Scilab Textbook Companion for Engineering Thermodynamics by P. K. Nag[1]

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Chapter 1

Introduction

Book Description

Scilab code Exa 1.1 `Calculting gas pressure`

```
d_r = 13640; // Density of mercury in kg/m3
g = 9.79; // Acceleration due to gravity in m/s2
z = 562e-03; // Difference in height in m
z0 = 761e-03; // Reading of barometer in m
P = (d_r*g*(z+z0))*(0.987/1e05); // Gas Pressure in bar
disp("bar",P,"Gas Pressure is ")
```

Title: Engineering Thermodynamics

Author: P. K. Nag

Scilab code Exa 1.2 `Calculating inlet and exhaust pressure in pascals`

```
d_r = 13.6e03; // Density of mercury in kg/m3
g = 9.81; // Acceleration due to gravity in m/s2
z = 710e-03; // Stean flow pressure in m
z0 = 772e-03; // Reading of barometer in m
P = 1.4e06; // Gauge pressure of applied steam in Pa
P0 = d_r*g*z0; // Atmospheric pressure in Pa
Pi = P+P0 ; // Inlet steam pressure in Pa
Pc = d_r*g*(z0-z); // Condenser pressure in Pa
```

```
disp("Pa",Pi,"Inlet steam pressure is")
disp("Pa",Pc,"Condenser pressure is")
```

Scilab code Exa 1.3 Converting various readings of pressure in kPa

```
z = 0.760; // Barometer reading in m
// Part (a)
h1 = 40e-02; // Mercury height in vaccume in m
d_r = 13.6e03; // Density of mercury in kg/m3
g = 9.80; // Acceleration due to gravity in m/s2
Patm = z*d_r*g; // Atmospheric pressure in Pas
Pv = h1*d_r*g; // Pressue in vaccume in Pa
Pabs = Patm-Pv; // Absolute pressure in Pa
disp("Pa",Pabs," 40cmHg vaccume is")
// Part (b)
h2 = 90e-02; // Mercury height in gauge in m
Pg = h2*d_r*g; // Gauge Pressure in Pa
Pabs1 = Patm + Pg ; // Absolute pressure in Pa
disp("Pa",Pabs1,"90cmHg gauge is")
// Part(c)
d_w = 1e03 ; // Density of water in kg/m3
h3 = 1.2 ; // Gauge Pressure water height in m
Pga = d_w*h3*g; // Gauge Pressure in Pa
Pabs3 = Patm + Pga ; // Absolute pressure in Pa
disp("Pa",Pabs3,"1.2 m H2O gauge is")
```

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Scilab code Exa 1.4 Calculating the depth of earth atmosphere required to pro

```
Pr = 1.033e05; // Required Pressure in bar
function y = pressure(p)
  y = p^(-0.714);
```

```
endfunction;
g = 9.81; // Acceleration due to gravity in m/s2
H = ((2.5e05^0.714)/g)*intg(0,Pr,pressure); // Depth of atmosphere required in m
disp("Km",H/1000,"The depth of atmosphere required is ")
```

Edition: 4

Scilab code Exa 1.5 Determining net upward force experienced by astrounaut

```
m = 68 ; // Astronaut mass in Kg
g = 9.806; // Acceleration due to gravity in m/s2
a = 10*g ; // Lift off acceleration in m/s2
F = m*a; // Net vertical force in N
disp("N",F,"Net vertical force experienced by astronaut is")
```

Year: 2008

Chapter 2

Temperature

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Scilab code Exa 2.1

Calculations on straight bore thermometer

```
d = 1; l = 1; // Assuming
A_ACDB = (%pi/4)*(1/3)*((1.05*d)^2)*10.5*l - (%pi/4)
    *(1/3)*d^2*10*l ; // Area of ABCD
A_AEFB = (%pi/4)*(1/3)*((1.1*d)^2)*11*l - (%pi/4)
    *(1/3)*d^2*10*l;
t = 100*(A_ACDB/A_AEFB);
disp("degree Celcius",t,"The straight bore
    thermometer reading would e")
```

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

Scilab code Exa 2.2 Calculation of thermometer reading

```
t = poly(0,'t');
e = (0.2*t)-(5e-04*t^2); // e.m.f. as a function
    of temperature in mV
e0 = horner(e, 0); // e.m.f. at t = 0 degree
e100 = horner(e, 100); // e.m.f. at t = 100
    degree
e50 = horner(e, 50); // e.m.f. at t = 50 degreer
r = (100/e100)*e50; // Reading of thermocouple
    at t = 50degree
disp("degree",r,"Reading of thermocouple at t =
    50degree is")
```

Exa Example (Solved example)

Scilab code Exa 2.3 `Calculting temperature for given resistance`

Eqn Equation (Particular equation of the above book)

```
R0 = 2.8; // Resistence at t=0 degree in ohm
R100 = 3.8; // Resistence at t = 100 degree in
    ohm
a = (R100/R0 - 1)*0.01; // alpha
R = 5.8; // Indicated ressistace in ohm
t = (R/R0 - 1)/a; // Temperature in degree
disp("degree",t,"The temperature when indicated
    resistance is 5.8 ohm is ")
```

Chapter 3

Work and heat transfer

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.

