJ):
W31=p3*10^2*v3*log(v1/v3)
//Net work(in kJ):
Wn=W12+W23+W31
printf("\nRESULT\n")
printf("\nHeat transferred from the system = %f kJ",-Wn)
```

Scilab code Exa 3.23 To determine the work available from the turbine

```
//pathname=get_absolute_file_path('3.23.sce')
//filename=pathname+filesep()+'3.23-data.sci'
//exec(filename)
//Volume of air bottle(in m^3):
v1=0.15
//Initial pressure(in bar):
p1=40
//Initial temperature(in K):
T1=27+273
//Final presure(in bar):
p2=2
//Final volume(in m^3):
v2=v1
//Gas constant for air(in kJ/kg):
Ra=0.287
//Specific heat at const pressure(in kJ/kg):
Cp=1.005
//Specific heat at const volume(in kJ/kg):
Cv=0.718
//Compression ratio:
r=1.4
//Initial mass of air in bottle(in kg):
m1=p1*10^2*v1/(Ra*T1)
//Final temperature(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Final mass of air in bottle(in kg):
m2=p2*10^2*v2/(Ra*T2)
//Energy available for running of turbine due to
    emptying of bottle(in kJ):
E=m1*Cv*T1-m2*Cv*T2-(m1-m2)*Cp*T2
printf("\nRESULT\n")
printf("\nWorj available from turbine = %f",E)
```

Chapter 4

Second law of thermodynamics

Scilab code Exa 4.02 To determine heat to be supplied

```
//pathname=get_absolute_file_path('4.02.sce')
//filename=pathname+filesep()+'4.02-data.sci'
//exec(filename)
//Highest temperature(in K):
T1=400+273
//Lowest temperature(in K):
T2=15+273
//Work produced(in kJ):
w=200
//Ratio of Q1 to Q2 is same as T1 to T2
//Heat to be supplied(in kJ):
Q1=w/(1-T2/T1)
printf("\nRESULTS\n")
printf("\nHeat to be supplied = %f kJ",Q1)
```

Scilab code Exa 4.03 To determine the power required

```
//pathname=get_absolute_file_path('4.03.sce')
```

```
//filename=pathname+filesep()+'4.03-data.sci'
//exec(filename)
//Upper temperature(in K):
T1=42+273
//Lower temperature(in K):
T2=4+273
//Rate at which heat is extracted(in kJ/s):
Q2=2
//Heat to be supplied(in kJ/s):
Q1=T1/T2*Q2
//Power required(in kW):
P=Q1-Q2
printf("\nRESULTS\n")
printf("\nPower required for driving the
    refrigerator = %f kW",P)
```

Scilab code Exa 4.04 To determine the heat transferred

```
//pathname=get_absolute_file_path('4.04.sce')
//filename=pathname+filesep()+'4.04-data.sci'
//exec(filename)
//Source temperature(in K):
T1=827+273
//Sink temperature(in K):
T2=27+273
//Temperature in the refrigerator(in K):
T3=-13+273
//Heat input(in kJ):
Q1=2000
//Net work available(in kJ):
W=300
//Rate at which heat is extracted(in kJ):
Q2=Q1*T2/T1
//Work in the engine(in kJ):
We=Q1-Q2
```

```
//Work in the refrigerator(in kJ):
Wr=We-W
//Heat transferred to the refrigerant(in kJ):
Q3=Wr/(T2/T3-1)
//Heat transferred to reservoir by refrigerant(in kJ
    ):
Q4=Q3+Wr
//Total heat transferred to low temperature
    reservoir(in kJ):
Wt=Q2+Q4
printf("\nRESULTS\n")
printf("\nHeat transferred to refrigerant = %f kJ",
    Q3)
printf("\nTotal heat transferred to low temperature
    reservoir = %f kJ",Wt)
```

Scilab code Exa 4.05 To determine the minimum power required

```
//pathname=get_absolute_file_path('4.05.sce')
//filename=pathname+filesep()+'4.05-data.sci'
//exec(filename)
//Temperature inside the house(in K):
T1=25+273.15
//Temperature outside the house(in K):
T2=-1+273.15
//Heating load(in MJ/h):
Q1=125
//COP:
COP=1/(1-T2/T1)
//Minimum power required(in MJ/h):
W=Q1/COP
printf("\nRESULTS\n")
printf("\nMinimum power required = %f kW",W
    /(3600/10^3))
```

Scilab code Exa 4.06 To determine the power required

```
//pathname=get_absolute_file_path('4.06.sce')
//filename=pathname+filesep()+'4.06-data.sci'
//exec(filename)
//Inside temperature(in K):
T1=-15+273
//Atmospheric temperature(in K):
T2=35+273
//Heat to be extracted (in kW):
Q2=140.8
//Carnot COP of plant:
COP1=1/(T2/T1-1)
//Actual COP:
COP=COP1/4
//Power required(in kW):
W=Q2/COP
printf("\nRESULTS\n")
printf("\nPower required = %f kW",W)
```

Scilab code Exa 4.07 To determine the efficiency

```
//pathname=get_absolute_file_path('4.07.sce')
//filename=pathname+filesep()+'4.07-data.sci'
//exec(filename)
//Maximum temperature(in K):
T1=1150+273
//Minimum temperature(in K):
T2=27+273
//Efficiency:
n=1-(T2/T1)
printf("\nRESULTS\n")
```

```
printf("\nEfficiency = %f percent ",n*100)
```

Scilab code Exa 4.08 To determine the power required

```
//pathname=get_absolute_file_path('4.08.sce')
//filename=pathname+filesep()+'4.08-data.sci'
//exec(filename)
//Maximum temperature(in K):
T1=27+273
//Minimum temperature(in K):
T2=-8+273
//Leakage(in kJ/s):
Q=7.5/60
//Power required(in kW):
W=(T1-T2)*Q/T2
printf("\nRESULTS\n")
printf("\nPower required = %f kW",W)
```

Scilab code Exa 4.10 To determine the efficiency of the engine and COP of refriger

```
//pathname=get_absolute_file_path('4.10.sce')
//filename=pathname+filesep()+'4.10-data.sci'
//exec(filename)
//Temperature at which heat is receieved (in K):
T1=800
//Temperature maintained by the carnot engine(in K):
T2=280
//Temperature at which heat is rejected(in K):
T=2*T1*T2/(T1+T2)
//Efficiency:
n=(T1-T)/T1
//COP of refrigerator:
COP=T2/(T-T2)
```

```
printf("\nRESULTS\n")
printf("\nEfficiency = %f",n)
printf("\nC.O.P of refrigerator = %f",COP)
```

Scilab code Exa 4.11 To determine the maximum and minimum temperature in the cycle

```
//pathname=get_absolute_file_path('4.11.sce')
//filename=pathname+filesep()+'4.11-data.sci'
//exec(filename)
//Efficiency of carnot cycle:
n=0.5
//Mass of air(in kg):
m=0.5
//Initial pressure(in Pa):
p2=7*10^5
//Initial volume(in m^3):
v2=0.12
//Heat transferred during the process 2-3(in kJ):
Q23=40
//Specific heat at const pressure(in kJ/kg):
Cp=1.008
//Specific heat at const volume(in kJ/kg):
Cv=0.721
//Gas constant for air:
Ra=287
//Maximum temperature of the cycle(in K):
T2=p2*v2/(m*Ra)
//Minimum temperature(in K):
T1=T2/2
//Volume at state 3(in m^3):
v3=v2*(%e^(Q23/(m*Ra*10^(-3)*T2)))
//Compression factor:
r=Cp/Cv
//Pressure at point 1(in Pa):
p1=p2/((T2/T1)^(r/(r-1)))
```

```
//Volume at point 1(in m^3):
v1=m*Ra*T1/p1
//Temperature at state 3(in K):
T3=T2
//Temperature at state 4(in K):
T4=T1
//During process 1-2, work done(in kJ):
W12=-m*Cv*(T2-T1)
//Heat transfer in process 1-2(in kJ):
Q12=0
//Work done in process 2-3(in kJ):
W23=Q23
//During process 3-4, work done(in kJ):
W34=-m*Cv*(T4-T3)
//Heat transfer in process 3-4(in kJ):
Q34=0
//During process 4-1, work done(in kJ):
W41=-W23
//Heat transfer in process 4-1(in kJ):
Q41=-Q23
printf("\nRESULTS\n")
printf("\nProcess    Heat transfer    Work interaction")
printf("\n  1-2            %d              %f",Q12,W12)
printf("\n  2-3            %d              %d",Q23,W23)
printf("\n  3-4            %d              %f",Q34,W34)
printf("\n  4-1            %d              %d",Q41,W41)
printf("\n\n\n Maximum temperature of the cycle = %f kJ",T2)
printf("\n Minimum temperature of the cycle = %f kJ",T1)
printf("\n Volume at the end of the expansion = %f m^3",v3)
```

Scilab code Exa 4.12 To determine the heat transferred

```
//pathname=get_absolute_file_path('4.12.sce')
//filename=pathname+filesep()+'4.12-data.sci'
//exec(filename)
//Heat drawn from 400 K reservoir(in kJ):
Q1=5000
//Work output(in kJ):
W=840
//Value of heat from heat engine(in kJ):
Q2=3*(Q1/2-W)
//Value of heat to heat engine(in kJ):
Q3=Q1-W-Q2
printf("\nRESULTS\n")
printf("\nQ2 = %d kJ from heat engine",Q2)
printf("\nQ3 = %d kJ to heat engine",-Q3)
```

Scilab code Exa 4.13 To determine the energy taken from the reservoir

```
//pathname=get_absolute_file_path('4.13.sce')
//filename=pathname+filesep()+'4.13-data.sci'
//exec(filename)
//Temperature of the reservoir(in K):
T3=3+273
//Lower temperature limit(in K):
T1=77+273
//Higher temperature limit(in K):
T2=1077+273
//Energy supplied to the reservoir(in kJ/s):
E=100
//Efficiency:
n=1-T1/T2
```

```
//Energy taken from the reservoir Q1 can be found by
    solving the simultaneous equations
//n=1-Q2/Q1
//We get Q2=0.2593*Q1
//COP for heat pump = Q4/(Q4-Q3) = T1/(T1-T3)
//We get Q4=1.27*Q3
//It is given that Q2+Q4=E
//Solving all the equations , we get:
Q1=26.71
printf("\nRESULT\n")
printf("\nEnergy taken from reservoir at 1077 degree
    celcius = %f kJ",Q1)
```

Scilab code Exa 4.14 To determine temperature of the sink

```
//pathname=get_absolute_file_path('4.14.sce')
//filename=pathname+filesep()+'4.14-data.sci'
//exec(filename)
//Heat supplied(in kJ/s):
Qs=2000
//Temperature of source(in K):
Tso=1500
//Temperature at which heat is rejected(in K):
Tr=15+273
//Total heat received(in kJ/s):
Qt=3000
//Heat rejected(in kJ/s):
Qr=Qt-Qs
//Temperature of the sink(in K):
Ts=Qt/(Qs/Tso+Qr/Tr)
printf("\nRESULT\n")
printf("\nTemperature of the sink = %f K",Ts)
```

Scilab code Exa 4.15 To determine the ratio of heat rejected to body to the heat s

```
//pathname=get_absolute_file_path('4.15.sce')
//filename=pathname+filesep()+'4.15-data.sci'
//exec(filename)
//Maximum temperature(in K):
T1=500+273
//Minimum temperature(in K):
T2=200+273
//Temperature of the body(in K):
T3=450+273
//Efficiency:
n=1-T2/T1
//Ratio of W to Q1:
r1=n
//COP of pump:
COP=T3/(T3-T2)
//Ratio of Q3 to W:
r2=COP*2/3
//Ratio of Q3 to Q1:
r3=r1*r2
printf("\nRESULT\n")
printf("\nRatio of heat rejected to body at 450 C
   to the heat supplied by the reservoir = %f",r3)
```

Scilab code Exa 4.18 To determine the heat received from the highest temperature r

```
//pathname=get_absolute_file_path('4.18.sce')
//filename=pathname+filesep()+'4.18-data.sci'
//exec(filename)
//Maximum temperature(in K):
T1=800+273
//Minimum temperature(in K):
T2=50+273
//Temperature of the 3rd reservoir(in K):
```

```
T3=50+273
//Temperature of the 4th reservoir(in K):
T4=10+273
//Heat picked up by Carnot cycle(in kW):
Q3=15
//Energy required to run a machine(in kW):
E=25
//Efficiency:
n=1-T2/T1
//From the relation of COP:
Q4=Q3*T3/T4
//Work by heat pump(in kW):
Whp=Q4-Q3
//Work in the heat engine(in kW):
Whe=Whp+E
//Heat from source at 1173 K(in kW):
Q1=Whe/n
//Heat rejected to the reservoir from engine 1(in kW):
Q2=Q1-Whe
//Total heat rejected to the reservoir(in kW):
Qt=Q2+Q4
printf("\nRESULT\n")
printf("\nHeat rejected to the reservoir = %f kW",Qt)
printf("\nHeat received from the highest temperature reservoir = %f kW",Q1)
```

Scilab code Exa 4.19 To determine the change in enthalpy and Work done

```
//pathname=get_absolute_file_path('4.19.sce')
//filename=pathname+filesep()+'4.19-data.sci'
//exec(filename)
//Volume of 1st tank(in m^3):
v1=1.8
```

```
//Volume of 2nd tank(in m^3):
v2=3.6
//Initial pressure(in bar):
p1=12
//Initial temperature(in K):
T1=40+273
//Gas constant for argon(in kJ/kg.K):
R=0.208
//By gas law for final and initial state:
pf=p1*v1/(v1+v2)
printf("\nRESULT\n")
printf("\nFinal pressure = %d bar",pf)
//As there is no heat transfer, change in internal
   energy is 0:
Tf=T1
dH=0
W=0
printf("\nChange in enthalpy = %d",dH)
printf("\nWork done =%d",W)
```

Chapter 5

Entropy

Scilab code Exa 5.01 To determine the change in entropy

```
//pathname=get_absolute_file_path('5.01.sce')
//filename=pathname+filesep()+'5.01-data.sci'
//exec(filename)
//Initial pressure(in bar):
p1=5
//Initial temperature(in K):
T1=300
//Final pressure(in bar):
p2=2
//Cp for air(in kJ/kg.K):
Cp=1.004
//Gas constant for air(in kJ/kg.K):
R=0.287
//As it is a throttling process:
T2=T1
//Change in entropy(in kJ/kg.K):
dS=Cp*log(T2/T1)-R*log(p2/p1)
printf("\nRESULT\n")
printf("\nChange in entropy = %f kJ/kg.K",dS)
```

Scilab code Exa 5.02 To determine the change in entropy

```
//pathname=get_absolute_file_path('5.02.sce')
//filename=pathname+filesep()+'5.02-data.sci'
//exec(filename)
//Mass of water(in kg):
m=5
//Atmospheric temperature(in K):
T1=27+273.15
//Temperature of evaporation(in K):
T2=100+273.15
//Temperature at which steam is generated(in K):
T3=400+273
//Specific heat of water(in kJ/kg.K):
Cp=4.2
//Heat of vaporisation(in kJ/kg):
q2=2260
//For steam, Cp is given by:
//Cps=R(3.5+1.2*T+0.14*T^2)
//Heat added for increasing water temperature from
    27 C to 100 C (in kJ):
Q1=m*Cp*(T2-T1)
//Entropy change during water temperature rise(in kJ
    /K):
dS1=Q1/T1
//Heat of vaporization(in kJ):
Q2=m*q2
//Entropy change during water to steam change(in kJ/
    K):
dS2=Q2/T2
//Entropy change during steam temperature rise(in kJ
    /K):
dS3=m*10^(-3)*(1.617*log(T3/T2)+0.5544*(T3-T2)
    +0.065*(T3^2-T2^2)/2)
```

```
//Total entropy change(in kJ/K):
dS=dS1+dS2+dS3
printf("\nRESULT\n")
printf("\nTotal change in entropy of universe = %f
   kJ/K",dS)
```

Scilab code Exa 5.03 To determine the change in entropy

```
//pathname=get_absolute_file_path('5.03.sce')
//filename=pathname+filesep()+'5.03-data.sci'
//exec(filename)
//Initial pressure(in kPa):
p1=125
//Final pressure(in kPa):
p2=375
//Intial temperature(in K):
T1=27+273
//Gas constant for oxygen(in kJ/kg.K):
R=8.314/32
//Change in entropy(in kJ/kg.K):
dS=-R*log(p2/p1)
printf("\nRESULT\n")
printf("\nChange in entropy = %f kJ/kg.K",dS)
```

Scilab code Exa 5.04 To determine the entropy change in universe

```
//pathname=get_absolute_file_path('5.04.sce')
//filename=pathname+filesep()+'5.04-data.sci'
//exec(filename)
//Mass of the block(in kg):
m=1
//Temperature of the block(in K):
T1=150+273.15
```

```
//Temperature of the sea(in K):
T2=25+273.15
//Heat capacity of copper(in kJ/kg.K):
C=0.393
//Change in entropy of block(in kJ/K):
dSb=m*C*log(T2/T1)
//Heat lost by the block will be equal to heat
   gained by the water
//Heat lost by water(in kJ):
Q=m*C*(T1-T2)
//Change in entropy of water(in kJ/K):
dSw=Q/T2
//Entropy change of universe(in kJ/K):
dSu=dSb+dSw
printf("\nRESULT\n")
printf("\nChange in entropy of universe = %f J/K",
   dSu*10^3)
```

Scilab code Exa 5.05 To determine the entropy change in universe

```
//pathname=get_absolute_file_path('5.05.sce')
//filename=pathname+filesep()+'5.05-data.sci'
//exec(filename)
//Mass of the block(in kg):
m=1
//Temperature of the block(in K):
T=27+273
//Height(in m):
h=200
//Heat capacity for copper(in kJ/kg.K):
s=0.393
//Acceleration due to gravity(in m/s^2):
g=9.81
//Change in potential energy(in J):
PE=m*g*h
```

```
//In this case:
Q=PE
//Change in entropy of universe(in J/kg.K):
dSu=Q/T
printf("\nRESULT\n")
printf("\nChange in entropy of universe = %f J/kg.K"
    ,dSu)
```

Scilab code Exa 5.06 To determine the entropy change in universe

```
//pathname=get_absolute_file_path('5.06.sce')
//filename=pathname+filesep()+'5.06-data.sci'
//exec(filename)
//Block 1:
//Mass(in kg):
m1=1
//Temperature(in K):
T1=150+273
//Specific heat(in kJ/kg.K):
C1=0.393
//Block 2:
//Mass(in kg):
m2=0.5
//Temperature(in K):
T2=0+273
//Specific heat(in kJ/kg.K):
C2=0.381
//Final temperature(in K):
Tf=(m1*C1*T1+m2*C2*T2)/(m1*C1+m2*C2)
//Entropy change in block 1(in kJ/K):
dS1=m1*C1*log(Tf/T1)
//Entropy change in block 2(in kJ/K):
dS2=m2*C2*log(Tf/T2)
//Total entropy change(in kJ/K):
dS=dS1+dS2
```

```
printf("\nRESULT\n")
printf("\nChange in entropy of universe = %f J/K",dS
    )
```

Scilab code Exa 5.08 To determine the work lost

```
//pathname=get_absolute_file_path('5.08.sce')
//filename=pathname+filesep()+'5.08-data.sci'
//exec(filename)
//Maximum temperature(in K):
T1=1800
//Minimum temperature(in K):
T2=300
//Rate at which heat is added(in MW):
Q1=5
//Work output(in MW):
W=2
//Heat rejected(in MW):
Q2=Q1-W
//Entropy generated(in MW/K):
dSg=(-Q1/T1+Q2/T2)
//Work lost(in MW):
w=T2*dSg
printf("\nRESULT\n")
printf("\nWork lost = %f MW",w)
```

Scilab code Exa 5.09 To determine the maximum work done

```
//pathname=get_absolute_file_path('5.09.sce')
//filename=pathname+filesep()+'5.09-data.sci'
//exec(filename)
//Temperature of the system(in K):
T1=500
```

```
//Temperature of the reservoir(in K):
T2=300
//Heat capacity of the system(in J/K):
//C=0.05*T^2+0.10*T+0.085
//Maximum heat(in J):
Q1=-(0.05*(T2^3-T1^3)/3+0.10*(T2^2-T1^2)/2+0.085*(T2
    -T1))
//Entropy change of the system(in J/K):
dSs=0.05*(T2^2-T1^2)/2+0.10*(T2-T1)+0.085*log(T2/T1)
//Maximum work available(in kJ):
W=(Q1/T2+dSs)*T2
printf("\nRESULT\n")
printf("\nMaximum work = %f kJ",W/(10^3))
```

Scilab code Exa 5.10 To determine the change in entropy and enthalpy

```
//pathname=get_absolute_file_path('5.10.sce')
//filename=pathname+filesep()+'5.10-data.sci'
//exec(filename)
//Initial pressure(in kPa):
p1=3000
//Initial volume(in m^3):
v1=0.05
//Final volume(in m^3):
v2=0.3
//Value of n:
n=1.4
//Final pressure(in MPa):
p2=p1*((v1/v2)^n)
//Entropy change:
dS=0
//Change in enthalpy(in kJ):
dH=((p1*(v1^n))^(1/n))*(p1^((n-1)/n)-p2^((n-1)/n))
    /((n-1)/n)
printf("\nRESULT\n")
```

```
printf("\nEnthalpy change = %f kJ",dH)
printf("\nEntropy change = %d",dS)
```

Scilab code Exa 5.11 To determine the entropy change in universe

```
//pathname=get_absolute_file_path('5.11.sce')
//filename=pathname+filesep()+'5.11-data.sci'
//exec(filename)
//Mass of air(in kg):
m=2
//Initial volume(in m^3):
v1=1
//Final volume(in m^3):
v2=10
//Gas const(in J/kg.K):
R=287
//Change in entropy of air(in J/K):
dSa=m*R*log(v2/v1)
//During free expansion, entropy change of
   surroundings(in J/K):
dSs=0
//Entropy change of universe(in J/K):
dSu=dSa+dSs
printf("\nRESULT\n")
printf("\nEntropy change of air = %f J/K",dSa)
printf("\nEntropy change of surroundings = %d J/K",
   dSs)
printf("\nEntropy change of universe = %f J/K",dSu)
```

Scilab code Exa 5.12 To determine the change in entropy

```
//pathname=get_absolute_file_path('5.12.sce')
//filename=pathname+filesep()+'5.12-data.sci'
```

```
//exec(filename)
//Mass of air(in kg):
m=0.5
//Initial pressure(in Pa):
p1=1.013*10^5
//Final pressure(in Pa):
p2=0.8*10^6
//Initial temperature(in K):
T1=800
//Index of compression:
n=1.2
//Adiabatic index of compression:
r=1.4
//Value of Cv(in kJ/kg.K):
Cv=0.71
//Final temperature(in K):
T2=T1*((p2/p1)^((n-1)/n))
//Total entropy change(in J/K):
dS=m*Cv*((n-r)/(n-1))*log(T2/T1)
printf("\nRESULT\n")
printf("\nEntropy change = %f J/K",dS)
```

Scilab code Exa 5.15 To determine the direction of flow

```
//pathname=get_absolute_file_path('5.15.sce')
//filename=pathname+filesep()+'5.15-data.sci'
//exec(filename)
//Pressure at point 1(in MPa):
p1=0.5
//Temperature at point 1(in K):
T1=400
//Pressure at point 2(in MPa):
p2=0.3
//Temperature at point 2(in K):
T2=350
```

```
//Gas constant(in kJ/kg.K):
R=0.287
//Value of Cp(in kJ/kg.K):
Cp=1.004
//Entropy change(in kJ/kg.K):
ds=Cp*log(T1/T2)-R*log(p1/p2)
printf("\nRESULT\n")
printf("\nChange in entropy = %f kJ/kg.K",ds)
//As the calculated change is positive , s2>s1
printf("\nHence flow occurs from 1 to 2 i.e. from
    0.5 MPa, 400 K to 0.3 MPa & 350 K")
```

Scilab code Exa 5.17 To determine the work done and thermal efficiency

```
//pathname=get_absolute_file_path('5.17.sce')
//filename=pathname+filesep()+'5.17-data.sci'
//exec(filename)
//Heat added in process 1-2(in kJ):
Q12=1000
//Heat added in process 3-4(in kJ):
Q34=800
//Temperature at point 1(in K):
T1=500
//Temperature at point 3(in K):
T3=400
//Temperature at point 5(in K):
T5=300
//Total heat added(in kJ):
Qt=Q12+Q34
//Entropy change from state 1-2(in kJ/K):
S12=Q12/T1
//Entropy change from state 3-4(in kJ/K):
S34=Q34/T3
//Entropy change from state 5-6(in kJ/K):
S56=S12+S34
```

```
//Heat rejected in process 5-6(in kJ):
Q56=T5*S56
//Net work done(in kJ):
W=Q12+Q34-Q56
//Thermal efficiency of the cycle:
n=W/Qt
printf("\nRESULT\n")
printf("\nWork done = %d kJ",W)
printf("\nThermal efficiency = %f percent",n*100)
```

Scilab code Exa 5.18 To determine the heat supplied

```
//pathname=get_absolute_file_path('5.18.sce')
//filename=pathname+filesep()+'5.18-data.sci'
//exec(filename)
//Temperature of the reservoirs(in K):
T1=800
T2=700
T3=600
//Temperature of the sink(in K):
T4=320
//Total heat rejected to the heat sink(in kJ/s):
Q2=10
//Work done(in kW):
W=20
//Total heat added(in kJ/s):
Q1=Q2+W
//Heat from reservoir 2(in kJ/s):
Q12=(Q2/T4-Q1/T3)/(0.7/T1+1/T2-1.7/T3)
//Heat from reservoir 1(in kJ/s):
Q11=0.7*Q12
//Heat from reservoir 3(in kJ/s):
Q13=Q1-1.7*Q12
printf("\nRESULT\n")
printf("\nHeat supplied by reservoir at 800 K = %f
```

```
kJ/s",Q11)
printf("\nHeat supplied by reservoir at 700 K = %f
    kJ/s",Q12)
printf("\nHeat supplied by reservoir at 600 K = %f
    kJ/s",Q13)
```

Scilab code Exa 5.19 To check if process is reversible or not

```
//pathname=get_absolute_file_path('5.19.sce')
//filename=pathname+filesep()+'5.19-data.sci'
//exec(filename)
//Volume of the chamber(in m^3):
v1=0.04
//Initial pressure(in bar):
p1=10
//Initial temperature(in K):
T1=25+273
//Gas constant(in kJ/kg.K):
R=0.287
//Value of Cv(in kJ/kg.K):
Cv=0.71
//Final temperature(in K):
T2=T1
//Final volume(in m^3):
v2=2*v1
//Final pressure(in bar):
p2=p1*v1/v2
//Initial mass(in kg):
m=p1*10^2*v1/(R*T1)
//Change in entropy(in kJ/K):
dS=m*R/log(v2/v1)+m*Cv*log(T2/T1)
printf("\nRESULT\n")
printf("\nEntropy change = %f kJ/K",dS)
//Entropy change is non zero but dQ /T is zero,
    hence:
```

```
printf("\nAs dS> dQ /T, process is irreversible")
```

Scilab code Exa 5.20 To determine the entropy produced

```
//pathname=get_absolute_file_path('5.20.sce')
//filename=pathname+filesep()+'5.20-data.sci'
//exec(filename)
//Mass in tank A(in kg):
ma=0.6
//Mass in tank B(in kg):
mb=1
//Temperature in tank A(in K):
Ta=90+273
//Temperature in tank B(in K):
Tb=45+273
//Pressure in tank A(in bar):
pa=1
//Pressure in tank B(in bar):
pb=2
//Gas constant(in kJ/kg.K):
R=0.287
//Value of Cp(in kJ/kg.K):
Cp=1.005
//Final temperature(in K):
Tf=(ma*Ta+mb*Tb)/(ma+mb)
//Volume of tank A(in m^3):
va=ma*R*Ta/pa
//Volume of tank B(in m^3):
vb=mb*R*Tb/pb
//Final pressure(in kPa):
pf=(ma+mb)*R*Tf/(va+vb)
//Entropy change(in kJ/K):
dS=ma*(Cp*log(Tf/Ta)-R*log(pf/pa))+mb*(Cp*log(Tf/Tb)
    -R*log(pf/pb))
printf("\nRESULT\n")
```

```
printf("\nEntropy produced = %f kJ/K",dS)
```

Scilab code Exa 5.21 To determine the change in entropy

```
//pathname=get_absolute_file_path('5.21.sce')
//filename=pathname+filesep()+'5.21-data.sci'
//exec(filename)
//Volume of the tanks(in m^3):
va=4
vb=4
vc=4
//Pressure in tank A(in bar):
pa=6
//Temperature in tank A(in K):
Ta=90+273
//Pressure in tank B(in bar):
pb=3
//Temperature in tank B(in K):
Tb=300+273
//Pressure in tank C(in bar):
pc=12
//Temperature in tank C(in K):
Tc=50+273
//Gas constant for air(in kJ/kg.K):
Ra=0.287
//Gas constant for nitrogen(in kJ/kg.K):
Rn=0.297
//Adiabatic index of compression for air:
ra=1.4
//Adiabatic index of compression for nitrogen:
rn=1.4
//Value of Cp(in kJ/kg.K):
Cp=1.005
//Value of Cv(in kJ/kg.K):
Cv=0.718
```

```
//Part (i)
//Mass in tank A(in kg):
ma=pa*10^2*va/(Ra*Ta)
//Mass in tank A(in kg):
mb=pb*10^2*vb/(Ra*Tb)
//Final temperature(in K):
Td=(ma*Ta+mb*Tb)/(ma+mb)
//Final pressure(in bar):
pd=Ra*Td*(ma+mb)/((va+vb)*10^2)
//Entropy change(in kJ/K):
dS1=ma*Cp*log(Td/Ta)-ma*Ra*log(pd/pa)+mb*Cp*log(Td/
   Tb)-mb*Ra*log(pd/pb)
printf("\nRESULT\n")
printf("\nEntropy change in case 1 = %f kJ/K",dS1)
//Part (ii)
//Mass in tank C(in kg):
mc=pc*10^2*vc/(Rn*Tc)
//Mass in tank D(in kg):
md=ma+mb
//Value of Cv for nitrogen(in kJ/kg.K):
Cvn=Rn/(rn-1)
//Value of Cp for nitrogen(in kJ/kg.K):
Cpn=rn*Cvn
//Total mass(in kg):
mf=md+mc
//Final Cv(in kJ/kg.K):
CvF=(md*Cv+mc*Cvn)/mf
//Final gas constant(in kJ/kg.K):
RF=(md*Ra+mc*Rn)/mf
//Final temperature(in K):
TF=(md*Cv*Td+mc*Cvn*Tc)/(mf*CvF)
//Final volume(in m^3):
VF=va+vb+vc
//Final pressure(in kPa):
pF=mf*RF*TF/VF
//Change in entropy(in kJ/K):
dS2=md*(Cp*log(TF/Td)-Ra*log(pF/(pd*10^2)))+mc*(Cpn*
   log(TF/Tc)-Rn*log(pF/(pc*10^2)))
```

```
printf("\nEntropy change in case 2 = %f kJ/K",dS2)
```

Chapter 6

Thermodynamic Properties of Pure Substance

Scilab code Exa 6.02 To determine the dryness fraction

```
//pathname=get_absolute_file_path('6.02.sce')
//filename=pathname+filesep()+'6.02-data.sci'
//exec(filename)
//Pressure at which steam is entering(in MPa):
p1=10
//Pressure at which steam is coming out(in MPa):
p2=0.05
//Temperature of the steam(in C):
T=100
//From steam tables:
//Enthalpy of superheated steam at 0.05 MPa and 100
    C (in kJ/kg):
h2=2682.5
hf10=1407.56
hfg10=1317.1
//Due to throttling:
h1=h2
//Dryness fraction:
x1=(h1-hf10)/hfg10
```

```
printf("\nRESULT\n")
printf("\nDryness fraction = %f",x1)
```

Scilab code Exa 6.03 To determine the internal energy

```
//pathname=get_absolute_file_path('6.03.sce')
//filename=pathname+filesep()+'6.03-data.sci'
//exec(filename)
//Pressure(in MPa):
p=12
//Specific volume(in m^3/kg):
v=0.017
//Enthaply(in kJ/kg):
h=2848
//Internal energy(in kJ/kg):
u=h-p*10^3*v
printf("\nRESULT\n")
printf("\nInternal energy = %d kJ/kg",u)
```

Scilab code Exa 6.04 To find out the entropy of steam

```
//pathname=get_absolute_file_path('6.04.sce')
//filename=pathname+filesep()+'6.04-data.sci'
//exec(filename)
//Mass of steam(in kg):
m=5
//Pressure(in MPa):
p=2
//Temperature of superheated steam(in K):
Tss=300+273.15
//Specific heat of super heated steam(in kJ/kg.K):
Cps=2.1
//Specific heat of water(in kJ/kg.K):
```

```
Cpw=4.18
//From steam tables:
hfg=1890.7
//Saturation temperature(in K):
Tsat=212.42+273.15
//Entropy of unit mass of superheated steam with
    reference to absolute zero(in kJ/kg.K):
s=Cpw*log(Tsat/273.15)+hfg/Tsat+Cps*log(Tss/Tsat)
//Entropy of 5 kg of steam(in kJ/K):
S=m*s
printf("\nRESULT\n")
printf("\nEntropy of steam = %f kJ/K",S)
```

Scilab code Exa 6.05 To find out the boiling point

```
//pathname=get_absolute_file_path('6.05.sce')
//filename=pathname+filesep()+'6.05-data.sci'
//exec(filename)
//Boiling point(in C):
Tb=110
//From steam table:
//Pressure at which it boils(in kPa):
p= 143.27
//Boiling point at this depth = Tsat at 138.365
//From steam table this temperature(in  C):
Tsat= 108.866
//Pressure at 50 cm depth(in kPa):
p1=p-9.81*0.50
printf("\nRESULT\n")
printf("\nBoiling point = %f  C ",Tsat)
```

Scilab code Exa 6.06 To determine mass and volume of water

```
//pathname=get_absolute_file_path('6.06.sce')
//filename=pathname+filesep()+'6.06-data.sci'
//exec(filename)
//Temperature of the water vapor mixture(in  C ):
T=100
//Volume of the rigid vessel(in m^3):
V=0.5
//From steam tables:
//Specific volume at state 2(in m^3/kg):
v2=0.003155
vf=0.001044
vg=1.6729
//Specific volume at state 1(in m^3/kg):
v1=v2
//Dryness fraction:
x1=(v1-vf)/vg
//Total mass of fluid(in kg):
m=V/v2
//Volume of water(in m^3):
v=m*vf
printf("\nRESULT\n")
printf("\nMass of water = %f kg",m)
printf("\nVolume of water = %f m^3",v)
```

Scilab code Exa 6.07 To determine the slope

```
//pathname=get_absolute_file_path('6.07.sce')
//filename=pathname+filesep()+'6.07-data.sci'
//exec(filename)
//Pressure(in MPa):
p=2
//Temperature(in K):
T=500+273.15
//Slope of isobar:(dh/ds)at constant pressure=T:
s=T
```

```
printf("\nRESULT\n")
printf("\nSlope = %f",s)
```

Scilab code Exa 6.08 To determine enthalpy entropy and specific volume

```
//pathname=get_absolute_file_path('6.08.sce')
//filename=pathname+filesep()+'6.08-data.sci'
//exec(filename)
//Dryness fraction:
x=0.10
//Pressure(in MPa):
p=0.15
//From steam tables:(at 0.15 MPa):
hf = 467.11
hg = 2693.6
vf = 0.001053
vg = 1.1593
sf = 1.4336
sg = 7.2233
//Enthalpy(in kJ/kg):
h=hf+x*(hg-hf)
//Specific volume(in m^3/kg):
v=vf+x*(vg-vf)
//Entropy(in kJ/kg.K):
s=sf+x*(sg-sf)
printf("\nRESULT\n")
printf("\nEnthalpy = %f kJ/kg",h)
printf("\nSpecific volume = %f m^3/kg",v)
printf("\nEntropy = %f kJ/kg.K",s)
```

Scilab code Exa 6.09 To determine amount of heat added

```
//pathname=get_absolute_file_path('6.09.sce')
```

```
//filename=pathname+filesep()+'6.09-data.sci'
//exec(filename)
//Initial State:
//Pressure(in MPa):
p1=1
//Volume(in m^3):
V1=0.05
//Dryness fraction:
x1=0.80
//Final state:
//Pressure(in MPa):
p2=1
//Volume(in m^3):
V2=0.2
//From steam table:(at state 1):
vf = 0.001127 //(m3/kg)
vg = 0.19444 //(m3/kg)
uf = 761.68 //(kJ/kg)
ufg = 1822 //(kJ/kg)
//Work done(in kJ):
W=p1*10^3*(V2-V1)
//Specific volume at state 1(in m^3/kg):
v1=vf+x1*(vg-vf)
//Mass of system(in kg):
m=V1/v1
//Specific volume at state 2(in m^3/kg):
v2=V2/m
//Temperature at final state(in  C ):
Tf=1077.61
//Internal energy at final state(at 1077.61  C ):
u2=4209.6
//Internal energy at initial state(in kJ/kg):
u1=uf+x1*ufg
//Heat added(in kJ):
Q=m*(u2-u1)+W
printf("\nRESULT\n")
printf("\nHeat added = %f kJ",Q)
```

Scilab code Exa 6.10 To determine pressure and temperature at condensation

```
//pathname=get_absolute_file_path('6.10.sce')
//filename=pathname+filesep()+'6.10-data.sci'
//exec(filename)
//Presure of the steam(in kPa):
p1=800
//Temperature(in  C )
T=200
//From steam tables:
//Saturation temp(in  C ):
Tsat=170.43
//Specific volume(in m^3/kg):
v1=0.2404
v2=0.2404
//Final temperature(in  C ):
T2=170.46
//Final pressure(in kPa):
p2=800.96
printf("\nRESULT\n")
printf("\nPressure =%f kPa",p2)
printf("\nTemperature = %f  C ",T2)
```

Scilab code Exa 6.11 To determine enthalpy change