Scilab code Exa 3.1 Calculation of magnitude of velocity

```
V1 = 100; // Initial velocity in m/s
g = 9.81; // Acceleration due to gravity in m/s2
z1 = 100; // Initial elevation in m
V = sqrt((2*g*z1)+(V1)^2); // Final velocity in m/s2
disp("m/s",V,"The velocity of the object just before
    ir hits the ground is")
```

Contents

List of Scilab Codes

Scilab code Exa 3.2 Calculation of work done on atmosphere by balloon

```
dV = 0.5; // Change in volume in m3
P = 101.325e03; // Atmospheric pressure in N/m2
Wd = P*dV; // Work done in J
disp("KJ",Wd/1000,"The amount of work done upon the
   atmosphere by the ballon is")
```

Scilab code Exa 3.3 Calculation of work done by atmosphere

```
dV = 0.6; // Change in volume in m3
P = 101.325e03; // Atmospheric pressure in N/m2
Wd = P*dV; // Work done in J
disp("KJ",Wd/1000,"The displacement work done by the
    air is")
```

Scilab code Exa 3.4 Calculation of net work transfer for the system

```
T = 1.275e-03; // Torque acting against the fluid in
    N
```

```
N = 10000; // Number of revolutions
W1 = 2*%pi*T*N; // Work done by stirring device upon the system
P = 101.325e03; // Atmospheric pressure in N/m2
d = 0.6; // Piston diameter in m
A = (%pi/4)*(d)^2; // Piston area in m
L = 0.80; // Displacement of diameter in m
W2 = (P*A*L)/1000; // Work done by the system on the surroundings i KJ
W = -W1+W2; // Net work tranfer for the system
disp("KJ",W,"The Net work tranfer for the system is")
```

Scilab code Exa 3.5 Calculation of net rate of work transfer from the gas to pisto

```
ad = 5.5e-04; // Area of indicator diagram
ld = 0.06; // Length of diagram
k = 147e06; // Spring constant in MPa/m
w = 150; // Speed of engine
L = 1.2 ; // Stroke of piston
d = 0.8; // Diameter of the cylinder in m
A = (%pi/4)*(0.8^2); // Area of cylinder
Pm = (ad/ld)*k; // Effective pressure
W1 = Pm*L*A*w; // Work done in 1 minute
W = (12*W1)/60; // The rate of work transfer gas to the piston in MJ/s
disp("kW",W/1000,"The rate of work transfer gas to the piston is")
```

Scilab code Exa 3.6 Calculation of dimension of cylindrical furnace

```
Tm = 1535; // Melting point of iron on degree
Ti = 15; // Initial temperature
```

```
Tf = 1650; // Final temperature
Lh = 270e03; // Latent heat of iron in J/Kg
ml = 29.93; // Atomic weight of iron in liquid state
m = 56; // Atomoc weight of iron
sh = 0.502e03; // Specific heat of iron in J/Kg
d = 6900; // Density of molten metal in kg/m3
H = (Tm-Ti)*sh + Lh + (ml/m)*(Tf-Tm)*1000; // Heat required
Mr = 5e03; // Melting rate in Kg/h
Hr = H*Mr ; // Rate of heat suppy
HrA = Hr/(0.7*3600) // Actual rate of heat supply
disp("W",HrA,"Rating of furnace would be")
V = (3*Mr)/d; // Volume required in m3
d = ((V/2)*(4/%pi))*(1/3); // Diameter of cylinder of furnace in m
l = 2*d; // Length of cylinder of furnace in m
disp("m",l," Length of cylinder of furnace is")
```

Scilab code Exa 3.7 Calculations on alluminium furnace

```
SH = 0.9; // Specific heat of alluminium in solid state
L = 390; // Latent heat
aw = 27; // Atomic weight
D = 2400; // Density in molten state
Tf = 700+273; // Final temperature
Tm = 660+273; // Melting point of aluminium
Ti = 15+273; // Intial temperature
HR = SH*(Tm-Ti)+L+(29.93/27)*(Tf-Tm); // Heat requires
HS = HR/0.7 ; // Heat supplied
RM = 217*1000*3600/HS ; // From the data of problem 3.7
V = 2.18; // Volume
M = V*D;
```

```
disp("tonnes",M*0.001,"Mass of alluminium that can
    be melted is")
disp("kg/h",RM,"Rate at which alluminium can be
    melted is")
```

Scilab code Exa 3.8 Calculation on work required for automization

```
dd = 60e-06;
mw = 1;
st = 0.07;
dw = 1000;
dp = 15e-03;
N = (mw*6)/(%pi*dd^3*dw);
Af = %pi*dd^2*N;
S_L = 4/(dp*dw);
W = st*(100-S_L);
disp("J",W,"Work done during automization is")
```

Scilab code Exa 3.9 Calcultion on electric motor

```
dc = 40e-02;
L = 30e-02;
P = 1e05; // Pressure in Pascal
I = 0.5;
V = 24;
t = 15*60; // in seconds
Wm = V*I*t;
Ws = 0.9*Wm;
W = P*(%pi/4)*dc^2*L;
disp("J",Wm,"Work input to the motor is")
disp("J",Ws,"Work input to the stirrer is")
disp("J",W,"Work done by the fluid on the atmosphere
     is")
```

Scilab code Exa 3.10 Calculation of work done by piston cylinder system

```
P1 = 100; P2 = 37.9; P3 = 14.4;
V1 = 0.1; V2 = 0.2; V3 = 0.4;
n1 = (log(P1/P2))/(log(V2/V1));
n2 = (log(P2/P3))/(log(V3/V2));
// n1 = n2
W = ((P1*V1)-(P3*V3))/(n1-1);
disp("kJ",W,"Work done by the system is")
```

Scilab code Exa 3.11 Calculation of work done in PV cycle

```
P1 = 20*1.01325e05;
V1 = 0.04; V2 = 2*V1;
n = 1.45;
P2 = (V1/V2)^n*P1;
W12 = ((P1*V1)-(P2*V2))/(n-1);
W23 = P2*(V2-V1);
Wc = W12-W23;
disp("J",Wc,"Work done in the cycle is")
```

Chapter 4

First law of thermodynamics

Scilab code Exa 4.1 Calculation of change in internal energy of gas

```
V1 = 0.3; // Initial volume in m3
V2 = 0.15; // Final volume in m3
P = 0.105e06; // Pressure in Pa
Q = -37.6e03; // Heat tranferred in J
W = P*(V2-V1); // Work done
U = Q-W; // Internal energy change
disp("Joule",U,"Change in the internal energy of the
    system is")
```

Scilab code Exa 4.2 Calculations on PV cycle

```
Qacb = 84e03;
Wacb = 32e03;
Uba = Qacb-Wacb; // Ub-Ua
// Part (a)
Wadb = 10.5e03;
Qadb = Uba+Wadb;
disp("J",Qadb,"The heat flow into the system along
   the path adb");
```

```
// Part (b)
Wb_a = -21e03;
Uab = - Uba;
Qb_a = Uab+Wb_a;
disp("J",Qb_a,"The heat liberated along the path b-a is")
// Part (c)
Wdb = 0; // Constant volume
Wad = 10.4e03;
Wadb = Wdb-Wad;
Ud = 42e03;
Ua = 0;
Qad = Ud-Ua+Wad;
Qdb = Qadb-Qad;
disp("J",Qdb,"and",Qad,"The heat absorbed in the path ad and db are")
```

Scilab code Exa 4.3 Calculation of net rate of work output in a piston and cylinde

```
// Process a-b
Qab = 0;
Wab = 2170; // in KJ/min
Eab = Qab-Wab;
// Process b-c
Qbc = 21000;
Wbc = 0;
Ebc = Qbc-Wbc;
// Process c-d
Qcd = -2100;
Ecd = -36600;
Wcd = Qcd-Ecd;
// Process d-a
Q = -17000; // Total heat transfer
Qda = Q-Qab-Qbc-Qcd;
Eda = -Eab-Ebc-Ecd;
```

```
Wda = Qda-Eda;
M = [Qab Wab Eab ; Qbc Wbc Ebc; Qcd Wcd Ecd; Qda Wda
    Eda];
disp(M,"The completed table is")
```

Scilab code Exa 4.4 Thermodynamics calculations of a substance with given internal

```
// Part (a)
m = 3;
V1 = 0.22;
P1 = 500e03;
P2 = 100e03;
V2 = V1*(P1/P2)^(1/1.2);
dU = 3.56*(P2*V2-P1*V1);
gama = 1.2;
W = (P2*V2-P1*V1)/(1-gama);
Q = dU+W;
disp("J respectively",dU,W,Q,"Q,W and dU of the
    quasi static process are")
// Part (b)
Qb = 30e03;
Wb = Qb-dU;
disp("Joule",Wb,"Work transfer for the process is")
// Part (c)
disp("Wb is not equal to integral(p*dv) since the
    process is not quasi static")
```

Scilab code Exa 4.5 Thermodynamics calculations of a cylinder with given internal

```
V1 = 0.03;
P1 = 170e03;
P2 = 400e03;
V2 = 0.06;
```

```
U = 3.15*(P2*V2-P1*V1);
B = [P1 P2]';
A = [1 V1; 1 V2];
x = inv(A)*B;
a = x(1); b = x(2);
function P = pressure(V)
  P = a+b*V;
endfunction;
W = intg(V1,V2,pressure);
Q = U+W;
disp("J",W,"The work done by the system is")
disp("J",U,"The internal energy change of the system is")
disp("J",Q,"The heat flow into the system is")
```

Scilab code Exa 4.6 Calculation on PV cycle of a stationary fluid system

```
// Process 1-2
Q12 = 235; // in KJ/Kg
W12 = 0 ;
U12 = Q12-W12;
// Process 2-3
Q23 = 0;
U23 = -70 ;
W23 = Q23-U23;
// Process 3-1
Q31 = - 200;
U31 = -U12-U23;
W31 = Q31-U31;
//
W = W12 + W23 + W31;
Q = Q12 + Q23 + Q31;
disp("KJ/Kg",Q,"Heat trasfer in the cycle is")
disp("KJ/Kg",W,"Work done during the the cycle is")
```

Chapter 5

First law applied to flow processes

Scilab code Exa 5.1 Calculation on an air compressor

```
// Part(a)
V1 = 0.95;
P1 = 100e03;
v1 = 7;
V2 = 0.19;
P2 = 700e03;
v2 = 5;
w = 0.5;
u21 = 90e03; // u21 = u2-u1
Q = -58e03; // As heat is added Q = dQ/dt
W = - w*( u21 + (P2*V2-P1*V1) + ((v2^2-v1^2)/2) ) +
    Q; // W = dW/dt
disp("Watt",W,"The rate of work input is")
// Part (b)
A = (v2/v1)*(V1/V2); // A = A1/A2
d = sqrt(A); // d = d1/d2
disp(d,"The ratio of the inlet pipe diameter and
   outer pipe diameter is")
```