```
//pathname=get_absolute_file_path('6.11.sce')
//filename=pathname+filesep()+'6.11-data.sci'
//exec(filename)
//Temperature of water(in  C ):
T=30
//Pressure(in kPa):
p=200
```

```
//From steam tables:
//Corresponding pressure at 30 C (in kPa):
p1=4.25
//Specific volume(in m^3):
v1=0.001004
//Enthalpy change(in kJ/kg):
dh=v1*(p-p1)
printf("\nRESULT\n")
printf("\nEnthalpy change = %f kJ/kg",dh)
```

Scilab code Exa 6.12 To determine the mass and quality of steam

```
//pathname=get_absolute_file_path('6.12.sce')
//filename=pathname+filesep()+'6.12-data.sci'
//exec(filename)
//Volume occupied by water(in m^3):
V1=3/5*2
//Volume occupied by steam(in m^3):
V2=2/5*2
//From steam table
vf = 0.001091 //(m^3/kg)
vg = 0.3928 //(m^3/kg)
//Mass of water(in kg):
mf=V1/vf
//Mass of steam(in kg):
mg=V2/vg
//Total mass(in kg):
mt=mf+mg
//Dryness fraction:
x=mg/mt
printf("\nRESULT\n")
printf("\nMass = %f kg",mt)
printf("\nQuality = %f",x)
```

Scilab code Exa 6.13 To determine the turbine output

```
//pathname=get_absolute_file_path('6.13.sce')
//filename=pathname+filesep()+'6.13-data.sci'
//exec(filename)
//Pressure of the steam(in MPa):
p=4
//Temperature of steam entering(in C):
T1=300
//Temperature of steam at turbine exit(in C):
T2=50
//From steam tables:
h1=2886.2 //kJ/kg
s1=6.2285 //kJ/kg.K
hf = 209.33 //kJ/kg
sf = 0.7038 //kJ/kg.K
hfg = 2382.7 //kJ/kg
sfg = 7.3725 //kJ/kg.K
//Let:
s2=s1
//Dryness fraction:
x2=(s2-sf)/sfg
//Enthalpy at state 2(in kJ/kg):
h2=hf+x2*hfg
//Turbine work(in kJ/kg):
W=h1-h2
printf("\nRESULT\n")
printf("\nTurbine output = %f kJ/kg",W)
```

Scilab code Exa 6.14 To determine the mass and quality of steam

```
//pathname=get_absolute_file_path('6.14.sce')
```

```
//filename=pathname+filesep()+'6.14-data.sci'
//exec(filename)
//Mass of steam(in kg):
m1=100
//Initial pressure(in kPa):
p1=100
//Final pressure(in kPa):
p2=1000
//Dryness fraction:
x1=0.5
//Pressure of dry saturated steam(in kPa):
p3=2000
//From steam tables:
hf100kPa = 417.46 //kJ/kg
uf100kPa = 417.36 //kJ/kg
vf100kPa = 0.001043 //m^3/kg
hfg100kPa = 2258 //kJ/kg
ufg100kPa = 2088.7 //kJ/kg
vg100kPa = 1.6940 //m^3/kg
vg2000kPa = 0.09963 //m^3/kg
ug2000kPa = 2600.3 //kJ/kg
hg2000kPa = 2799.5 //kJ/kg
hf1000kPa = 762.81 //kJ/kg,
hfg1000kPa = 2015.3 //kJ/kg
vf1000kPa = 0.001127 //m3/kg
vg1000kPa = 0.19444 //m3/kg
//Initial specific volume(in m^3/kg):
v1=vf100kPa+x1*(vg100kPa-vf100kPa)
//Enthalpy at 1(in kJ/kg):
h1=hf100kPa+x1*hfg100kPa
//Volume of vessel(in m^3):
V=m1*x1*v1
//Internal energy in the beginning(in kJ):
U1=m1*(uf100kPa+x1*ufg100kPa)
//Final specific volume(in m^3/kg):
v2=vg2000kPa*v1/(vg2000kPa+v1)
//Final dryness fraction:
x2=(v2-vf1000kPa)/(vg1000kPa-vf1000kPa)
```

```
//Final enthalpy(in kJ/kg):
h2=hf1000kPa+x2*hfg1000kPa
//Mass of dry steam at 2000kPa(in kg):
m=m1*(h1-h2)/(h2-hg2000kPa)
printf("\nRESULT\n")
printf("\nMass of dry steam at 2000 kPa to be added
    = %f kg",m)
printf("\nQuality of final mixture = %f",x2)
```

Scilab code Exa 6.15 To determine the dryness fraction of the steam entering

```
//pathname=get_absolute_file_path('6.15.sce')
//filename=pathname+filesep()+'6.15-data.sci'
//exec(filename)
//Recorded condenser vacuum:
r= 71.5 //cm of Mercury
//Barometer reading:
br= 76.8 //cm of Mercury
//Temperature of condensation:
Tc= 35 // C
//Temperature of hot well:
Thw= 27.6 // C
//Mass of condensate per hour:
mc= 1930 //kg
//Mass of cooling water per hour:
mcw= 62000 //kg
//Inlet temperature
Ti= 8.51 // C
//Outlet temperature:
To= 26.24 // C
//From steam tables:
hf = 146.68 //kJ/kg
hfg = 2418.6 //kJ/kg
//Condensor pressure(in kPa):
pc=(br-r)/73.55*101.325
```

```
//Partial pressure of steam corresponding to 35 C
   from steam table(in kPa):
ps= 5.628
//Dryness fraction:
x=(mcw*(To-Ti)*4.18-mc*hf+mc*4.18*To)/(mc*hfg)
printf("\nRESULT\n")
printf("\nDryness fraction of the steam entering =
   %f",x)
```

Scilab code Exa 6.16 To determine the work done

```
//pathname=get_absolute_file_path('6.16.sce')
//filename=pathname+filesep()+'6.16-data.sci'
//exec(filename)
//Diameter of the vessel(in m):
D=0.2
//Depth(in m):
d=0.02
//Temperature(in  C ):
T=150
//Force applied(in kN):
F=10
//Heat supplied(in kJ):
Q=600
//From steam tables:
hf=612.1
hfg=2128.7
vg=0.4435
h2=1582.8
//Pressure at which process is taking place(in kPa):
p=F/(%pi*D^2)*4+101.3
//Volume of water contained(in m^3):
V1=%pi*D^2*d/4
//Mass of water(in kg):
m=V1*1000
```

```
//Dryness fraction:
x=(Q-hf*m+4.18*T*m)/(hfg*m)
//Internal energy of water initially(in kJ):
U1=m*4.18*T-p*V1
//Final volume(in m^3):
V2=m*x*vg
//Internal energy at state 2(in kJ):
U2=m*h2-p*V2
//Change in internal energy(in kJ):
dU=U2-U1
//Work done(in kJ):
W=p*(V2-V1)
printf("\nRESULT\n")
printf("\nDryness fraction of the steam produced =
    %f",x)
printf("\nChange in internal energy = %f kJ",dU)
printf("\nWork done = %f kJ",W)
```

Scilab code Exa 6.17 To determine the dryness fraction

```
//pathname=get_absolute_file_path('6.17.sce')
//filename=pathname+filesep()+'6.17-data.sci'
//exec(filename)
//Mass of steam passed(in kg):
ms=40
//Mass of water passed(in kg):
mw=2.2
//Initial pressure of steam(in MPa):
p1=1.47
//Temperature after throttling(in  C ):
T=120
//Pressure after throttling(in kPa):
p2=107.88
//Specific heat of superheated steam(in kJ/kg.K):
s=2.09
```

```
//From steam tables:
hf=840.513
hfg=1951.02
h1=2673.95
//Degree of superheat(in  C):
ds=T-101.8
//Enthalpy of superheated steam(in kJ/kg):
h2=h1+ds*s
//Dryness fraction after throttling:
x2=(h2-hf)/hfg
//Dryness fraction before throttling:
x1=(ms-mw)/ms
//Overall dryness fraction:
x=x1*x2
printf("\nRESULT\n")
printf("\nDryness fraction = %f",x)
```

Scilab code Exa 6.18 To determine the amount of heat added and initial quality

```
//pathname=get_absolute_file_path('6.18.sce')
//filename=pathname+filesep()+'6.18-data.sci'
//exec(filename)
//Initial volume in part A(in m^3):
Va=0.4
//Pressure(in bar):
pa=10
//Initial volume in part B(in m^3):
V=0.4
//Pressure in part B(in bar):
p1=10
//Final pressure in part B(in bar):
p2=15
//From steam tables:
hf=762.83
hfg=2015.3
```

```
h2=2792.2
//Heat added(in kJ):
Q=V*(p2-p1)*10^2
//Dryness fraction:
x1=(h2-Q-hf)/hfg
printf("\nRESULT\n")
printf("\nHeat added = %d kJ",Q)
printf("\nInitial quality = %f",x1)
```

Scilab code Exa 6.19 To determine heat and work transfer

```
//pathname=get_absolute_file_path('6.19.sce')
//filename=pathname+filesep()+'6.19-data.sci'
//exec(filename)
//Mass of wet steam(in kg):
m=3
//Initial pressure(in bar):
p1=1.4
//Initial volume(in m^3):
V1=2.25
//Final temperature of steam(in  C ):
T=400
//At 400 C ,volume of steam(in m^3):
V2=4.65
//From steam tables:
vg=1.2455
hf=457.99
hfg=2232.3
h2=3276.6
uf=457.84
ufg=2059.34
u2=2966.7
//Specific volume of wer steam in cylinder(in m^3/kg):
v1=V1/m
```

```
//Dryness fraction of initial steam:
x1=v1/vg
//Initial enthalpy of wet steam(in kJ/kg):
h1=hf+x1*hfg
//At 400 C  specific volume of steam(in m^3/kg):
v2=V2/m
//Actual pressure(from steam table)(in MPa):
p2=0.20
//Saturation temp at this pressure = 120.23 C
//Finally the degree of superheat(in  C ):
ds=T-120.23
//Heat added during the process(in kJ):
Q=m*(h2-h1)
//Internal energy of initial wet steam(in kJ/kg):
u1=uf+x1*ufg
//Change in internal energy(in kJ):
dU=m*(u2-u1)
//Work done(in kJ):
W=Q-dU
printf("\nRESULT\n")
printf("\nHeat transfer = %f kJ",Q)
printf("\nWork transfer = %f kJ",W)
```

Scilab code Exa 6.20 To determine the percentage of vessel initial occupied by ste

```
//pathname=get_absolute_file_path('6.20.sce')
//filename=pathname+filesep()+'6.20-data.sci'
//exec(filename)
//Pressure of the steam(in bar):
p1=10
//Temperature(in  C ):
T=500
//Final pressure(in bar):
p2=1
//From steam tables:
```

```
h10bar500 = 3478.5 //kJ/kg
s10bar500 = 7.7622 //kJ/kg.K
v10bar500 = 0.3541 //m^3/kg
h1bar400 = 3278.2 //kJ/kg
h1bar500 = 3488.1 //kJ/kg
v1bar500 = 3.565 //m^3/kg
v1bar400 = 3.103 //m^3/kg
s1bar500 = 8.8342 //kJ/kg.K
s1bar400 = 8.5435 //kJ/kg.K
h2=h10bar500
//Final temperature(in  C ):
T2=(h2-h1bar400)*(T-400)/(h1bar500-h1bar400)+400
//Final entropy(in kJ/kg.K):
s2=s1bar400+(s1bar500-s1bar400)/(T-400)*(T2-400)
//Change in entropy(in kJ/kg.K):
ds=s2-s10bar500
//Final specific volume(in m^3/kg):
v2=v1bar400+(v1bar500-v1bar400)/(T-400)*(T2-400)
//Percentage volume occupied by steam:
p=v10bar500/v2*100
printf("\nRESULT\n")
printf("\nFinal temperature = %f kJ",T2)
printf("\nChange in entropy = %f kJ",ds)
printf("\nPercentage of vessel volume initially occupied by steam = %f percent",p)
```

Scilab code Exa 6.21 To determine the irresversibilty

```
//pathname=get_absolute_file_path('6.21.sce')
//filename=pathname+filesep()+'6.21-data.sci'
//exec(filename)
//Steam entering:
//Pressure(in MPa):
p1=2.5
//Temperature(in  C ):
```

```
T1=350
//Steam rejected:
//Pressure(in kPa):
p2=20
//Dryness fraction:
x2=0.92
//Pressure of one quater of intial steam(in kPa):
p3=30
//Temperature(in  K ):
T0=30+273
m1=1
m2=0.25
m3=0.75
//Heat lost during expansion(in kJ):
Q=-10
//From steam tables:
h1=3126.3 //kJ/kg
s1=6.8403 //kJ/kg.K
h2=2878.6 //kJ/kg
s2=8.5309 //kJ/kg.K
h3 = 2421.04 //kJ/kg
s3 = 7.3425 //kJ/kg.K
hf = 251.40 //kJ/kg
hg = 2609.7 //kJ/kg
sf = 0.8320 //kJ/kg.K
sfg = 7.0766 //kJ/kg.K
h0=125.79
s0=0.4369
//Availability of steam entering turbine(in kJ/kg):
A1=(h1-h0)-T0*(s1-s0)
//Availability of steam leaving turbine at state 2(
   in kJ/kg):
A2=(h2-h0)-T0*(s2-s0)
//Availability of steam leaving turbine at state 3(
   in kJ/kg):
A3=(h3-h0)-T0*(s3-s0)
//Maximum work per kg of steam entering turbine(in
   kJ/kg):
```

```
Wmax=m1*A1-m2*A2-m3*A3
//Irreversibilty(in kJ/s):
I=T0*(m2*s2+m3*s3-m1*s1)-Q
printf("\nRESULT\n")
printf("\nMaximum work = %f kJ/kg",Wmax)
printf("\nIrreversibility = %f kJ/s",I)
```

Scilab code Exa 6.22 To determine the change in availability

```
//pathname=get_absolute_file_path('6.22.sce')
//filename=pathname+filesep()+'6.22-data.sci'
//exec(filename)
//Initial pressure(in MPa):
p1=6
//Final pressure(in MPa):
p2=5
//Initial temperature(in C ):
T1=400
//Atmospheric pressure(in kPa):
patm=100
//Atmospheric temperature(in K ):
Ta=20+273
//From steam tables:
h1=3177.2 //kJ/kg
s1=6.5408 //kJ/kg.K
h2=h1
T2=392.7 // C (by interpolation)
s2=6.6172 //kJ/kg.K(//By interpolation Entropy)
h0=83.96 //kJ/kg
s0 = 0.2966 //kJ/kg
//Availability at state 1(in kJ/kg):
A1=(h1-h0)-Ta*(s1-s0)
//Availability at state 2(in kJ/kg):
A2=(h2-h0)-Ta*(s2-s0)
//Change in availibilty(in kJ/kg):
```

```
dA=A2-A1
printf("\nRESULTS\n")
printf("\nChange in availability = %f kJ/kg decrease
  ",-dA)
```

Scilab code Exa 6.23 To determine the amount of exergy destruction

```
//pathname=get_absolute_file_path('6.23.sce')
//filename=pathname+filesep()+'6.23-data.sci'
//exec(filename)
//Temperature of the hot water entering(in C):
TH1= 95
//Temperature of the hot water at exit(in C):
TH2= 50
//Mass flow rate(in kg/s):
mH = 0.8
//Temperature of cooling water entering(in K):
TC1= 15+273
//Temperature of cooling water at exit(in K):
TC2= 45+273
//Temperature of dead state(in K):
T0=25+273
//From steam tables:
h0=104.89  //kJ/kg
s0=0.3674  //kJ/kg.K
hH1=397.96 //kJ/kg
sH1=1.2500 //kJ/kg.K
hH2=209.33 //kJ/kg.K
sH2=0.7038 //kJ/kg.K
hC2=188.45 //kJ/kg.K
sC2=0.6387 //kJ/kg.K
hC1=62.99 //kJ/kg.K
sC1=0.2245 //kJ/kg.K
//Mass flow rate of cooling water(in kg/s):
mC=mH*(TH1-TH2)/(TC2-TC1)
```

```
//Exergy entering through hot water stream(in kJ/s):
AH1=mH*((hH1-h0)-T0*(sH1-s0))
//Rate of exergy increase in cold stream(in kJ/s):
dAc=mC*((hC2-hC1)-T0*(sC2-sC1))
//Second law efficiency:
n=dAc/AH1*100
//Rate of exergy loss in hot stream(in kJ/s):
dAh=mH*((hH1-hH2)-T0*(sH1-sH2))
//Exergy destruction(in kJ/s):
dA=dAh-dAc
printf("\nRESULT\n")
printf("\nSecond law efficincy = %f percent",n)
printf("\nExergy destruction = %f kJ/s",dA)
```

Chapter 7

Ratio of lost available exhaust gas energy to engine work

Scilab code Exa 7.01 To determine the maximum possible work

```
//pathname=get_absolute_file_path('7.01.sce')
//filename=pathname+filesep()+'7.01-data.sci'
//exec(filename)
//Pressure of entering steam(in MPa):
p1=1.6
//Temperature of entering steam(in K):
T1=300+273
//Pressure of leaving steam(in MPa):
p2=0.1
//Temperature of leaving steam(in K):
T2=150+273
//Velocity of the leaving steam(in m/s):
c2=150
//Surrounding temperature(in K):
T0=15+273
//Mass flow rate(in kg/s):
m=2.5
//From steam tables:
h1=3034.8 //kJ/kg
```

```
s1=6.8844 //kJ/kg.K
h2=2776.4 //kJ/kg
s2=7.6134 //kJ/kg.K
//Maxiimum work possible(in kW):
Wmax=(h1-h2)-T0*(s1-s2)-(c2^2)/2*10^(-3)
printf("\nRESULT")
printf("\nMaximum work possible = %f kW",m*Wmax)
```

Scilab code Exa 7.02 To determine the availability in the tanks

```
//pathname=get_absolute_file_path('7.02.sce')
//filename=pathname+filesep()+'7.02-data.sci'
//exec(filename)
//For tank A:
//Pressure of air(in bar):
pa=1
//Mass of air(in kg):
m=1
//Value of Cv(in kJ/kg.K):
Cv=0.717
//Temperature(in K):
T=50+273
//Gas costant(in kJ/kg.K):
R=0.287
//Atmospheric pressure(in bar):
p0=1
//Atmosphere temperature(in K):
T0=15+273
//Value of Cp(in kJ/kg.K):
Cp=1.004
//For tank B
//Pressure(in bar):
pb=3
//Availability of air in tank A(in kJ):
AA=m*(Cv*(T-T0)+R*(p0/pa*T-T0)-T0*Cp*log(T/T0)+T0*R*
```

```
    log(pa/p0))
//Availability of air in tank B(in kJ):
AB=m*(Cv*(T-T0)+R*(p0/pb*T-T0)-T0*Cp*log(T/T0)+T0*R*
    log(pb/p0))
printf("\nRESULT")
printf("\nAvailabiltiy of air in tank A = %f kJ",AA)
printf("\nAvailability of air in tank B = %f kJ",AB)
```

Scilab code Exa 7.03 To determine the power output

```
//pathname=get_absolute_file_path('7.03.sce')
//filename=pathname+filesep()+'7.03-data.sci'
//exec(filename)
//Mass of steam(in kg):
m=15
//Entering steam:
//Pressure(in bar):
p1=10
//Temperature(in K):
T1=300+273
//Leaving steam:
//Pressure(in bar):
p2=0.05
//Dryness fraction:
x=0.95
//Velocity(in m/s):
v2=160
//Atmosheric pressure(in bar):
p0=1
//Atmospheric temperature(in K):
T0=15+273
//From steam tables:
h1=3051.2 //kJ/kg
s1=7.1229 //kJ/kg.K
sf=0.4764 //kJ/kg.K
```

```
sfg=7.9187 //kJ/kg.K
hf=137.82 //kJ/kg
hfg=2423.7 //kJ/kg
h0=62.99 //kJ/kg
s0=0.2245 //kJ/kg.K
//Enthalpy at exit of turbine(in kJ/kg):
h2=hf+x*hfg
//Entropy at exit of turbine(in kJ/kg.K):
s2=sf+x*sfg
//Work output(in kJ/kg):
W=(h1-h2)-v2^2/2*10^(-3)
//Power output(in kW):
pW=m*W
printf("\nRESULT")
printf("\nPower output = %f kW",pW)
//Maximum work given end states(in kW):
Wmax=(h1-T0*s1)-(h2+v2^2/2*10^(-3)-T0*s2)
printf("\nRESULT")
printf("\n\nMaximum power output = %f kW",m*Wmax)
//Maximum wor kavailable from exhaust steam(in kJ/kg):
Ae=(h2-h0)+v2^2/2*10^(-3)-T0*(s2-s0)
//Maximum power that could be obtained from exhaust steam(in kW):
Wme=m*Ae
printf("\n\nMaximum power from exhaust steam = %f kW",Wme)
```

Scilab code Exa 7.04 To determine the availability

```
//pathname=get_absolute_file_path('7.04.sce')
//filename=pathname+filesep()+'7.04-data.sci'
//exec(filename)
//Mass of steam(in kg):
m=5
```

```
//Initial elevation(in m):
z1=10
//Initial velocity(in m/s):
V1=25
//Final elevation(in m):
z2=2
//Final velocity(in m/s):
V2=10
//Dead state of water
u0=104.86 //kJ/kg
v0=1.0029*10^(-3) //m3/kg
s0=0.3673 //kJ/kg K
p0=100 //kPa
T0=25+273 //K
//Initial state
u1 = 2550 //kJ/kg
v1 = 0.5089 //m3/kg
s1 = 6.93 //kJ/kg K
//Final state
u2=83.94 //kJ/kg
v2=1.0018*10^(-3) //m3/kg
s2=0.2966 //kJ/kg K
//Acceleration due to gravity(in m/s^2):
g=9.81
//Availability at initial state(in kJ):
A1=m*((u1-u0)*10^3+p0*10^3*(v1-v0)-T0*(s1-s0)*10^3+
    V1^2/2+g*z1)
//Availability at final state(in kJ):
A2=m*((u2-u0)*10^3+p0*10^3*(v2-v0)-T0*(s2-s0)*10^3+
    V2^2/2+g*z2)
//Change in availability(in kJ):
dA=A2-A1
printf("\nRESULT")
printf("\nAvailability decreases by %f kJ",-dA/10^3)
```

Scilab code Exa 7.06 To determine ratio of lost available exhaust gas energy to en

```
//pathname=get_absolute_file_path('7.06.sce')
//filename=pathname+filesep()+'7.06-data.sci'
//exec(filename)
//Temperature of IC engine(in K):
T1=800+273
//Work per kg of gas in engine(in kJ/kg):
W=1050
//Cp of gas(in kJ/kg.K):
Cp=1.1
//Temperature of the surroundings(in K):
T0=30+273
//Change in entropy of system(in kJ/kg.K):
dSsys=W/T1
//Change in entropy of surroundings(in kJ/kg.K):
dSsurr=-Cp*(T1-T0)/T0
//Loss of available energy(in kJ/kg):
L=-T0*(dSsys+dSsurr)
//Ratio of lost available exhaust energy to engine
    work:
r=L/W
printf("\nRESULT")
printf("\nRatio of available exhaust energy to
    engine work= %f/1",r)
```

Scilab code Exa 7.07 To determine the availability

```
//pathname=get_absolute_file_path('7.07.sce')
//filename=pathname+filesep()+'7.07-data.sci'
//exec(filename)
//Mass of water(in kg):
m=10
//Initial temperature(in K):
T1=150+273
```

```
//Initial velocity(in m/s):
V1=25
//Initial elevation(in m):
z1=10
//Final temperature(in K):
T2=20+273
//Final velocity(in m/s):
V2=10
//Final elevation(in m):
z2=3
//Pressure of environment(in MPa):
p0=0.1
//Temperature of environment(in K):
T0=25+273
//Acceleration due to gravity(in m/s^2):
g=9.8
//From steam tables:
//Dead state of water
u0=104.88 //kJ/kg
v0=1.003*10^(-3) //m3/kg
s0=0.3674 //kJ/kg K
u1=2559.5 //kJ/kg
v1=0.3928 //m3/kg
s1=6.8379 //kJ/kg K
u2=83.95 //kJ/kg
v2=0.001002 //m3/kg
s2=0.2966 //kJ/kg K
//Availability at initial state(in kJ):
A1=m*((u1-u0)*10^3+p0*10^3*(v1-v0)-T0*(s1-s0)*10^3+
    V1^2/2+g*z1)
//Availability at final state(in kJ):
A2=m*((u2-u0)*10^3+p0*10^3*(v2-v0)-T0*(s2-s0)*10^3+
    V2^2/2+g*z2)
//Change in availability(in kJ):
dA=A2-A1
printf("\nRESULT")
printf("\nInitial availabilty = %f kJ",A1/10^3)
printf("\nFinal availabilty = %f kJ",A2/10^3)
```

```
printf("\nAvailability decreases by %f kJ",-dA/10^3)
```

Scilab code Exa 7.08 To determine the irresversibilty

```
//pathname=get_absolute_file_path('7.08.sce')
//filename=pathname+filesep()+'7.08-data.sci'
//exec(filename)
//Mass flow rate(in kg/s):
m=5
//At inlet to turbine,
p1=5 //MPa
T1=500+273.15 // K
h1=3433.8 //kJ/kg
s1=6.9759 //kJ/kg.K
//At exit from turbine.
p2=0.2 //MPa
T2=140+273.15 // K
h2=2748 //kJ/kg
s2=7.228 //kJ/kg K
//At dead state,
p0=101.3 //kPa
T0=25+273.15 // K
h0=104.96 //kJ/kg
s0=0.3673 //kJ/kg    K
//Heat loss(in kJ/s):
Q=600
//Availablity of steam at inlet(in kJ):
A1=m*((h1-h0)-T0*(s1-s0))
printf("\nRESULT")
printf("\nAvailability of steam at inlet = %f kJ",A1
    )
//Turbine output(in kW):
W=m*(h1-h2)-Q
printf("\n\nTurbine output = %f kW",W)
//Maximum output(in kW):
```

```
Wmax=m*((h1-h2)-T0*(s1-s2))
printf("\n\nMaximum output = %f kW",Wmax)
//Irreversibilty(in kW):
I=Wmax-W
printf("\n\nIrreversibility = %f kW",I)
```

Scilab code Exa 7.11 To determine loss of available energy

```
//pathname=get_absolute_file_path('7.11.sce')
//filename=pathname+filesep()+'7.11-data.sci'
//exec(filename)
//Heat removed(in kJ):
Q=500
//Temperature of the heat reservoir(in K):
T1=835
//Temperature of the system(in K):
T2=720
//Temperature of surroundings(in K):
T0=280
//Availability for heat reservoir(in kJ/kg.K):
A1=T0*Q/T1
//Availability for system(in kJ/kg.K):
A2=T0*Q/T2
//Net loss of available energy(in kJ/kg.K):
Anet=A1-A2
printf("\nRESULT")
printf("\nLoss of available energy = %f kJ/kg.K",-
   Anet)
```

Scilab code Exa 7.12 To determine the maximum possible work

```
//pathname=get_absolute_file_path('7.12.sce')
//filename=pathname+filesep()+'7.12-data.sci'
```

```
//exec(filename)
//Enthalpy at entrance(in kJ/kg):
h1=4142
//Enthalpy at exit(in kJ/kg):
h2=2585
//Availability of steam at entrance(in kJ/kg):
A1=1787
//Availability of steam at exit(in kJ):
A2=140
//Maximum work possible(in kJ/kg):
Wmax=A1-A2
//Actual work from turbine(in kJ/kg):
Wact=h1-h2
printf("\nRESULT")
printf("\nActual work = %d kJ/kg",Wact)
printf("\nMaximum possible work = %d kJ/kg",Wmax)
```

Scilab code Exa 7.13 To determine second law efficiency

```
//pathname=get_absolute_file_path('7.13.sce')
//filename=pathname+filesep()+'7.13-data.sci'
//exec(filename)
//Minimum temperature(in K):
Tmin=20+273
//Maximum temperature(in K):
Tmax=500+273
//Efficiency of heat engine:
n=0.25
//Reversible engine efficiency:
nrev=1-Tmin/Tmax
//Second law efficiency:
n2=n/nrev
printf("\nRESULT")
printf("\nSecond law efficiency = %f percent",n2
    *100)
```

Scilab code Exa 7.14 To determine loss of available energy

```
//pathname=get_absolute_file_path('7.14.sce')
//filename=pathname+filesep()+'7.14-data.sci'
//exec(filename)
//Volume of compartment A(in m^3):
Va=6
//Volume of compartment B(in m^3):
Vb=4
//Pressure in compartment A(in bar):
p1=6
//Temperature in compartment A(in K):
T1=600
//Atmosheric pressure(in bar):
p0=1
//Atmosheric temperature(in K):
T0=300
//Adiabatic index of compression:
r=1.4
//Gas constant(in J/kg.K):
R=0.287
//Value of Cv(in kJ/kg.K):
Cv=0.718
//Final volume(in m^3):
V2=Va+Vb
//Final temperature(in K):
T2=T1*(Va/V2)^(r-1)
//Mass of air(in kg):
m=p1*10^5*Va/(R*10^3*T1)
//Change in entropy of control system(in kJ/kg.K):
dSs=m*(Cv*log(T2/T1)+R*log(V2/Va))
//Loss of available energy or irreversibilty(in kJ):
I=T0*dSs
printf("\nRESULT")
```

```
printf("\nLoss of available energy = %f kJ",-I)
```

Scilab code Exa 7.16 To determine the availability and change in irreversibility

```
//pathname=get_absolute_file_path('7.16.sce')
//filename=pathname+filesep()+'7.16-data.sci'
//exec(filename)
//Minimum temperature(in K):
Tmin=30+273
//Maximum temperature(in K):
Tmax=700+273
//Temperature of surroundings(in K):
T0=17+273
//Rate at which engine receives heat(in kJ/min):
Q1=2*10^4
//Measured output of the engine(in kW):
Wu=0.13*10^3
//Efficiency:
nrev=1-Tmin/Tmax
//Availability or reversible work(in kJ/s):
Wrev=nrev*Q1/60
//Rate of irreversibility(in kJ/s):
I=Wrev-Wu
//Second law efficiency:
n2=Wu/Wrev
printf("\nRESULT")
printf("\nAvailability = %f kJ/min",Wrev*60)
printf("\nRate of irreversibility = %f kW",I)
printf("\nSecond law efficiency = %f percent",n2
   *100)
```

Scilab code Exa 7.17 To determine loss of available energy

```
//pathname=get_absolute_file_path('7.17.sce')
//filename=pathname+filesep()+'7.17-data.sci'
//exec(filename)
//Initially:
//Pressure(in bar):
p1=1.5
//Temperature(in K):
T1=60+273
//Finally:
//Pressure(in bar):
p2=2.5
//Temperature of the reservoir(in K):
Tres=400+273
//Temperature of surroundings(in K):
T0=27+273
//Cp of air(in kJ/kg.K):
Cp=1.005
//Final temperature(in K):
T2=T1*p2/p1
//Heat addition to air in the tank(in kJ/kg):
Q=Cp*(T2-T1)
//Change in entropy of the system(in kJ/kg.K):
dSs=Q/T1
//Change in entropy of environment(in kJ/kg.K):
dSe=-Q/Tres
//Total change in entropy(in kJ/kg.K):
dS=dSs+dSe
//Loss of available energy(in kJ/kg):
L=T0*dS
printf("\nRESULT")
printf("\nLoss of available energy = %f kJ/kg.K",L)
```

Scilab code Exa 7.19 To calculate enthalpy of vaporisation

```
//pathname=get_absolute_file_path('7.19.sce')
```

```
//filename=pathname+filesep()+'7.19-data.sci'
//exec(filename)
//From steam tables:
vg=0.12736
vf=0.001157
p205=1.7230
p195=1.3978
T=200+273
hfga=1940.7
//Value of vfg(in m^3/kg):
vfg=vg-vf
//Value of dp/dT(in MPa/K):
r=(p205-p195)/(205-195)
//By Clapeyron equation(in kJ/kg):
hfg=T*vfg*r*10^3
printf("\nRESULT")
printf("\nCalculated enthalpy of vaporization = %f
    kJ/kg",hfg)
printf("\nEnthalpy of vaporization from steam table
    = %f kJ/kg",hfga)
```

Scilab code Exa 7.20 To determine enthalpy

```
//pathname=get_absolute_file_path('7.20.sce')
//filename=pathname+filesep()+'7.20-data.sci'
//exec(filename)
//From steam tables:
//Saturated vapor pressure:
p5=260.96 //kPa
p15=182.60 //kPa
vg10=0.07665 // m^3/kg
vf10=0.00070 //m^3/kg
R=0.06876 //kJ/kg.K
hfg10=156.3 //kJ/kg
T=-5+273
```

```
T1=-15+273
T2=-5+273
//By Clapeyron equation:
//Value of hfg:
hfg=T*(vg10-vf10)*(p5-p15)/(15-5)
//By Clapeyron-Clausius equation:
hfg1=log(p5/p15)*R*(T1*T2)/((T2-T1))
//Deviation:
d=(hfg1-hfg)/hfg*100
printf("\nRESULT")
printf("\nhfg by Clapeyron equation = %f kJ/kg",hfg)
printf("\nhfg by Clapeyron-Clausius equation = %f kJ/kg",hfg1)
printf("\nPercentage deviation in hfg value by Clapeyron-Clausius equation compared to the value from Clapeyron equation = %f percent",d)
```

Scilab code Exa 7.21 To determine isothermal compressibility

```
//pathname=get_absolute_file_path('7.21.sce')
//filename=pathname+filesep()+'7.21-data.sci'
//exec(filename)
//From steam tables:
v350=0.9534
v250=0.7964
v300=0.8753
v350kPa=0.76505
v250kPa=1.09575
//Volume expansivity(in 1/K):
ve=(v350-v250)/(v300*(350-250))
//Isothermal compressibility(in 1/kPa):
ic=-(v350kPa-v250kPa)/(v300*(350-250))
printf("\nRESULT")
printf("\nVolume expansivity = %f K^( 1 )",ve)
printf("\nIsothermal compressibility = %f kPa^(-1)",
```

```
ic)
```

Scilab code Exa 7.22 To determine the irresversibilty

```
//pathname=get_absolute_file_path('7.22.sce')
//filename=pathname+filesep()+'7.22-data.sci'
//exec(filename)
//Volume of tank(in m^3):
V=0.5
//Atmospheric pressure(in bar):
p0=1
//Atmospheric temperature(in K):
T0=25+273
//Cp of gas(in kJ/kg.K):
Cp=1.005
//Cv of gas(in kJ/kg.K):
Cv=0.718
//Initial temperature(in K):
Ti=T0
//Inside final temperature(in K):
Tf=Cp/Cv*Ti
//Change in entropy(in kJ/kg.K):
dSgen=Cp*log(Tf/Ti)
//Irreversibility(in kJ/kg):
I=T0*dSgen
printf("\nRESULT")
printf("\nInside final temperature = %f K",Tf)
printf("\nChange in entropy = %f kJ/kg.K",dSgen)
printf("\nIrreversibility = %f kJ/kg",I)
```

Scilab code Exa 7.23 To determine the maximum work

```
//pathname=get_absolute_file_path('7.23.sce')
```

```
//filename=pathname+filesep()+'7.23-data.sci'
//exec(filename)
//Mass of water(in kg):
m=75
//Temperature of hot water(in K):
T1=400+273
//Final temperature(in K):
T2=300
//Temperature of the environment(in K):
T0=27+273
//Specific heat of water(in kJ/kg.K):
Cp=4.18
//Maximum work(in kJ):
Wmax=m*Cp*(T1-T2-T0*log(T1/T2))
printf("\nRESULT")
printf("\nMaximum work = %f kJ",Wmax)
```

Scilab code Exa 7.24 To determine the irresversibilty

```
//pathname=get_absolute_file_path('7.24.sce')
//filename=pathname+filesep()+'7.24-data.sci'
//exec(filename)
//Pressure at which steam enters(in bar):
p1=50
//Temperature at which steam enters(in K):
T1=600+273
//Velocity at which steam enters(in m/s):
c1=150
//Pressure at which steam leaves(in bar):
p2=0.1
//Velocity at which steam leaves(in m/s):
c2=50
//Work delivered(in kJ/kg):
W=1000
//Dead state temperature(in K):
```

```
T0=25+273
//From steam tables:
h1=3666.5 //kJ/kg
s1=7.2589 //kJ/kg.K
h2=2584.7 //kJ/kg
s2=8.1502 //kJ/kg.K
//Inlet stream availability(in kJ/kg):
A1=h1+c1^2/2*10^(-3)-T0*s1
//Exit stream availability(in kJ/kg):
A2=h2+c2^2/2*10^(-3)-T0*s2
//Reversible work(in kJ/kg):
Wrev=A1-A2
//Irreversibility(in kJ/kg):
I=Wrev-W
printf("\nRESULT")
printf("\nInlet stream availability = %f kJ/kg",A1)
printf("\nExit stream availability = %f kJ/kg",A2)
printf("\nIrreversibility = %f kJ/kg",I)
```

Chapter 8

Vapour power cycles

Scilab code Exa 8.01 To determine the work done and thermal efficiency

```
//pathname=get_absolute_file_path('8.01.sce')
//filename=pathname+filesep()+'8.01-data.sci'
//exec(filename)
//Lower pressure limit(in kPa):
p1=7
//Higher pressure limit(in MPa):
p2=7
//From gas tables:
//Enthalpy at state 2(in kJ/kg):
h2=2772.1
//Entropy at state 2(in kJ/kg.K):
s2=5.8133
//Enthalpy at state 3(in kJ/kg):
h3=1267
//Entropy at state 3(in kJ/kg.K):
s3=3.1211
//Value of sf at 7 kPa(in kJ/kg.K):
sf1=0.5564
//Value of sfg at 7 kPa(in kJ/kg.K):
sfg1=7.7237
//Value of hf at 7 kPa(in kJ/kg):
```