Scilab code Exa 5.2 Calculations across a control volume

```
V1 = 0.37;
P1 = 600e03;
v1 = 16;
V2 = 0.62;
P2 = 100e03;
v2 = 270;
Z1 = 32;
Z2 = 0;
g = 9.81;
Q = -9e03; // heat loss Q = dQ/dt
W = 135e03; // Work done W = dW/dt
U12 = (P2*V2-P1*V1) + ((v2^2-v1^2)/2) + (Z2-Z1)*g +
    W - Q; // U12 = U1-U2
disp("Joule",U12,"The internal energy decreases by")
```

Scilab code Exa 5.3 Calculation of steam flow rate between a boiler and turbine

```
P1 = 4e06;
t1 = 400;
h1 = 3213e03;
V1 = 0.073;
P2 = 3.5e06;
t2 = 392;
h2 = 3202e03;
V2 = 0.084;
Q = -8.5e03;
v1 = sqrt((2*(h1-h2+Q))/(1.15^2-1));
A1 = (%pi/4)*0.2^2;
w = (A1*v1)/V1;
disp("Kg/s",w,"The stean flow rate is")
```

Scilab code Exa 5.4 Calculation of quantity of steam supplied to a heater

```
h1 = 313.93;
h2 = 2676;
h3 = 419;
w1 = 4.2;
w = poly(0,'w') // w = w2
P = w1*h1 + w*h2 - h3*(4.2+w)
function [x] = stress(a,b,f)
  N = 100;
  eps = 1e-5;
  if((f(a)*f(b))>0) then
    error('no root possible f(a)*f(b)>0');
    abort;
  end;
  if(abs(f(a))<eps) then
    error('solution at a');
    abort;
  end
  if(abs(f(b))<eps) then
    error('solution at b');
    abort;
  end
  while(N>0)
    c = (a+b)/2
    if(abs(f(c))<eps) then
      x = c ;
      x;
      return;
    end;
    if((f(a)*f(c))<0 ) then
      b = c ;
    else
      a = c ;
```

```
    end
    N = N-1;
  end
  error('no convergence');
  abort;
endfunction

deff('[y]=p(w)',['y = - 441.294 + 2257*w '])
w = stress(0.1,0.2,p);
disp("Kg/h",w*3600,"The amount of heat that should
   be supplied is")
```

Scilab code Exa 5.5 `Calculations across a heat exchanger`

```
t1 = 15; t2 = 800; t3 = 650; t4 = 500;
v1 = 30; v2 = 30 ; v3 = 60;
w = 2;
cp = 1005;
Q1_2 = w*cp*(t2-t1);
disp("KJ/s",Q1_2/1000,"The rate of heat transfer to
   the air in the heat exchanger is")
W_T = w*( ((v2^2-v3^2)/2) + cp*(t2-t3));
disp("KW",W_T/1000,"The power output from the
   turbine assuming no heat loss")
v4 = sqrt( (v3^2) + (2*cp*(t3-t4)) );
disp("m/s",v4,"The velocity at the exit of the
   nozzle is")
```

Scilab code Exa 5.6 `Calculations on a gas turbine`

```
w = 5;
h1 = 900e03;
h2 = 400e03;
```

```
v1 = 50; v2 = 150;
Q = -25*5; // Q = dQ/dt for w = 5kg
W = w*( (h1-h2) + ((v1^2-v2^2)/2) ) + Q; // W = dW/dt
disp("kW",W/1000,"The power output of the turbine is")
R = 285; T1 = 300; P1 = 100e03;
V = (w*R*T1)/P1; // V = dV/dt
A1 = V/v1;
D1 = sqrt((4*A1)/%pi);
disp("m",D1,"The diameter of the inlet pipe is")
```

Scilab code Exa 5.7 Calculation of velocity of exhaust jet

```
ha = 260; // Enthalpy of air
hg = 912; // Enthalpy of gas
Va = 270; // Velocity of air
f = 0.0190; // Fuel to air ratio wf/wa
Ef = 44500; // Chemical energy of fuel in kJ/kg
Q = 21; // Heat loss from the engine
Eg = 0.05*f*Ef/(1+f); // As 5% of chemical energy is not released in reaction
Vg = sqrt(2000*(((ha+(Va^2*0.001)/2+(f*Ef)-Q)/(1+f))-hg-Eg));
disp("m/s",Vg,"Velocity of exhaust gas is")
```

Scilab code Exa 5.9 Thermodynamics calculations of air with given internal energy

```
u0 = 0.718*273*1e03;
t = poly(0,'t');
u = u0+718*t; // in SI unit
hp = u + 285*(t+273); // ""
h = horner(hp,150); // h = hp(150)
```

```
W = 100; // W = dW/dt
m = W/h;
disp("kg/h",m*3600,"The rate at which air flows out
    of the tank")
```

Chapter 6

Second law of thermodynamics

Scilab code Exa 6.1 Calculation of least rate of heat rejection by a cyclic heat e

```
T1 = 800;
T2 = 30;
e_max = 1-((T2+273)/(T1+273));
Wnet = 1; // in kW
Q1 = Wnet/e_max;
Q2 = Q1-Wnet;
disp("KW",Q2,"Least rate of heat rejection is")
```

Scilab code Exa 6.2 Calculation of least power for a domestic food freezer

```
T1 = -15+273;
T2 = 30+273;
Q2 = 1.75; // in kJ/sec
Q1 = (T1/T2)*Q2;
W = Q1-Q2;
disp("kW",W,"Least Power necessary to pump the heat
    out is")

// There is a calculation mistake in the book
```

Scilab code Exa 6.4 Calculations on a carnot engine

```
Q1 = 200;
T1 = 373.15;
T2 = 273.16;
Q2 = Q1*(T2/T1);
W = Q1-Q2;
e = W/Q1;
disp("respectively",e,"J",W,"J",Q2,"The heat
   rejected , the work done and the thermal effiency
   of the engine is")
```

Scilab code Exa 6.5 Calculations on reversible heat engine

```
T1 = 873;
T2 = 313;
T3 = 253;
Q1 = 2000e03; // In joule
W = 360e03; // in joule
// Part (a)
e_max = 1-(T2/T1);
W1 = e_max*Q1;
COP = T3/(T2-T3);
W2 = W1-W;
Q4 = COP*W2;
Q3 = Q4+W2;
Q2 = Q1-W1;
disp("J",Q2+Q3,"The heat rejection to the 40 degree
   reservior is")
// Part (b)
e_max_ = 0.4*e_max;
```

```
W1_ = e_max_*Q1;
W2_ = W1_-W;
COP_ = 0.4*COP;
Q4_ = COP_*W2_;
Q3_ = Q4_+W2_;
Q2_ = Q1-W1_;
disp("J",Q2_+Q3_,"The heat rejection to the 40
   degree reservior is")
```

Scilab code Exa 6.7 Determination of heat multiplication factor

```
T1 = 473;
T2 = 293;
T3 = 273;
MF = (T2*(T1-T3))/(T1*(T2-T3));
disp(MF," The multiplication factor is ")
```

Scilab code Exa 6.8 Estimation of minimum collector area of solar area

```
T1 = 363;
T2 = 293;
W = 1; // Kj/s
e_max = 1-(T2/T1);
Qmin = W/e_max ;
Qmin_ = Qmin*3600;
E = 1880; // in kJ/m2 h
Amin = Qmin_/E ;
disp("m2",Amin,"Minimum area required for the
   collector plate")
```

Scilab code Exa 6.9 `Determination of minimum solar panel area`

```
T1 = 1000;
W = 1000; // in W
K = 5.67e-08;
Amin = (256*W)/(27*K*T1^4);
disp("m2",Amin,"Area of the panel")
```

Chapter 7

Entropy

Scilab code Exa 7.1 Calculation of entropy change of water

```
T1 = 37+273;
T2 = 35+273;
m = 1 ;
cv = 4.187;
S = m*cv*log(T2/T1); // S = S2-S1
disp("KJ/K",S,"Change in the entropy of the water is
    ")
```

Scilab code Exa 7.2 Entropy change calculations of a heat reservoir and universe

```
// Part (a)
T1 = 273;
T2 = 373;
m = 1 ;
cv = 4.187;
Ss = m*cv*log(T2/T1); // S = S2-S1
Q = m*cv*(T2-T1);
Sr = -(Q/T2);
```

```
S = Ss+Sr;
disp("kJ/K",S,"The entropy change of the universe is")
// Part (b)
T3 = 323;
Sw = m*cv*(log(T3/T1)+log(T2/T3));
Sr1 = -m*cv*(T3-T1)/T3;
Sr2 = -m*cv*(T2-T3)/T2;
Su = Sw+Sr1+Sr2;
disp("kJ/K",Su,"The entropy change of the universe is")
```

Scilab code Exa 7.3 Entropy change calculations between ice and universe

```
// Part (a)
m = 1;
T1 = -5+273;
T2 = 20+273;
T0 = 0+273;
cp = 2.093;
cv = 4.187;
lf = 333.3;
Q = m*cp*(T0-T1)+1*333.3+m*cv*(T2-T0);
Sa = -Q/T2;
Ss1 = m*cp*log(T0/T1);
Ss2 = lf/T0;
Ss3 = m*cv*log(T2/T0);
St = Ss1+Ss2+Ss3;
Su = St+Sa;
disp("kJ/K",Su,"The entropy change of the universe is")
// Part (b)
S = 1.5549; // S = S4-S1
Wmin = T2*(S)-Q;
disp("kJ",Wmin,"The minimum risk required is")
```

Scilab code Exa 7.5 Calculation of entropy change for a gas

```
Vo = 8.4;
Vh = 14;
n1 = Vo/22.4; n2 = Vh/22.4;
R = 8.31;
x1 = n1/(n1+n2);
x2 = n2/(n1+n2);
S = -R*(n1*log(x1)+n2*log(x2));
disp("J/K",S,"Entropy change for the process is")
```