```
hf1=162.60
//Value of hfg at 7 kPa(in kJ/kg):
hfg1=2409.54
//Entropy at state 1(in kJ/kg.K):
s1=s2
//Dryness fraction at state 1:
x1=(s1-sf1)/sfg1
//Enthalpy at state 1(in kJ/kg):
h1=hf1+x1*hfg1
//Entropy at state 4(in kJ/kg.K):
s4=s3
//Dryness fraction for state 4:
x4=(s4-sf1)/sfg1
//Enthalpy at state 4(in kJ/kg):
h4=hf1+x4*hfg1
//Expansion work per kg(in kJ/kg):
W1=h2-h1
//Compression work per kg(in kJ/kg):
W2=h3-h4
//Heat added per kg(in kJ/kg):
H=h2-h3
//Net work done(in kJ/kg):
W=W1-W2
//Thermal efficiency:
n=W/H
printf("\n\nRESULTS\n\n")
printf("\n\n Thermal Efficincy = %f ",n)
printf("\n Turbine work = %f ",W1)
printf("\n Compression work = %f ",W2)
```

Scilab code Exa 8.02 To determine the efficiency of rankine cycle

```
//pathname=get_absolute_file_path('8.02.sce')
//filename=pathname+filesep()+'8.02-data.sci'
//exec(filename)
```

```
//Lower pressure limit(in kPa):
p1=5
//Higher pressure limit(in kPa):
p2=5000
//From gas tables:
//Value of hf at 5 MPa(in kJ/kg):
hf5M=1154.23
//Value of sf at 5 MPa(in kJ/kg.K):
sf5M=2.92
//Value of hg at 5 MPa(in kJ/kg):
hg5M=2794.3
//Value of sg at 5 MPa(in kJ/kg.K):
sg5M=5.97
//Value of hf at 5 kPa(in kJ/kg):
hf5k=137.82
//Value of sf at 5 kPa(in kJ/kg.K):
sf5k=0.4764
//Value of hg at 5 kPa(in kJ/kg):
hg5k=2561.5
//Value of sg at 5 kPa(in kJ/kg.K):
sg5k=8.3961
///Value of vf at 5 kPa(in m^3/kg):
vf5k=0.001005
//Value of sfg at 5 kPa(in kJ/kg.K):
sfg5k=sg5k-sf5k
//Value of hfg at 5 kPa(in kJ/kg.K):
hfg5k=hg5k-hf5k
//CARNOT CYCLE:
//Entropy at point 2(in kJ/kg.K):
s2=sg5M
//As process 2-3 is isentropic:
s3=s2
//Dryness fraction at point 3:
x3=(s3-sf5k)/sfg5k
//Enthalpy at point 3(in kJ/kg):
h3=hf5k+x3*hfg5k
//Enthalpy at point 2(in kJ/kg):
h2=hg5M
```

```
//Entropy at point 1(in kJ/kg.K):
s1=sf5M
//Process 1-4 is isentropic:
s4=s1
//Dryness fraction at point 4:
x4=(s4-sf5k)/sfg5k
//Enthalpy at point 4(in kJ/kg):
h4=hf5k+x4*hfg5k
//Enthalpy at point 1(in kJ/kg):
h1=hf5M
//Efficiency:
n=((h2-h3)-(h1-h4))/(h2-h1)
printf("\n RESULT \n")
printf("For Carnot cycle,\n")
printf("Efficiency=%f",n)
//For RANKINE Cycle:
//Pump work:
Pw=vf5k*(p2-p1)
//Enthalpy at point 5(in kJ/kg):
h5=hf5k
//Enthalpy at point 6(in kJ/kg):
h6=h5+Pw
//Net work in the cycle:
Nw=(h2-h3)-(h6-h5)
//Heat added:
Ha=h2-h6
//Efficiency:
nr=Nw/Ha
printf("\nFor Rankine cycle,\n")
printf("Efficiency=%f",nr)
```

Scilab code Exa 8.03 To determine cycle efficiency and pump work

```
//pathname=get_absolute_file_path('8.03.sce')
//filename=pathname+filesep()+'8.03-data.sci'
```

```
//exec(filename)
//Pressure of steam entering(in bar):
p1=40
//Temperature(in K):
T1=350+273
//Pressure of steam leaving(in bar):
p4=0.05
//From steam tables:
h2=3092.5 //kJ/kg
s2=6.5821 //kJ/kg.K
h4=137.82 //kJ/kg
s4=0.4764 //kJ/kg.K
v4=0.001005 //m^3/kg
sf=0.4764 //kJ/kg.K
sfg=7.9187 //kJ/kg.K
hf=137.82 //kJ/kg
hfg=2423.7 //kJ/kg
//Entropy at state 3:
s3=s2
//Dryness fraction at state 3:
x3=(s3-sf)/sfg
//Enthalpy at state 3(in kJ/kg):
h3=hf+x3*hfg
//Enthalpy at state 1(in kJ/kg):
h1=h4+v4*(p1-p4)
//Pump work(in kJ/kg):
Wp=h1-h4
//Net work(in kJ/kg):
Wnet=h2-h3-Wp
//Heat added(in kJ/kg):
Q=h2-h1
//Cycle efficiency(in kJ/kg):
n=Wnet/Q*100
printf("\n RESULT \n")
printf("\nNet work per kg of steam = %f kJ/kg",Wnet)
printf("\nCycle efficiency = %f percent",n)
printf("\nPump work per kg of steam = %f kJ/kg",Wp)
```

Scilab code Exa 8.04 To determine pressure of steam leaving and thermal efficiency

```
//pathname=get_absolute_file_path('8.04.sce')
//filename=pathname+filesep()+'8.04-data.sci'
//exec(filename)
//Pressure of the steam entering(in MPa):
p1=20
//Temperature(in K):
T1=500+273
//Dryness fraction of the steam leaving:
x=0.90
//Condensor pressure(in MPa):
p6=0.005
//From steam tables:
h2=3238.2 //kJ/kg
s2=6.1401 //kJ/kg.K
s3=s2
hf=137.82 //kJ/kg
hfg=2423.7 //kJ/kg.K
sf=0.4764 //kJ/kg.K
sfg=7.9187 //kJ/kg.K
h6=137.82 //kJ/kg
h4=3474.1 //kJ/kg
sf1=2.2842 //kJ/kg.K
sfg1=4.1850 //kJ/kg.K
hf1=830.3 //kJ/kg
hfg1=1959.7 //kJ/kg
v6=0.001005 //m^3/kg
//Enthalpy at state 5(in kJ/kg):
h5=hf+x*hfg
s5=sf+x*sfg
//By interpolation, pressure at state 4(in bar):
p4=1.4
//Dryness fraction at state 3:
```

```
x3=(s3-sf1)/sfg1
//Enthalpy at state 3(in kJ/kg):
h3=hf1+x3*hfg1
//Enthalpy at state 1(in kJ/kg):
h1=h6+v6*(p1-p6)*10^3
//Net work per kg of steam(in kJ/kg):
Wnet=(h2-h3)+(h4-h5)-(h1-h6)
//Heat added per kg of steam(in kJ/kg):
Q=h2-h1
//Thermal efficiency:
n=Wnet/Q*100
printf("\n RESULT \n")
printf("\nPressure of steam leaving HP turbine = %f
   MPa",p4)
printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.05 To determine the work done and thermal efficiency and ratio o

```
//pathname=get_absolute_file_path('8.05.sce')
//filename=pathname+filesep()+'8.05-data.sci'
//exec(filename)
//Pressure of steam leaving the boiler(in MPa):
p1=10
//Temperature(in K):
T1=700+273
//Pressure of steam leaving the turbine(in MPa):
p4=0.005
//Output of the plant(in MW):
W=50
//Temperature of the cooling water entering and
   leaving the condensor(in K):
Twin=15+273
Twout=30+273
//From steam tables:
h2=3870.5 //kJ/kg
```

```
s2=7.1687 //kJ/kg.K
s3=s2
sf=0.4764 //kJ/kg.K
sfg=7.9187 //kJ/kg.K
hf=137.82 //kJ/kg
hfg=2423.7 //kJ/kg
h4=hf
v4=0.001005 //m^3/kg
//Specific heat of water(in kJ/kg.K):
Cp=4.18
//Dryness fraction at state 3:
x3=(s3-sf)/sfg
//Enthalpy at state 3(in kJ/kg):
h3=hf+x3*hfg
//Enthalpy at state 1(in kJ/kg):
h1=h4+v4*(p1-p4)
//Net output per kg of steam(in kJ/kg):
Wnet=(h2-h3)-(h1-h4)
//Mass flow rate of steam(in kg/s):
ms=W*10^3/Wnet
//Mass flow rate of water(in kg/s):
mw=(h3-h4)*ms/(Cp*(Twout-Twin))
//Heat added per kg of steam(in kJ/kg):
Q=h2-h1
//Thermal efficiency:
n=Wnet/Q
//Ratio of heat supplied:
r=(h2-h1)/(h3-h4)
printf("\n RESULT \n")
printf("\nMass flow rate of steam = %f kg/s",ms)
printf("\nMass flow rate of condensor cooling water
    = %f kg/s",mw)
printf("\nThermal efficiency=%f",n*100)
printf("\nRatio of heat supplied and rejected = %f",
    r)
```

Scilab code Exa 8.06 To determine cycle efficiency

```
//pathname=get_absolute_file_path('8.06.sce')
//filename=pathname+filesep()+'8.06-data.sci'
//exec(filename)
//Pressure of steam leaving the boiler(in MPa):
p1=200
//Temperature(in K):
T1=650+273
//Pressure of steam leaving the turbine(in MPa):
p4=0.05
//From steam tables:
h2=3675.3 //kJ/kg
s2=6.6582 //kJ/kg.K
s3=s2
h4=137.82 //kJ/kg
v4=0.001005 //m^3/kg
sf=0.4764 //kJ/kg.K
sfg=7.9187 //kJ/kg.K
hf=137.82 //kJ/kg
hfg=2423.7 //kJ/kg
//For case b:
s6=s2
hf8=721.11 //kJ/kg
hfg8=2048 //kJ/kg
vf8=0.001115 //m^3/kg
sf8=2.0462 //kJ/kg.K
sfg8=4.6166 //kJ/kg.K
//For case c:
s10=s2
s9=s2
T10=370.36+273 //K(by interpolation)
h10=3141.81 //kJ/kg
sf4=1.7766 //kJ/kg.K
```

```
sfg4=5.1193 //kJ/kg.K
hf4=604.74 //kJ/kg
hfg4=2133.8 //kJ/kg
h11=hf4
h13=1087.31 //kJ/kg
v11=0.001084 //m^3/kg
v13=0.001252 //m^3/kg
p10=40 //bar
p9=4 //bar
//Case a:
//Dryness farction at state 3:
x3=(s3-sf)/sfg
//Enthalpy at state 3(in kJ/kg):
h3=hf+x3*hfg
//Enthalpy at state 1(in kJ/kg):
h1=h4+v4*(p1-p4)
//Net output per kg of steam(in kJ/kg):
Wnet=(h2-h3)-(h1-h4)
//Heat added(in kJ/kg):
Q=h2-h1
//Thermal efficiency:
na=Wnet/Q*100
printf("\n RESULT \n")
printf("\nThermal efficiency in case a=%f percent",
    na)
//Case b:
//Dryness fraction at state 6(in kJ/kg.K):
x6=(s6-sf8)/sfg8
//Enthalpy at state 6(in kJ/kg):
h6=hf8+x6*hfg8
//Enthalpy at state 7(in kJ/kg):
h7=hf8
//Enthalpy at state 5(in kJ/kg):
h5=h4+v4*(p1-p4)*10^2
//Mass of steam(in kg):
m=(h7-h5)/(h6-h5)
//Enthalpy at state 1(in kJ/kg):
h1=h7+vf8*(p1-p4)*10^2
```

```
//Thermal efficiency:
nb=((h2-h6)+(1-m)*(h6-h3)-((1-m)*(h5-h4)+(h1-h7)))/(
   h2-h1)*100
printf("\nThermal efficiency in case b=%f percent",
   nb)
//Case c:
//Dryness fraction at state 9:
x9=(s9-sf4)/sfg4
//Enthalpy at state 9(in kJ/kg):
h9=hf4+x9*hfg4
//Enthalpy at state 8(in kJ/kg):
h8=h4+v4*(p9-p4)*10^2
//Enthalpy at state 12(in kJ/kg):
h12=h11+v11*(p10-p9)*10^2
//Enthalpy at state 1'(in kJ/kg):
h1a=h13+v13*(p1-p10)*10^2
//Mass of steam flowing through first heater:
m1=(h13-h12)/(h10-h12)
//Mass of steam flowing through second heater:
m2=((1-m1)*h11-(1-m1)*h8)/(h9-h8)
//Work done by Condensate extraction pump(in kJ/kg):
Wcep=(1-m1-m2)*(h8-h4)
//Work done by feed pump 1(in kJ/kg):
WFP1=h1a-h13
//Work done by feed pump 2(in kJ/kg):
WFP2=(1-m1)*(h12-h11)
//Thermal efficiency:
nc=((h2-h10)+(1-m1)*(h10-h9)+(1-m1-m2)*(h9-h3)-(Wcep
   +WFP1+WFP2))/(h2-h1a)*100
printf("\nThermal efficiency in case c=%f percent",
   nc)
```

Scilab code Exa 8.07 To determine cycle efficiency and specific steam consumption

```
//pathname=get_absolute_file_path('8.07.sce')
```

```
//filename=pathname+filesep()+'8.07-data.sci'
//exec(filename)
//Pressure at which steam is generated(in bar):
p1=50
//Temperature of the steam(in K):
T1=500+273
//Pressure upto which steam is expanded(in bar):
p3=5
//Temperature(in K):
T3=400+273
//Final pressure(in bar):
p5=0.05
//From steam tables:
h2=3433.8 //kJ/kg
s2=6.9759 //kJ/kg.K
s3=s2
T3=183.14+273 //K(by interpolation)
h3=2818.03 //kJ/kg
h4=3271.9 //kJ/kg
s4=7.7938 //kJ/kg.K
s5=s4
sf=0.4764 //kJ/kg.K
sfg=7.9187 //kJ/kg.K
hf=137.82 //kJ/kg
hfg=2423.7//kJ/kg
h6=hf
v6=0.001005 //m^3/kg
//Dryness fraction at state 5:
x5=(s5-sf)/sfg
//Enthalpy at state 5(in kJ/kg):
h5=hf+x5*hfg
//Enthalpy at state 1(in kJ/kg):
h1=h6+v6*(p1-p5)*10^2
//Turbine work(in kJ/kg):
Wt=(h2-h3)+(h4-h5)
//Pump work(in kJ/kg):
Wp=h1-h6
//Net output per kg of steam(in kJ/kg):
```

```
Wnet=Wt-Wp
//Heat added per kg of steam(in kJ/kg):
Q=h2-h1
//Cycle efficiency:
n=Wnet/Q
//Specific steam consumption(in kg/hp.hr):
ssc=0.7457*3600/Wnet
//Work ratio:
r=Wnet/Wt
printf("\n RESULT \n")
printf("\nCycle efficiency=%f",n*100)
printf("\nSpecific steam consumption = %f kg/hp.hr",
   ssc)
printf("\nWork ratio = %f",r)
```

Scilab code Exa 8.08 To determine efficiency of the boiler

```
//pathname=get_absolute_file_path('8.08.sce')
//filename=pathname+filesep()+'8.08-data.sci'
//exec(filename)
//Pressure of steam fed in HP turbine(in bar):
p1=60
//Temperature of the steam(in K):
T1=450+273
//Pressure of steam entering LP turbine(in bar):
p3=3
//Pressure of steam leaving the LP turbine(in bar):
p4=0.05
//Condensate temperature(in C):
T3=115
//Alternator output(in MW):
W=30
//Boiler efficiency:
nb=0.90
//Alternator efficiency:
```

```
na=0.98
//From steam tables:
h2=3301.8 //kJ/kg
s2=6.7198 //kJ/kg.K
hf=137.82 //kJ/kg
hfg=2423.7 //kJ/kg
h5=hf
vf=0.001005 //m^3/kg
v5=vf
h8=561.47 //kJ/kg
s3=s2
s4=s2
sf3=1.6718 //kJ/kg.K
sfg3=5.3201 //kJ/kg.K
hf3=561.47 //kJ/kg
hfg3=2163.8 //kJ/kg
sf=0.4764 //kJ/kg.K
sfg=7.9187 //kJ/kg.K
h9=h8
v6=v5
//Dryness fraction at state 3:
x3=(s3-sf3)/sfg3
//Dryness fraction at state 4:
x4=(s4-sf)/sfg
//Enthalpy at state 3(in kJ/kg):
h3=hf3+x3*hfg3
//Enthalpy at state 4(in kJ/kg):
h4=hf+x4*hfg
//Enthalpy at state 1(in kJ/kg):
h1=4.18*T3
//Pumping work(in kJ/kg):
Wp=v5*(p1-p4)
//Mass of steam entering the feed pump(in kg):
m=0.144
printf("\n RESULT \n")
printf("\nSteam bled for feed heating = %f kg",m)
//Net output(in kJ/kg):
Wnet=(h2-h3)+(1-m)*(h3-h4)-(1-m)*Wp
```

```
//Mass of steam required to be generated(in kg/hr):
ms=W*10^3/(na*Wnet)
printf("\nCapacity of boiler = %f kg/hr",ms)
//Heat added(in kJ/kg):
Q=(h2-h1)/nb
//Overall thermal efficiency:
no=Wnet/Q*100
printf("\nOverall thermal efficiency = %f percent",
   no)
```

Scilab code Exa 8.09 To determine capacity of the drain pump

```
//pathname=get_absolute_file_path('8.09.sce')
//filename=pathname+filesep()+'8.09-data.sci'
//exec(filename)
//Pressure of steam entering(in bar):
p1=30
//Temperature(in C):
T1=300
//Pressure of steam leaving the first stage(in bar):
p3=6
//Steam leaving second stage at pressure(in bar):
p4=1
//Pressure of steam leaving the third stage(in bar):
p5=0.075
//Condenstate temperature(in C):
T=38
//Temperature of water after leaving first and
   second heater(in C):
T8=150
T13=95
//Efficiency of turbine:
n=0.8
//Turbine output(in MW):
W=15
```

```
//From steam tables:
h2=3230.9 //kJ/kg
s2=6.9212 //kJ/kg.K
s3=s2
T3=190.97 //K(by interpolation)
h3=2829.63 //kJ/kg
s3a=7.1075 //kJ/kg.K
s4=s3a
sf1=1.3026 //kJ/kg.K
sfg1=6.0568 //kJ/kg.K
hf1=417.46 //kJ/kg
hfg1=2258 //kJ/kg
h5=234.64 //kJ/kg
hf6=670.56 //kJ/kg
h11=hf6
//Actual enthalpy at state 3(in kJ/kg):
h3a=h2-n*(h2-h3)
//Dryness fraaction at state 4:
x4=(s4-sf1)/sfg1
//Enthalpy at state 4(in kJ/kg):
h4=hf1+x4*hfg1
//Actual enthaly at state 4(in kJ/kg):
h4a=h3a-n*(h3a-h4)
//Actual dryness fraction at state 4:
x4a=(h4a-hf1)/hfg1
//Actual entropy at state 4(in kJ/kg.K):
s4a=sf1+x4a*sfg1
//Entropy at state 5(in kJ/kg.K):
s5=s4a
//Dryness fraction:
x5=0.8735
//Enthalpy at state 5(in kJ/kg):
h5=2270.43
//Actual enthalpy at state 5(in kJ/kg):
h5a=h4a-n*(h4a-h5)
//By calculation:
m1=0.1293 //kg
m2=0.1059 //kg
```

```
//Turbine output(in kJ/kg):
Wt=(h2-h3a)+(1-m1)*(h3a-h4a)+(1-m1-m2)*(h4a-h5a)
//Rate of steam generation required(in kg/hr):
r=W*10^3/Wt*3600
//Capacity of drain pump(in kg/hr):
c=(m1+m2)*r
printf("\n RESULT \n")
printf("\nCapacity of drain pump = %f kg/hr",c)
```

Scilab code Exa 8.10 To determine the thermal efficiency

```
//pathname=get_absolute_file_path('8.10.sce')
//filename=pathname+filesep()+'8.10-data.sci'
//exec(filename)
//Pressure of the steam entering(in bar):
p1=70
//Temperature of the steam entering the HP turbine(
   in C):
T1=450
//Pressure at which steam is extracted(in bar):
p3=30
//Temperature at which it is reheated(in C):
T4=400
//Pressure of steam after expanding(in bar):
p6=0.075
//Temperature at which steam is bled(in C):
T=140
//Efficiency of HP turbine:
nh=0.80
//Efficiency of LP turbine:
nl=0.85
//From steam tables:
h2=3287.1 //kJ/kg
s2=6.6327 //kJ/kg.K
h3=3049.48 //kJ/kg
```

```
h4=3230.9 //kJ/kg
s4=6.9212 //kJ/kg.K
s6=s4
h6=2158.55 //kJ/kg
s5=s4
p5=3.61 //bar
h5=2712.38 //kJ/kg
h9=1008.42 //kJ/kg
v7=0.001008 //m^3/kg
h7=168.79 //kJ/kg
h8=169.15 //kJ/kg
v9=0.00108 //m^3/kg
//Actual enthalpy at state 3(in kJ/kg):
h3a=h2-nh*(h2-h3)
//Actual enthaly at state 6(in kJ/kg):
h6a=h4-nl*(h4-h6)
//Actual enthaly at state 5(in kJ/kg):
h5a=h4-nl*(h4-h5)
//Enthalpy at state 8(in kJ/kg):
h8=h7+v7*(p5-p6)*10^2
//Mass of bled steam per kg of steam generated(in kg/kg steam generated):
m=(h9-h8)/(h5a-h8)
//Enthalpy at state 1(in kJ/kg):
h1=h9+v9*(p1-p5)*10^2
//Net work per kg of steam generated(in kJ/kg):
Wnet=(h2-h3a)+(h4-h5a)+(1-m)*(h5a-h6a)-((1-m)*(h8-h7)+(h1-h9))
//Heat added per kg of steam generated(in kJ/kg):
Q=(h2-h1)+(h4-h3a)
//Thermal efficiency:
n=Wnet/Q*100
printf("\n RESULT \n")
printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.11 To determine cycle thermal efficiency and net power developed

```
//pathname=get_absolute_file_path('8.11.sce')
//filename=pathname+filesep()+'8.11-data.sci'
//exec(filename)
//Pressure of the steam entering the boiler(in bar):
p1=150
//Temperature of the steam entering the turbine(in C
   ):
T1=450
//Condensor pressure(in bar):
p6=0.05
//Pressure of steam bled out between 1st & 2nd stage
    and 2nd & 3rd(in bar):
p3=10
p4=1.5
//Temperature of feed water leaving closed water
   heater(in C):
T11=150
//Mass flow rate(in kg/s):
m=300
//From steam tables:
h2=3308.6 //kJ/kg
s2=6.3443 //kJ/kg.K
s3=s2
s4=s2
s5=s2
h3=2667.26 //kJ/kg
h4=2355.18 //kJ/kg
h5=1928.93 //kJ/kg
h6=137.82 //kJ/kg
v6=0.001005 //m^3/kg
h8=467.11 //kJ/kg
v8=0.001053 //m^3/kg
h10=1610.5 //kJ/kg
v10=0.001053 //m^3/kg
//Enthalpy at state 7(in kJ/kg):
h7=h6+v6*(p4-p6)*10^2
```

```
//Enthalpy at state 9(in kJ/kg):
h9=h8+v8*(p1-p4)*10^2
//Enthalpy at state 12(in kJ/kg):
h12=h10+v10*(p1-p3)*10^2
//Mass of steam bled out in closed feed water heater
    (in kg/kg of steam generated):
m1=(4.18*T11-h9)/(h3-h9+4.18*T11-h10)
m2=((1-m1)*(h8-h7))/(h4-h7)
//Enthalpy at state 1(in kJ/kg):
h1=(4.18*T11)*(1-m1)+m1*h12
//Net work output per kg of steam generated(in kJ/kg
    ):
Wnet=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)-((1-m1
    -m2)*(h7-h6)+(1-m1)*(h9-h8)+m1*(h12-h10))
//Heat added(in kJ/kg):
Q=h2-h1
//Cycle thermal efficiency:
n=Wnet/Q*100
printf("\n RESULT \n")
printf("\nCycle thermal efficiency = %f percent",n)
printf("\nNet power developed = %f kW",Wnet)
```

Scilab code Exa 8.12 To determine thermal efficiency and steam generation rate

```
//pathname=get_absolute_file_path('8.12.sce')
//filename=pathname+filesep()+'8.12-data.sci'
//exec(filename)
//Pressure of the steam entering the boiler(in bar):
p1=100
//Temperature of the steam entering the turbine(in C
    ):
T1=500
//Condensor pressure(in bar):
p6=0.075
//Pressure at which steam is extracted at exit of
```

```
HPT(in bar):
p3=20
//Pressure at which steam is extracted at exit of
  IPT(in bar):
p4=4
//Temperature at which feed water leaves closed feed
  warere heater(in C):
T=200
//Net power output(in MW):
W=100
//From steam tables:
h2=3373.7 //kJ/kg
s2=6.5966 //kJ/kg.K
s3=s2
s4=s2
s5=s2
T3=261.6 //C(by interpolation)
h3=2930.57 //kJ/kg
h4=2612.65 //kJ/kg
h5=2055.09 //kJ/kg
h10=908.79 //kJ/kg
h8=604.74 //kJ/kg
h1=4.18*T
h11=h10
v6=0.001008 //m^3/kg
h6=168.79 //kJ/kg
h8=604.74 //kJ/kg
v8=0.001084 //m^3/kg
//For modified part:
h3a=3247.6 //kJ/kg
s3a=7.1271 //kJ/kg.K
s4a=s3a
s5a=s3a
T4=190.96 //C(by interpolation)
h4a=2841.2 //kJ/kg
h5a=2221.11 //kJ/kg
//Enthalpy at state 7(in kJ/kg):
h7=h6+v6*(p4-p6)*10^2
```

```
//Enthalpy at state 9(in kJ/kg):
h9=h8+v8*(p3-p4)*10^2
//Mass of steam bled out in closed feed water heater
    (in kg/kg of steam generated):
m1=(h1-h9)/(h3-h10)
m2=((h8-h7)-m1*(h11-h7))/(h4-h7)
//Net work per steam generated(in kJ/kg):
Wnet=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)-((1-m1
    -m2)*(h7-h6)+(h9-h8))
//Heat added(in kJ/kg):
Q=h2-h1
//Thermal efficiency:
n=Wnet/Q*100
//Steam genration rate(in kg/s):
sgc=W*10^3/Wnet
printf("\n RESULT \n")
printf("\nThermal efficiency = %f percent",n)
printf("\nSteam generation rate = %f kg/s",sgc)
//For modified part:
//Mass of steam bled out in closed feed water heater
    (in kg/kg of steam generated):
m2a=((h8-h7)-m1*(h11-h7))/(h4a-h7)
//Net work per steam generated(in kJ/kg):
Wneta=(h2-h3)+(1-m1)*(h3a-h4a)+(1-m1-m2a)*(h4a-h5a)
    -((1-m1-m2a)*(h7-h6)+(h9-h8))
//Heat added(in kJ/kg):
Qa=h2-h1+(1-m1)*(h3a-h3)
//Thermal efficiency:
na=Wneta/Qa*100
//% Increase in thermal efficiency due to reheating:
I=(na-n)/n*100
printf("\n\nThermal efficiency = %f percent",na)
printf("\n Percentage increase in efficiency due to
    reheating = %f percent",I)
```

Scilab code Exa 8.13 To determine the thermal efficiency

```
//pathname=get_absolute_file_path('8.13.sce')
//filename=pathname+filesep()+'8.13-data.sci'
//exec(filename)
//Enthalpy of dry saturated vapour at 8.45 bar
hd=349 //kJ/kg
//Enthalpy after isentropic expansion to 0.07 bar
hi=234.5 //kJ/kg
//Enthalpy of saturated liquid at 0.07 bar
hs= 35 //kJ/kg
//Capability:
n1=0.85
//Specific heat of water:
Cpw=4.18
//From steam tables:
h1=2767.13 //kJ/kg
h2=3330.3 //kJ/kg
s2=6.9363 //kJ/kg.K
s3=s2
s4=s2
s5=s2
h3=2899.23 //kJ/kg
x4=0.93
h4=2517.4 //kJ/kg
x5=0.828
h5=2160.958 //kJ/kg
h6=168.79 //kJ/kg
v6=0.001008 //m^3/kg
h7=168.88 //kJ/kg
h9=417.46 //kJ/kg
h13=721.11 //kJ/kg
v13=0.001252 //m^3/kg
T1=150 //C
h10=418.19 //kJ/kg
m1=0.102
m2=0.073
//For mercury cycle:
```

```
//Isentropic heat drop:
qd=hd-hi
//Actual heat drop:
qda=n1*qd
//Heat rejected in condenser(in kJ/kg):
qre=hd-qda-hs
//Heat added in the boiler(in kJ/kg):
qa=hd-hs
//Heat added in the condenser of mercury cycle(in kJ
    /kg):
qam=h1-Cpw*T1
//Mercury per steam required per kg of steam:
m=qam/qre
//Pump work(in kJ/kg):
Wp=v13*(40-8)*10^2
//Total heat supplied(in kJ/kg steam):
qt=m*qa+h2-h1
//Work done in mercury cycle(in kJ/kg):
Wm=m*qda
//Work done in steam cycle(in kJ/hr):
Ws=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)-(1-m1-m2
    )*(h7-h6)-m2*(h10-h9)-m1*Wp
//Total work done(in kJ/kg):
Wt=Wm+Ws
//Thermal efficiency:
n=Wt/qt*100
printf("\n RESULT \n")
printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.15 To determine the thermal efficiency

```
//pathname=get_absolute_file_path('8.15.sce')
//filename=pathname+filesep()+'8.15-data.sci'
//exec(filename)
//Specific heat of water:
```

```
Cpw=4.18
//From steam tables:
h2=2960.7 //kJ/kg
s2=6.3615 //kJ/kg
s3=s2
x3=0.863
h3=2404.94 //kJ/kg
h7=358.59 //kJ/kg
s10=s3
x10=0.754
h10=1982.91 //kJ/kg
//Mass pf moisture in separator(in kg):
m1=(1-x3)*0.5
//Mass of steam entering LPT(in kg):
m2=0.5-m1
//Mass of water entering the hot well(in kg):
m3=0.5+m1
//Temperature of water leaving hotwell(in C):
T=(m3*90+m2*40)
//Heat transferred per kg steam generated:
Q=0.5*(h3-h7)
printf("\n RESULT \n")
printf("\nTemperature of water leaving hotwell = %f C",T)
printf("\nHeat transferred per kg steam generated = %f kJ/kg steam",Q)
//Net work output(in kJ/kg):
Wnet=(h2-h3)*1+m2*(h3-h10)
//Heat added(in kJ/kg):
Qa=h2-Cpw*T
//Thermal efficiency:
n=Wnet/Qa*100
printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.16 To determine cycle thermal efficiency and net power developed

```
//pathname=get_absolute_file_path('8.16.sce')
//filename=pathname+filesep()+'8.16-data.sci'
//exec(filename)
//Steam flow rate(in kg/s):
m=35
//From steam tables:
h1=3530.9 //kJ/kg
s1=6.9486 //kJ/kg.K
s2=s1
x2=0.864
h2=2288.97 //kJ/kg
v3=0.001017 //m^3/kg
h3=251.40 //kJ/kg
//Pump work(in kJ/kg):
Wp=v3*(70-0.20)*10^2
//Turbine work(in kJ/kg):
Wt=h1-h2
//Net work(in kJ/kg):
Wnet=Wt-Wp
//Power produced(in MW):
P=m*Wnet/10^3
//Enthalpy at state 4(in kJ/kg):
h4=h3+Wp
//Total heat supplied to the boiler(in kJ/s):
Q=m*(h1-h4)
//Thermal efficiency:
n=Wnet*m/Q*100
printf("\n RESULT \n")
printf("\nNet power = %f MW",P)
printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.17 To determine the amount of heat added

```
//pathname=get_absolute_file_path('8.17.sce')
//filename=pathname+filesep()+'8.17-data.sci'
```

```
//exec(filename)
//State of steam entering HP stage : 10 MPa, 600 C
//State of steam entering LP stage: 2 MPa, 400 C
//Condenser pressure: 10 KPa
//Output(in MW):
P=10
//From steam tables:
h1=3625.3 //kJ/kg
s1=6.9029 //kJ/kg.K
s2=s1
s3=s2
h2=3105.08 //kJ/kg
x3=0.834
h3=2187.43
h6=908.79 //kJ/kg
h5=191.83 //kJ/kg
h4=h5
h7=h6
//Steam bled per kg of steam passing through HP
    stage:
mb=(h6-h5)/(h2-h5)
printf("\n RESULT \n")
printf("\nSteam bled per kg of steam passing through
    HP stage = %f kg",mb)
//Mass of steam leaving boiler(in kg/s):
m=P*10^3/((h1-h2)+(1-mb)*(h2-h3))
//Heat supplied to the boiler(in kJ/s):
Q=m*(h1-h7)
printf("\nHeat added = %f kJ/s",Q)
```

Scilab code Exa 8.18 To determine the thermal efficiency and amount of steam bled

```
//pathname=get_absolute_file_path('8.18.sce')
//filename=pathname+filesep()+'8.18-data.sci'
//exec(filename)
```

```
//Net output(in MW):
P=50
//From steam tables:
h1=3373.7 //kJ/kg
s1=6.5966 //kJ/kg.K
s6=s1
s2=s1
s3=7.7622 //kJ/kg.K
s8=s3
s4=s3
h6=2930.572 //kJ/kg
h3=3478.5 //kJ/kg
T2=181.8//C
h2=2782.8 //kJ/kg
T8=358.98//C
h8=3188.7 //kJ/kg
x4=0.95
h4=2462.99 //kJ/kg
h11=856.8 //kJ/kg
h9=604.74 //kJ/kg
h7=908.79 //kJ/kg
h7a=h7
h4a=191.83 //kJ/kg
v4a=0.001010//m^3/kg
v9=0.001084//m^3/kg
//Enthalpy at state 5(in kJ/kg):
h5=h4a+v4a*(4-0.1)*10^2
//Enthalpy at state 10(in kJ/kg):
h10=h9+v9*(100-4)*10^2
//Mass per kg of steam from boiler(in kg):
m6=(h11-h10)/(h6-h7)
m8=(h9-(1-m6)*h5-m6*h7a)/(h8-h5)
m6=0.135
m8=0.105
//Work in turbines(in kJ/kg):
Whpt=(h1-h6)+(1-m6)*(h6-h2)
Wlpt=(1-m6)*(h3-h8)+(1-m6-m8)*(h8-h4)
//Pump works(in kJ/kg)
```

```
Wcep=(1-m6-m8)*(h5-h4a)
Wfp=h10-h9
//Mass of steam entering first stage of turbine(in
    kg/s):
m=P*10^3/(Whpt+Wlpt-Wcep-Wfp)
//Heat supplied in the boiler(in kJ/s):
Q=m*(h1-h11)
//Thermal efficiency:
n=P*10^3/Q*100
printf("\n RESULT \n")
printf("\nMass of steam bled at 20 bar = %f kg per
    kg of steam entering first stage",m6)
printf("\nMass of steam bled at 4 bar = %fkg per kg
    of steam entering first stage",m8)
printf("\nMass of steam entering first stage = %f kg
    /s",m)
printf("\nThermal efficiency = %f percent",n)
```

Scilab code Exa 8.19 To determine mass of steam bled

```
//pathname=get_absolute_file_path('8.19.sce')
//filename=pathname+filesep()+'8.19-data.sci'
//exec(filename)
//Turbine efficiency:
nt=0.85
//Generator efficiency:
ng=0.90
//Mechanical efficiency:
nm=0.95
//Specific heat of water:
Cpw=4.18
//From steam tables:
h1=3450.02 //kJ/kg
s1=6.6923 //kJ/kg.K
h3=3576.99 //kJ/kg
```

```
s3=7.52411 //kJ/kg.K
h2=3010 //kJ/kg
h9=3175 //kJ/kg
h4=2300 //kJ/kg
h5=137.82 //kJ/kg
v5=0.001005 //m^3/kg
h8=962.11 //kJ/kg
h12=1407.56 //kJ/kg
h10=670.56 //kJ/kg
v10=0.001101 //m^3/kg
//Enthalpy at state 2'(in kJ/kg):
h2a=h1-(h1-h2)*nt
//Enthalpy at state 9'(in kJ/kg):
h9a=h3-(h3-h9)*nt
//Enthalpy at state 4'(in kJ/kg):
h4a=h3-(h3-h4)*nt
//Enthalpy at state 6(in kJ/kg):
h6=h5+v5*(6-0.05)*10^2
//Enthalpy at state 6'(in kJ/kg):
h6a=h5+(h6-h5)/ng
//Enthalpy at state 11(in kJ/kg):
h11=h10+v10*(100-6)*10^2
//Enthalpy at state 11'(in kJ/kg):
h11a=h10+(h11-h10)/ng
//Mass flow rate(in kg/kg steam):
m1=(h11a-h12)/(h8-h2a)
m2=(h10-m1*h8-(1-m1)*h6a)/(h9-h6a)
//Work from HP turbine(in kJ/kg):
Whp=h1-h2a
//Work from LP turbine(in kJ/kg):
Wlp=(1-m1)*(h3-h9a)+(1-m1-m2)*(h9a-h4a)
//Pump work:
Wp=(1-m1-m2)*(h6a-h5)+(h11a-h10)
//Net work(in kJ/kg):
Wnet=Whp+Wlp-Wp
//Specific steam consumption(in kg/kw.h):
ssc=3600/(Wnet*ng*nm)
ssc=3.93
```

```
//Overall thermal efficiency:
no=Wnet*nm*ng/((h1-h12)+(1-m1)*(h3-h2a))*100
//Mass of steam required(in kg/hr):
m=ssc*120*103
m=471600
printf("\n RESULT \n")
printf("\nSpecific steam consumption = %f kg/kw.h",
    ssc)
printf("\nOverall efficiency = %f percent",no)
printf("\nMass of steam bled from HP turbine = %f kg
    /hr",m1*m)
printf("\nMass of steam bled from LP turbine = %f kg
    /hr",m2*m)
```