Scilab code Exa 7.8 Calculation of highest temperature in three body system of con

```
T = poly(0,'T'); // T = Tf
Tf_ = 700-2*T; // Tf_ = Tf'
// Bisection method to solve for the polynomial
function [x] = Temperature(a,b,f)
  N = 100;
  eps = 1e-5;
  if((f(a)*f(b))>0) then
    error('no root possible f(a)*f(b)>0');
    abort;
  end;
  if(abs(f(a))<eps) then
    error('solution at a');
    abort;
  end
  if(abs(f(b))<eps) then
    error('solution at b');
    abort;
  end
```

```
  while(N>0)
    c = (a+b)/2
    if(abs(f(c))<eps) then
      x = c ;
      x;
      return;
    end;
    if((f(a)*f(c))<0 ) then
      b = c ;
    else
      a = c ;
    end
    N = N-1;
  end
  error('no convergence');
  abort;
endfunction
deff('[y]=p(T)',['y = 2*T^3-700*T^2+9000000 '])
T = Temperature(100,200,p);

Tf_ = horner(Tf_,T);
disp("K",Tf_,"The final temperature of the body C is
   ")
```

Scilab code Exa 7.9 Calculation of mxaximum amount of work for a system with given

```
T1 = 200;
T2 = 100;
A = 0.042;
Q1 = integrate('A*T^2','T',T1,T2);
S =  integrate('A*T^2/T','T',T1,T2);
W = poly(0,'W');
Z = (-Q1-W)/T2 + S; // Polynomial to be solved for W
// Bisection method to solve for the Work
function [x] = Work(a,b,f)
```

```
  N = 100;
  eps = 1e-5;
  if((f(a)*f(b))>0) then
    error('no root possible f(a)*f(b)>0');
    abort;
  end;
  if(abs(f(a))<eps) then
    error('solution at a');
    abort;
  end
  if(abs(f(b))<eps) then
    error('solution at b');
    abort;
  end
  while(N>0)
    c = (a+b)/2
    if(abs(f(c))<eps) then
      x = c ;
      x;
      return;
    end;
    if((f(a)*f(c))<0 ) then
      b = c ;
    else
      a = c ;
    end
    N = N-1;
  end
  error('no convergence');
  abort;
endfunction
deff('[y]=p(W)',['y = 350-0.01*W '])
W = Work(34000,36000,p);

disp("kJ",W/1000,"The maximum work that can be
   recovered is")
```

Scilab code Exa 7.10 Heat calculation for a reversible adiabatic compression cycle

```
P1 = 0.5e06;
V1 = 0.2; V2 = 0.05;
n = 1.3
P2 = P1*(V1/V2)^n;
function y = H(p)
  y = ((P1*V1^n)/p)^(1/n);
endfunction
H = integrate('H','p',P1,P2); // H = H2-H1
U = H-(P2*V2-P1*V1);
W12 = -U;
disp("kJ",H/1000,"Change in enthalpy is")
disp("kJ",U/1000,"Change in internal energy is")
disp("kJ",0,"and",0,"The change in entropy and heat
    transfer are")
disp("kJ",W12/1000,"The work transfer during the
    process is ")
```

Scilab code Exa 7.11 Establishment of direction of flow in a insulated duct

```
Pa = 130e03; Pb = 100e03;
Ta = 50+273; Tb = 13+273;
cp = 1.005;
Ss = integrate('cp/T','T',Ta,Tb)-integrate('0.287/p'
    ,'p',Pa,Pb);
Ssy = 0;
Su = Ss+Ssy;
disp("kJ/Kg K",Su,"Change in the entropy of the
    universe is")
disp("As the change in entropy of the universe in
    the process A-B is negative so the flow must be
```

```
    from B−A")
```

Scilab code Exa 7.12 Determination of possibility of a hypothetical device thermod

```
T1 = 300; T2 = 330; T3 = 270;
P1 = 4; P2 =1 ; P3 =1 ;
cp = 1.0005; R = 0.287;
S21 = cp*log(T2/T1)-R*log(P2/P1); // S21 = S2−S1
S31 = cp*log(T3/T1)-R*log(P3/P1); // S31 = S3−S1
Sgen = 1*S21 + 1*S31;
disp("kW/K",Sgen,"The entropy generated during the
    process is")
disp("As the entropy generated is positive so such
    device is possible")
```

Scilab code Exa 7.13 Calculation of heat transfer through a room

```
A = 5*7;
k = 0.71;
L = 0.32;
Ti = 21+273;
To = 6+273;
Q = k*A*(Ti-To)/L ;
disp("W",Q,"The rate of heat transfer through the
    wall is")
Sgen_wall = Q/To - Q/Ti;
disp("W/K",Sgen_wall,"The rate of entropy through
    the wall is")
Tr = 27+273;
Ts = 2+273;
Sgen_total = Q/Ts-Q/Tr;
disp("W/K",Sgen_total,"The rate of total entropy
    generation with this heat transfer process is")
```

Chapter 8

Available energy Availability and irreversibility

Scilab code Exa 8.1 Calculation of fraction of available energy in heat transfer

```
T0 = 308;
T1 = 693;
T1_ = 523; // T1_ = T1'
T1_ = 523; // ""
f = (T0*(T1-T1_))/(T1_*(T1-T0));
disp(f,"The fraction of energy that becomes
    unavailable due to irreversible heat transfer is"
    )
```

Scilab code Exa 8.2 Calculation of increase in available energy in a steam boiler

```
lhw = 1858.5; // Latent heat of water
Tew = 220+273;
Sw = lhw/Tew;
Tig = 1100; // Initial temperature of the gas
Tfg = 550; // Final ""
```

```
k = 1*lhw/(Tig-Tfg); // k = mg_dot*cpg
Tg2 = 823; Tg1 = 1373
Sg = integrate('k/T','T',Tg1,Tg2)
St = Sg+Sw;
disp("kJ/K",St,"Total change in entropy is ")
T0 = 303;
disp("kJ",T0*St,"Increase in unavailable energy is")
```

Scilab code Exa 8.3 Calculation of available energy in water

```
Tw = 75+273;
Ts = 5+273; // Ts = T0
m = 40;
cp = 4.2;
W = integrate('m*cp*(1-(Ts/T))','T',Ts,Tw);
Q1 = m*cp*(Tw-Ts);
UE = Q1-W;
disp("kJ",W,"Total work")
disp("kJ",Q1,"Heat released")
disp("kJ",UE,"Internal energy change")
```

Scilab code Exa 8.4 Calculation of decrease in available energy in water

```
Ts = 273+15;
Tw1 = 95+273;
Tw2 = 35+273;
m1 = 25; m2 = 35;
cp = 4.2;
AE25 = integrate('m1*cp*(1-(Ts/T))','T',Ts,Tw1);
AE35 = integrate('m2*cp*(1-(Ts/T))','T',Ts,Tw2);
AEt = AE25 + AE35;
Tm = (m1*Tw1+m2*Tw2)/(m1+m2); // Temperature after
    mixing
```

```
AE60 = integrate('(m1+m2)*cp*(1-(Ts/T))','T',Ts,Tm);
AE = AEt - AE60;
disp("kJ",AE,"The decrease in the totla energy is")
```

Scilab code Exa 8.5 Calculation of the final RPM of the flywheel

```
N1 = 3000;
w1 = (2*%pi*N1)/60;
I = 0.54;
Ei = 0.5*I*w1^2;
ti = 15+273;
m = 2;
dt = Ei/(1000*2*4.187);
tf = ti+dt;
AE = integrate('m*4.187*(1-(ti/T))','T',ti,tf);
UE = Ei/1000 - AE;
w2 = sqrt(AE*1000*2/I);
N2 = (w2*60)/(2*%pi);
disp(N2,"The final RPM of the flywheel would be")
```

Scilab code Exa 8.6 Energy calculations on air

```
T1 = 353; T2 = 278;
V2 = 2; V1 = 1;
P0 = 100; P1 = 500;
R = 0.287; cv = 0.718;
m = 2;
S = integrate('(m*cv)/T','T',T1,T2) + integrate('(m*
   R)/V','V',V1,V2); // S = S1-S2
U = m*cv*(T1-T2);
Wmax = U-(T2*(-S));
V1_ = (m*R*T1)/P1;
CA = Wmax-P0*(V1_); // Change in availability
```

```
I = T2*S;
disp("kJ",Wmax,"The maximum work is")
disp("kJ",CA,"Change in availability is")
disp("kJ",I,"Irreversibility is")
```

Scilab code Exa 8.7 Energy calculation of air through a turbine

```
P1 = 500; P2 = 100;
T1 = 793; T2 = 573;
cp = 1.005; T0 = 293; R = 0.287;
S21 = (R*log(P2/P1))-(cp*log(T2/T1))
CA = cp*(T1-T2)-T0*S21; // Change in v=availability
disp("kJ/kg",CA,"The decrease in availability is")
Wmax = CA;
disp("kJ/kg",Wmax,"The maximum work is")
Q = -10;
W = cp*(T1-T2)+Q ;
I = Wmax-W;
disp("kJ/kg",I,"The irreversibility is")
// Altenatively
Ssystem = -Q/T0;
Ssurr = -S21;
I1 = T0*(Ssystem+Ssurr);
```

Scilab code Exa 8.8 Energy calculation on a air preheater

```
T0 = 300;
Tg1 = 573; Tg2 = 473;
Ta1 = 313;
cpg = 1.09; cpa = 1.005;
mg = 12.5; ma = 11.15;
f1 = cpg*(Tg1-T0)-T0*cpg*(log(Tg1/T0));
f2 = cpg*(Tg2-T0)-T0*cpg*(log(Tg2/T0));
```

```
disp("kJ/Kg respectively",f2,"and",f1,"The initial
   and final availbility of the products are")
// Part (b)
Dfg = f1-f2;
Ta2 = Ta1 + (mg/ma)*(cpg/cpa)*(Tg1-Tg2);
Ifa = cpa*(Ta2-Ta1)-T0*cpa*(log(Ta2/Ta1));
I = mg*Dfg-ma*Ifa;
disp("kW",I,"The irreversibility of the process is")
// Part (c)
Ta2_ = Ta1*(%e^(-(mg/ma)*(cpg/cpa)*log(Tg2/Tg1)));
Q1 = mg*cpg*(Tg1-Tg2);
Q2 = ma*cpa*(Ta2_-Ta1);
W = Q1-Q2;
disp("kW",W,"Tota power generated by the heat engine
   ")
```