Scilab code Exa 8.20 To determine power available to the generator

```
//pathname=get_absolute_file_path('8.20.sce')
//filename=pathname+filesep()+'8.20-data.sci'
//exec(filename)
//Power required(in kW):
P=14000
//Efficiency ratio of turbine:
r=0.75
//From steam tables:
h1=3137 //kJ/kg
s1=6.9563 //kJ/kg.K
s2=s1
x2=0.765
h2=2170.38 //kJ/kg
hf=467.11 //kJ/kg
//Enthalpy at state 2'(in kJ/kg):
h2a=h1-(h1-h2)*r
//Mass of steam required(in kg/s):
m=P/(h2a-hf)
//Power available to the generator(in kW):
```

```
P1=m*(h1-h2a)
printf("\n RESULT \n")
printf("\nPower available to the generator = %f kW",
    P1)
```

Scilab code Exa 8.21 To determine heat consumption in the boiler

```
//pathname=get_absolute_file_path('8.21.sce')
//filename=pathname+filesep()+'8.21-data.sci'
//exec(filename)
//Turbine efficiency:
nt=0.80
//Boiler efficiency:
nb=0.80
//Power required(in kW):
P=9000
//From steam tables:
h1=3137 //kJ/kg
s1=6.9563 //kJ/kg.K
s2=s1
x2=0.960
h2=2638.34 //kJ/kg
hf=503.71 //kJ/kg
//Enthalpy at state 2'(in kJ/kg):
h2a=h1-(h1-h2)*nt
//Mass flow rate(in kg/s):
ms=P/(h2a-hf)
//Power developed(in kW):
P1=ms*(h1-h2a)
//Total heat consumption in the bolier(in kW):
pt=(h1-hf)*ms
//Actual heat consumption(in kJ/s):
pa=pt/nb
printf("\n RESULT \n")
printf("\nPower developed = %f kW",P1)
```

```
printf("\nActual heat consumption = %f kJ/s",pa)
```

Scilab code Exa 8.22 To determine total power produced

```
//pathname=get_absolute_file_path('8.22.sce')
//filename=pathname+filesep()+'8.22-data.sci'
//exec(filename)
//Total power required(in kW):
P=4500
//Heat load(in kW):
Q=15000
//Efficiency of turbines:
n=0.80
//Steam consumption rate(in kg/s):
m=10
//From steam tables:
h1=3137 //kJ/kg
s1=6.9563 //kJ/kg.K
T2=179.18 //C
h2=2813.41 //kJ/kg
hf=640.23 //kJ/kg
//For case 1:
T2a=213.34 //C
s2a=7.125 //kJ/kg.K
s3=s2a
x3=0.853
h3=2221.11 //kJ/kg
//For case 2:
h2a=2878.13 //kJ/kg
h3aa=h2a
T3aa=210.04 //C
s3aa=7.138 //kJ/kg.K
s4=s3aa
x4=0.855
h4=2225.92 //kJ/kg
```

```
//Enthalpy at state 2'(in kJ/kg):
h2a=h1-(h1-h2)*n
//Heat available for process heating(in kJ/kg):
q=h2a-hf
//Mass flow rate(in kg/s):
msh=Q/q
//Enthalpy at state 3'(in kJ/kg):
h3a=h2-(h2a-h3)*n
//Mass of steam produced:
mshp=(P+msh*(h2a-h3a))/((h1-h2a)+(h2a-h3a))
//For case 2:
mshpn=10
mshn=6.7
//Power produced by HP turbine(in kW):
Pn=mshpn*(h1-h2a)
M3aa=mshpn-mshn
//Enthalpy at state 4'(in kJ/kg):
h4a=h3aa-(h3aa-h4)*n
//Power produced by LP turbine(in kW):
Pn1=M3aa*(h3aa-h4a)
//Total power produced(in kW):
Pt=Pn+Pn1
printf("\n RESULT \n")
printf("\nTotal power produced = %f kW",Pt)
```

Scilab code Exa 8.23 To determine heat available for heating process

```
//pathname=get_absolute_file_path('8.23.sce')
//filename=pathname+filesep()+'8.23-data.sci'
//exec(filename)
//Alternator efficiency:
na=0.975
//Turbine efficiency:
nt=0.80
//Turbine's losses(in kW):
```

```
L=50
//Electric power developed(in mW):
p=8
//Condenser discharge(in kg/s):
m=8
//From steam tables:
h1=3137 //kJ/kg
s1=6.9563 //kJ/kg.K
h1a=h1
s1a=7 //kJ/kg.K
s2=s1a
h2=2830 //kJ/kg
h4=2210 //kJ/kg
hf=376.92 //kJ/kg
//Enthalpy at state 2'(in kJ/kg):
h2a=h1a-(h1a-h2)*nt
h3=h2a
//Enthalpy at state 4'(in kJ/kg):
h4a=h3-(h3-h4)*nt
//Power available to the alternator(in MW):
P=m/na
//Total power produced(in kW):
Pt=P*10^3+L
//Power produced by LP turbine(in kW):
plp=m*(h3-h4)
//Power produced by LP turbine(in kW):
php=Pt-plp
//Mass flow rate through HP turbine(in kg/s):
m1=php/(h1a-h2a)
//Heat available for process heating(in kW):
ph=(m1-m)*(h2-hf)
printf("\n RESULT \n")
printf("\nHeat available for process heating = %f kW
   ",ph)
```

Scilab code Exa 8.24 To determine steam consumption

```
//pathname=get_absolute_file_path('8.24.sce')
//filename=pathname+filesep()+'8.24-data.sci'
//exec(filename)
//Turbine efficiency:
nt=0.80
//Mechanical efficiency:
nm=0.90
//Power delivered by turbine(in kW):
p=720
//From steam tables:
h1=3045.8 //kJ/kg
s1=7.0317 //kJ/kg.K
s4=s1
x4=0.841
h4=2192.24 //kJ/kg.K
h2=2706.7 //kJ/kg
s2=7.1271 //kJ/kg.K
s3=s2
x3=0.854
h3=2223.51 //kJ/kg
//Enthalpy at state 4'(in kJ/kg):
h4a=h1-(h1-h4)*nt
//Enthalpy at state 3'(in kJ/kg):
h3a=h2-(h2-h3)*nt
//Power developed in the turbine(in kW):
P=p/nm
//HP steam consumption(in kg/kW.h):
m1=3600/(h1-h4a)
//LP steam consumption(in kg/kW.h):
m2=3600/(h2-h3a)
printf("\n RESULT \n")
printf("\nHP steam consumption = %f kg/kW.h",m1)
printf("\nLP steam consumption = %f kg/kW.h",m2)
```

Scilab code Exa 8.25 To the determine the power generated

```
//pathname=get_absolute_file_path('8.25.sce')
//filename=pathname+filesep()+'8.25-data.sci'
//exec(filename)
//Mass flow rate(in kg/s):
mhp=2
mlp=1.5
//Expansion efficiency:
n=0.90
//Power developed by the turbine(in kW):
P=3000
//From steam tables:
h1=3034.8 //kJ/kg
s1=6.8844 //kJ/kg.K
s3=s1
x3=0.9566
h3=2611.04 //kJ/kg
h2=2706.7 //kJ/kg
hin=h2
xout=0.8535
hout=2222.31 //kJ/kg
h4=2676.25 //kJ/kg
h5=2290 //kJ/kg
//Enthalpy at state 3'(in kJ/kg):
h3a=h1-(h1-h3)*n
//Enthalpy of steam going out(in kJ/kg):
houta=hin-(hin-hout)*n
//Mass flow rate of steam(in kg/s):
ms=P/(hin-hout)
//Enthalpy at state 5'(in kJ/kg):
h5a=h4-(h4-h5)*n
//Power output from mixed pressure turbine(in kW):
p=mhp*(h1-h3a)+(mhp+mlp)*(h4-h5a)
```

```
printf("\n RESULT \n")
printf("\nPower = %f kW",p)
```

Chapter 9

Gas power cycles

Scilab code Exa 9.01 To determine the mep

```
//pathname=get_absolute_file_path('9.01.sce')
//filename=pathname+filesep()+'9.01-data.sci'
//exec(filename)
//Compression ratio:
r=6
//Swept volume(in m^3):
v=0.15
//Pressure at the beginning of compression(in kPa):
p1=98
//Temperature at the beginning of compression(in K):
T1=60+273.15
//Heat supplied(in kJ/kg):
Q23=150
//Value of Cp(in kJ/kg):
Cp=1
//Value of Cv(in kJ/kg):
Cv=0.71
//Adiabatic compression factor:
n=Cp/Cv
//Gas constant(in kJ/kg.K):
R=Cp-Cv
```

```
//Volume at point 2(in m^3):
v2=v/(r-1)
//Total cylinder volume(in m^3):
v1=r*v2
//Mass(in kg):
m=p1*v1/(R*T1)
//Pressure at point 2(in kPa):
p2=p1*(v1/v2)^n
//Temperature at state 2(in K):
T2=p2*v2*T1/(p1*v1)
//Temperature at state 3(in K):
T3=Q23/(m*Cv)+T2
v3=v2
//Pressure at point 3(in kPa):
p3=p2*v2*T3/(v3*T2)
v4=v1
//Pressure at point 4(in kPa):
p4=p3*(v3/v4)^n
//Temperature at point 4(in K):
T4=p4*v4*T3/(p3*v3)
//Entropy change(in kJ/K):
dS=m*Cv*log(T4/T1)
//Heat rejected(in kJ):
Q41=m*Cv*(T4-T1)
//Net work done(in kJ):
W=Q23-Q41
//Efficiency:
e=W/Q23
//Mean effective pressure(in kPa):
mep=W/v
printf("\nRESULT")
printf("\nm.e.p = %f kPa",mep)
```

Scilab code Exa 9.02 To determine the compression ratio

```
//pathname=get_absolute_file_path('9.02.sce')
//filename=pathname+filesep()+'9.02-data.sci'
//exec(filename)
//Pressure at A(in kPa):
pa=138
//Pressure at B(in kPa):
pb=1380
//Thermal efficiency:
nt=0.5
//Mechanical efficiency:
nm=0.8
//Calorific value of fuel(in kJ/kg):
c=41800
//Adiabatic compressive index:
n=1.4
//Ratio of va to vb:
r1=(pb/pa)^(1/n)
//Compression ratio:
r=(7/8*r1-1/8)/(7/8-r1/8)
//Cut off ratio:
p=(r-1)/15+1
//Air standard efficiency for Diesel cycle:
nd=1-1/(r^(n-1)*n)*(p^n-1)/(p-1)
//Overall efficiency:
no=nd*nt*nm
//Fuel consumption,bhp/hr(in kg):
fc=75*60*60/(no*c*10^2)
printf("\nRESULT")
printf("\nCompression ratio = %f",r)
printf("\nAir standard efficiency = %f percent",nd
    *100)
printf("\nFuel consumption,bhp/hr = %f kg",fc)
```

Scilab code Exa 9.03 To find out the efficiencies

```
//pathname=get_absolute_file_path('9.03.sce')
//filename=pathname+filesep()+'9.03-data.sci'
//exec(filename)
//Total heat added(in kJ/kg):
Q=1700
//Maximum pressure(in kPa):
p3=5000
//Temperature at the beginning of compression(in K):
T1=100+273.15
//Pressureat beginning of compression(in kPa):
p1=103
//Value of Cp(in kJ/kg.K):
Cp=1.005
//Value of Cv(in kJ/kg.K):
Cv=0.71
//For Otto cycle:
//Adiabatic index of compression:
n=1.4
//Gas constant(in kJ/kg.K):
R=Cp-Cv
//Considernig 1 kg of air, volume at 1(in m^3):
m=1
V1=m*R*T1/p1
//By solving, volume at 2(in m^3):
V2=0.18
//Compression ratio:
r=V1/V2
//Otto cycle efficiency:
no=1-1/(r^(n-1))
//For mixed cycle:
//By calculating, volume at state 2':
V21=0.122
//Upon subtituting:
p21 = 2124.75 //kPa
T31 = 2082 //K
T21 = 884.8 //K
T41 = 2929.5 //K
V31=V21
```

```
//Volume at state 4(in m^3):
V41=V31*T41/T31
//Temperature at state 5(in K):
T5=T41*(V41/V1)^(n-1)
//Heat rejected in the process 5-1(in kJ):
Q51=Cv*(T5-T1)
//Efficiency of mixed cycle:
nm=(Q-Q51)/Q
printf("\nRESULT")
printf("\nEfficiency of Otto cycle = %f percent",no
    *100)
printf("\nEfficiency of mixed cycle = %f percent",nm
    *100)
```

Scilab code Exa 9.04 To determine the compressor efficiency

```
//pathname=get_absolute_file_path('9.04.sce')
//filename=pathname+filesep()+'9.04-data.sci'
//exec(filename)
//Maximum temperature(in K):
T3 = 1200
//Minimum temperature(in K):
T1 = 300
//Adiabatic compression ratio:
n=1.4
//Value of Cp(in kJ/kg.K):
Cp=1.005
//Optimum pressure ratio for maximum work output:
rp=(T3/T1)^(n/(2*(n-1)))
//Temperature at state 2(in K):
T2=T1*rp^((n-1)/n)
//Temperature at state 4(in K):
T4=T3*rp^((1-n)/n)
//Heat supplied(in kJ/kg):
Q23=Cp*(T3-T2)
```

```
//Compressor work(in kJ/kg):
Wc=Cp*(T2-T1)
//Turbine work(in kJ/kg):
Wt=Cp*(T3-T4)
//Thermal efficiency:
nth=(Wt-Wc)/Q23*100
printf("\nRESULT")
printf("\nCompressor work = %f kJ/kg",Wc)
printf("\nTurbine work = %f kJ/kg",Wt)
printf("\nThermal efficiency = %f percent",nth)
```

Scilab code Exa 9.05 To determine the thermal efficiency

```
//pathname=get_absolute_file_path('9.05.sce')
//filename=pathname+filesep()+'9.05-data.sci'
//exec(filename)
//Pressure at state 1(in bar):
p1=1
//Pressure at state 2(in bar):
p2=6.2
//Pressure at state 3(in bar):
p3=6.2
//Pressure at state 4(in bar):
p4=1
//Temperature at state 1(in K):
T1=300
//Fuel by air ratio:
r=0.017
//Compressor effeciency:
nc=0.88
//Turbine internal efficiency:
nt=0.90
//Heating value of fuel(in kJ/kg):
H=44186
//Adiabatic index of compression:
```

```
n=1.4
n1=1.33
//Value of Cp for combination(in kJ/kg.K):
Cpc=1.147
//Value of Cp for air(in kJ/kg.K):
Cpa=1.005
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((n-1)/n)
//Actual temperature after compression(in K):
T21=(T2-T1)/nc+T1
//Temperature at state 3(in K):
T3=(r*H+Cpa*T21)/((1+r)*Cpc)
//Temperature at state 4(in K):
T4=T3*(p4/p3)^((n1-1)/n1)
//Actual temperature at turbine inlet considering
    internal efficiency of turbine(in K):
T41=T3-nt*(T3-T4)
//Compressor work, per kg of air compressed(in kJ/kg
    ):
Wc=Cpa*(T21-T1)
//Turbine work, per kg of air compressed(in K):
Wt=Cpc*(T3-T41)
//Net work(in kJ/kg):
Wnet=Wt-Wc
//Heat supplied(in kJ/kg):
Q=r*H
//Thermal effeciency:
nth=Wnet/Q*100
printf("\nRESULT")
printf("\nCompressor work = %f kJ/kg of air",Wc)
printf("\nTurbine work = %f kJ/kg of air",Wt)
printf("\nThermal efficiency = %f percent",nth)
```

Scilab code Exa 9.06 To determine optimum pressure ratio

```
//pathname=get_absolute_file_path('9.06.sce')
//filename=pathname+filesep()+'9.06-data.sci'
//exec(filename)
//Maximum temperature(in K):
T5=1200
//Minimum temperature(in K):
T1=300
T3=300
//Isentropic efficiency:
ni=0.85
//Turbine efficiency:
nt=0.9
//Adiabatic index of compression:
n=1.4
//Overall optimum pressure ratio:
rpopt=(T1/(T5*ni*nt))^(2*n/(3*(1-n)))
printf("\nRESULT")
printf("\nOverall optimum pressure ratio = %f",rpopt
  )
```

Scilab code Exa 9.07 To determine the power required

```
//pathname=get_absolute_file_path('9.07.sce')
//filename=pathname+filesep()+'9.07-data.sci'
//exec(filename)
//Ratio of pressure:
rp=1.35
//Flow rate through compressor(in kg/s):
m=50
//Overall efficiency:
no=0.90
//Initial pressure(in bar):
p1=1
//Initial temperature(in K):
T1=313
```

```
//Adiabatic index of compression:
r=1.4
//Gas constant(in kJ/kg.K):
R=0.287
//Exit pressure(in bar):
p9=p1*rp^8
//Temperature at exit(in K):
T9=T1*(p9/p1)^((r-1)/r)
//Considerinf efficiency , actual temperature at exit
    (in K):
T9a=(T9-T1)/0.82+T1
//Actual index of compression:
n=log(p9/p1)/(log(p9/p1)-log(T9a/T1))
printf("\nRESULT")
printf("\nPressure at exit of comppressor = %f bar",
    p9)
printf("\nTemperature at the exit of compressor = %f
    K",T9a)
//Polytropic efficiency:
np=((r-1)/r)*(n/(n-1))
printf("\n\nPolytropic efficiency = %f percent",np
    *100)
//Temperature at state 2(in K):
T2=T1*rp^((r-1)/r)
//Actual temperature at state 2(in K):
T2a=T1*(rp)^((n-1)/n)
//Stage efficiency:
ns1=(T2-T1)/(T2a-T1)
printf("\n\nStage efficiency = %f percent",ns1*100)
//Work done by compressor(in kJ/s):
Wc=(n/(n-1))*m*R*T1*((p9/p1)^((n-1)/n)-1)
//Actual compressor work(in kJ/s):
Wca=Wc/no
printf("\n\nPower required to drive compressor = %f
    kJ/s",Wca)
```

Scilab code Exa 9.09 To determine specific work output

```
//pathname=get_absolute_file_path('9.09.sce')
//filename=pathname+filesep()+'9.09-data.sci'
//exec(filename)
//Temperature at which air is supplied(in K):
T1=27+273
//Initial pressure(in bar):
p2=8
p3=p2
//Temperature of air leaving the combustion chamber(
    in K):
T3=1100
//Pressure at state 4(in bar):
p4=1
p1=p4
//Effectiveness of heat exchanger:
E=0.8
//Polytropic efficiency of the compressor:
npc=0.85
//Polytropic efficinency of the turbnie:
npt=0.90
//Adiabatic index of compression:
r=1.4
//Value of Cp(in kJ/kg.K):
Cp=1.0032
//Compression index:
nc=r*npc/(r*npc-(r-1))
//Expansion index:
nt=r/(r-npt*(r-1))
//Temperature at state 2:
T2=T1*(p2/p1)^((nc-1)/nc)
//Temperature at state 4(in K):
T4=T3*(p4/p3)^((nt-1)/nt)
```

```
//Using heat exchanger effectiveness , temperature at
    state 5(in K):
T5=(T4-T2)*E+T2
//Heat added in combustion chambers(in kJ/kg):
qa=Cp*(T3-T5)
//Compressor work(in kJ/kg):
Wc=Cp*(T2-T1)
//Turbine work(in kJ/kg):
Wt=Cp*(T3-T4)
//Cycle efficiency:
ncycle=(Wt-Wc)/qa
//Work ratio:
Wr=(Wt-Wc)/Wt
//Specific work output(in kJ/kg):
swo=Wt-Wc
printf("\nRESULT")
printf("\nCycle efficiency = %f percent",ncycle*100)
printf("\nWork ratio = %f",Wr)
printf("\nSpecific work output = %f kJ/kg",swo)
```

Scilab code Exa 9.10 To determine isentropic efficiency

```
//pathname=get_absolute_file_path('9.10.sce')
//filename=pathname+filesep()+'9.10-data.sci'
//exec(filename)
//Initial pressure(in bar):
p1=1
//Initial temperature(in K):
T1=27+273
//Pressure at state 2(in bar):
p2=5
//Isentropic efficiency:
nc=0.85
//Temperature at state 3(in K):
T3=1000
```

```
//Pressure at state 3(in bar):
p3=p2-0.2
//Pressure at state 4(in bar):
p4=p1
//Thermal efficiency of plant:
nth=0.20
//Adiabatic index of compression:
r=1.4
//Value of Cp(in kJ/kg.K):
Cp=1.0032
//Temperature at state 2'(in K):
T21=T1*(p2/p1)^((r-1)/r)
//Temperature at state 2(in K):
T2=(T21-T1)/nc+T1
//Temperature at state 4'(in K):
T41=T3*(p4/p3)^((r-1)/r)
//Compressor work per kg(in kJ/kg):
Wc=Cp*(T2-T1)
//Heat added(in kJ/kg):
qa=Cp*(T3-T2)
//Temperature at state 4(in K):
T4=T3-(qa*(-nth)+Wc)/Cp
//Isentropic efficiency of turbine:
nt=(T3-T4)/(T3-T41)
printf("\nRESULT")
printf("\nTurbine isentropic efficiency = %f percent
   ",nt*100)
```

Scilab code Exa 9.11 To determine the thermal efficiency and air fuel ratio

```
//pathname=get_absolute_file_path('9.11.sce')
//filename=pathname+filesep()+'9.11-data.sci'
//exec(filename)
//Pressure at which air is supplied(in bar):
p1=1
```

```
p8=p1
//Temperature at which air is supplied(in K):
T1=27+273
//Maximum temperature in the cycle(in K):
T5=1000
//Pressure at state 6(in bar):
p6=3
p7=p6
p4=10
p5=p4
p3=3
//Temperature at state 7(in K):
T7=995
//Calorific value of fuel(in kJ/kg):
c=42000
//Value of Cp(in kJ/kg):
Cp=1.0032
//Air flow in compressor(in kg/s):
m=30
//Isentropic efficiency of compression:
nc=0.85
//Isebtropic efficiency of expansion:
ne=0.90
//Adiabatic index of compression:
r=1.4
//Pressure ratio for perfect intercooling:
rp=sqrt(10)
//Temperature at state 2'(in K):
T21=T1*rp^((r-1)/r)
//Temperature at state 2(in K):
T2=(T21-T1)/nc+T1
//For perfect intercooling:
T3=T1
//Temperature at state 4'(in K):
T41=T3*(p4/p3)^((r-1)/r)
//Temperature at state 4(in K):
T4=(T41-T3)/nc+T3
//Total compressor work(in kJ/kg):
```

```
Wc=2*Cp*(T2-T1)
//Temperature at state 6'(in K):
T61=T5*(p6/p5)^((r-1)/r)
//Temperature at state 6(in K):
T6=T5-(T5-T61)*ne
//Temperature at state 8'(in K):
T81=T7*(p8/p7)^((r-1)/r)
//Temperature at state 8(in K):
T8=T7-(T7-T81)*ne
//Expansion work output per kg air(in kJ/kg):
Wt=Cp*(T5-T6+T7-T8)
//Heat added per kg air(in kJ/kg):
qa=Cp*(T5-T4+T7-T6)
//Fuel required per kg of air:
mf=qa/c
//Air-fuel ratio:
afr=1/mf
//Net output(in kW):
Wnet=(Wt-Wc)*m
//Thermal efficiency:
nth=(Wt-Wc)/qa
printf("\nRESULT")
printf("\nThermal efficiency = %f percent",nth*100)
printf("\nNet output = %f kW",Wnet)
printf("\nA/F ratio = %f",afr)
```

Scilab code Exa 9.12 To determine the thermal efficiency

```
//pathname=get_absolute_file_path('9.12.sce')
//filename=pathname+filesep()+'9.12-data.sci'
//exec(filename)
//Pressure of air at each state(in bar):
p1=1
p2=4
p3=4
```

```
p4=8
p6=p4
p7=4
p8=4
p9=1
//Temperature at each state(in K):
T1=300
T3=290
T6=1300
T8=1300
//Effectiveness:
E=0.80
//Heating value of fuel(in kJ/kg):
c=42000
//Adiabatic index of combustion:
r=1.4
//Value of Cp(in kJ/kg):
cp=1.0032
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Temperature at state 4(in K):
T4=T3*(p4/p3)^((r-1)/r)
//Temperature at state 7(in K):
T7=T6*(p7/p6)^((r-1)/r)
//Temperature at state 9(in K):
T9=T8*(p9/p8)^((r-1)/r)
//Temperature at state 5(in K):
T5=(T9-T4)*E+T4
//Compressor work per kg of air(in kJ/kg):
Wc=Cp*(T2-T1+T4-T3)
//Turbine work per kg of air(in kJ/kg):
Wt=Cp*(T6-T7+T8-T9)
//Heat added per kg air(in kJ/kg):
qa=Cp*(T6-T5+T8-T7)
//Total fuel per kg of air:
mf=qa/c
//Net work(in kJ/kg):
Wnet=Wt-Wc
```

```
//Cycle thermal efficiency:
n=Wnet/qa*100
//Fuel per kg air in combustion chamber 1:
afr1=Cp*(T6-T5)/c
//Fuel per kg air in combustion chamber 2:
afr2=Cp*(T8-T7)/c
printf("\nRESULT")
printf("\nA/F ratio in the two combustion chambers=
    %f, %f",afr1,afr2)
printf("\nTotal turbine work = %f kJ/kg",Wt)
printf("\nCycle thermal efficiency = %f percent",n)
```

Scilab code Exa 9.13 To determine the brake output and stroke volume

```
//pathname=get_absolute_file_path('9.13.sce')
//filename=pathname+filesep()+'9.13-data.sci'
//exec(filename)
//Maximum temperature(in K):
T2=700
//Minimum temperature(in K):
T1=300
//Compression ratio:
r=3
//Total heat added(in kJ/s):
qa=30
//Regenerator efficiency:
E=0.90
//Pressure at the beginning of compression(in bar):
p=1
//Number of cycles:
n=100
//Value of Cv:
Cv=0.72
//Gas constant(in kJ/kg.K):
R=29.27
```

```
//Work done per kg of air(in kJ/kg):
W=R*(T2-T1)*log(r)
//Heat added per kg of air(in kJ/kg):
q=R*T2*log(r)+(1-E)*Cv*(T2-T1)
//Mass of air for 30 kJ/s of heat supplied(in kg/s):
m=qa/q
//Mass of air per cycle(in kg/cycle):
mc=m/n
//Brake output(in kW):
BP=W*m
//Stroke volume(in m^3):
V=mc*R*T1/(p*10^2)
printf("\nRESULT")
printf("\nBrake output = %f kW",BP)
printf("\nStroke volume = %f m^3",V)
```

Scilab code Exa 9.15 To determine the overall efficiency

```
//pathname=get_absolute_file_path('9.15.sce')
//filename=pathname+filesep()+'9.15-data.sci'
//exec(filename)
//Ambient temperature(in K):
T1=17+273
//Temperature at state 3(in K):
T3=1400
T5=420
//Ambient pressure(in bar):
p1=1
//As pressure ratio is 10, pressure at state 2(in
    bar):
p2=10
p3=10
p4=1
//Pressure in HSRG(in kPa):
ph=6000
```

```
//Condensor pressure(in kPa):
pc=15
//Combined cycle output(in MW):
O=37.3
//Adiabatic index of compression:
r=1.4
//Value of Cp(in kJ/kg.K):
Cp=1.0032
//From steam tables:
ha=3177.2 //kJ/kg
sa=6.5408 //kJ/kg.K
sb=sa
x=0.7976
hb=2118.72 //kJ/kg
hc=225.94  //kJ/kg
vc=0.001014 //m^3/kg
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Temperature at state 4(in K):
T4=T3*(p4/p3)^((r-1)/r)
//Compressor work per kg(in kJ/kg):
Wc=Cp*(T2-T1)
//Turbine work per kg(in kJ/kg):
Wt=Cp*(T3-T4)
//Heat added in combustion chamber(in kJ/kg):
qa=Cp*(T3-T2)
//Net gas turbine output(in kJ/kg air):
WnetGT=Wt-Wc
//Heat recovered in HSRG for steam generation(in kJ/
    kg):
qHSRG=Cp*(T4-T5)
//Enthalpy at exit of feed pump(in kJ/kg):
hd=vc*(ph-pc)*10^2
//Heat added per kg of steam(in kJ/kg):
had=ha-hd
//Mass of steam generated per kg of air:
m=qHSRG/had
//Net steam turbine cycle output(in kJ/kg):
```

```
WnetST=ha-hb-(hd-hc)
//Steam cycle output per kg(in kJ/kg air):
sco=WnetST*m
//Total combined output(in kJ/kg air):
tco=WnetGT+sco
//Combined cycle efficiency:
ncc=tco/qa
//Gas turbine efficiency:
ngt=WnetGT/qa
printf("\nRESULT")
printf("\nOverall efficiency = %f percent",ncc*100)
printf("\nSteam per kg of air =%f kg steam/kg air",m
  )
```

Scilab code Exa 9.16 To determine air standard fuel efficiency

```
//pathname=get_absolute_file_path('9.16.sce')
//filename=pathname+filesep()+'9.16-data.sci'
//exec(filename)
//Temperature of working fuel at the beginning of
  compression(in K):
T1=27+273
//Pressure ratio:
rp=70
//Compression ratio:
rv=15
//Adiabatic index of compression:
r=1.4
//Temperature at state 2(in K):
T2=T1*(rv)^(r-1)
//Temperature at state 3(in K):
T3=T2*rp/(rv^r)
//Temperature at state 4(in K):
T4=T3+(T3-T2)/r
//Temperature at state 5(in K):
```

```
T5=T4*(T3/T4*rv)^(1-r)
//Air standard thermal efficiency:
n=1-(T5-T1)/(r*(T4-T3)+(T3-T2))
printf("\nRESULT")
printf("\nAir standard thermal efficiency = %f
   percent",n*100)
```

Chapter 11

Boilers and boiler calculations

Scilab code Exa 11.01 To determine temperature of burnt gases

```
//pathname=get_absolute_file_path('11.01.sce')
//filename=pathname+filesep()+'11.01-data.sci'
//exec(filename)
//Height of chimney(in m):
H=30
//Ambient air temperature(in K):
Ta=27+273
//Mass per kg of fuel required for complete
    combustion(in kg):
m=20
//Height in the water column(in mm):
hw=12
//Temperature of burnt gases(in K):
Tg=(Ta*353*H)/(353*H-hw*Ta)*(m)/(m+1)
printf("\n RESULT \n")
printf("\nTemperature of the burnt gases = %f K",Tg)
```

Scilab code Exa 11.02 To determine height of the chimney

```
//pathname=get_absolute_file_path('11.02.sce')
//filename=pathname+filesep()+'11.02-data.sci'
//exec(filename)
//Mass per kg of fuel required for complete
   combustion(in kg):
m=18
//Height in the water column(in mm):
hw=20
//Ambient air temperature(in K):
Ta=27+273
//Temperature of burnt gases(in K):
Tg=300+273
//Height of chimney(in m):
H=hw/(353*(1/Ta-(m+1)/(m*Tg)))
printf("\n RESULT \n")
printf("\nHeight of chimney = %f m",H)
```

Scilab code Exa 11.03 To determine the air supplied and draught

```
//pathname=get_absolute_file_path('11.03.sce')
//filename=pathname+filesep()+'11.03-data.sci'
//exec(filename)
//Height of chimney(in m):
H=20
//Temperature of burnt gases(in K):
Tg=380+273
//Ambient air temperature(in K):
Ta=27+273
//Air supplied(in kg air per fuel):
m=2*Ta/(Tg-2*Ta)
printf("\n RESULT \n")
printf("\nAir supplied = %f kg/kg of fuel",m)
//Draught in water column(in mm):
hw=353*H*(1/Ta-(m+1)/(m*Tg))
printf("\nDraught = %f mm of water",hw)
```

Scilab code Exa 11.04 To determine the draught and chimney efficiency

```
//pathname=get_absolute_file_path('11.04.sce')
//filename=pathname+filesep()+'11.04-data.sci'
//exec(filename)
//Height of chimney(in m):
H=60
//Ambient air temperature(in K):
Ta=17+273
//Temperature of burnt gases(in K):
Tg=300+273
//Temperature of the artificial burnt gases(in K):
Tga=150+273
//Mass per kg of fuel required for complete
    combustion(in kg):
m=19
//Specific heat of hot gases(in kJ/kg.K):
Cpg=1.0032
//Calorific value of burnt fuel(in kJ/kg):
c=32604
//Draught (in mm of water column):
hw=353*H*(1/Ta-(m+1)/(m*Tg))
//Chimney efficiency:
n=9.81*H*(m/(m+1)*Tg/Ta-1)/(Cpg*(Tg-Tga)*10^3)*100
//Extra heat carried away by flue gases(in kJ):
Q=(m+1)*Cpg*(Tg-Tga)
printf("\n RESULT \n")
printf("\nDraught = %f mm of water",hw)
printf("\nChimney efficiency = %f percent",n)
printf("\nExtra heat carried away by flue gases per
    kg of fuel burnt = %f kJ",Q)
```

Scilab code Exa 11.05 To determine the draught and chimney efficiency

```
//pathname=get_absolute_file_path('11.05.sce')
//filename=pathname+filesep()+'11.05-data.sci'
//exec(filename)
//Height of chimney(in m):
H=80
//Ambient air temperature(in K):
Ta=27+273
//Mass per kg of fuel required for complete
   combustion(in kg):
m=20
//Temperature of the artificial burnt gases(in K):
Tga=110+273
//Specific heat of hot gases(in kJ/kg.K):
Cpg=1.0032
//Temperature of burnt gases(in K):
Tg=Ta*2*(m+1)/m
//Draught in water column(in mm):
hw=353*H*(1/Ta-(m+1)/(m*Tg))
//Chimney efficiency:
n=9.81*H*(m/(m+1)*Tg/Ta-1)/(Cpg*(Tg-Tga)*10^3)*100
printf("\n RESULT \n")
printf("\nHot gas temperature in chimney = %d K",Tg)
printf("\nNatural draught = %f mm of water",hw)
printf("\nChimney efficiency = %f percent",n)
```

Scilab code Exa 11.06 To determine height and diamter of the chimney

```
//pathname=get_absolute_file_path('11.06.sce')
//filename=pathname+filesep()+'11.06-data.sci'
//exec(filename)
//Rate at which coal is burnt(in kg/hr):
R=2.5*10^3
//Mass per kg of fuel required for complete
```

```
   combustion(in kg):
m=20
//Temperature of burnt gases(in K):
Tg=327+273
//Ambient air temperature(in K):
Ta=27+273
//Pressure head(in mm):
h=7+6+3+2
//Ratio of actual natural draught to theoretical
   draught:
na=0.90
//Acceleration due to gravity(in m/s^2):
g=9.81
//Actual natural draught(in mm of water):
hw=h/na
//Height of chimney(in m):
H=hw/(353*(1/Ta-(m+1)/(m*Tg)))
//Density of hot gases(in kg/m^3):
dg=353/Tg*(m+1)/m
//Height of hot gases column(in m):
hg=H*((m+1)/m*Tg/Ta-1)
//Mass flow rate of hot gases(in kg/s):
Mg=R*hw/3600
//Velocity of got gases(in m/s):
C=sqrt(2*g*hg)
//Diameter of chimney(in m):
D=sqrt((4*Mg)/(%pi*C*dg))
printf("\n RESULT \n")
printf("\nDiameter of chimney = %f m",D)
```

Scilab code Exa 11.07 To determine power of the fan

```
//pathname=get_absolute_file_path('11.07.sce')
//filename=pathname+filesep()+'11.07-data.sci'
//exec(filename)
```

```
//Draught in water column(in mm):
hw=50
//Temperature of burnt gases(in K):
T=300+273
//Rate at which coal is burnt(in kg/s):
M=2000/3600
//Mass per kg of fuel required for complete
   combustion(in kg):
m=19
//Ambient air temperature(in K):
T1=27+273
//Zero temperature(in K):
T0=273
//Mechanical efficiency:
n=0.90
//Pressure applied by the draught water(in N/m^2):
P=hw*9.81
//Density of hot gases(in kg/m^3):
d=1.293
//Power required in FD fan(kW):
PFD=P*m*M*T1/(d*T0*n*1000)
//Power required in 1D fan(kW):
P1D=P*m*M*T/(d*T0*n*1000)
printf("\n RESULT \n")
printf("\nPower for FD fan = %f kW",PFD)
printf("\nPower for 1D fan = %f kW",P1D)
```

Scilab code Exa 11.08 To determine the ratio of power required

```
//pathname=get_absolute_file_path('11.08.sce')
//filename=pathname+filesep()+'11.08-data.sci'
//exec(filename)
//Specific heat of hot gases(in kJ/kg.K):
Cpg=1.0032
//Temperature of burnt gases(in K):
```

```
Tg=177+273
//Ambient air temperature(in K):
Ta=27+273
//Natural draught temperature(in K):
Tn=327+273
//Mass per kg of fuel required for natural draught(
   in kg):
mn=25
//Mass per kg of fuel required for artificial
   draught(in kg):
ma=20
//Ratio of brake power for induced draught to forced
    draught:
r=Tg/Ta
//Heat carried by hot flue gases in artificial
   draught(in per kg of fuel burnt):
Qgad=(ma+1)*Cpg*(Tg-Ta)
//Heat carried by hot flue gases in natural draught(
   in per kg of fuel burnt):
Qgnd=(mn+1)*Cpg*(Tn-Ta)
//Ratio of heat carried away:
rh=Qgad/Qgnd
printf("\n RESULT \n")
printf("\nRatio of power required = %f",r)
printf("\nRatio of heat carried away = %f",rh)
```

Scilab code Exa 11.09 To determine amount of evaporation

```
//pathname=get_absolute_file_path('11.09.sce')
//filename=pathname+filesep()+'11.09-data.sci'
//exec(filename)
//Feed water supply temperature(in K):
T=27+273
//Mean steam generation pressure(in bar):
P=10
```

```
//Dryness fravtion of steam generated:
x=0.95
//Feed water supplied(in kg/hr):
Q=2500
//Coal burnt(in kg/hr):
Q1=275
//Difference in mass of water after trial:
d=300
//From steam tables:
hf=762.81 //kJ/kg
hg=2778.1 //kJ/kg
hfg=2015.29 //kJ/kg
//Enthalpy of steam generated(in kJ/kg):
h=hf+x*hfg
//Mass of water evaporator per hour(in kg/hr):
mw=Q+d
//Actual evaporation(in per kg of coal):
Ae=mw/Q1
//Equivalent evaporation(in kg per kg of coal):
Ee=Ae*h/2257
printf("\n RESULT \n")
printf("\nActual evaporation = %f kg per kg of coal"
    ,Ae)
printf("\nEquivalent evaporation = %f kg per kg of
    coal",Ee)
```

Scilab code Exa 11.10 To determine amount of evaporation

```
//pathname=get_absolute_file_path('11.10.sce')
//filename=pathname+filesep()+'11.10-data.sci'
//exec(filename)
//Average pressure of the steam(in bar):
p=10
//Weight of water consumed(in ton):
Ww=15
```

```
//Weight of coal produced(in ton):
Wc=1.5
//Percentage coal that caan be burnt:
n=1-0.03-0.04
//Composition of moisture in coal:
nm=0.03
//Temperature of feed water(in C):
Tf=35
//From steam tables:
hg=2778.1 //kJ/kg
//Enthalpy of steam generated(in kJ/kg):
h=hg-4.18*Tf
//Steam generated per kg of coal(in kg):
m=Ww/Wc
//Boiler efficiency:
nb=m*h/(30.1*10^3)*100
//Equivalent evaporation per kg of dry coal(in kg:
Ee=m*h/(2257*(1-nm))
//Equivalent evaporation per kg of combustible
    present in coal(in kg):
Eea=Ee*(1-nm)/n
printf("\n RESULT \n")
printf("\nBoiler efficiency = %f percent",nb)
printf("\nEquivalent evaporation per kg of dry coal
    = %f kg",Ee)
printf("\nEquivalent evaporation per kg of
    combustible present in coal = %f kg",Eea)
```

Scilab code Exa 11.11 To determine boiler efficiency

```
//pathname=get_absolute_file_path('11.11.sce')
//filename=pathname+filesep()+'11.11-data.sci'
//exec(filename)
//Time of trial(in hrs):
t=24
```

```
//Pressure at which steam is generated(in bar):
p=16
//Coal consumed(in kg):
c=10000
//Rate of steam generation(in kg/hr):
r=2500
//Feed water temperature(in C):
Tf=27
//Total heating surface area(in m^2):
hsa=3000
//Total grate area(in m^2):
ga=4
//Calorific value of coal(in kJ/kg):
C=28000
//From steam tables:
hg=2794 //kJ/kg
//Latent heat at 100 C:
L=2257
//Coal  burnt per hour(in kg/hr):
m=c/t
//Coal burnt per m^2 of grate per hour:
mg=m/ga
//Rate of steam generated per kg of coal(in kg steam
    /kg coal):
r1=r/m
//Heat added to steam per kg of coal(in kJ):
Q=r1*(hg-4.18*Tf)
//Equivalent evaporation from and at 100 C per kg of
    coal(in kg):
Ee=Q/L
//Equivalent evaporation from and at 100 C per m^2
    of total surface per hour(in kg):
Eepm=Ee*m/hsa
//Boiler efficiency:
n=Ee*L/C*100
printf("\n RESULT \n")
printf("\nMass of coal burnt per m^2 of grate per
    hour = %f kg",mg)
```

```
printf("\nEquivalent evaporation from and at 100 C
   per kg of coal = %f kg",Ee)
printf("\nEquivalent evaporation from and at 100 C
   per m^2 of total surface per hour = %f",Eepm)
printf("\nBoiler efficiency = %f percent",n)
```

Scilab code Exa 11.12 Boiler efficiency

```
//pathname=get_absolute_file_path('11.12.sce')
//filename=pathname+filesep()+'11.12-data.sci'
//exec(filename)
//Pressure at which steam is generated(in bar):
p=30
//Temperature of steam(in C):
Ts=300
//Rate at which feed water enters(in kg/s):
r=11
//Temperature at which feed water enters the
   economiser(in C):
T1=100
//Mass of fuel used(in kg):
m=5000
//Calorific value of fuel(in kJ/kg.K):
C=35000
//Temperature of feed water(in C):
T=27
//From steam tables:
hg=2993.5
//Latent heat at 100 C:
L=2257
//Mass of steam genrated per kg of fuel(in kg/kg
   fuel):
ms=r*3600/m
//Heat added per kg of fuel(in kJ):
Q=hg-4.18*T
```

```
//Equivalent evaporation from and at 100 C per kg of
    coal(in kg):
Ee=ms*Q/L
//Boiler efficiency:
n=Ee*L/C*100
//Heat utilised in economiser per kg of fuel(in kJ):
Q1=ms*4.18*(T1-T)
//Percentage of energy utilised in economiser:
P=Q1/C*100
printf("\n RESULT \n")
printf("\nEquivalent evaporation per kg of fuel = %f
    kg",Ee)
printf("\nBoiler efficiency = %f percent",n)
printf("\nPercentage of energy utilised in
    economiser = %f percent",P)
```

Scilab code Exa 11.13 `Boiler efficiency`

```
//pathname=get_absolute_file_path('11.13.sce')
//filename=pathname+filesep()+'11.13-data.sci'
//exec(filename)
//Mass of steam genrated per kg of fuel:
m=8
//Temperature of steam(in C):
Ts=400
//Pressure of feed water(in bar):
p=30
//Temperature of feed water(in C):
T=40
//Temperature at which feed water leaves the
    economiser(in C):
T1=150
//Dryness fraction:
x=0.98
//Calorific value(in kJ/kg.K):
```

```
C=29000
//From steam tables:
//Enthalpy of steam generated(in kJ/kg):
h=3230.9
hf=1008.42 //kJ/kg
hfg=1795.78 //kJ/kg
//Heat to be added(in kJ):
Q=h-4.18*T
//Boiler efficiency:
n=m*Q/C*100
//Heat added in economiser per kg of steam generated
    (in kJ/kg):
Q1=4.18*(T1-T)
//Percentage fraction of heat in economiser:
r1=Q1/Q*100
//Heat added in evaporator per kg of steam generated
    (in kJ/kg):
Q2=(hf+x*hfg)-4.18*T1
//Percentage fraction of heat in economiser:
r2=Q2/Q*100
//Heat added in super heater per kg of steam
    generated by difference(in kJ/kg):
Q3=Q-Q1-Q2
//Percentage fraction of heat in economiser:
r3=Q3/Q*100
printf("\n RESULT \n")
printf("\nBoiler efficiency = %f percent",n)
printf("\nPercentage fraction of heat in economiser
    = %f percent",r1)
printf("\nPercentage fraction of heat in evaporator
    = %f percent",r2)
printf("\nPercentage fraction of heat in superheater
     = %f percent",r3)
```

Scilab code Exa 11.14 `Air leakage`

```
//pathname=get_absolute_file_path('11.14.sce')
//filename=pathname+filesep()+'11.14-data.sci'
//exec(filename)
//Temperature at which feed water enters and leaves
   the economiser(in C):
T1=20
T2=125
//Rate at which feed water leaves the economiser(in
   kg/s):
r=3
//Temperature of flue gases at inlet and outlet of
   economiser(in C):
T3=425
T4=300
//Rate at which coal is supplied(in kg/min):
r1=18
//% of C in coal:
nc=0.80
//Specific heat of flue gases(in kJ/kg.K):
Cpg=1.05
//Atmospheric temperature(in C):
Ta=15
//From table:
//Mass of dry flue gases at inlet and exit of
   economiser(in kg):
m1=23.65
m2=24.78
//Air leakage in economiser per kg of coal:
A=m2-m1
//Heat entering economiser with flue gases and
   leakage(in kJ):
Q1=m1*Cpg*T3+A*Cpg*Ta
//Heat entering economiser with flue gases and
   leakage(in kJ):
Q2=m2*Cpg*T4
//Heat lost in economiser per kg of coal(in kJ):
Q=Q1-Q2
//Heat picked up by feed water in economiser per kg
```

```
    of coal(in kJ):
Q3=(r*60/r1)*4.18*(T2-T1)
printf("\n RESULT \n")
printf("\nHeat released by the flue gases = %f kJ
    per kg of coal",Q)
printf("\nAir leakage = %f kg per kg of coal",A)
printf("\nHeat gained by feed water = %d kJ per kg
    of coal",Q3)
```

Scilab code Exa 11.15 Boiler efficiency

```
//pathname=get_absolute_file_path('11.15.sce')
//filename=pathname+filesep()+'11.15-data.sci'
//exec(filename)
//Atmospheric air temperature: 15C
//Steam generation: 40 bar, 400C
//Steam generated per kg of coal = 8 kg
//Feed water temperature at inlet to economiser = 27
    C
//Feed water temperature at exit of economiser = 137
    C
//Moisture in coal burnt = 1.5%
//Flue gas temperature entering air heater =300C
//Flue gas temperature leaving air heater and
    entering chimney = 150C
//Temperature of air entering boiler furnace = 120C
//Dry coal composition by mass = 84% C, 4% H2, 7% O2
     and remainder ash
//Dry flue gas composition by volume = 12.5% CO2,
    7.5% O2, 80% N2
//Datum temperature = 15C
//Calorific value of coal = 32600 kJ/kg
//For air and dry flue gas, cp =1.0032 kJ/kg K
//Partial pressure of vapour in flue gas = 0.075 bar
//Specific pressure of vapour = 2.0064 kJ/kg K
```

```
//Mass of dry flue gas per kg of coal:
md=0.84/0.0495
//H2O produced during the combustion(in kg):
mh=0.04*9
//Amount of air supplied for combustion of one kg of
    dry coal(in kg):
ma=16.97-(1-0.05-0.36)
//Moisture per kg of dry coal(in kg):
m=0.015/(1-0.015)
//Total moisture per kg of coal(in kg):
mt=mh+m
//Steam generated per kg of dry coal(in kg steam):
ms=8/(1-0.015)
//Boiler efficiency:
n=25178.01/32600*100
//Efficiency of heat exchange in air heater:
na=1725.4/2897.67*100
printf("\n RESULT \n")
printf("\nBoiler efficiency = %f percent",n)
printf("\nEfficiency of heat exchange in air heater
   = %f percent",na)
```

Scilab code Exa 11.17 Saving of coal

```
//pathname=get_absolute_file_path('11.17.sce')
//filename=pathname+filesep()+'11.17-data.sci'
//exec(filename)
//Pressure at which steam is generated(in bar):
p=20
//Temperature at which steam is generated(in C):
Ts=300
//Temperature of feed water supplied to the boiler(
   in C):
T1=50
//Calorific value of fuel(in kJ/kg):
```

```
C=30000
//Rate at which coal is used(in kg/hr):
r=600
//Rate at which steam is generated(in kg/hr):
r1=5000
//Temperature of the boiler unit(in C):
T=100
//Latent heat(in kJ/kg.K):
L=2257
//Steam generation per unit coal burnt per hour:
ms=r1/r
//Final enthalpy of the steam(in kJ/kg):
hfi=3023.5
//Enthalpy of feed water(in kJ/kg):
hfw=209.33
//Overall efficiency of boiler:
no=ms*(hfi-hfw)/C*100
//Equivalent evaporation of boiler unit(in kg steam
    per kg of coal):
Ee=ms*(hfi-hfw)/L
//Equivalent evaporation of boiler unit at 100 C(in
    kg/hr):
Eea=Ee*r
//After fitting economiser the enthalp of feed water
    (in kJ/kg):
hfw1=313.93
//Modified overall efficiency of boiler unit:
nom=no+5
//Coal consumption(in kg/hr):
mc=(hfi-hfw1)*r1*100/(C*nom)
//Saving of coal(in kg/hr):
s=r-mc
printf("\n RESULT \n")
printf("\nSaving of coal = %f kg/hr",s)
```

Scilab code Exa 11.18 Temperature of flue gases

```
//pathname=get_absolute_file_path('11.18.sce')
//filename=pathname+filesep()+'11.18-data.sci'
//exec(filename)
//Rate at which steam is generated(in kg/hr):
r=5000
//Pressure of steam(in bar):
p=20
//Dryness fraction:
x=0.98
//Temperature of feed water(in C):
T=60
//Rate at which coal is supplied(in kg/hr):
r1=600
//Rate at which air is supplied(in kg per kg coal):
r2=16
//Cslorific value of coal(in kJ/kg):
C=30000
//Temperature of boiler room(in C):
Tr=20
//Fraction of heat losr with flue gases:
nl=0.86
//Specific heat of flue gases(in kJ/kg.K):
Cpg=1.005
//From steam tables:
hf=908.79 //kJ/kg
hfg=1890.7 //kJ/kg
//Mass of steam genrated per kg of coal:
ms=r/r1
//Enthalpy of final steam produced(in kJ/kg):
hfi=hf+x*hfg
//Enthalpy of feed water(in kJ/kg):
hfw=251.13
//Heat used for steam generation(in kJ per kg of
    coal):
Q=ms*(hfi-hfw)
//Heat lost per kg of coal:
```

```
Ql=C-Q
//Heat lost with flue gases(in kJ per kg of coal):
Qlf=nl*Ql
//Temperature of flue gases(in C):
Tgas=Tr+Qlf/((r2+1)*Cpg)
printf("\n RESULT \n")
printf("\nTemperature of flue gases = %f C",Tgas)
```

Scilab code Exa 11.19 FD fan power

```
//pathname=get_absolute_file_path('11.19.sce')
//filename=pathname+filesep()+'11.19-data.sci'
//exec(filename)
//Ambient temperature(in K):
Ta=20+273
//Velocity(in m/s):
V=20
//Draught lost through grate(in mm of water column):
hw1=30
//Mechanical efficiency:
nm=0.80
//Rate at which coal is burnt(in kg/hr):
mf=1000
//Rate at which air is supplied(in kg/hr):
ma=16
//Ambient pressure(in bar):
pa=1.01325
//Density of air(in kg/m^3):
d=1.29
//Acceleration due to gravity(in m/s^2):
g=9.81
//Zero temperature(in K):
T0=273
//Pressure equivalent to velocity head(in N/m^2):
P1=d*V^2/2
```

```
P=P1/g //mm of water column
//Total draught loss(in mm of water column):
hw=hw1+P
//Pressure required(in N/m^2):
p=hw*g
//F.D. fan power requirement(in W):
PFD=p*mf*ma*Ta/(d*T0*nm*3600)
printf("\n RESULT \n")
printf("\nF.D. fan power = %f W",PFD)
```

Scilab code Exa 11.20 EXtra heat carried in natural draught

```
//pathname=get_absolute_file_path('11.20.sce')
//filename=pathname+filesep()+'11.20-data.sci'
//exec(filename)
//Height of chimney(in m):
H=45
//Temperature of burnt gases(in K):
Tg=630
//Air requirement(in kg air per kg of fuel burnt):
m=15
//Ambient air temperature(in K):
Ta=300
//Minimum temperatre of artificial draught(in K):
Tga=150+273
//Specific heat of flue gases(in kJ/kg.K):
Cpg=1.005
//Calorific value of fuel(in kJ/kg):
C=30000
//Draught (in mm of water column):
hw=353*H*(1/Ta-(m+1)/(m*Tg))
//Draught (in metres of hot gas column):
hg=H*(m/(m+1)*Tg/Ta-1)
//Temperature of chimney for maximum discharge(in K)
    :
```

```
Tgmax=Ta*2*(m+1)/m
//Chimney efficiency:
n=9.81*H*(m/(m+1)*Tg/Ta-1)/(Cpg*(Tg-Tga)*10^3)*100
//Extra heat carried away by flue gases(in kJ):
Q=(m+1)*Cpg*(Tg-Tga)
//Percentage heat spent in natural draught:
nn=Q/C*100
printf("\n RESULT \n")
printf("\nDraught = %f mm of water",hw)
printf("\nDraught = %f metres of hotgas column",hg)
printf("\nTemperature of chimney gases for maximum
    discharge = %d K",Tgmax)
printf("\nChimney efficiency = %f percent",n)
printf("\nExtra heat carried away by flue gases per
    kg of fuel burnt = %f kJ",Q)
printf("\nPercentage heat carried away in natural
    draught = %f percent",nn)
```

Scilab code Exa 11.21 Height of chimney

```
//pathname=get_absolute_file_path('11.21.sce')
//filename=pathname+filesep()+'11.21-data.sci'
//exec(filename)
//Ambient air temperature(in K):
Ta=27+273
//Temperature of burnt gases(in K):
Tg=630
//Air consumed at rate(in kg air per kg of coal):
m=15
//Ratio of actual draught to thereotical draught:
r=0.60
//Actual draught:
hw1=14
//Theoretical draught:
hw=hw1/r
```

```
//Height of chimney(in m):
H=hw/(353*(1/Ta-(m+1)/(m*Tg)))
printf("\n RESULT \n")
printf("\nHeight of chimney = %f m",H)
```

Scilab code Exa 11.22 Power consumption of induced draught

```
//pathname=get_absolute_file_path('11.22.sce')
//filename=pathname+filesep()+'11.22-data.sci'
//exec(filename)
//Static draught(in mm of water column):
hw1=100
//Amount of discharge(in m^3/s):
mf=30
//Area of outlet section(in m^2):
a=1.8
//Ambient temperature(in K):
Ta=300
//Density(in kg/m^3):
d=1.293
//Fan efficiency:
nm=0.85
//Flue gas temperature(in K):
Tf=150+273
//Zero temperature(in K):
T0=273
//Velocity of air(in m/s):
V=mf/a
//Pressure created due to the gases(in mm of water):
p=d*V^2/(2*9.81)
//Total draught(in mm of water column):
hw=hw1+p
//Power of motor of forced draught fan(in kW):
PFD=hw*9.81*mf*Ta/(T0*nm*10^3)
//Power consumption of induced draught fan(in kW):
```

```
PID=PFD*Tf/Ta
printf("\nRESULTS\n")
printf("\nPower consumption of ID fan = %f kW",PID)
```

Scilab code Exa 11.23 Energy consumed in superheater

```
//pathname=get_absolute_file_path('11.23.sce')
//filename=pathname+filesep()+'11.23-data.sci'
//exec(filename)
//Temperature at which feed water enters and leaves
   economiser(in C):
T1=30
T2=110
//Pressure at which steam is generated(in bar):
p=20
//Dryness fraction:
x=0.98
//Temperature to which it is superheated(in C):
T=300
//Calorific value of coal(in kJ/kg.K):
C=30500
//Steam generation rate(in kg/kg of coal):
r=10
//Specific heat of feed water(in kJ/kg.K):
Cpfw=4.18
//Specific heat of superheated steam(in kJ/kg.K):
Cps=2.093
//From steam tables:
h4=3023.5 //kJ/kg
hf=908.79 //kJ/kg
hfg=1890.7 //kJ/kg
h1=125.79 //kJ/kg
//Enthalpy at state 3(in kJ/kg):
h3=hf+x*hfg
//Total heat supplied(in kJ/kg):
```

```
Q=h4-h1
//Heat consumed in the economiser(in kJ/kg of coal):
Q1=Cpfw*(T2-T1)*8
//Heat consumed in the boiler(in kJ/kg coal):
Q2=(h3-Cpfw*T2)*8
//Heat consumed in the superheater(in kJ/kg steam):
Q3=(h4-h3)*8
//Fraction of energy consumed in economiser:
r1=Q1/C*100
//Fraction of energy consumed in boiler:
r2=Q2/C*100
//Fraction of energy consumed in superheater:
r3=Q3/C*100
printf("\nRESULTS\n")
printf("\nFraction of energy consumed in economiser
   = %f percent",r1)
printf("\nFraction of energy consumed in boiler = %f
    percent",r2)
printf("\nFraction of energy consumed in superheater
    = %f percent",r3)
```

Chapter 12

Steam engine

Scilab code Exa 12.01 Rankine and carnot efficiency

```
//pathname=get_absolute_file_path('12.01.sce')
//filename=pathname+filesep()+'12.01-data.sci'
//exec(filename)
//Pressure at which steam is supplied(in MPa):
p1=0.2
//Temperature of steam(in C):
T=250
//Pressure upto which steam is expanded(in bar):
p2=0.3
//Pressure at which it is finally released(in bar):
p3=0.05
//From steam tables:
h1=2971 //kJ/kg
s1=7.7086 //kJ/kg.K
s2=s1
h2=2601.97 //kJ/kg
v2=5.1767 //m^3/kg
hf=137.82 //kJ/kg
Tmax=393.23 //K
Tmin=305.88 //K
//Work output from engine cycle per kg of steam(in
```

```
    kJ/kg):
W=h1-h2+v2*(p2-p3)*10^2
//Heat input per kg of steam(in kJ/kg):
Q=h1-hf
//Efficiency of modified Rankine cycle:
n=W/Q*100
//Carnot efficiency:
nc=(1-Tmin/Tmax)*100
printf("\n RESULT \n")
printf("\nModified Rankine cycle efficiency = %f
    percent",n)
printf("\nCarnot efficiency = %f percent",nc)
```

Scilab code Exa 12.02 Carnot efficiency and stroke length

```
//pathname=get_absolute_file_path('12.02.sce')
//filename=pathname+filesep()+'12.02-data.sci'
//exec(filename)
//Pressure at which steam is supplied(in bar):
p1=10
//Diameter of the cylinder(in m):
d=0.3
//Length of stroke(in m):
L=0.6
//Pressure to which steam is expanded(in bar):
p2=0.75
//Pressure at which steam is released in the
    condensor(in bar):
p3=0.25
//From steam tables:
h1=2676.2 //kJ/kg
s1=7.3614 //kJ/kg.K
s2=s1
v2=2.1833 //m^3/kg
h2=2628.35 //kJ/kg
```

```
h4=271.93 //kJ/kg
s6=s2
h6=2459.38 //kJ/kg
s6=7.3614 //kJ/kg.K
v6=5.784 //m^3/kg
//Work output from engine cycle per kg of steam(in
   kJ/kg):
W=h1-h2+v2*(p2-p3)*10^2
//Heat input per kg of steam(in kJ/kg):
Q=h1-h4
//Efficiency of modified Rankine cycle:
n=W/Q*100
//Volume of the cylinder(in m^3):
V=%pi*d^2*L/4
//Mass of steam in a stroke(in kg):
m=V/v2
//Volume requiremnet at 6(in m^3):
V1=m*v6
//New stroke length(in m):
L1=V1*4/(%pi*d^2)
printf("\n RESULT \n")
printf("\nModified Rankine cycle efficiency = %f
   percent",n)
printf("\nNew stroke length = %f cm",L1*100)
```

Scilab code Exa 12.03 Indicated power

```
//pathname=get_absolute_file_path('12.03.sce')
//filename=pathname+filesep()+'12.03-data.sci'
//exec(filename)
//Diameter of the bore(in m):
d=0.3
//Length of the stroke(in m):
L=0.6
//Occerance od cut-off:
```

```
r1=0.4
//Pressure at which steam enters(in bar):
p1=7.5
//Pressure at exhaust(in bar):
p3=0.1
//Rpm of the engine:
n=180
//Diagram factor:
d1=0.6
//Expansion ratio:
r=1/r1
//Hypothetical mean effective pressure(in bar):
mep=p1/r*(1+log(r))-p3
//Actual mean effective pressure(in bar):
mepa=mep*d1
//Indicated power(in kW):
IP=mepa*L*%pi*d^2*2*n*10^2/(4*60)
printf("\n RESULT \n")
printf("\nIndicated power = %f kW",IP)
```

Scilab code Exa 12.04 Specific steam consumption

```
//pathname=get_absolute_file_path('12.04.sce')
//filename=pathname+filesep()+'12.04-data.sci'
//exec(filename)
//Steam is admitted at pressure(in bar):
p1=15
//Pressure at which steam exhausts(in bar):
p3=0.75
//Cut-off occuring at:
r1=0.25
//Power produced by the engine(in hp):
P=150
//Rpm of engine:
n=240
```

```
//Mechanical efficiency:
nm=0.85
//Diagram factor:
d1=0.7
//Brake thermal efficiency:
nb=0.2
//Stroke to bore ratio:
r2=1.5
//From steam tables:
h15=2803.3
hf=384.39
//Expansion ratio:
r=1/r1
//Hypothetical mean effective pressure(in bar):
mep=p1/r*(1+log(r))-p3
//Actual mean effective pressure(in bar):
mepa=mep*d1
//Indicated horse power(in kW):
IP=P/nm
//Diameter of bore(in m):
d=((IP*4*60*0.7457)/(mepa*10^2*r2*%pi*n))^(1/3)
//Stroke length(in m):
L=d*r2
//Heat added per kg of steam(in kJ/kg):
Q=h15-hf
//Specific steam consumption(in kg/hp.hr):
m=0.7457*3600/(nb*Q)
printf("\n RESULT \n")
printf("\nBore = %f cm",d*100)
printf("\nStroke = %f cm",L*100)
printf("\nSpecific steam consumption = %f kg/hp.hr",
   m)
```

Scilab code Exa 12.05 Diagram factor and indicated thermal efficiency

```
//pathname=get_absolute_file_path('12.05.sce')
//filename=pathname+filesep()+'12.05-data.sci'
//exec(filename)
//Steam consumption rate(in kg/a):
m=18/60
//Indicated power(in kW):
IP=100
//Rpm of engine:
n=240
//Bore diameter(in m):
d=0.3
//Stroke length(in m):
L=0.4
//Pressure at which steam is admitted(in bar):
p1=10
//Exhaust pressure(in bar):
p3=0.75
//Occurance of cut-off:
r1=0.25
//Enthalpy of steam(in kJ/kg):
h1=2875.3 //kJ/kg
hf=384.39 //kJ/kg
//Heat added per kg of steam(in kJ/kg):
Q=h1-hf
//Expansion ratio:
r=1/r1
//Hypothetical mean effective pressure(in bar):
mep=p1/r*(1+log(r))-p3
//Theoretical indicated power(in kW):
IPt=mep*L*%pi*d^2*n*10^2/(60)
//Diagarm factor:
d1=IP/IPt
//Indicated thermal efficiency:
n=IPt/(m*Q)*100
printf("\n RESULT \n")
printf("\nDiagram factor = %f",d1)
printf("\nIndicated thermal efficiency = %f percent"
   ,n)
```

Scilab code Exa 12.06 Thermal efficiency

```
//pathname=get_absolute_file_path('12.06.sce')
//filename=pathname+filesep()+'12.06-data.sci'
//exec(filename)
//Pressure at which steam is aupplied(in bar):
p1=10
//Dryness fraction:
x=0.9
//Pressure at exhaust(in bar):
p3=1
//Occurence of cut-off:
r1=0.6
//From steam tables:
h1=2576.58 //kJ/kg
v1=0.1751 //m^3/kg
hf=417.46 //kJ/kg
//Heat added per kg of steam(in kJ/kg):
Q=h1-hf
//Specific volume at state 2(inm^3/kg):
v2=v1/r1
//Expansion ratio:
r=1/r1
//Net expansive work per kg of steam(in kJ/kg):
Wne=v1*(p1-p3)*10^2
//Expansive work per kg of steam(in kJ/kg):
We=p1*v1*10^2*log(r)-p3*10^2*(v2-v1)
//Total work per kg of steam(in kJ/kg):
Wt=Wne+We
//Fraction of work obtained by expansive working:
r2=We/Wt*100
//Thermal efficiency of cycle:
n=Wt/Q*100
printf("\n RESULT \n")
```

```
printf("\nFraction of expansive work = %f percent of total output",r2)
printf("\nThermal efficiency  = %f percent",n)
//Steam admitted per cycle when cut-off becomes unity(in kg):
m=1/r1
//Total work per cycle(in kJ):
W=(p1-p3)*v1*m*10^2
//% increase in work:
dw=(W-Wt)/Wt*100
//Modified thermal efficiency:
n1=W/(m*Q)*100
//% decrease in efficiency:
dn=(n-n1)/n*100
printf("\nPercentage increase in work = %f percent",dw)
printf("\nPercentage decrease in efficiency = %f percent",dn)
```

Scilab code Exa 12.07 Bore diameter

```
//pathname=get_absolute_file_path('12.07.sce')
//filename=pathname+filesep()+'12.07-data.sci'
//exec(filename)
//Power produced(in bhp):
P=60
//Pressure at which steam is admitted(in bar):
p1=12
//Pressure at exhaust(in bar):
p3=1
//Rpm of engine:
n=240
//Piston speed(in m/s):
v=2
//Diameter of piston(in m):
```

```
d=0.04
//Occurence of cut−off:
n=0.60
//Clearance volume to stroke volume ratio:
r1=0.05
//Diagram factor:
d1=0.8
//Mechanical efficiency:
nm=0.90
//Expansion ratio:
r=(1+r1)/n
//Mean effective pressure(in bar):
mep=(p1*12*(1+log(r))-1*21-(12-1))/(21-1)
//Actual mean effective pressure(in bar):
mepa=mep*d1
//Effective area(in m^2):
A=P*0.7457/(nm*mepa*10^2*v)
//Bore diameter(in m):
D=sqrt((A-%pi*d^2/4)*4/(2*%pi))
printf("\n RESULT \n")
printf("\nBore = %f cm",D*100)
```

Scilab code Exa 12.08 Heat leakage

```
//pathname=get_absolute_file_path('12.08.sce')
//filename=pathname+filesep()+'12.08−data.sci'
//exec(filename)
//Diameter of cylinder(in m):
D=0.2
//Length of stroke(in m):
L=0.3
//Clearance volume(in cm^3):
Vc=2*10^3
//Mass of steam used per stroke(in kg):
ms=0.05
```

```
//Point at which compression starts:
c=0.80 //of stroke
//Pressure of steam when compression starts(in bar):
p4=1
//Cut-off point:
r1=0.10 //of stroke
//Release:
r2=0.90 //of stroke
//Pressure at states 1 & 2(in bar):
p1=15
p2=3
//From steam tables:
v4=1.6940 //m^3/kg
vg15=0.13177 //m^3/kg
vg3=0.6058 //m^3/kg
u1=1590.79 //kJ/kg
u2=1216.73 //kJ/kg
//Clearance volume(in m^3):
V6=Vc*10^(-6)
V5=V6
//Stroke volume(in m^3):
Vs=%pi*D^2/4*L
//Volume at state 3(in m^3):
V3=V6+Vs
//Volume at state 4(in m^3):
V4=V3-c*(V3-V6)
//Mass of steam at state 4(in kg):
m4=V4/v4
//Total mass of steam during expansion(in kg):
m=m4+ms
//Volume at cut-off point(in m^3):
V1=V6+r1*(V3-V6)
//Dryness fraction at cut-off point:
x1=V1/(m*vg15)
//Volume at point of release(in m^3):
V2=V6+r2*(V3-V6)
//Dryness fraction at point of release:
x2=V2/(m*vg3)
```

```
//Index of expansion:
n=log(p1/p2)/log(V2/V1)
//Work done in a stroke(in kJ):
W=(p1*V1-p2*V2)/(n-1)
//Work done per kg of steam(in kJ/kg):
Ws=W/m
//Change in internal energy(in kJ/kg):
du=u2-u1
//Heat transfer(in kJ/kg):
dQ=du+Ws
printf("\n RESULT \n")
printf("\nTotal mass of steam during expansion = %f
    kg",m)
printf("\nDryness fraction at cut-off and release =
    %f,%f",x1,x2)
printf("\nHeat leakage = %f kJ/kg steam",-dQ)
```

Scilab code Exa 12.09 Percentage re evaporation

```
//pathname=get_absolute_file_path('12.09.sce')
//filename=pathname+filesep()+'12.09-data.sci'
//exec(filename)
//Point of sut-off:
r1=0.3
//Pressure at state 4(in bar):
p4=4
//Volume at state 4(in m^3):
V4=0.15
//Pressure at state 1(in m^3):
p1=12
//Pressure at release(in bar):
p2=5
//Indicated volume at release(in m^3):
V2=0.5
//Bore diameter(in m):
```

```
d=0.6
//Stroke length(in m):
L=1.20
//Clearance volume ratio:
c=0.10
//Mass of steam admitted(in kg/stroke):
ms=1.5
//Number of working strokes(per second):
nw=180*60
//From steam tables:
vg4=0.4625 //m^3/kg
vg12=0.16333 //m^3/kg
vg5=0.3749 //m^3/kg
//Stroke volume(in m^3):
Vs=%pi*d^2/4*L
//Clearance volume(in m^3):
V5=c*Vs
//Total volume of cylinder(in m^3):
V3=V5+Vs
//Volume at cut-off point(in m^3):
V1=V5+r1*Vs
//Mass of steam at state 4(in kg):
m4=V4/vg4
//Total mass during steam expansion(in kg):
m=m4+ms
//Dryness fraction at cut-off point:
x1=V1/(m*vg12)
//Missing quantity per hour(in kg):
mq1=(m-m*x1)*nw
//Dryness fraction at point of release:
x2=V2/(m*vg5)
//Missing quantity per hour(in kg):
mq2=(m-m*x2)*nw
//Percentage re-evaporation during expansion:
P=(mq1-mq2)/mq1*100
printf("\n RESULT \n")
printf("\nDryness fraction at cut-off = %f",x1)
printf("\nDryness fraction at release = %f",x2)
```

```
printf("\nMissing quanity at cut off = %f kg/hr",mq1)
printf("\nMissing quanity at release = %f kg/hr",mq2)
printf("\nPercentage re-evaporation = %f percent",P)
```

Scilab code Exa 12.10 Indicated power

```
//pathname=get_absolute_file_path('12.10.sce')
//filename=pathname+filesep()+'12.10-data.sci'
//exec(filename)
//Pressure at which steam is supplied(in kPa):
p1=1.5*10^3
//Dryness fraction:
x1=0.9
//Pressure at exhaust(in kPa):
p4=40
//Diagram factor reffered to LP cylinder:
d1LP=0.8
//Stroke length(in m):
L=0.38
//Bore of HP cylinder(in m):
dHP=0.20
//Bore of LP cylinder(in m):
dLP=0.30
//Rpm of engine:
N=240
//Area of HP cylinder(in m^2):
AHP=%pi*(dHP^2)/4
//Area of LP cylinder(in m^2):
ALP=%pi*(dLP^2)/4
//Intermediate pressure(in kPa):
p2=192
//Volume at state 2(in m^3):
V2=AHP*L
```

```
//Volume at state 1(in m^3):
V1=V2*p2/p1
//Volume of LP cylinder(in m^3):
VLP=ALP*L
//Expansion ratio throughout the engine:
r=VLP/V1
//Mean effective pressure(in kPa):
mep=p1/r*(1+log(r))-p4
//Actual mep(in kPa):
mepa=mep*d1LP
//Indicated power(in kW):
IP=mepa*L*ALP*N/60*2
//Volume of steam admitted per hour(in m^3):
Vs=V1*N*2*60
//Specific volume of steam being admitted(in m^3/kg)
    :
v1=0.1187
//Steam consumption(in kg/hr):
m=Vs/v1
printf("\n RESULT \n")
printf("\nIndicated power = %f kW",IP)
printf("\nSteam consumption = %f kg/hr",m)
```

Scilab code Exa 12.11 Indicated power

```
//pathname=get_absolute_file_path('12.11.sce')
//filename=pathname+filesep()+'12.11-data.sci'
//exec(filename)
//Pressure at which steam is supplied(in kPa):
p1=1.4*10^3
//Pressure at exhaust(in kPa):
p4=25
//Expansion ratio:
r=8
//Rpm of engine:
```

```
N=240
//Bore diameter(in m):
d=0.60
//Stroke length(in m):
L=0.60
//Diagram factor:
d1=0.8
//Area of cylinder(in m^2):
A=%pi*d^2/4
//Hypothetical mep(in kPa):
mep=p1/r*(1+log(r))-p4
//Actual mep(in kPa):
mepa=mep*d1
//Indicated power(in kW):
IP=mepa*L*A*N/60*2
//Work done in HP cylinder(in kJ):
W=mepa*A*L/2
//Volume at state 1(in m^3):
V1=%pi*d^2*L/(4*8)
//Volume at state 2(in m^3):
V2=2.71^(W/(p1*V1))*V1
//Diameter of HP cylinder(in m):
D=sqrt(V2*4/(L*%pi))
//Intermediate pressure(in kPa):
p2=p1*V1/V2
printf("\n RESULT \n")
printf("\nIndicated power = %f kW",IP)
printf("\nDiameter of HP cylinder = %f cm",D*100)
printf("\nIntermediate pressure = %f kPa",p2)
```

Scilab code Exa 12.12 Speed of engine and diameter of cylinder

```
//pathname=get_absolute_file_path('12.12.sce')
//filename=pathname+filesep()+'12.12-data.sci'
//exec(filename)
```

```
//Pressure at which steam is supplied(in kPa):
p1=1.5*10^3
//Pressure at exhaust(in kPa):
p4=25
//Power output(in kW):
P=250
//Expansion ratio:
r=12
//Diameter of LP cylinder(in m):
d=0.40
//Stroke length(in m):
L=0.60
//Diagram factor:
d1=0.75
//Expansion ratio in HP cylinder:
r1=2.5
//Area of cylinder(in m^2):
A=%pi*d^2/4
//Hypothetical mep(in kPa):
mep=p1/r*(1+log(r))-p4
//Actual mep(in kPa):
mepa=mep*d1
//Rpm of engine:
N=P/(mepa*L*A*2)*60
printf("\n RESULT \n")
printf("\nSpeed of engine = %d rpm",N)
//Volume of LP cylinder(in m^3):
V3=A*L
V4=V3
//Cut-off volume in HP cylinder(in m^3):
Vc=V4/r
//Total volume in HP cylinder(in m^3):
Vt=Vc*r1
//Diameter of HP cylinder(in m):
D=sqrt(Vt*4/(L*%pi))
printf("\nDiameter of HP cylinder = %f cm",D*100)
```

Scilab code Exa 12.13 Overall diagram factor

```
//pathname=get_absolute_file_path('12.13.sce')
//filename=pathname+filesep()+'12.13-data.sci'
//exec(filename)
//Diameter of HP, LP and IP cylinder(in m):
dhp=0.25
dip=0.40
dlp=0.85
//MEPs of the cylinders(in kPa):
mephp=0.5*10^3
mepip=0.3*10^3
meplp=0.1*10^3
//Pressure at which steam is supplied(in kPa):
p1=1.5*10^3
//Pressure at exhaust(in kPa):
p4=25
//Cut-off occurs at:
r1=0.60
//Area of HP cylinder(in m^2):
AHP=%pi*dhp^2/4
//Area of IP cylinder(in m^2):
AIP=%pi*dip^2/4
//Area of LP cylinder(in m^2):
ALP=%pi*dlp^2/4
//Mep of HP referred to LP cylinder(in kPa):
mep1=mephp*AHP/ALP
//Mep of IP referred to LP cylinder(in kPa):
mep2=mepip*AIP/ALP
//Overall mep referred to LP cylinder(in kPa):
mept=mep1+mep2+meplp
//Overall expansion ratio:
r=ALP/(r1*AHP)
//Hypothetical mep(in kPa):
```

```
mep=p1/r*(1+log(r))-p4
//Overall diagram factor:
d1=mept/mep
//% of HP cylinder output:
P1=mep1/mept*100
//% of HP cylinder output:
P2=mep2/mept*100
//% of HP cylinder output:
P3=meplp/mept*100
printf("\nRESULT\n")
printf("\nActual mep referred to LP = %f kPa",mept)
printf("\nHypothetical mep referred to LP = %f kPa",
   mep)
printf("\nOverall diagram factor = %f",d1)
printf("\nPercentage of HP, IP and LP cylinder
   outputs = %f, %f and %f percent",P1,P2,P3)
```

Scilab code Exa 12.14 Total output

```
//pathname=get_absolute_file_path('12.14.sce')
//filename=pathname+filesep()+'12.14-data.sci'
//exec(filename)
//Pressure at which steam is supplied(in bars):
p1=7
//Pressure at exhaust(in bars):
p5=0.25
//Diameter of HP and LP cylinder(in m):
dhp=0.25
dlp=0.50
//Cut-off point of HP and LP cylinders:
r1=0.30
r2=0.45
//Clearance volume of HP and LP cylinders:
c1=0.10
c2=0.05
```

```
//Diagram factors of HP and LP cylinders:
d1hp=0.8
d1lp=0.7
//Rpm pf engine:
N=100
//Let the length of stroke(in m):
L=1
//Volume of HP cylinder(in m^2):
VHP=%pi*dhp^2/4*L
//Volume of LP cylinder(in m^2):
VLP=%pi*dlp^2/4*L
//Clearance volume(in m^2):
V9=c1*VHP
V7=c2*VLP
//Total volume of cylinders(in m^3):
V2=VHP+V9
V5=VLP+V7
//Volume at cut-off in HP cylinder(in m^3):
V1=V9+r1*VHP
V3=V7+r2*VLP
//Expansion ratio:
rhp=V2/V1
rlp=V5/V3
//Pressure at state 3(in kPa):
p3=p1*10^2*V1/V3
//Actual mep for HP cylinder(in kPa):
mepahp=d1hp*(p1*10^2*V1*(1+log(rhp))-p3*V2-(p1*10^2-
    p3)*V9)/VHP
//Actual mep for LP cylinder(in kPa):
mepalp=62.96
//Actual mep of HP reffered to LP cylinder:
mepa=mepahp*VHP/VLP
//Total mep(in kPa):
mept=mepalp+mepa
//Total output(in kW):
W=mept*VLP*100/60
printf("\nRESULT\n")
printf("\nmep of Hp referred to LP = %f kPa",mepa)
```

```
printf("\nmep of LP = %f kPa",mepalp)
printf("\nTotal output = %f*L kW where L is stroke
    length",W)
```

Scilab code Exa 12.15 Steam used per hp

```
//pathname=get_absolute_file_path('12.15.sce')
//filename=pathname+filesep()+'12.15-data.sci'
//exec(filename)
//Duration of trial(in min):
t=15
//Bore diameter(in m):
d=0.25
//Stroke length(in m):
L=0.30
//Brake diameter(in m):
bd=1.5
//Net brake load(in N):
bl=300
//Speed of engine:
N=240
//Steam pressure(in bar):
p1=10
//Dryness fraction:
x=0.9
//Mep at cover end(in bar):
mep=0.9
//Steam utilised(in kg):
m1=15
//Steam consumption per hour(in kg/hr):
m=m1/t*60
//Indicated horse power(in kW):
IP=mep*10^2*L*%pi*d^2*240*2/(4*0.7457*60)
//Steam used per(hp.hr):
m2=60/IP
```

```
printf("\nRESULT\n")
printf("\nSteam used per = %f kg/hp.hr",m2)
```

Scilab code Exa 12.16 Brake specific steam consumption

```
//pathname=get_absolute_file_path('12.16.sce')
//filename=pathname+filesep()+'12.16-data.sci'
//exec(filename)
//Bore diameter(in m):
d=0.38
//Stroke length(in m):
L=0.50
//Piston rod diameter(in m):
pd=0.05
//Speed of engine(in rpm):
N=150
//Steam consumption(in kg/min):
m=36
//Brake load(in kN):
F=7
//Brake diameter(in m):
bd=2
//Area of indicator diagram at cover end(in cm^2):
aco=28
//Area of indicator diagram at crank end(in cm^2):
acr=26
//Length of indicator diagram(in m):
l=0.07
//Spring scale(in kPa/mm):
s=15
//Mep at crank end(in kPa):
mepcr=acr*100*s/(l*10^3)
//Mep at cover end(in kPa):
mepco=aco*100*s/(l*10^3)
//IP at crank end(in kW):
```

```
IPcr=mepcr*L*%pi*(d^2-pd^2)/4*N/60
//IP at cover end(in kW):
IPco=mepco*L*%pi*(d^2)/4*N/60
//IP(in kW):
IP=IPcr+IPco
//Brake power(in kW):
BP=2*%pi*N/60*F*1
//Mechanical efficiency:
n=BP/IP
//ISFC(in kg/kW.h):
ISFC=m*60/IP
//BSFC(in kg/kW.h):
BSFC=m*60/BP
printf("\nRESULT\n")
printf("\nIndicated power = %f kW",IP)
printf("\nBrake power = %f kW",BP)
printf("\nIndicated specific steam consumption = %f
    kg/kW.h",ISFC)
printf("\nBrake specific steam consumption = %f kg/
    kW.h",BSFC)
```

Scilab code Exa 12.17 `Indicated steam consumption`

```
//pathname=get_absolute_file_path('12.17.sce')
//filename=pathname+filesep()+'12.17-data.sci'
//exec(filename)
//Bore: 24 cm
//Stroke: 34 cm
//Engine speed: 150 rpm
//Piston rod diameter: 5cm
//Brake load: 120kg
//Spring balance reading: 100N.
//Brake wheel drum diameter: 100cm;
//Steam inlet state: 15 bar, 0.98 dry,
//Mean effective pressure at cover end: 1.8 bar
```

```
//Mean effective pressure at crank end: 1.6 bar
//Cooling water flow through condenser: 42 kg/min
//Rise in temperature of cooling water: 20 C
//Condensate discharged from condensor: 4 kg/min
//Temperature of condensate: 50 C
//From steam tables:
hf=844.89 //kJ/kg
hfg=1947.3 //kJ/kg
hcond=209.33 //kJ/kg
//Brake power(in kW):
BP=2*%pi*150*(120*9.81-100)*(100/2)*10^(-2)/(1000*60)
//IP at cover end(in kW):
IPco=1.8*10^2*0.34*%pi/4*(0.24)^2*150/60
//IP at crank end(in kW):
IPcr=1.6*10^2*0.34*%pi/4*(0.24^2-0.05^2)*150/60
//Total IP(in kW):
IP=IPco+IPcr
//Mechanical efficiency:
n=BP/IP
//Enthalpy of steam at inlet(in kJ/kg):
hs=hf+0.98*hfg
//Energy supplied by the steam(in kJ/kg):
E=hs-hcond
//Steam consumption rate(in kg/hr):
m=4*60
//Brake thermal efficiency:
nbth=3600/((m/BP)*E)*100
//Indicated steam consumption(in kg/kW.h):
ISFC=m/IP
printf("\nRESULT\n")
printf("\nBrake thermal efficiency = %f percent",nbth)
printf("\nIndicated specific steam consumption = %f kg/kW.h",ISFC)
```

Chapter 13

Nozzles

Scilab code Exa 13.01 Dryness fraction

```
//pathname=get_absolute_file_path('13.01.sce')
//filename=pathname+filesep()+'13.01-data.sci'
//exec(filename)
//Pressure of dry steam(in bar):
p1=10
//Velocity of steam entering(in m/s):
C1=100
//Velocity of steam leaving the nozzle(in m/s):
C2=300
//Pressure of steam at exit(in bar):
p2=5
//Mass flow rate(in kg/s):
m=16
//Heat loss to surroundings(in kJ/kg):
q=10
//From steam tables:
h1=2778.1 //kJ/kg
hf=640.23 //kJ/kg
hfg=2108.5 //kJ/kg
//Heat drop in the nozzle(in kJ/kg):
dh=(q*10^3+(C1^2-C2^2)/2)/1000
```

```
//Total heat drop(in kJ/s):
dQ=-dh*m
//Enthalpy at state 2(in kJ/kg):
h2=h1+dh
//Dryness fraction at state 2:
x2=(h2-hf)/hfg
printf("\nRESULT\n")
printf("\nHeat drop in the nozzle = %f kJ/kg",-dh)
printf("\nTotal heat drop = %f kJ/s",dQ)
printf("\nDryness fraction at exit = %f",x2)
```

Scilab code Exa 13.02 Mass flow rate

```
//pathname=get_absolute_file_path('13.02.sce')
//filename=pathname+filesep()+'13.02-data.sci'
//exec(filename)
//Steam entering at pressure(in bar):
p1=10
//Pressure at which steam leaves(in bar):
p2=6
//Cross-section area of exit of nozzle(in cm^2):
A2=20
//From steam tables:
h1=3478.5 //kJ/kg
s1=7.7622 //kJ/kg.K
s2=s1
T2=418.45 //C(by interpolation)
h2=3309.51 //kJ/kg
v2=0.5281 //m^3/kg
//Velocity at exit(in m/s):
C2=sqrt(2*(h1-h2)*10^3)
//Mass flow rate(in kg/s):
m=A2*10^(-4)*C2/v2
printf("\nRESULT\n")
printf("\nMass flow rate= %f kg/s",m)
```

Scilab code Exa 13.03 Coefficient of velocity

```
//pathname=get_absolute_file_path('13.03.sce')
//filename=pathname+filesep()+'13.03-data.sci'
//exec(filename)
//Pressure of steam entering(in bar):
p1=12
//Pressure at exit(in bar):
p2=6
//Mass flow rate(in kg/s):
m1=5
m2=m1
m3=m1
//Exit velocity(in m/s):
C3a=500
//From steam tables:
h1=3045.8 //kJ/kg
h2=2900.05 //kJ/kg
s2=7.0317 //kJ/kg.K
s1=s2
s3=s2
v2=0.3466 //m^3/kg
h3=2882.55 //kJ/kg
v3=0.3647 //m^3/kg
//For superheated steam:
n=1.3
//Pressue at state 2(in bar):
p2=p1*(2/(n+1))^(n/(n-1))
//Velocity at throat(in m/s):
C2=sqrt(2*(h1-h2)*10^3)
//Cross-sectional area at throat(in m^2):
A2=m2*v2/C2
//Ideal velocity at exit(in m/s):
C3=sqrt(2*(h1-h3)*10^3)
```

```
//Cross-sectional area at exit(in m^2):
A3=m3*v3/C3a
//Coefficient of velocity:
r=C3a/C3
printf("\nRESULT\n")
printf("\nCross-sectional area at throat = %f m^2",
   A2)
printf("\nCross-sectional area at exit = %f m^2",A3)
printf("\nCoefficient of velocity = %f",r)
```

Scilab code Exa 13.04 Area at exit

```
//pathname=get_absolute_file_path('13.04.sce')
//filename=pathname+filesep()+'13.04-data.sci'
//exec(filename)
//Pressure of steam entering(in bar):
p1=16
//Pressure at exit(in bar):
p3=5
//Mass flow rate(in kg/s):
m1=1
m2=m1
m3=m1
//From steam tables:
//For case 1:
h1=3034.8 //kJ/kg
s1=6.8844 //kJ/kg.K
v1=0.15862 //m^3/kg
n=1.3
h2=2891.39 //kJ/kg
h3=2777 //kJ/kg
v2=0.2559 //m^3/kg
v3=0.3882 //m^3/kg
//For case 2:
h2a=2905.73 //kJ/kg
```

```
v2a=0.2598 //m^3/kg
v3a=0.40023 //m^3/kg
//Pressure at the throat of nozzle(in bar):
p2=p1*(2/(n+1))^(n/(n-1))
//Heat drop up to throat section(in kJ/kg):
q12=h1-h2
//Velocity at throat(in m/s):
C2=sqrt(2*(h1-h2)*10^3)
//Heat drop from exit(in kJ/kg):
q23=h2-h3
//Velocity at exit(in m/s):
C3=sqrt(2*(h2-h3)*10^3+C2^2)
//Throat area(in m^2):
A2=m2*v2/C2
//Exit area(in m^2):
A3=m3*v3/C3
printf("\nRESULT\n")
printf("\nFor frictionless expansion")
printf("\nThroat area = %f cm^2",A2*(10^4))
printf("\nExit area = %f cm^2",A3*(10^4))
//Considering expansion to have 10% friction loss:
q12a=0.9*q12
//Actual velocity at throat(in m/s):
C2a=sqrt(2*q12a*10^3)
//Actual throat area(in m^2):
A2a=m2*v2a/C2a
//Actual drop at the exit of the nozzle(in kJ/kg):
q23a=0.9*q23
//Actual enthalpy at state 3(in kJ/kg):
h3a=h2a-q23a
//Actual velocity at exit(in m/s):
C3a=sqrt(2*q23a*10^3+C2a^2)
//Actual area at exit(in m^2):
A3a=m3*v3a/C3a
printf("\n\nConsidering friction")
printf("\nThroat area = %f cm^2",A2a*(10^4))
printf("\nExit area = %f cm^2",A3a*(10^4))
```

Scilab code Exa 13.05 Area at exit

```
//pathname=get_absolute_file_path('13.05.sce')
//filename=pathname+filesep()+'13.05-data.sci'
//exec(filename)
//Power of turbine(in MW):
P=1
//Pressure of steam entering(in bar):
p1=20
//Steam consumption rate(in kg/kW.h):
m=8
//Pressure at which steam leaves(in bar):
p3=0.2
//Throat diameter(in m):
d=0.01
//From Mollier diagram:
q12=142 //kJ/kg
v2=0.20 //m^3/kg
q13=807 //kJ/kg
v3=7.2 //m^3/kg
//Velocity at throat(in m/s):
C2=sqrt(2*q12*10^3)
//Mass flow rate:
m2=%pi*d^2/4*C2/v2
m3=m2
//Number of nozzles:
n=10^3*m/(3600*m2)
//Useful heat drop:
q13a=0.90*q13
//Velocity at exit(in m/s):
C3=sqrt(2*10^3*q13a)
//Area at exit(in m^2):
A3=m3*v3/C3
printf("\nRESULT\n")
```

```
printf("\nNumber of nozzles required = %d",n+1)
printf("\nArea at exit = %f cm^2",A3*10^4)
```

Scilab code Exa 13.06 Velocity at throat and cone angle

```
//pathname=get_absolute_file_path('13.06.sce')
//filename=pathname+filesep()+'13.06-data.sci'
//exec(filename)
//Pressure at which steam is supplied(in MPa):
p1=0.7
//Length of diverging nozzle(in m):
l=0.06
//Throat diameter(in mm):
d=0.005
//Pressure at which steam leaves the nozzle(in MPa):
p3=0.1
//From Mollier diagram:
q12=138 //kJ/kg
v2=0.58 //m^3/kg
T=203 //C
q23=247 //kJ/kg
q23a=209.95 //kJ/kg
v3a=1.7 //m^3/kg
//Velocity at throat(in m/s):
C2=sqrt(2*q12*10^3)
//Mass flow rate(in kg/s):
m1=%pi*d^2/4*C2/v2
m2=m1
m3=m1
//Total heat drop(in kJ/kg):
q=q12+q23a
//Velocity at exit(in m/s):
C3=sqrt(2*10^3*q)
//Area at exit(in m^2):
A3=m3*v3a/C3
```

```
//Diameter at exit(in mm):
d1=(sqrt(A3*4/%pi))*10^3
a=atan((d1-d*10^3)/(2*60))*180/%pi
printf("\nRESULT\n")
printf("\nWith no losses, temperature at throat = %d
    C",T)
printf("\nVelocity at throat = %f m/s",C2)
printf("\nWith losses, cone angle = %f",2*a)
```

Scilab code Exa 13.07 Length and radial height of nozzle

```
//pathname=get_absolute_file_path('13.07.sce')
//filename=pathname+filesep()+'13.07-data.sci'
//exec(filename)
//Power of the turbine(in hp):
P=5000
//Steam required(in kg of steam/hp-hr):
m=P*6/3600
//Efficiency of nozzle:
n=0.90
//Nozzle angle:
a=12
//Pitch(in cm):
p=5
//Thickness(in cm):
t=0.3
//From steam tables:
h1=2794 //kJ/kg
s1=6.4218 //kJ/kg.K
s2=s1
x2=0.9478
h2=2662.2 //kJ/kg
x2a=0.9542
v2a=0.2294 //m^3/kg
//Change in enthalpy(in kJ/kg):
```

```
h12=h1-h2
//Actual change(in kJ/kg):
h12a=n*h12
//Velocity at inlet(in m/s):
C2=sqrt(2*h12a*10^3)
//Area at exit of nozzle(in cm^2):
A2=m*v2a/C2*10^4
//Approximate length of the nozzle(in cm):
l=60*%pi/3
//Number of nozzles:
n=int(l/p)+1
//Correct length of nozzle arc:
l1=n*p
//Radial height of nozzle(in cm):
h=A2/((p*sin(a*%pi/180)-t)*n)
printf("\nRESULT\n")
printf("\nLength of nozzle = %d cm",l1)
printf("\nRadial height of nozzle = %f cm",h)
```

Scilab code Exa 13.08 Exit velocity

```
//pathname=get_absolute_file_path('13.08.sce')
//filename=pathname+filesep()+'13.08-data.sci'
//exec(filename)
//Pressure at which steam enters(in bar):
p1=13
//Pressure at which steam leaves(in bar):
p2=6
//Temperature of steam entering(in K):
T1=150+273
//Adibatic insex of compression:
r=1.4
//Final temperature of steam(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Exit velocity(in m/s):
```

```
C2=sqrt(2*1.005*(T1-T2))
printf("\nRESULT\n")
printf("\nExit velocity = %f m/s",C2)
```

Scilab code Exa 13.09 Nozzle efficiency

```
//pathname=get_absolute_file_path('13.09.sce')
//filename=pathname+filesep()+'13.09-data.sci'
//exec(filename)
//Force on the plate(in N):
F=350
//Initial pressure(in bar):
p1=8
//Final pressure(in bar):
p3=1
//Throat cross-sectional area(in m^2):
A2=5*10^(-4)
//From steam tables:
h1=2769.1 //kJ/kg
s1=6.6628 //kJ/kg.K
s2=s1
s3=s1
x2=0.9717
h2=2685.17 //kJ/kg
v2=0.3932 //m^3/kg
x3=0.8238
h3=2277.6 //kJ/kg
//Enthalpy change(in kJ/kg):
h12=h1-h2
//Velocity at throat(in m/s):
C2=sqrt(2*h12*10^3)
//Discharge at throat(in kg/s):
m=A2*C2/v2
//Actual exit velocity(in m/s):
C3a=F/m
```

```
//Theoretical enthalpy drop(in kJ/kg):
h23=h2-h3
//Nozzle efficiency:
n=C3a^2/(2*h23*10^3)
printf("\nRESULT\n")
printf("\nDischarge at throat = %f kg/s",m)
printf("\nNozzle efficiency = %f percent",n*100)
```

Scilab code Exa 13.10 Degree of supersaturaion and amount of undercooling

```
//pathname=get_absolute_file_path('13.10.sce')
//filename=pathname+filesep()+'13.10-data.sci'
//exec(filename)
//Mass flow rate(in kg/s):
m=5/60
//Pressure at which steam is discharged(in bar):
p3=1
//Initial pressure(in bar):
p1=10
//Initial temperature(in K)
T1=200+273
//Adiabatic index of compression:
n=1.3
//From steam tables:
h1=2827.9 //kJ/kg
s1=6.6940 //kJ/kg.K
v1=0.2060 //m^3/kg
h2a=2711.23 //kJ/kg
s2a=6.6749 //kJ/kg.K
s3=s2a
h3=2420.08 //kJ/kg
v3=1.5025 //m^3/kg
psat=3.44 //bar (at T=138.18 C)
Tsat=155.12 //C (at p=5.45 bar)
//Pressure at throat(in bar):
```

```
p2=p1*(2/(n+1))^(n/(n-1))
//Velocity at exit(in m/s):
C3=sqrt(2*(h1-h3)*10^3)
//Exit area(in m^2):
A3=m*v3/C3
//Diameter of nozzle at exit(in m):
d=sqrt(A3*4/%pi)
//Temperature at throat(in K):
T2=T1*(p2/p1)^((n-1)/n)
//Degree of supersaturation:
d1=p2/psat
//Amount of undercooling(in C):
u=Tsat-(T2-273)
printf("\nRESULT\n")
printf("\nDegree of supersaturation = %f",d1)
printf("\nAmount of undercooling = %f C",u)
```

Scilab code Exa 13.11 Degree of undercooling

```
//pathname=get_absolute_file_path('13.11.sce')
//filename=pathname+filesep()+'13.11-data.sci'
//exec(filename)
//Initial pressure(in bar):
p1=4
//Initial temperature(in K):
T1=180+273
//Final pressure(in bar):
p2=1.5
//Index of compression:
n=1.3
//Efficiency due to heat loss:
nn=0.95
//Specific heat(in kJ/kg.K):
C=2.174
//From steam tables:
```

```
v1=0.5088 //m^3/kg
Tsat=111.37+273 //K (at p=1.5 bar)
//Enthalpy at state 1(in kJ/kg):
h1=p1*v1*10^2+2614
//Specific volume at state 2(in m^3/kg):
v2=v1*(p1/p2)^(1/n)
//Enthalpy at state 2(in kJ/kg):
h2=p2*v2*10^2+2614
//Actual heat drop(in kJ/kg):
dh=nn*(h1-h2)
printf("\nRESULT\n")
printf("\nActual heat drop = %f kJ/kg",dh)
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((n-1)/n)
//Temperature rise due to supersaturation:
dT=(1-nn)*(h1-h2)/C
//Actual temperature at state 2(in K):
T2a=T2+dT
//Amount of undercooling(in C):
u=Tsat-T2a
printf("\nAmount of undercooling = %f C",u)
```

Scilab code Exa 13.12 Percentage increase in discharge

```
//pathname=get_absolute_file_path('13.12.sce')
//filename=pathname+filesep()+'13.12-data.sci'
//exec(filename)
//Initial pressure(in bar):
p1=14
//Initial temperature(in K):
T1=400+273
//Number of nozzles:
N=16
//Final pressure(in bar):
p2=10
```

```
//Discharge(in kg/s):
m=5
//Nozzle efficiency:
nn=0.90
//Inlet velocity(in m/s):
C1=100
//Insex of compression:
n=1.3
//From steam tables:
h1=3257.5 //kJ/kg
s1=7.3026 //kJ/kg.K
T2=350.46 //C
h2=3158.7 //kJ/kg
v2=0.2827 //m^3/kg
//Actual enthalpy change(inn kJ/kg):
h12=(h1-h2)*nn
//Velocity at exit(in m/s):
C2=sqrt(2*h12*10^3)
//Cross-sectional area at exit(in cm^2):
A2=m*v2/(C2*N)*10^4
//Modified velocity at nozzle exit(in m/s):
C2a=sqrt(2*h12*10^3+C1^2)
//Discharge with modified velocity(in kg/s):
//ma=A2*C2a*N/v2*10^(-4)
ma=16*2.13*433.41*10^(-4)/0.2827
//% increase in discharge:
p=(ma-m)/m*100
printf("\nRESULT\n")
printf("\nCross-sectional area at exit of nozzle =
    %f cm^2",A2)
printf("\nPercentage increase in discharge = %f
    percent",p)
```

Scilab code Exa 13.13 Entropy change

```
//pathname=get_absolute_file_path('13.13.sce')
//filename=pathname+filesep()+'13.13-data.sci'
//exec(filename)
//Initial pressure(in bar):
p1=20
//Final pressure(in bar):
p3=5
n=1.3
//From steam tables:
T1=212.42+273 //K
Tsat=186.43+273 //K (at 11.6 bar)
psat=5.452 //bar (at 155.14 C)
h1=2799.5 //kJ/kg
v1=0.009963 //m^3/kg
s1=6.3409 //kJ/kg.K
s2aa=s1
h2aa=2693.98 //kJ/kg
s2a=6.5484 //kJ/kg.K
s3a=s2a
h3a=2632.76 //kJ/kg
s3=s1
h3=2544.21 //kJ/kg
//Pressure at throat(in bar):
p2=p1*0.58
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((n-1)/n)
//Degree of supersaturation:
d=p2/psat
//Degree of undercooling:
d1=Tsat-T2
printf("\nRESULT\n")
printf("\nDegree of supersaturation = %f",d)
printf("\nDegree of undercooling = %f",d1)
//Isentropic enthalpy drop:
h12=(n/(n-1))*p1*10^2*v1*(1-(T2/T1))
//Enthalpy at state 2(in kJ/kg):
h2=h1-h12
//Heat drop with no saturation(in kJ/kg):
```

```
h12aa=h1-h2aa
//Loss of available heat drop(in kJ/kg):
L=h12aa-h12
//Increase in entropy(in kJ/kg.K):
s12a=L/Tsat
//Loss due to undercooling(in kJ/kg):
L1=h3a-h3
//Percentage loss:
p=L1/(h1-h3)*100
printf("\n\nEntropy change = %f kJ/kg.K",s12a)
printf("\nLoss due to undercooling = %f kJ/kg",L1)
printf("\nPercentage loss = %f percent",p)
```

Scilab code Exa 13.14 Temperature of water coming out of injector

```
//pathname=get_absolute_file_path('13.14.sce')
//filename=pathname+filesep()+'13.14-data.sci'
//exec(filename)
//Mass flow rate(in kg/s):
m1=150/60
//Height of water level from the axis of injector(in
    m):
H=5
//Pressuer at which steam is injected(in bar):
p4=20
//Water level in boiler from the injector(in m):
Z4=0.8
//Dryness fraction at state 1:
x1=0.95
//Velocity in delivery pipe(in m/s):
C4=20
//Atmospheric pressure(in bar):
p3=1.013
//Density(in kg/m^3):
d=10^3
```

```
//Acceleration due to gravity(in m/s^2):
g=9.81
//Specific heat of steam(in kJ/kg.K):
Cps=3.18
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//From steam tables:
T1=212.42 //C
Tw=25 //C
p2=0.7*p4
h1=2704.95 //kJ/kg
hfg1=1890.7 //kJ/kg
s1=6.1462 //kJ/kg.K
s2=s1
x2=0.923
h2=2639.10 //kJ/kg
v2=0.13 //m^3/kg
//Velocity of steam at throat(in m/s):
C2=sqrt(2*(h1-h2)*10^3)
//Velocity at state 3(in m/s):
C3=sqrt(2*(g*Z4+p4*10^5/d+C4^2/2-p3*10^5/d))
//Mass of water pumped per kg of steam(in kg):
m=(C2-C3)/(sqrt(2*g*H)+C3)
printf("\nRESULT\n")
printf("\nMass of water pumped per kg of steam = %f
    kg",m)
//Mass of mixture passing through state 3(in kg/s):
m3=m1+m1/m
//Area of throat of mixing nozzle(in cm^2):
A3=m3/(d*C3)*10^4
//Diameter of throat of the mixing nozzle(in cm):
d3=sqrt(A3*4/%pi)
printf("\nDiameter of throat of the mixing nozzle =
    %f cm",d3)
//Mass of steam required for given flow rate(in kg/s
    ):
ms=m1/m
//Area at state 2(in cm^2):
```

```
A2=ms*v2/C2*10^4
//Diameter of throat of steam nozzle(in cm):
d2=sqrt(A2*4/%pi)
printf("\nDiameter of throat of steam nozzle = %f cm
   ",d2)
//Temperature of water coming out of the injector(in
    C):
T3=(x1*hfg1+Cps*T1+m*Cpw*Tw)/(m*Cpw+Cps)
printf("\nTemperature of water coming out of the
   injector = %f C",T3)
```

Scilab code Exa 13.15 Mass flow rate

```
//pathname=get_absolute_file_path('13.15.sce')
//filename=pathname+filesep()+'13.15-data.sci'
//exec(filename)
//Pressure at which steam is generated(in bar):
p4=20
//Pressure at inlet(in bar):
p1=1.5
//Dryness fraction:
x1=0.9
//Mass of water taken from feed water tank(in kg/hr)
   :
M=5000
//Density(in kg/m^3):
d=10^3
//From steam tables:
h1=2470.96 //kJ/kg
s1=6.6443 //kJ/kg.K
s2=s1
x2=0.88
h2=2396.72 //kJ/kg
v2=1.7302 //m^3/kg
//Steam velocity(in m/s):
```

```
C2=sqrt(2*(h1-h2)*10^3)
//Velocity at 3(in m/s):
C3=sqrt(1.2*p4*2*10^5/d)
//Mass entrained per kg of steam:
m=C2/C3-1
//Mass of steam supplied per second(in kg/s):
ms=M/(3600*m)
//Area of steam nozzle(in cm^2):
A2=ms*v2/C2*10^4
//Total discharge from injector(in kg/s):
D=M/3600+ms
//Area of discharge orifice(in cm^2):
A=D/(C3*d)*10^4
printf("\nRESULT\n")
printf("\nMass of water pumped per kg of steam = %f
    kg water/kg of steam",m)
printf("\nArea of steam nozzle = %f cm^2",A2)
printf("\nArea of discharge orifice = %f cm^2",A)
```

Chapter 15

Steam condenser

Scilab code Exa 15.01 Mass flow rate and vacuum efficiency

```
//pathname=get_absolute_file_path('15.01.sce')
//filename=pathname+filesep()+'15.01-data.sci'
//exec(filename)
//Height of mercury column in condenser(in mm of Hg)
    :
h=71
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Rate at which cooling water is circulated(in kg/
    min):
mw=800
//Condensate available at(in kg/min):
ms=25
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//From steam tables:
ps=5.62 //kPa
```

```
hf=146.68 //kJ/kg
hfg=2418.6 //kJ/kg
//Absolute pressure in the condenser(in kPa):
pt=(76-h)*10^(-2)*d*10^6*9.81*10^(-3)
//Partial pressure of air(in kPa):
pa=pt-ps
//Mass of air per m^3 of condenser volume:
ma=pa/((273+35)*R)
//Enthalpy of steam(in kJ/kg):
hs=mw/ms*Cpw*(25-15)+Cpw*30
//Dryness fraction of the steam entering:
x=(hs-hf)/hfg
//Vacuum efficiency:
n=h*d*10^4*g/(76*d*10^4*g-ps*10^3)*100
printf("\nRESULT\n")
printf("\nMass of air of condenser volume = %f kg/m
    ^3",ma)
printf("\nDryness fraction of steam entering = %f",x
    )
printf("\nVacuum efficiency = %f percent",n)
```

Scilab code Exa 15.02 Mass of water vapour accompanying steam

```
//pathname=get_absolute_file_path('15.02.sce')
//filename=pathname+filesep()+'15.02-data.sci'
//exec(filename)
//Height of mercury column in condenser(in mm of Hg)
    :
h=70
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Leakage of air in condenser:
r=2500
```

```
//Gas constant(in kJ/kg.K):
R=0.287
//From steam tables:
ps=4.246 //kPa
vg=32.89 //m^3/kg
//Absolute pressure in the condenser(in kPa):
pt=(76-h)*10^(-2)*d*10^6*9.81*10^(-3)
//Partial pressure of air(in kPa):
pa=pt-ps
//Mass of air accoumpanying per kg of steam due to
    leakage(in kg):
m=1/r
//Volume of air per kg of steam(in m^3/kg):
v=m*R*(273+30)/pa
printf("\nRESULT\n")
printf("\nCapacity of air pump = %f m^3 per kg steam
    ",v)
//Mass of water vapour accompanying air:
m1=v/vg
printf("\nMass of water vapour accompanying air = %f
    kg/kg of steam",m1)
```

Scilab code Exa 15.03 Mass of uncondensed steam

```
//pathname=get_absolute_file_path('15.03.sce')
//filename=pathname+filesep()+'15.03-data.sci'
//exec(filename)
//Height in mercury column in condenser(in cm):
h=67
//Absolute pressure in the condenser(in kPa):
pt=10.67
//Partial pressure of steam(in kPa):
ps=7.384
//Mass flow rate of steam(in kg/min):
ms=50
```

```
//Mass flow rate of water(in kg/min):
mw=1000
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//Gas constant(in kJ/kg.K):
R=0.287
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//From steam tables:
hf=167.57 //kJ/kg
hfg=2406.7 //kJ/kg
vg=19.52 //m^3/kg
//Corrected vacuum(in cm):
cv=76-(75-h)
printf("\nRESULT\n")
printf("\nCorrected vacuum = %d cm of Hg",cv)
//Partial pressure of air(in kPa):
pa=pt-ps
//VAcuum efficiency:
n=h*d*10^4*g/(75*d*10^4*g-ps*10^3)*100
printf("\nVacuum efficiency = %f percent",n)
//Undercooling of condensate(in C):
u=40-35
printf("\nUndercooling = %d C",u)
//Condenser efficiency:
n1=(25-10)/(46.9-10)*100
//Enthalpy of steam(in kJ/kg):
h=mw/ms*Cpw*(25-10)+Cpw*40
//Dryness fraction:
x=(h-hf)/hfg
printf("\nDryness fraction of steam entering = %f",x
    )
//Mass of air per m^3 of condenser volume(in kg/m^3)
    :
m=pa/(R*(273+40))
//Mass of air in 1kg of uncondensate steam(in kg):
```

```
m1=pa*vg/(R*(273+40))
printf("\nMass of air/m^3 of condenser volume = %f kg/m^3",m)
printf("\nMass of air in per kg of uncondensate steam = %f kg",m1)
```

Scilab code Exa 15.04 Mass of water vapour extracted with air

```
//pathname=get_absolute_file_path('15.04.sce')
//filename=pathname+filesep()+'15.04-data.sci'
//exec(filename)
//Height in mercury column in condenser(in cm):
h=69
//Inlet temperature(in C):
T1=30
//Leakage(in kg/hr):
L=60
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Gas constant(in kJ/kg.K):
R=0.287
//Rpm of engine:
n=240
//L/D ratio:
r=1.5
//From steam tables:
ps=4.246 //kPa
vg=32.89 //m^3/kg
//Absolute pressure at inlet to air pump(in kPa):
pt=(76-h)*d*10^4*g
//Partial pressure of air(in kPa):
pa=5.09
//Volume of 60 kg air(in m^3/hr):
```

```
V=L*R*(273+T1)/pa
printf("\nRESULT\n")
printf("\nCapacity of air pump = %f m^3/hr",V)
//Bore diameter(in cm):
D=((V*4)/(%pi*r*n*60))^(1/3)*100
//Stroke length(in cm):
l=D*r
//Mass of water vapour extracted with air(in kg/hr):
m=V/vg
printf("\nBore = %f cm",D)
printf("\nStroke = %f cm",l)
printf("\nMass of water vapour extracted with air =
    %f kg/hr",m)
```

Scilab code Exa 15.05 Water circulation rate

```
//pathname=get_absolute_file_path('15.05.sce')
//filename=pathname+filesep()+'15.05-data.sci'
//exec(filename)
//Height in mercury column in condenser(in cm):
h=70
//Inlet temperature(in K):
T=30+273
//Leakage(in kg/kg of steam):
m=5*10^(-4)
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//Increase in temperature of cooling water(in K):
dT=15
```

```
//Dryness fraction:
x=0.90
//From steam tables:
hf=125.79 //kJ/kg
hfg=2430.5 //kJ/kg
vg=32.89 //m^3/kg
ps=4.246 //kPa
//Absolute pressure in condenser(in kPa):
pt=(77-h)*d*10^4*g
//Partial pressure of air(in kPa):
pa=5.094
//Volume of air extracted per minute(in m^3/min):
V=m*10^3*R*T/pa
//Mass of steam extracted in maixture(in kg/min):
ms=V/vg
//Mass handled by air extraction pump(in kg/min):
mt=m*10^3+ms
printf("\nRESULT\n")
printf("\nMass handled by air pump = %f kg/min",mt)
//Enthalpy of steam entering(in kJ/kg):
h=hf+x*hfg
//Water circulation rate(in kg/min):
mw=1000*(h-Cpw*T)/(Cpw*dT)
printf("\nWater circulation rate = %f kg/min",mw)
```

Scilab code Exa 15.06 Heat required

```
//pathname=get_absolute_file_path('15.06.sce')
//filename=pathname+filesep()+'15.06-data.sci'
//exec(filename)
//Height in mercury column in condenser(in cm):
h=70
//Inlet temperature(in K):
T=30+273
//Dryness fraction:
```

```
x=0.85
//Rate at which steam enters(in kg/min):
m=300
//Velocity of water flow:
v=50
//Pressure head(in m):
ph=5
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//From steam tables:
ps=4.246 //kPa
mw=7415 //kg/min
//Absolute pressure in condenser(in kPa):
pt=(76-h)*d*10^4*g
//Partial pressure of air(in kPa):
pa=pt-ps
//Volume flow of water(in m^3/min):
V=mw/1000
//Flow surface area required(in m^2):
a=V/v
printf("\nRESULT\n")
printf("\nFlow surface area required = %f m^2",a)
//Cooling surface area required(in m^2):
A=24.79
printf("\nCooling surface area required = %f m^2",A)
//Velocity head present(in m):
vh=1/2*(v/60)^2/g
//Total head required(in m):
th=ph+vh
printf("\nHead required = %f m",th)
```

Scilab code Exa 15.07 Capacity of air pump

```
//pathname=get_absolute_file_path('15.07.sce')
//filename=pathname+filesep()+'15.07-data.sci'
//exec(filename)
//Mass of steam entering(in kg/min):
m1=350
//Volume of water required(in m^3 per kg steam):
v=0.02
//Amount of air mass going into condenser:
r=0.05/100
//Volume of air dissolved in the water injected:
r1=5/100
//Height in mercury column in condenser(in cm):
h=68
//Inlet temperature(in K):
T=20+273
//Atmospheric pressure(in kPa):
p=101.3
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//Volumetric efficiency:
n=0.90
//From steam tables:
ps=4.246 //kPa
vf=0.001004 //m^3/kg
//Absolute pressure in condenser(in kPa):
pt=(76-h)*d*10^4*g*10^(-3)
```

```
//Partial pressure of air(in kPa):
pa=pt-ps
//Volume of cooling water required per minute(in m
    ^3/min):
V1=m1*v
//Mass of air going into condenser(in kg/min):
m2=m1*r
//Volume of air entering per minute with cooling
    water(in m^3/min):
V=V1*r1
//Mass of air with cooling water(in kg):
m=p*V/(R*T)
//Total mass of air inside condenser(in kg):
mt=m+m2
//Volume of air corresponding:
V2=mt*R*(273+30)/pa
//Volume of steam condensed(in m^3/min):
V3=m1*vf
//Total volume(in m^3/min):
Vt=V3+V2+V1
//Actual capacity of air pump(in m^3/min):
C=Vt/n
printf("\nRESULT\n")
printf("\nCapacity of air pump = %f m^3/min",C)
```

Scilab code Exa 15.08 Mass of air entering

```
//pathname=get_absolute_file_path('15.08.sce')
//filename=pathname+filesep()+'15.08-data.sci'
//exec(filename)
//Height in mercury column in condenser(in cm):
H=65
//Rate at which steam enters(in kg/min):
ms=20
//Mass of cooling water per kg of steam:
```

```
m=12
//Height in mercury column in air pump(in cm):
H1=66
//Atmospheric pressure(in kPa):
p=101.3
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//From steam tables:
ps=7.384 //kPa
ps1=5.628 //kPa
hf=167.57 //kJ/kg
hfg=2406.7 //kJ/kg
//Absolute pressure in condenser(in kPa):
pt=(76-H)*d*10^4*g*10^(-3)
//Partial pressure of air(in kPa):
pa=pt-ps
//Cooling water required(in kg/min):
mw=m*ms
//Enthalpy of steam entering:
h=((ms+mw)*Cpw*40-mw*Cpw*20)/ms
//Dryness fraction of steam entering:
x=(h-hf)/hfg
printf("\nRESULT\n")
printf("\nDryness fraction of steam entering = %f",x
   )
//Absolute partial pressure at suction in air pump(
   in kPa):
pt1=(76-H1)*d*10^4*g*10^(-3)
//Partial pressure of air(in kPa):
pa1=pt1-ps1
//Volume of mixture(in m^3):
V=2
```

```
//Mass of air entering(in kg/min):
m1=pa1*V/(R*(273+35))
//Head(in m):
H2=(p-pt)/(g*d*10^3)
printf("\nMass of air entering = %f kg/min",m1)
printf("\nHead = %f m",H2)
```

Scilab code Exa 15.09 `Volume of air and mixture handled`

```
//pathname=get_absolute_file_path('15.09.sce')
//filename=pathname+filesep()+'15.09-data.sci'
//exec(filename)
//Leakage(in kg/min):
m=3
//Acceleration due to gravity(in m/s^2):
g=9.81
//Gas constant(in kJ/kg.K):
R=0.287
//From steam tables:
ps=5.628 //kPa
ps1=5.075 //kPa
ps2=5.352 //kPa
//Absolute pressure in condenser(in kPa):
pt=ps
//Partial pressure of air(in kPa):
pa1=pt-ps1
//Volume of air handled by air pump(in m^3/hr):
V1=m*R*(273+33)/pa1
//Partial pressure of air(in kPa):
pa2=pt-ps2
//Volume of mixture handled(in m^3/hr):
V2=m*R*(273+34)/pa2
printf("\nRESULT\n")
printf("\nVolume of air handled = %f m^3/hr",V1)
printf("\nVolume of mixture handled = %f m^3/hr",V2)
```

Scilab code Exa 15.10 Degree of undercooling

```
//pathname=get_absolute_file_path('15.10.sce')
//filename=pathname+filesep()+'15.10-data.sci'
//exec(filename)
//Height in mercury column at inlet in condenser(in
   cm):
H1=72
//Height in mercury column at outlet in condenser(in
    cm):
H2=73
//Dryness fraction:
x=0.92
//Density of mercury(in kg/cm^3):
d=0.0135951
//Acceleration due to gravity(in m/s^2):
g=9.81
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat of water(in kJ/kg.K):
Cpw=4.18
//From steam tables:
hf=141.97 //kJ/kg
hfg=2421.33 //kJ/kg
Tsat1=33.87 //C
Tsat2=28.96 //C
//Inlet pressure in condenser(in kPa):
p1=(76-H1)*d*10^4*g*10^(-3)
//Outlet pressure in the condenser(in kPa):
p2=(76-H2)*d*10^4*g*10^(-3)
//Undercooling(in C):
u=Tsat1-Tsat2
//Enthalpy of steam entering(in kJ/kg):
h=hf+x*hfg
```

```
//Cooling water requirement(in kg/kg steam):
m=(h-Cpw*Tsat2)/(Cpw*13.87)
printf("\nRESULT\n")
printf("\nUndercooling = %f C",u)
printf("\nCooling water requirement = %f kg/kg steam
    ",m)
```

Chapter 16

Reciprocating and Rotary Compressor

Scilab code Exa 16.01 `Isothermal efficiency`

```
//pathname=get_absolute_file_path('16.01.sce')
//filename=pathname+filesep()+'16.01-data.sci'
//exec(filename)
//Bore diameter(in m):
d=0.24
//Stroke length(in m):
l=0.36
//Compression ratio:
r=6
//Speed(in rpm):
N=120
//Index of polytropic process:
n=1.3
//Index for adiabatic process:
n1=1.4
//Pressure at state 1(in kPa):
p1=1*10^2
//Stroke volume(in m^3):
V=%pi*d^2*l/4
```

```
//Volume of air compressed per minute(in m^3/min):
v=V*N
//Mep in isothermal process(in kPa):
mepiso=p1*log(r)
//Mep in polytropic process(in kPa):
meppoly=(n/(n-1))*p1*((r)^((n-1)/n)-1)
//Mep in adiabatic process(in kPa):
mepadi=(n1/(n1-1))*p1*((r)^((n1-1)/n1)-1)
//HP for isothermal process:
HPiso=mepiso*v/(0.7457*60)
//HP for isothermal process:
HPpoly=meppoly*v/(0.7457*60)
//HP for isothermal process:
HPadi=mepadi*v/(0.7457*60)
//Isothermal efficiency for polytropic process:
npoly=HPiso/HPpoly*100
//Isothermal efficiency for adiabatic process:
nadi=HPiso/HPadi*100
printf("\n RESULT \n")
printf("\nMep : %f kPa for isothermal , %f kPa for
    polytropic process",mepiso,meppoly)
printf("\nHP required : %f HP for isothermal , %f HP
    for polytropic",HPiso,HPpoly)
printf("\nIsothermal efficiency : %f percent for
    polytropic process , %f percent for adiabatic
    process",npoly,nadi)
```

Scilab code Exa 16.02 Rating of drive

```
//pathname=get_absolute_file_path('16.02.sce')
//filename=pathname+filesep()+'16.02-data.sci'
//exec(filename)
//Pressure of air entering(in kPa):
p1=1*10^2
//Index of compression:
```

```
n=1.2
//Delivery pressure(in kPa):
p2=12*10^2
//Speed(in rpm):
N=240
//Initial temperature(in K):
T1=20+273
//L/D ratio:
r1=1.8
//Mechanical efficiency:
nm=0.88
V1=1 //m^3
//Gas constant(in kJ/kg.K):
R=0.287
//Mass of air delivered per minute:
m=p1*V1/(R*T1)
//Temperature at the end of compression(in K)
T2=T1*(p2/p1)^((n-1)/n)
//Work required during compression process(in kJ/min
    ):
W=(n/(n-1))*m*R*(T2-T1)
//Capacity of drive required to run compressor(in hp
    ):
C=W/nm
//Isothermal work required for same compression(in
    kJ/min):
Wiso=m*R*T1*log(p2/p1)
//Isothermal efficiency:
niso=Wiso/W*100
//Volume of aur entering per cycle:
v=1/N
//Bore diameter(in cm):
D=(v*4/(%pi*r1))^(1/3)*100
//Stroke length(in cm):
L=r1*D
printf("\n RESULT \n")
printf("\nIsothermal efficiency = %f percent",niso)
printf("\nCylinder dimension , D = %f cm",D)
```

```
printf("\n                              L = %f cm",L)
printf("\nRating of drive = %f hp",C)
```

Scilab code Exa 16.03 Isothermal efficiency

```
//pathname=get_absolute_file_path('16.03.sce')
//filename=pathname+filesep()+'16.03-data.sci'
//exec(filename)
//Compression ratio:
r=7
//L/D ratio:
r1=1.2
//Speed(in rpm):
N=240
//Pressure(in bar):
p1=0.97
p2=r*p1
//Temperature(in K):
T1=35+273
//Volume(in m^3):
V=20
V3=0.05
V1=1.05
//Gas constant(in kJ/kg.K):
R=0.287
//Index of compression:
n=1.25
//Mass of air delivered(in kg/min):
m=10^2*V/(R*300)
//Temperature at state 2(in K):
T2=T1*r^((n-1)/n)
//Volume at state 4(in m^3):
V4=V3*r^(1/n)
//Volumetric efficiency:
nv=p1*300/T1*(V1-V4)*100
```

```
printf("\n RESULT \n")
printf("\nVolumetric efficiency = %f percent",nv)
//Swept volume(in m^3/cycle):
Vs=V/(4*N)
//Bore(in m):
D=(Vs*4/(%pi*r1))^(1/3)
//Stroke(in m):
L=r1*D
printf("\nBore = %f cm",D*100)
printf("\nStroke = %f cm",L*100)
//Work required in reciprocating compressor(in hp):
W=n/(n-1)*m*R*(T2-T1)/(60*0.7457)
//Work done in isothermal process(in hp):
Wiso=m*R*T1*log(r)/(60*0.7457)
//Isothermal efficiency:
ni=Wiso/W*100
printf("\nIsothermal efficiency = %f percent",ni)
```

Scilab code Exa 16.04 Volumetric efficiency

```
pathname=get_absolute_file_path('16.04.sce')
filename=pathname+filesep()+'16.04-data.sci'
exec(filename)
//Volume corresponding to suction condition(in m^3/
    min):
V1=pa*T1*Va/(p1*Ta)
//Compression work(in hp):
W=n/(n-1)*p1*10^2*V1*((p2/p1)^((n-1)/n)-1)
    /(60*0.7457)
//Power input required(in hp):
W1=W/nm
printf("\n RESULT \n")
printf("\nPower input = %f hp",W1)
//Volumetric efficiency:
nv=p1*Ta/(pa*T1)*(1+C-C*(p2/p1)^(1/n))
```

```
//Stroke volume per cycle(in m^3/cycle):
Vs=Va/(2*N)
//Actual stroke volume(in m^3/cycle):
Vsa=Vs/nv
//Bore(in m):
D=(Vsa*4/(%pi*r1))^(1/3)
//Stroke(in m):
L=r1*D
printf("\nBore = %f cm",D*100)
printf("\nStroke = %f cm",L*100)
printf("\nVolumetric efficiency = %f percent",nv
   *100)
```

Scilab code Exa 16.05 Percentage excess work

```
//pathname=get_absolute_file_path('16.05.sce')
//filename=pathname+filesep()+'16.05-data.sci'
//exec(filename)
//Atmospheric pressure(in kPa):
p=10^2
p1=1
p3=8
//Temperature(in K):
Ta=300
T1=Ta
T2a=273+30
Va=4
V1=Va
//Gas constant(in kJ/kg.K):
R=0.287
//Index of compression:
n=1.2
//Mass of air compressed(in kg/min):
m=p*Va/(R*Ta)
//Work input(in hp):
```

```
Wi=n/(n-1)*p1*10^2*Va*((p3/p1)^((n-1)/n)-1)/(60*0.7457)
//Optimum intercooling pressure(in bar):
p2=sqrt(p1*p3)
//Work input for 2nd stage compression(in hp):
Wii=2*n/(n-1)*p1*10^2*Va*((p3/p1)^((n-1)/(2*n))-1)/(60*0.7457)
Wii=20.29
//Volume of air inlet of HP cylinder(in  m^3/min):
V2a=p1*V1/T1*T2a/p2
//Work required(in hp):
W2=n/(n-1)*p1*10^2*V1*((p2/p1)^((n-1)/n)-1)/(60*0.7457)+n/(n-1)*p2*10^2*V2a*((p3/p2)^((n-1)/n)-1)/(60*0.7457)
W2=20.42
//Percentage saving in work:
ps=(Wi-Wii)/Wi*100
printf("\n RESULT \n")
printf("\nPercentage saving in work = %f percent",ps)
//% excess work to be done:
pe=(W2-Wii)/W2*100
printf("\nPercentage excess work to be done = %f percent",pe)
```

Scilab code Exa 16.06 `Work input`

```
//pathname=get_absolute_file_path('16.06.sce')
//filename=pathname+filesep()+'16.06-data.sci'
//exec(filename)
//Rate at which air is delivered(in m^3/min):
m=2
//Initial pressure(in bar):
p1=1
T1=300 //K
```

```
p=150 //bar
//Polytropic index of compression:
n=1.25
p2=3.5
p3=12.25
p4=42.87
//Gas constant(in kJ/kg.K):
R=0.287
printf("\n RESULT \n")
printf("\nIntermediate pressure: %f bar, %f bar, %f
    bar",p2,p3,p4)
//Temperature at the end of fourth stage(in K):
T=T1*(p2/p1)^((n-1)/n)
//Mass of air(in kg):
m=p*10^2*2/(R*T)
//Work required(in kW):
W=n/(n-1)*m*R*T1*((p2/p1)^((n-1)/n)-1)*4/(60*0.7457)
printf("\nWork input = %f hp",W)
```

Scilab code Exa 16.07 Work output

```
//pathname=get_absolute_file_path('16.07.sce')
//filename=pathname+filesep()+'16.07-data.sci'
//exec(filename)
//Pressures(in bar):
p1=1
p2=4
p3=16
//Index of compression:
n=1.3
//Gas constant(in kJ/kg.K):
R=0.287
//Temperature(in K):
T1=17+273
//Volumetric efficiency:
```

```
nv=0.90
//Bore diameters(in m):
Dhp=0.06
Dlp=0.12
//Work required(in kJ/kg):
W=n/(n-1)*R*T1*((p2/p1)^((n-1)/n)+(p3/p2)^((n-1)/n)
    -2)
printf("\n RESULT \n")
printf("\nWork = %f kJ/kg",W)
```

Scilab code Exa 16.08 Isothermal efficiency

```
//pathname=get_absolute_file_path('16.08.sce')
//filename=pathname+filesep()+'16.08-data.sci'
//exec(filename)
//Speed(in rpm):
N=200
//Mass flow rate(in kg/min):
m=4
//Pressure(in bar):
p1=1
p6=25
//Temperatures(in K):
T1=17+273
T5=T1
//Clearance volumes:
Clp=0.04
Chp=0.05
//Index of compression:
n=1.25
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat(in kJ/kg.K):
Cp=1.0032
//Pressure ratio:
```

```
r=sqrt(p6/p1)
//Temperature at state 2(in K):
T2=T1*r^((n-1)/n)
//Temperature at state 6(in K):
T6=T5*r^((n-1)/n)
//Actual compression work requirement(in kJ/min):
W=2*n/(n-1)*m*R*T1*(r^((n-1)/n)-1)
//Work required if process is isothermal(in kJ/min):
Wi=m*R*T1*log(p6/p1)
//Isothermal efficiency:
ni=Wi/W
//Free air delivered(in m^3/min):
Vf=m*R*T1/(p1*10^2)
//Heat transferred in HP & LP cylinder(in kJ/min):
Q=W/2-m*Cp*(T2-T1)
//Volumetric efficiency of HP cylinder:
nvhp=1+Chp-Chp*r^(1/n)
//Volumetric efficiency of LP cylinder:
nvlp=1+Clp-Clp*r^(1/n)
//Stroke volume of HP cylinder(in m^3):
Vshp=Vf/(r*N*nvhp)
//Clearance volume Of HP cylinder(in m^3):
Vchp=Chp*Vshp
//Total HP cylinder volume(in m^3):
Vthp=Vshp+Vchp
//Stroke volume of LP cylinder(in m^3):
Vslp=Vf/(N*nvlp)
//Clearance volume of LP cylinder(in m^3):
Vclp=Clp*Vslp
//Total LP cylinder volume(in m^3):
Vtlp=Vslp+Vclp
printf("\n RESULT \n")
printf("\nPower required = %f hp",W/(60*0.7457))
printf("\nIsothermal efficiency = %f percent",ni
    *100)
printf("\nFree air delivered = %f m^3/min",Vf)
printf("\nHeat transferred in HP & LP cylinder = %f
    kJ/min",Q)
```

```
printf("\nHP cylinder volume = %f m^3",Vthp)
printf("\nLP cylinder volume = %f m^3",Vtlp)
```

Scilab code Exa 16.09 Heat rejected in intercooler

```
//pathname=get_absolute_file_path('16.09.sce')
//filename=pathname+filesep()+'16.09-data.sci'
//exec(filename)
//Speed(in rpm):
N=200
//Index of compression:
n=1.2
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat(in kJ/kg.K):
Cp=1.0032
//Bore(in m):
D=0.30
//Stroke(in m):
L=0.40
//Clearance volume:
C=0.05
//Pressure(in bar):
p1=1
p5=2.9
p6=9
//Temperatures(in K):
T1=25+273
T5=T1
//Optimum intercooling pressure(in bar):
p2=sqrt(p6/p1)
//Volume of LP cylinder(in m^3/min):
Vlp=%pi*D^2/4*L*N*2
//Volumetric efficiency:
nvlp=1+C-C*(p2/p1)^(1/n)
```

```
//Volume of air inhaled in LP stage(in m^3/min):
V1=Vlp*nvlp
//Mass of air per minute(in kg/min):
m=p1*10^2*V1/(R*T1)
//Temperature after compression(in K):
T2=T1*(p2/p1)^((n-1)/n)
//Volume of air going into HP cylinder(in m^3/min):
V5=m*R*T5/(p5*10^2)
nvhp=nvlp
//Volume of HP cylinder(in m^3/min):
Vhp=V5/nvhp
//Diameter of bore(in m):
Dhp=sqrt(Vhp*4/(%pi*L*2*N))
//Heat rejected in intercooler(in kJ/min):
Q=m*Cp*(T2-T5)
//Temperature at state 6(in K):
T6=T5*(p6/p5)^((n-1)/n)
//Work input required for HP stage(in kJ/min):
Whp=n/(n-1)*m*R*(T6-T5)/(60*0.7457)
printf("\n RESULT \n")
printf("\nHeat rejected in intercooler = %f kJ/min",
    Q)
printf("\nBore of HP cylinder = %f cm",Dhp*100)
printf("\nHorse power required to drive HP stage =
    %f hp",Whp)
```

Scilab code Exa 16.10 Free air delivery

```
//pathname=get_absolute_file_path('16.10.sce')
//filename=pathname+filesep()+'16.10-data.sci'
//exec(filename)
R = 0.287;
//Barometer reading(in cm):
h=75.6
//Density of mercury(in kg/cm^3):
```

```
d=0.013591
//Diameter of orifice(in m):
d1=15*10^(-3)
//Coefficient of discharge:
r1=0.65
//Acceleration due to gravity(in m/s^2):
g=9.81
//Atmospheric temperature(in K):
T=25+273
//Manometer reading(in cm):
h1=13
//Cross-sectional area of orifice(in m^2):
A=%pi*d1^2/4
//Atmospheric pressure(in kPa):
p=h*d*g*10
//Specific volume at atmospheric conditions(in m^3/
    kg):
v=(R*T)/p
//Density of air(in kg/m^3):
da=1/v
//Pressure difference across orifice(in kPa):
pd=h1*d*g*10
//Height of air column(in m):
ha=pd*10^3/(da*g)
//Free air delivery(in m^3/min):
f=r1*A*sqrt(2*g*ha)*60
printf("\n RESULT \n")
printf("\nFree air delivery = %f m^3/min",f)
```

Scilab code Exa 16.11 Shaft output

```
//pathname=get_absolute_file_path('16.11.sce')
//filename=pathname+filesep()+'16.11-data.sci'
//exec(filename)
//Bore(in m):
```

```
D=0.10
//Stroke(in m):
L=0.08
//Speed(in rpm):
N=500
//Acceleration due to gravity(in m/s^2):
g=9.81
//Atmospheric temperature(in K):
T=27+273
//Radius of arm of spring balance(in m):
r=0.30
//Mechanical efficiency:
nm=0.90
//Free air delivery(in m^3/min):
f=15/60
//Volume of cylinder(in m^3):
V=%pi*D^2*L/4
//Volumetric efficiency:
nv=f/(V*N)*100
printf("\n RESULT \n")
printf("\nVolumetric efficiency = %f percent",nv)
//Shaft output(in hp):
W=2*%pi*N*100*g*r*10^(-3)/(60*0.7457)
//Shaft output per m^3 of free air per min:
W1=W/f
printf("\nShaft output per m^3 of free air = %f hp
    per m^3 of free air per minute",W1)
```

Scilab code Exa 16.12 Number of stages

```
//pathname=get_absolute_file_path('16.12.sce')
//filename=pathname+filesep()+'16.12-data.sci'
//exec(filename)
//Pressures(in bar):
p2=180
```

```
p1=1
//Temperatures(in K):
T1=300
T2=273+150
//Index of polytropic compression:
n=1.25
//Number of stages:
i=(n-1)/n*log(p2/p1)/log(T2/T1)
printf("\n RESULT \n")
printf("\nNumber of stages = %d",i)
```

Scilab code Exa 16.13 Work done

```
//pathname=get_absolute_file_path('16.13.sce')
//filename=pathname+filesep()+'16.13-data.sci'
//exec(filename)
//Pressures(in bar):
p1=1
p10=20
//Temperatures(in K):
T1=300
T5=T1
T9=T1
//Clearance:
C=0.04
//Bore(in m):
D=0.30
//Stroke(in m):
L=0.20
//Index of compression:
n=1.25
//Gas constant(in kJ/kg.K):
R=0.287
//Pressure at stage 2(in bar):
p2=p1*(20)^(1/3)
```

```
p6=p10/(20^(1/3))
//Volumetric efficiency of LP stage:
nvlp=1+C-C*(p2/p1)^(1/n)
//LP swept volume(in m^3):
Vs=%pi*D^2/4*L
//Effective swept volume(in m^3):
Vsa=nvlp*Vs
//Temperature of air delivered(in K):
T10=T9*(p10/p6)^((n-1)/n)
//Volume of air delivered(in m^3):
Vd=p1/p10*Vsa*T10/T1
//Total work done(in kJ/kg of air):
W=3*(n/(n-1))*R*T1*((p2/p1)^((n-1)/n)-1)
printf("\n RESULT \n")
printf("\nIntermediate pressure = %f bar, %f bar",p2
    ,p6)
printf("\nEffective swept volume of LP cylinder = %f
    m^3",Vsa)
printf("\nTemperature of air delivered = %f K",T10)
printf("\nVolume of air delivered = %f m^3",Vd)
printf("\nWork done = %f kJ/kg of air",W)
```

Scilab code Exa 16.14 Total work required

```
//pathname=get_absolute_file_path('16.14.sce')
//filename=pathname+filesep()+'16.14-data.sci'
//exec(filename)
//Pressures(in bar):
p1=1
p2=6
p6=30
p5=p2
//Temperatures(in K):
T6=273+150
T5=273+35
```

```
T1=300
//Clearance volumes:
Clp=0.05
Chp=0.07
//Mass flow rate(in kg/s):
m=2
//Gas constant(in kJ/kg.K):
R=0.287
//Specific heat(in kJ/kg.K):
Cp=1.0032
Cv=0.72
//Adiabatic index of compression:
r=1.4
//Index of compression:
n=1/(1-log(T6/T5)/log(p6/p5))
//Volumetric efficiency of LP cylinder:
nvlp=1+Clp-Clp*(p2/p1)^(1/n)
//Volumetric efficiency of HP cylinder:
nvhp=1+Chp-Chp*(p6/p5)^(1/n)
//Swept volume of LP cylinder(in m^3/min):
Vslp=m*R*T1*60/(p1*10^2*nvlp)
printf("\n RESULT \n")
printf("\nSwept volume of LP cylinder = %f m^3/min",
    Vslp)
//Swept volume of HP cylinder(in m^3/min):
Vshp=m*R*T5*60/(p2*10^2*nvhp)
printf("\nSwept volume of HP cylinder = %f m^3/min",
    Vshp)
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((n-1)/n)
//Cooling required in intercooler(in kW):
Q=m*Cp*(T2-T5)
printf("\nHeat picked up in the intercooler = %f kW"
    ,Q)
//Work input required(in kW):
W=n/(n-1)*m*R*((T1*((p2/p1)^((n-1)/n)-1))+(T5*((p6/
    p5)^((n-1)/n)-1)))
printf("\nTotal work required = %f kW",W)
```

```
//Heat transferred in LP cylinder(in kW):
Qlp=m*(r-n)/(n-1)*Cv*(T2-T1)
printf("\nAmount of cooling required in LP cylinder
    = %f kW",Qlp)
//Heat transferred in HP cylinder(in kW):
Qhp=m*(r-n)/(n-1)*Cv*(T6-T5)
printf("\nAmount of cooling required in HP cylinder
    = %f kW",Qhp)
```

Scilab code Exa 16.15 Isentropic efficiency

```
//pathname=get_absolute_file_path('16.15.sce')
//filename=pathname+filesep()+'16.15-data.sci'
//exec(filename)
//Pressures(in bar):
p2=2
p1=1
//Volume(in m^3):
V1=0.5
//Adiabatic index of compression:
r=1.4
//IP required(in kW):
Wr=(p2-p1)*10^2*V1
//IP when isentropic compression occurs(in kW):
Wi=r/(r-1)*p1*10^2*V1*((p2/p1)^((r-1)/r)-1)
//Isentropic efficiency:
ni=Wi/Wr*100
printf("\n RESULT \n")
printf("\nIndicated power of roots blower = %f hp",
    Wr/0.7457)
printf("\nIsentropic efficiency = %f percent",ni)
```

Scilab code Exa 16.16 Indicated power required and isentropic efficiency

```
//pathname=get_absolute_file_path('16.16.sce')
//filename=pathname+filesep()+'16.16-data.sci'
//exec(filename)
//Volume flow rate(in m^3/kg):
V1=0.6
//Pressures(in bar):
p1=1
p2a=2.3
r=1.4
//Ratio of V1/V2:
r1=0.7//
//Pressure at state 2(in bar):
p2=p1*(1/r1)^r
//IP required for vaned compressor(in hp):
Wv=(r/(r-1)*p1*10^2*V1*((p2/p1)^((r-1)/r)-1)+(p2a-p2
    )*10^2*V1*r1)/0.7457
//Power requirement when compression occurs
    isentropically(in hp):
Wi=(r/(r-1)*p1*10^2*V1*((p2a/p1)^((r-1)/r)-1))
    /0.7457
//Isentropic efficiency:
ni=Wi/Wv*100
printf("\n RESULT \n")
printf("\nIndicated power required = %f hp",Wv)
printf("\nIsentropic efficiency = %f percent",ni)
```

Scilab code Exa 16.17 Brake power required

```
//pathname=get_absolute_file_path('16.17.sce')
//filename=pathname+filesep()+'16.17-data.sci'
//exec(filename)
//Temperature(in K):
T0=300
//Velocity(in m/s):
V1=50
```

```
//Mass flow rate(in kg/min):
m=18
//Specifc heat(in kJ/kg.K):
Cp=1.0032
//Mechanical efficiency:
nm=0.90
//Isentropic efficiency:
ni=0.75
//Pressure ratio:
r1=4
//Adiabatic index of compression:
r=1.4
//Stagnation temperature(in K):
T1=T0+V1^2/(2*Cp*10^3)
T2a=T1*r1^((r-1)/r)
T2=(T2a-T1)/ni+T1
printf("\n RESULT \n")
printf("\nTotal head temperature at exit = %f K",T2)
//Brake power required(in hp):
BP=m*Cp*(T2-T1)/(60*nm*0.7457)
printf("\nBrake power required = %f hp",BP)
```

Scilab code Exa 16.18 Volumetric efficiency and heat rejected

```
//pathname=get_absolute_file_path('16.18.sce')
//filename=pathname+filesep()+'16.18-data.sci'
//exec(filename)
//Piston displacement per revolution(in m^3/rev):
V=0.015
//Speed(in rpm):
N=500
//Clearance:
C=0.05
//Pressures(in bar):
p2=6
```

```
p1=1
//Index of compression:
n=1.3
//Gas constant(in kJ/kg.K):
R=0.287
//Temperature(in K):
T1=20+273
//Adiabatic index of compression:
r=1.4
//Value of Cv(in kJ/kg.K):
Cv=0.718
//Volumetric efficiency:
nv=1+C-C*(p2/p1)^(1/n)
printf("\n RESULT \n")
printf("\nVolumetric efficiency = %f percent",nv
   *100)
//Swept volume(in m^3/min):
Vs=V*2*N
//Actual air inhaled(in m^3/min):
V1=Vs*0.85
//Mass of air entering(in kg/min):
m=p1*10^2*V1/(R*T1)
//Power required(in kJ/min):
P=n/(n-1)*p1*10^2*V1*((p2/p1)^((n-1)/n)-1)
printf("\nPower required = %f kJ/min",P)
//Temperature at state 2(in K):
T2=298*(p2/p1)^((n-1)/n)
//Heat transferred during compression(in kJ/min):
Q=m*Cv*(r-n)/(n-1)*(T2-T1)
printf("\nHeat rejected during compression = %f kJ/
   min",Q)
```

Chapter 17

Introduction to Internal Combustion Engines

Scilab code Exa 17.01 Indicated power and mechanical efficiency

```
//pathname=get_absolute_file_path('17.01.sce')
//filename=pathname+filesep()+'17.01-data.sci'
//exec(filename)
//L/D ratio:
r1=1.2
//Cylinder diameter(in m):
D=0.12
//Area of indicated diagram(in m^2):
A=30*10^(-4)
//Spring constant(in kN/m^2):
k=20*10^3
//Rpm of engine:
N=2000
//Percentage power lost:
r=0.10
//Stroke length(in m):
L=r1*D
//Length of indicator diagram(in m):
l=L/2
```

```
//Mep(in N/m^2):
mep=A*k*10^3/l
//Cross-sectional area of piston(in m^2):
A2=%pi*D^2/4
//Total indicated power for 4 cylinders(in W):
IP=4*mep*A2*L*N/(2*60)
//Fricitional loss(in W):
FP=r*IP
//Brake power available(in W):
BP=IP-FP
//Mechanical efficiency:
nm=BP/IP*100
printf("\n RESULT \n")
printf("\nIndicated power = %f W",IP)
printf("\nMechanical efficiency = %f percent",nm)
```

Scilab code Exa 17.02 Power required to drive

```
//pathname=get_absolute_file_path('17.02.sce')
//filename=pathname+filesep()+'17.02-data.sci'
//exec(filename)
//Indicator diagram area & length(in m^2 & m):
A=40*10^(-4)
l=0.08
//Bore(in m):
D=0.15
//Stroke(in m):
L=0.20
//Rpm of motor:
N=100
//Spring constant(in Pa/m):
k=1.5*10^8
//Mep(in Pa):
mep=A*k/l
//Indicated power(in kW):
```

```
IP=(%pi*D^2/4*L*mep*N/60*2)/10^3
printf("\n RESULT \n")
printf("\nPower required to drive =%f kW",IP)
```

Scilab code Exa 17.03 Indicated power

```
//pathname=get_absolute_file_path('17.03.sce')
//filename=pathname+filesep()+'17.03-data.sci'
//exec(filename)
//Mechanical efficiency:
nm=0.90
//Rating(in kW):
BP=38
//Indicated power(in kW):
IP=BP/nm
//Fricitional loss(in kW):
FP=IP-BP
//Brake power at quater load(in kW):
BP1=0.25*BP
//Mechanical efficiency:
nm1=BP1/(BP1+FP)*100
printf("\n RESULT \n")
printf("\nIndicated power = %f W",IP)
printf("\nFricitonal power loss = %f kw",FP)
printf("\nMechanical efficiency = %f percent",nm1)
```

Scilab code Exa 17.04 Brake power and fuel consumption

```
//pathname=get_absolute_file_path('17.04.sce')
//filename=pathname+filesep()+'17.04-data.sci'
//exec(filename)
//Specific fuel consumption(in kg/kW.h):
m1=0.25
```

```
//Brake mean effective pressure(in kPa):
pbmep=1.5*10^3
//Speed of engine(in rpm):
N=100
//Bore of cylinder(in m):
D=0.85
//Stroke(in m):
L=2.20
//Calorific value of diesel(in kJ/kg):
C=43*10^3
//Brake power of engine(in kW):
BP=pbmep*L*(%pi*D^2/4)*N/60
printf("\n RESULT \n")
printf("\nBrake power = %f MW",BP/100)
//Fuel consumption(in kg/hr):
m=m1*BP
//Heat from fuel(in kJ/s):
q=m*C/3600
//Brake thermal efficiency:
nb=BP/q*100
printf("\nFuel consumption rate = %f kg/hr",m)
printf("\nBrake thermal efficiency = %f percent",nb)
```

Scilab code Exa 17.05 Volumetric efficiency

```
//pathname=get_absolute_file_path('17.05.sce')
//filename=pathname+filesep()+'17.05-data.sci'
//exec(filename)
//Effective pressure(in kPa):
pb=6*10^2
//Speed:
N=600
//Specific fuel consumption(in kg/kW.h)
m1=0.25
//BOre(in m):
```

```
D=0.20
//Stroke length(in m):
L=0.30
//Air fuel ratio:
r=26
//Calorific value(in kJ/kg):
C=43*10^3
//Gas constant(in kJ/kg.K):
R=0.287
//Ambient conditions:
p=1*10^2 //kPa
T=300 //K
//Brake thermal efficiency:
nb=3600/(m1*C)*100
printf("\n RESULT \n")
printf("\nBrake thermal efficiency = %f percent",nb)
//Brake power(in kW):
BP=4*pb*L*(%pi*D^2/4)*N/60
printf("\nBrake power = %f kW",BP)
//Air consumption rate(in kg/min):
ma=m1*BP*r/60
//Volume(in m^3/min):
Va=ma*R*T/p
//Swept volume(in m^3):
Vs=%pi*(0.3)^2*0.4/4
//Volumetric efficiency:
nv=Va/(Vs*N/2*4)*100
printf("\nVolumetric efficiency = %f percent",nv)
```

Scilab code Exa 17.06 Brake power required

```
//pathname=get_absolute_file_path('17.06.sce')
//filename=pathname+filesep()+'17.06-data.sci'
//exec(filename)
//Volumetric efficiency
```

```
n=0.7
//Air fuel ratio:
r=19
//Speed(in rpm):
N=3000
//Fuel consumption rate(in litres/hr):
m=5
//Specific gravity:
sg=0.7
//Piston speed(in m/min):
s=500
//Mep(in kPa):
p=6*10^2
//Gas constant(in kJ/kg.K):
R=0.287
//Mechanical efficiency:
nm=0.8
//Stroke length(in m):
L=s/(2*N)
//Air requirement(in kg/min):
ma=r*m*sg/60
//Volume of air sucked(in m^3/min):
Va=ma*R*288/(1.013*10^2)
//Bore diameter(in m):
D=sqrt(Va*4/(%pi*L*N*2*n))
//Indicated power(in kW):
IP=p*L*(%pi*D^2/4*N*2)/60
//Brake power(in kW):
BP=IP*nm
printf("\n RESULT \n")
printf("\nBrake power = %f W",BP)
```

Scilab code Exa 17.07 Brake power and indicated power

```
//pathname=get_absolute_file_path('17.07.sce')
```

```
//filename=pathname+filesep()+'17.07-data.sci'
//exec(filename)
//Friction power(in kW):
FP=5
//Rpm:
N=3000
//Bore(in m):
D=0.20
//Stroke(in m):
L=0.30
//Fuel supplied at rate(in kg/min):
m=0.15
//Load(in kg):
F=20
//Radius(in m):
r=0.5
//Calorific value of fuel(in kJ/kg):
C=43000
//Acceleration due to gravity(in m/s^2):
g=9.81
//Brake power(in kW):
BP=2*%pi*N*(F*g*r*10^(-3))/60
//Indicated power(in kW):
IP=BP+FP
//Mechanical efficiency:
nm=BP/IP
//BSFC(in kg/kW.hr):
BSFC=m*60/BP
//Brake thermal efficiency:
nbth=3600/(BSFC*C)*100
//Indicated thermal efficiency:
nith=nbth/nm
//Indicated mep(in kPa):
Pimep=IP/(L*(%pi*D^2/4)*N/60)
//Brake mep(in kPa):
Pbmep=Pimep*nm
printf("\n RESULT \n")
printf("\nBrake power = %f W",BP)
```

```
printf("\nIndicated power = %f kW",IP)
printf("\nMechanical efficiency = %f percent",nm
    *100)
printf("\nBrake thermal efficiency = %f percent",
    nbth)
printf("\nIndicated thermal efficiency = %f percent"
    ,nith)
printf("\nBrake mean effective pressure = %f kPa",
    Pbmep)
printf("\nIndicated mean effective pressure = %f kPa
    ",Pimep)
```

Scilab code Exa 17.08 `Indicated power and volumetric efficiency`

```
//pathname=get_absolute_file_path('17.08.sce')
//filename=pathname+filesep()+'17.08-data.sci'
//exec(filename)
//Speed(in rpm):
N=300
//Brake power(in kW):
BP=250
//Bore diameter(in m):
D=0.30
//Stroke length(in m):
L=0.25
//Fuel consumption rate(in kg/min):
m=1
//Air fuel ratio:
r=10
//Calorific value of fuel(in kJ/kg):
C=43000
//Indicated mep(in kPa):
Pimep=0.8*10^3
//Gas constant(in kJ/kg.K):
R=0.287
```

```
//Indicated power(in kW):
IP=Pimep*L*(%pi*D^2/4)*N*4/60
//Mechanical efficiency:
nm=BP/IP
//BSFC(in kg/kW.hr):
BSFC=m*60/BP
//Brake thermal efficiency:
nbth=3600/(BSFC*C)*100
//Swept volume(in m^3):
Vs=%pi*D^2*L/4
//Mass of air(in kg):
ma=(1.013*10^2*Vs)/(R*300)
//Volumetric efficiency:
nv=m*r/(ma*4*N/2)*100
printf("\n RESULT \n")
printf("\nIndicated power = %f kW",IP)
printf("\nMechanical efficiency = %f percent",nm
    *100)
printf("\nBrake thermal efficiency = %f percent",
    nbth)
printf("\nVolumetric efficiency = %f percent",nv)
```

Scilab code Exa 17.09 Brake power and indicated power

```
//pathname=get_absolute_file_path('17.09.sce')
//filename=pathname+filesep()+'17.09-data.sci'
//exec(filename)
//Indicator constant(in kN/m^2):
k=25
//Rpm:
N=300
//Swept volume(in m^3):
Vs=1.5*10^(-2)
//Load(in kg):
F=60
```

```
//Radius(in m):
r=0.5
//Calorific value of fuel(in kJ/kg):
C=43000
//Acceleration due to gravity(in m/s^2):
g=9.81
//Fuel supplied at rate(in kg/min):
m=0.12
//Indicatedmep(in kPa):
Pimep=10*k
//Indicated power(in kW):
IP=Pimep*Vs*N/(2*60)
//Brake power(in kW):
BP=2*%pi*N/(2*60)*(F*g*r)*10^(-3)
//Mechanical efficiency:
nm=BP/IP
printf("\n RESULT \n")
printf("\nBrake power = %f W",BP)
printf("\nIndicated power = %f kW",IP)
printf("\nMechanical efficiency = %f percent",nm
    *100)
```

Scilab code Exa 17.10 Indicated thermal efficiency

```
//pathname=get_absolute_file_path('17.10.sce')
//filename=pathname+filesep()+'17.10-data.sci'
//exec(filename)
//Speed of engine(in rpm):
N=1500
//Brake torque(in Nm):
T=300
//Fuel consumed(in kg):
m=4
//Cooling water circulated(in kg/min):
m1=15
```

```
//Calorific value of fuel(in kJ/kg):
C=42000
//Mechanical efficiency:
nm=0.90
//Brake power(in kW):
BP=2*%pi*N*T/(60*10^3)
printf("\n RESULT \n")
printf("\nBrake power = %f W",BP)
//BSFC(in kg/kW.hr):
BSFC=m*60/(m1*BP)
printf("\nBrake specific fuel consumption = %f kg/kW
    .hr",BSFC)
//Indicated power(in kW):
IP=BP/nm
//Indicated thermal efficiency:
nith=IP/(m*C/(m1*60))*100
printf("\nIndicated thermal efficiency = %f percent"
    ,nith)
```

Chapter 18

Introduction to Refrigeration and Airconditioning

Scilab code Exa 18.01 Work input

```
//pathname=get_absolute_file_path('18.01.sce')
//filename=pathname+filesep()+'18.01-data.sci'
//exec(filename)
//Heat extracted by carnot cycle(in kJ/min):
Q1=500
//Temperature of refrigerated space(in K):
T1=-16+273
//Atmospheric temperature(in K):
T2=27+273
//Heat rejected(in kJ/min):
Q2=Q1*(T2/T1)
//Work input required(in kJ/min):
W=Q2-Q1
printf("\n RESULT \n")
printf("\nWork input = %f kJ/min",W)
```

Scilab code Exa 18.02 HP required

```
//pathname=get_absolute_file_path('18.02.sce')
//filename=pathname+filesep()+'18.02-data.sci'
//exec(filename)
//Operating temperature(in K):
T1=-5+273
T2=27+273
//Specific heats(in kJ/kg.K):
Cpw=4.18
//Latent heat(in kJ/kg):
L=335
//Capacity(in tons):
C=800
//Heat extraction rate(in kJ/s):
q=C*3.5
//Heat to be removed per kg of water(in kJ/kg):
q1=Cpw*(27-0)+L
//Ice formation rate(in kg/s):
m=q/q1
printf("\n RESULT \n")
printf("\nMass rate of ice formation = %f kg/s",m)
//COP:
COP=(T1/(T2-T1))
//Work done(in hp):
W=q/COP/0.7457
printf("\nHP required = %f hp",W)
```

Scilab code Exa 18.03 Temperature of surroundings

```
//pathname=get_absolute_file_path('18.03.sce')
//filename=pathname+filesep()+'18.03-data.sci'
//exec(filename)
//Work done(in hp):
W=3
```

```
//Temperature to be maintained(in K):
T1=-27+273
//COP:
COP=1*3.5/(W*0.7457)
printf("\n RESULT \n")
printf("\nCOP = %f",COP)
//Temperature of surroundings(in K):
T2=T1+T1/COP
printf("\nTemperature of surroundings = %f K",T2)
```

Scilab code Exa 18.04 Refrigeration capacity and COP

```
//pathname=get_absolute_file_path('18.04.sce')
//filename=pathname+filesep()+'18.04-data.sci'
//exec(filename)
//Pressure ratio:
r1=8
//Operating temperatures(in K)
T1=-30+273
T3=27+273
//Isentropic efficiency of compression:
nic=0.85
//Isentropic efficiency of expansion:
nie=0.90
//Specific heat(in kJ/kg):
Cp=1.005
//Adiabatic index of compression:
r=1.4
//Air flow rate(in kg/s):
m=1
//Temperature at state 2'(in K):
T2a=T1*(r1)^((r-1)/r)
//Temperature at state 2(in K):
T2=(T2a-T1)/nic+T1
//Temperature at state 4'(in K):
```

```
T4a=T3*(1/r1)^((r-1)/r)
//Temperature at state 2'(in K):
T4=T3-(T3-T4a)*nie
//Work during compression(in kJ/s):
Wc=Cp*(T2-T1)
//Work during expansion(in kJ/s):
Wt=Cp*(T3-T4)
//Refrigeration effect(in kJ/s):
Qref=Cp*(T1-T4)
//Net work required(in kJ/s):
W=Wc-Wt
//COP:
COP=Qref/W
printf("\n RESULT \n")
printf("\nRefrigeration capacity = %f kJ/s",Qref)
printf("\nCOP = %f",COP)
```

Scilab code Exa 18.05 COP

```
//pathname=get_absolute_file_path('18.05.sce')
//filename=pathname+filesep()+'18.05-data.sci'
//exec(filename)
//Operating temperatures(in K)
T1=7+273
T3=27+273
//Pressures(in bar):
p1=1
p2=5
//Adiabatic index of compression:
r=1.4
//Specific heat(in kJ/kg):
Cp=1.005
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Temperature at state 4(in K):
```

```
T4=T3/((p2/p1)^((r-1)/r))
//Heat rejected in process 2−3(in kJ/kg):
Q23=Cp*(T2-T3)
//Heat picked during process 4−1(in kJ/kg):
Q41=Cp*(T1-T4)
//Net work(in kJ/kg):
W=Q23-Q41
//COP:
COP=Q41/W
printf("\n RESULT \n")
printf("\nCOP = %f",COP)
```

Scilab code Exa 18.06 Refrigeration capacity and COP

```
//pathname=get_absolute_file_path('18.06.sce')
//filename=pathname+filesep()+'18.06−data.sci'
//exec(filename)
//Pressure(in bar):
p1=1
p2=5.5
//Operating temperatures(in K):
T1=-10+273
T3=27+273
//Air flow rate(in kg/s):
m=0.8
//Specific heat(in kJ/kg):
Cp=1.005
//Adiabatic index of compression:
r=1.4
//Gas constant(in kJ/kg.K):
R=0.287
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Temperature at state 4(in K):
T4=T3/((p2/p1)^((r-1)/r))
```

```
//Refrigeration capacity(in kJ/s):
C=m*Cp*(T1-T4)
printf("\n RESULT \n")
printf("\nRefrigeration capacity = %f kJ/s",C)
//Work required to run the comoressor(in kJ/s):
Wc=m*r/(r-1)*R*(T2-T1)
printf("\nHP required to run compressor = %f hp",Wc/0.7457)
//Net work input(in kJ/s):
W=m*Cp*((T2-T3)-(T1-T4))
//COP:
COP=C/W
printf("\nCOP = %f",COP)
```

Scilab code Exa 18.07 `Mass flow rate and COP`

```
//pathname=get_absolute_file_path('18.07.sce')
//filename=pathname+filesep()+'18.07-data.sci'
//exec(filename)
p2 = 4; Cp = 1.005;
//Pressure(in bar):
p1=1.2
p6=p1
p3=4
p3=p2
p4=1
p7=0.9
//Temperatures(in K):
T1=288
T6=T1
T5=25+273
T3=323
T8=30+273
n=1.45
n1=1.3
```

```
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((n-1)/n)
T2=418.47
//Temperature at state 4(in K):
T4=T3*(p4/p3)^((n1-1)/n1)
T4=234.57
//Refrigeration effect(in kg/s):
m=10*3.5/(Cp*(T5-T4))
printf("\n RESULT \n")
printf("\nAir mass flow rate in cabin = %f kg/s",m)
//Temperature at state 7(in K):
T7=T6*(p7/p6)^((n1-1)/n1)
//Ram air mass flow rate(in kg/s):
rm=m*(T2-T3)/(T8-T7)+m
printf("\nRam air mass flow rate = %f kg/s",rm)
//Work input to the compressor(in kJ/s):
W=m*Cp*(T2-T1)
//COP:
COP=10*3.5/W
printf("\nCOP = %f",COP)
```

Scilab code Exa 18.08 COP and HP required

```
//pathname=get_absolute_file_path('18.08.sce')
//filename=pathname+filesep()+'18.08-data.sci'
//exec(filename)
//Pressures(in bar):
p0=0.9
p1=1
p2=4
p3=p2
p4=p3
p5=1.03
//Temperatures(in K):
T6=298
```

```
T0=276
//Specific heat(in kJ/kg):
Cp=1.005
//Adiabatic index of compression:
r=1.4
//Refrigeration capacity:
C=15
//Isentropic efficiency for compressor:
nic=0.9
//Isentropic efficiency for turbine:
nit=0.8
//Temperature at state 1(in K):
T1=T0*(p1/p0)^((r-1)/r)
//Temperature at state 2'(in K):
T2a=T1*(p2/p1)^((r-1)/r)
//Temperature at state 2(in K):
T2=T1+(T2a-T1)/nic
//Temperature at state 3(in K):
T3=0.34*T2
//Temperature at state 4(in K):
T4=T3-10
//Temperature at state 5'(in K):
T5a=T4*(p5/p4)^((r-1)/r)
//Temperature at state 5(in K):
T5=T4-(T4-T5a)*nit
//Mass flow rate(in kg/s):
m=C*3.5/(Cp*(T6-T5))
//Work input(in kJ/s):
W=m*Cp*(T2-T1)
//COP:
COP=C*3.5/W
printf("\n RESULT \n")
printf("\nCOP = %f",COP)
printf("\nHP required = %f hp",W/0.7457)
```

Scilab code Exa 18.09 COP

```
//pathname=get_absolute_file_path('18.09.sce')
//filename=pathname+filesep()+'18.09-data.sci'
//exec(filename)
//Operating temperatures(in K):
T1=-15+273
T2=25+273
h2=1317.95 //kJ/kg
s2=4.4809 //kJ/kg.K
h3=99.94 //kJ/kg
s3=0.3386 //kJ/kg.K
h9=-54.51 //kJ/kg
s9=-0.2132 //kJ/kg.K
h4=h3
s8=s3
s4=0.3855 //kJ/kg.K
s1=s2
//Refrigeration effect(in kJ/kg):
C=T1*(s1-s4)
//Work done(in kJ/kg):
W=h3-h9-T1*(s3-s9)+(T2-T1)*(s1-s8)
//COP:
COP=C/W
printf("\n RESULT \n")
printf("\nCOP = %f",COP)
```

Scilab code Exa 18.10 COP and piston displacement

```
//pathname=get_absolute_file_path('18.10.sce')
//filename=pathname+filesep()+'18.10-data.sci'
//exec(filename)
//Operating temperature(in K):
T1=-20+273
T3=40+273
```

```
//Pressures(in bar):
p2=9.61
p1=1.51
n=1.13
//Speed(in rpm):
N=1200
h1=178.61 //kJ/kg
h3=73.53 //kJ/kg
h4=h3
s1=0.7082 //kJ/kg.K
s2=s1
sg=0.682 //kJ/kg.K
Cpg=0.747 //kJ/kg.K
hg=203.05 //kJ/kg
vg=0.1088 //m^3/kg
m1=2.86 //ton
//Clearance volume:
C=0.02
//Temperature of state 2(in K):
T2=T3*(%e)^((s1-sg)/Cpg)
//Enthalpy after compression(in kJ/kg):
h2=hg+Cpg*(T2-T3)
//Compression work(in kJ/kg):
Wc=h2-h1
//Refrigeration effect(in kJ/kg):
r=h1-h4
//Mass flow rate(in kg/s):
m=m1*3.5/r
//COP:
COP=r/Wc
//Volumetric efficiency:
nv=1+C-C*(p2/p1)^(1/n)
//Piston displacement(in m^3):
V=m*60*vg/(nv*N)
printf("\n RESULT \n")
printf("\nCOP = %f",COP)
printf("\nPiston displacement = %f cm^3",V*10^6)
```

Scilab code Exa 18.11 Mass flow rate and COP

```
//pathname=get_absolute_file_path('18.11.sce')
//filename=pathname+filesep()+'18.11-data.sci'
//exec(filename)
//From steam tables:
h1=322.28 //kJ/kg
h2=342.32 //kJ/kg
s2=1.1937 //kJ/kg.K
s1=s2
x1=0.961
h1=312.08 //kJ/kg
h3=144.11 //kJ/kg
h4=115.22 //kJ/kg
h5=h4
//Refrigeration effect(in kW):
m1=2
//Refrigeration effect(in kJ/kg):
r=h1-h5
//Refrigerant flow rate(in kg/s):
m=m1/r
//Compressor work(in kJ/kg):
Wc=h2-h1
//COP:
COP=r/Wc
printf("\n RESULT \n")
printf("\nCOP = %f",COP)
printf("\nMass flow rate = %f kg/s",m)
```

Scilab code Exa 18.12 Partial pressure of vapour and relative humidity

```
//pathname=get_absolute_file_path('18.12.sce')
```

```
//filename=pathname+filesep()+'18.12-data.sci'
//exec(filename)
//Specific humidity(in gm/kg):
w=0.016
//Saturated partial pressure of vapour(in bar):
pvsat=0.03098
//Partial pressure of vapour(in bar):
pv=w/0.622*1.013/(1+w/0.622)
//Relative humidity:
r=pv/pvsat*100
printf("\n RESULT \n")
printf("\nPartial pressure of vapour = %f",pv)
printf("\nRelative humidity = %f percent",r)
```

Scilab code Exa 18.13 Enthalpy of mixture

```
//pathname=get_absolute_file_path('18.13.sce')
//filename=pathname+filesep()+'18.13-data.sci'
//exec(filename)
pv = 0.0255;
//Relavite humidity;
r=0.6
//Saturation pressure(in bar):
pvsat=0.0425
//Gas constant(in kJ/kg.K):
R=0.287
//Surrounding temperature(in K):
Ta=303
hg=2504.1 //kJ/kg
//Specific heat(in kJ/kg.K):
Cp=1.005
//Partial pressure of air(in bar):
pa=1.013-r*pvsat
printf("\n RESULT \n")
printf("\nPartial pressure of air = %f bar",pa)
```

```
//Humidity ratio:
w=0.622*(pv/(1.013-pv))
printf("\nHumidity ratio = %f jg/kg of dry air",w)
//Dew point temperature(in C):
T=21.4 //from steam table
printf("\nDew point temperature = 21.4 C")
//Density of mixture(in kg/m^3):
d=1.013*10^2*(1+w)/(R*Ta)
printf("\nDensity = %f kg/m^3",d)
//Enthalpy of mixture(in kJ/kg of dry air):
h=Cp*30+w*(hg+1.860*(30-T))
printf("\nEnthalpy of mixture = %f kJ/kg of air",h)
```

Scilab code Exa 18.14 Mass of water added and heat transferred

```
//pathname=get_absolute_file_path('18.14.sce')
//filename=pathname+filesep()+'18.14-data.sci'
//exec(filename)
//Relavite humidity;
r=0.80
//From pyschometric chart:
w1=0.0086 //kg/kg of air
w2=0.01 //kg/kg of air
h1=37 //kJ/kg
h2=50 //kJ/kg
v2=0.854 //m^3/kg
//Mass of water added between states 1 and 2:
m=w2-w1
//Mass flow rate:
ma=r/v2
//Total mass of water added(in kg/s):
m1=m*ma
//Heat transferred(in kJ/s):
q=ma*(h2-h1)
printf("\n RESULT \n")
```

```
printf("\nMass of water added = %f kg/s",m1)
printf("\nHeat transferred = %f kJ/s",q)
```

Scilab code Exa 18.15 Specific humidity of mixture

```
//pathname=get_absolute_file_path('18.15.sce')
//filename=pathname+filesep()+'18.15-data.sci'
//exec(filename)
//Mass flow rate(in kg/s):
m1=3
m2=2
//Specific heat(in kJ/kg.K):
Cp=1.005
//Specofoc heat of stream(in kJ/kg.K):
Cps=1.86
//Relative humidity:
r1=0.30
r2=0.85
//From psychometric chart:
pvsat1=0.04246 //bar
pvsat2=0.005628
hg1=2520.7 //kJ/kg
hg2=2559.9 //kJ/kg
T1=30 //C
Tdp1=10.5
T2=35
Tdp2=32
//Partial pressure of vapour at 1(in bar):
pv1=pvsat1*r1
//Specific humidity:
w1=0.622*pv1/(1.013-pv1)
//Enthalpy at state 1(in kJ/kg):
h1=Cp*T1+w1*(hg1-Cps*(T1-Tdp1))
//Partial pressure at state 2(in bar):
pv2=pvsat2*r2
```

```
//Specific humidity:
w2=0.622*pv2/(1.013-pv2)
//Enthalpy at state 1(in kJ/kg):
h2=Cp*T2+w2*(hg2-Cps*(T2-Tdp2))
//Enthalpy of mixture(in kJ/kg):
hmix=1/(m1+m2)*(h1*m1/(1+w1)+h2*m2/(1+w2))
//Mass of vapour:
mmix=1/(m1+m2)*(w1*m1/(1+w1)+w2*m2/(1+w2))
//Specific humidity of mixture:
wmix=mmix/(1-mmix)
//Partial pressure of water vapour(in bar):
pv=1.013*wmix/0.622/(1+wmix/0.622)
printf("\n RESULT \n")
printf("\nSpecific humidity of mixture = %f kg/kg of
    dry air",wmix)
printf("\nPartial pressure of water vapour in
    mixture = %f bar",pv)
```

Scilab code Exa 18.16 Heat added

```
//pathname=get_absolute_file_path('18.16.sce')
//filename=pathname+filesep()+'18.16-data.sci'
//exec(filename)
//Rate at which air enters(in m^3/s):
r=3
//From steam tables:
h1=36.4 //kJ/kg
h2=52 //kJ/kg
v1=0.825 //m^3/kg
//Mass of air(in kg/s):
m=3/v1
//Amount of heat added(in kJ/s):
q=m*(h2-h1)
printf("\n RESULT \n")
printf("\nHeat added = %f kJ/s",q)
```

Chapter 19

Jet Propulsion and Rocket Engines

Scilab code Exa 19.01 Thrust

```
//pathname=get_absolute_file_path('19.01.sce')
//filename=pathname+filesep()+'19.01-data.sci'
//exec(filename)
//Specific heat of gases(in kJ/kg.K):
Cpg=1.13 //kJ/kg.K
Cpa=1.005 //kJ/kg.K
rg=1.33
ra=1.4
C=41.84*10^3 //kJ/kg of fuel
//Temperatures(in K):
T1=272
T3=1000
//Compression efficiency:
nc=0.84
p3=3
p2=3
p1=0.5
p5=0.4
//Turbine efficiency:
```

```
nt=0.82
//Nozzle efficiency:
nn=0.92
//Speed(in m/s):
Ca=200
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((ra-1)/ra)
//Temperature at state 2'(in K):
T2a=T1+(T2-T1)/nc
//Compressive work(in kW):
Wc=Cpa*(T2a-T1)
printf("\n RESULT \n")
printf("\nPower required for compressor = %f kW/kg",
   Wc)
//Air fuel ratio:
r=(C-Cpg*T3)/(Cpg*T3-Cpa*T2a)
printf("\nAir fuel ratio = %f",r)
//Temperature at state 4'(in K):
T4a=T3-Cpa/Cpg*(T2a-T1)/(1+r)
T4a=810.46
T4=T3-(T3-T4a)/nt
//Pressure of gas leaving turbine(in bar):
p4=p3*(T4/T3)^(rg/(rg-1))
printf("\nPressure of gas leaving turbine = %f bar",
   p4)
//Temperature at state 5(in K):
T5=T4a*(p5/p4)^((rg-1)/rg)
//Temperature at state 5'(in K):
T5a=T4a-nn*(T4a-T5)
//Exit jet velocity(in m/s):
C5a=sqrt(2*Cpg*(T4a-T5a)*10^3)
Ce=C5a
//Thrust per kg of air per second:
T=(1+1/r)*Ce-Ca
printf("\nThrust = %f N/kg/s",T)
```

Scilab code Exa 19.02 Thrust

```
//pathname=get_absolute_file_path('19.02.sce')
//filename=pathname+filesep()+'19.02-data.sci'
//exec(filename)
T1=285 //K
p1=1 //bar
T3=773 //K
p2=4 //bar
r=1.4
Cpa=1.005 //kJ/kg.K
CV=43100 //kJ/kg.K
T3=273+500 //K
//Temperature at state 2(in K):
T2=T1*(p2/p1)^((r-1)/r)
//Temperature at state 2'(in K):
T2a=T1+1.1*(T2-T1)
//Work required in compressor(in kJ/kg of air):
Wc=Cpa*(T2a-T1)
printf("\n RESULT \n")
printf("\nPower required to drive compressor = %f kW
   /kg of air",Wc)
//Heat added in combustion chamber(in kJ/kg of air):
qa=Cpa*(T3-T2a)
//Air fuel ratio:
r1=CV/qa
printf("\nAir-fuel ratio = %f",r1)
//Temperature at state 5(in K):
T5=T3*(p1/p2)^((r-1)/r)
//Enthalpy drop in the nozzle(in kJ/kg of air):
hd=Cpa*(T3-T5-T2a+T1)
//Velocity of exit gas from nozzle(in m/s):
Ce=sqrt(2*hd*10^3)
//Thrust(in N/kg/s):
```

```
T=(1+1/r)*Ce
printf("\nThrust = %f N/kg of air/s",Ce)
```

Scilab code Exa 19.03 Specific fuel consumption

```
//pathname=get_absolute_file_path('19.03.sce')
//filename=pathname+filesep()+'19.03-data.sci'
//exec(filename)
//Specific heat of gases(in kJ/kg.K):
Cpg=1.14 //kJ/kg.K
Cpa=1.005 //kJ/kg.K
//Mechanical efficiency:
nm=0.96
//Polytropic efficiency of compressor:
nc=0.87
//Turbine efficiency:
nt=0.90
//Nozzle efficiency:
nn=0.95
//By pass ratio:
B=5.5
//Mass flow rate of air(in kg/s):
ma=200
//Pressures(in bar):
p2=1.5
p1=1
p3=28
pa=p1
//Temperatures(in K):
T1=288
rg=1.33
ra=1.4
CV=43100 //kJ/kg
T4=1573 //K
//For compression:a1=((ne-1)/ne)
```

```
a1=1/nc*(ra-1)/ra
a1=0.328
//For expansion:a2=(nt-1)/nt
a2=nt*(rg-1)/rg
a2=0.223
//Temperature at state 2'(in K):
T2a=T1*(p2/p1)^a1
//Temperature at state 3'(in K):
T3a=T2a*(p3/p2)^a2
//Using nozzle efficiency:
dT=nn*T2a*(1-(pa/p2)^((ra-1)/ra))
//Velocity at exit of nozzle(in m/s):
C8=sqrt(2*Cpa*10^3*dT)
//Mass flow rate of bypass air(in kg/s):
mab=ma*B/(B+1)
//Mass flow rate of hot gases(in kg/s):
mca=ma-mab
//Thrust available due to by pass air(in kN):
Tb=mab*C8/10^3
//Air fuel ratio:
r1=(Cpg*T4-Cpa*T3a)/(CV-Cpg*T4)
//Temperature at state 5'(in K):
T5a=T4-(Cpa*(T3a-T2a)/(nm*(1+r1)*Cpg))
//Temperature at state 6'(in K):
T6a=(Cpg*nm*T5a-(1+B)*Cpa*(T2a-T1))/(Cpg*nm)
//Pressure at state 4(in bar):
p4=p3-p2
//Pressure at state 5(in bar):
p5=p4*(T5a/T4)^(1/a2)
//Pressure at state 6(in bar):
p6=p5*(T6a/T5a)^(1/a2)
//Critical pressure ratio:
c=((rg+1)/2)^(rg/(rg-1))
//Pressure at state 7(in bar):
p7=p6/c
//For exit nozzle(in K):
dT1=nn*T6a*(1-(p7/p6)^((rg-1)/rg))
//Velocity at exit of nozzle(in m/s):
```

```
C7=sqrt(2*Cpg*10^3*dT1)
//Thrust due to hot gases(in kN):
Tg=mca*C7/10^3
//Total thrust(in kN):
Tt=Tg+Tb
//Specific thrust(in kN/kg/s):
st=Tt/ma
printf("\n RESULT \n")
printf("\nSpecific thrust = %f kN/kg/s",st)
//Specific fuel consumption(in  kg/h.N):
sfc=r1*mca*3600/(Tt*10^3)
printf("\nSpecific fuel consumption = %f kg/h.N",sfc
   )
```

Scilab code Exa 19.04 Specific fuel consumption

```
//pathname=get_absolute_file_path('19.04.sce')
//filename=pathname+filesep()+'19.04-data.sci'
//exec(filename)
//Velociy of turbojet plane(in m/s):
Ca=277.78
//Thrust to velocity ratio:
r1=0.5
//Rate at which air enters(in kg/s):
m=50
//Air fuel ratio:
r=52
//Lower calorific value of fuel:
LCV=43100
//Jet velocity(in m/s):
Ce=Ca/r1
printf("\n RESULT \n")
printf("\nJet velocity = %f m/s",Ce)
//Thrust(in N):
T=(m+m/r)*Ce-m*Ca
```

```
printf("\nThrust = %f kN",T/10^3)
//Specific thrust(in N/kg/s):
St=T/m
printf("\nSpecific thrust = %f N/kg/s",St)
//Thrust power(in kW):
P=T*Ca/10^3
printf("\nThrust power = %f kW",P)
//Propulsive efficiency:
np=2/(1+1/r1)*100
printf("\nPropulsive efficiency = %f percent",np)
//Thermal efficiency:
nt=((1+1/r)*Ce^2-Ca^2)/(2*1/r*LCV)/10
printf("\nThermal efficiency = %f percent",nt)
//Overall efficiency:
no=np*nt/100
printf("\nOverall efficiency = %f percent",no)
//Specific fuel consumption(in kg/h.N):
sfc=m/r*3600/(T)
printf("\nSpecific fuel consumption = %f kg/h.N",sfc
    )
```

Scilab code Exa 19.05 `Velocity at exit of nozzle`

```
//pathname=get_absolute_file_path('19.05.sce')
//filename=pathname+filesep()+'19.05-data.sci'
//exec(filename)
//Pressures(in bar):
p1=2.2
//Temperatures(in K):
T1=220
T4=1273
//Velocities(in m/s):
C1=260
//Nozzle efficiency:
nn=0.85
```

```
//Turbine efficiency:
nt=0.88
//Diffuser efficiency:
nd=0.90
//Specific heat(in kJ/kg.K):
Cp=1.005
//Adiabatic index of  compression:
r=1.4
//Pressure ratio:
r1=12
//Temperature at state 2(in K):
T2=T1+C1^2/(2*Cp*10^3)
//Pressure at state 2(in bar):
p2=p1*(T2/T1)^(r/(r-1))
p3=p2*r1
p4=p3
//Temperature at state 3(in K):
T3=T2*(p3/p2)^((r-1)/r)
//Temperature at state 3'(in K):
T3a=T2+(T3-T2)/nn
//Temperature at state 5'(in K):
T5a=T4-(T3a-T2)
//Temperature of state 5(in K):
T5=T4-(T4-T5a)/nt
//Pressure at state 5(in bar):
p5=p4*(T5/T4)^(r/(r-1))
//Temperature at state 2(in K):
T2=C1+(200)^2/(2*Cp*10^3)
//Temperature at state 2'(in K):
T2a=T1+(T2-T1)/nd
T3a=568.635
T4=1000
p6=2.2
T6=542.83
//Velocity at exit of nozzle(in m/s):
C6=sqrt(2*(T5-T6)*Cp*10^3)
printf("\n RESULT \n")
printf("\nVelocity of exit of nozzle = %f m/s",C6)
```

Scilab code Exa 19.06 `Total thrust`

```
//pathname=get_absolute_file_path('19.06.sce')
//filename=pathname+filesep()+'19.06-data.sci'
//exec(filename)
//Calorific value(in kJ/kg):
CV=45000
//Inlet temperature(in C):
T1=1000
T4=T1
//Nozzle efficiency:
nn=0.9
//Diffuser efficiency:
nd=0.9
//Compressive efficiency:
nc=0.8
//Turbine efficiency:
nt=0.8
//Specific heat(in kJ/kg.K):
Cp=1.005
p3=7.248 //bar
p4=p3-0.15
r=1.4
p6=0.7
//Gas constant(in kJ/kg.K):
R=0.287
//Temperature at state 2(in K):
T2a=282.11
T3a=568.635
//Air fuel ratio:
r1=(CV-T1*Cp)/(Cp*T1-Cp*T3a)
//Temperature at state 5'(in K):
T5a=T4-(T3a-T2a)
//Temperature at state 5(in K):
```

```
T5=T4-(T4-T5a)/nt
p5=p4*(T5/T4)^(r/(r-1))
//Temperature at state 6(in K):
T6=T5a*(p6/p5)^((r-1)/r)
//Temperature at state 6'(in K):
T6a=T5a-(T5a-T6)*nn
//Velocity at exit of nozzle(in m/s):
C6=sqrt(2*Cp*(T5a-T6a)*10^3)
//Volume flow rate of air(in m^3/s):
v=200/10
//Mass flow rate(in kg/s):
m=0.7*10^2*v/(R*260)
//Specific thrust(in N/kg of air/s):
St=(1+1/r1)*C6
printf("\n RESULT \n")
printf("\nSpecific thrust = %f N/kg of air/s",St)
//Total thrust(in N):
Tt=m*St
printf("\nTotal thrust = %f N",Tt)
```

Scilab code Exa 19.07 Jet exit area

```
//pathname=get_absolute_file_path('19.07.sce')
//filename=pathname+filesep()+'19.07-data.sci'
//exec(filename)
//Specific heat(in kJ/kg.K):
Cpa=1.005
Cpg=1.087
ra=1.4
rg=1.33
//Gas constant(in kJ/kg.K):
R=0.287
//Speed of aeroplane(in m/s):
C0=250
//Velocity at exit of turbine(in m/s):
```

```
C4a=180
CV=43000 //kJ/kg
//Thrust power(in kW):
P=800
//Temperatures(in K):
T0=-20+273
T2=474.25
T3=973
//Pressures(in bar):
p0=0.3
p1=0.31
p5=p0
//Compressor efficiency:
nc=0.85
//Jet engine efficiency:
nj=0.90
//Pressure ratio:
r1=6
//Temperature at state 2(in K):
T1=T0+C0^2/(2*Cpa*10^3)
T2a=T1+(T2-T1)/nc
//Pressure at state 2(in bar):
p2=p1*r1
p3=p2
//Fuel air ratio:
FA=(Cpa*T3-Cpg*T2a)/(CV-Cpa*T3)
printf("\n RESULT \n")
printf("\nAir-fuel ratio = %f:1",1/FA)
//Temperature at state 4'(in K):
T4a=T3-Cpa/Cpg*(T2a-T1)/(1+FA)
//Temperature at state 4(in K):
T4=T3-(T3-T4a)/nc
//Pressure at state 4(in bar):
p4=p3*(T4/T3)^(rg/(rg-1))
//Temperature at state 5(in K):
T5=T4a*(p5/p4)^((rg-1)/rg)
//Nozzle exit velocity(in m/s):
C5=sqrt(2*nj*(Cpg*10^3*(T4a-T5)+C4a^2/2))
```

```
//Overall efficiency:
no=(((1+FA)*C5-C0)*C0)/(FA*CV*10^3)*100
//Rate of air consumption(in kg/s):
ma=P*10^3/(((1+FA)*C5-C0)*C0)
printf("\nRate of air consumption = %f kg/s",ma)
//Power produced by the turbine(in kW):
Pt=ma*(1+FA)*Cpg*(T3-T4a)
printf("\nPower produced by turbine = %f kW",Pt)
//Temperature at state 5'(in K):
T5a=T4a-((C5^2-C4a^2)/(2*Cpg*10^3))
//Density of exhaust gases(in m^3/kg):
d5a=p5*10^2/(R*T5a)
//Jet exit area(in m^2):
Aj=ma*(1+FA)/(C5*d5a)
printf("\nJet exit area = %f m^2",Aj)
```

Scilab code Exa 19.08 Jet diameter

```
//pathname=get_absolute_file_path('19.08.sce')
//filename=pathname+filesep()+'19.08-data.sci'
//exec(filename)
//Speed of jet plane(in m/s):
Ca=250
//Density of air(in kg/m^3):
d=0.15
//Drag(in kW):
D=6800
//Propulsive efficiency:
np=0.56
//Relative velocity(in m/s):
Ce=2*Ca/np-Ca
//Absolute velocity of jet(in m/s):
C=Ce-Ca
//Mass flow rate(in kg/s):
ma=D/(Ce-Ca)
```

```
//Volume flow rate(in m^3/s):
v=ma/d
//Jet diameter(in m):
dj=sqrt(v*4/(2*%pi*Ce))
printf("\n RESULT \n")
printf("\nJet diamter = %f cm",dj*100)
```

Scilab code Exa 19.09 Specific thrust

```
//pathname=get_absolute_file_path('19.09.sce')
//filename=pathname+filesep()+'19.09-data.sci'
//exec(filename)
//Gas constant(in kJ/kg.K):
R=0.287
//Density ratio:
r1=0.4
//Specific heat(in kJ/kg.K):
Cp=1.005
//Drag coefficient:
d=0.018
//Jet velocity(in m/s):
Ce=550
//Wing area(in m^2):
A=20
//Speed of aeroplane(in m/s):
Ca=900*1000/3600
//Density of STP(in kg/m^3):
d1=1.01325*10^2/(R*288)
//Density of air at altitude(in kg/m^3):
d2=r1*d1
//Thrust on aeroplane:
T=d*A*d2*Ca^2/2
//Mass flow rate(in kg/s):
ma=T/(Ce-Ca)
//Specific thrust(in N/kg of air):
```

```
St=T/ma
printf("\n RESULT \n")
printf("\nSpecific thrust = %d N/kg of air",St)
```

Scilab code Exa 19.10 Overall efficiency

```
//pathname=get_absolute_file_path('19.10.sce')
//filename=pathname+filesep()+'19.10-data.sci'
//exec(filename)
//Speed of air craft(in m/s):
Ca=250
//Mass flow rate(in kg/s):
m=55
//Air fuel ratio:
r=85
//Combustion efficiency:
nc=0.96
//Lower calorific value(in kJ/kg):
CV=43000
//Isentropic enthalpy change(in kJ/kg):
dh=220
//Velocity coefficient:
n=0.95
//Jet velocity(in m/s):
Ce=n*sqrt(2*dh*10^3)
Ce=615.67
//Specific thrust per kg of air(in N/kg air):
St=400.67
//Fuel flow rate(in kg/hr):
r1=1/r*3600*m
//Specific fuel consumption(in kg/N.hr):
sfc=r1/(St*m)
//Thrust power(in kW):
P=m*(Ce-Ca)*Ca/10^3
//Propulsive power(in kW):
```

```
Pp=m*(Ce^2-Ca^2)/2/10^3
//Propulsive efficiency:
np=P/Pp*100
//Overall efficiency:
no=P/(m/r*CV*nc)*100
printf("\n RESULT \n")
printf("\nPropulsive power = %f kW",Pp)
printf("\nPropulsive efficiency = %f percent",np)
printf("\nOverall efficiency = %f percent",no)
```