Scilab code Exa 8.9 Calculation of rate of energy degradation of gas flowing throu

```
T2 = 1063;
T1 = 1073;
T0 = 300;
m = 2; cp = 1.1;
I = m*cp*((T1-T2)-T0*(log(T1/T2)));
disp("kW",I,"The irrevesibility rate is")
// At lower temperature
T1_ = 353; T2_ = 343;
I_ = m*cp*((T1_-T2_)-T0*(log(T1_/T2_)));
disp("kW",I_,"The irrevesibility rate at lower
   temperature is")
```

Scilab code Exa 8.10 Calculation of rate of energy lossof gas flowing through a pi

```
m = 3; R = 0.287;
```

```
T0 = 300; k = 0.10; // k = dP/P1
Sgen = m*R*k;
I = Sgen*T0;
disp("kW",I,"The rate of energy loss because of the pressure drop due to friction")
```

Scilab code Exa 8.11 Energy calculation on mixing of stream of water

```
m1 = 2; // m1_dot
m2 = 1;
T1 = 90+273;
T2 = 30+273;
T0 =300;
m = m1+m2;
x = m1/m;
t = T2/T1; // Tau
cp = 4.187;
Sgen = m*cp*log((x+t*(1-x))/(t^(1-x)));
I = T0*Sgen;
disp("kW/K",Sgen,"The rate of entropy generation is")
disp("kW",I,"The rate of energy loss due to mixing is")
// Alternatively
T = (m1*T1+m2*T2)/(m1+m2); // euilibrium temperature
Sgen1 = m1*cp*log(T/T1)+m2*cp*log(T/T2);
I1 = T0*Sgen1;
```

Scilab code Exa 8.12 Calculations on efficiency of burning of fuel

```
Qr = 500; // Heat release in kW
Tr = 2000;
```

```
T0 = 300;
// Part (a)
Qa = 480; Ta = 1000;
n1a = (Qa/Qr);
n2a = n1a*(1-(T0/Ta))/(1-(T0/Tr));
disp("PART (A)")
disp("%",n1a*100,"The first law efficiency is")
disp("%",n2a*100,"The Second law efficiency is")
// Part (b)
Qb = 450; Tb = 500;
n1b = (Qb/Qr);
n2b = n1b*(1-(T0/Tb))/(1-(T0/Tr));
disp("PART (B)")
disp("%",n1b*100,"The first law efficiency is")
disp("%",n2b*100,"The Second law efficiency is")
// Part (c)
Qc = 300; Tc = 320;
n1c = (Qc/Qr);
n2c = n1c*(1-(T0/Tc))/(1-(T0/Tr));
disp("PART (C)")
disp("%",n1c*100,"The first law efficiency is")
disp("%",n2c*100,"The Second law efficiency is")
// Part (d)
Qd = 450;
n1d = (Qd/Qr);
n2a_= n1d*(1-(T0/Ta))/(1-(T0/Tr));
n2b_= n1d*(1-(T0/Tb))/(1-(T0/Tr));
n2c_= n1d*(1-(T0/Tc))/(1-(T0/Tr));
disp("Part (D)")
disp("%",n1d*100,"The first law efficiency is")
disp("%",n2a_*100,"The Second law efficiency of part
    (a) is")
disp("%",n2b_*100,"The Second law efficiency of part
    (b) is")
disp("%",n2c_*100,"The Second law efficiency of part
    (c) is")
```

Scilab code Exa 8.14 Calculation of power and efficiency in a compressor

```
cp = 1.005; T2 = 433; T1 = 298;
T0 = 298; R = 0.287; P2 = 8; P1 = 1;
Q = -100; m = 1;
W = Q + m*cp*(T1-T2);
AF = cp*(T2-T1)-T0*((cp*log(T2/T1))-(R*log(P2/P1)))
    ; // AF = af2-af1
e = AF/-W; // efficiency
disp("kW",W,"The power input is")
disp(e,"The second law efficiency of the compressor
    is")
```

Scilab code Exa 8.15 Determination of energy of vaccume

```
// Since vaccume has zero mass
U = 0; H0 = 0; S = 0;
// If the vaccume ha reduced to dead state
U0 = 0; H0 = 0 ; S0 = H0; V0 = 0;
P0 = 100; V = 1;
fi = P0*V;
disp("kJ",fi,"The energy of the complete vaccume is"
    )
```

Scilab code Exa 8.16 Calculation of energy produced in chilling process of fish

```
m = 1000; T0 = 300; P0 = 1;
T1 = 300;
T2 = 273-20; Tf = 273-2.2;
```

```
Cb = 1.7; Ca = 3.2;
Lh = 235;
H12 = m*((Cb*(Tf-T2))+Lh+(Ca*(T1-Tf)));
H21 = -H12;
S12 = m*((Cb*log(Tf/T2))+(Lh/Tf)+(Ca*log(T1/Tf)));
S21 = -S12;
E = H21-T0*S21;
disp("kJ",E,"Energy produced is")
```

Scilab code Exa 8.17 Thermodynamic calculation on air

```
cv = 0.718; T2 = 500; T1 = 300;
m = 1; T0 = 300;
// Case (a)
Sua = cv*log(T2/T1);
Ia = T0*Sua;
disp("kJ/kg",Ia,"The irreversibility in case a is")
// Case (b)
Q = m*cv*(T2-T1);
T = 600;
Sub = Sua-(Q/T);
Ib = T0*Sub;
disp("kJ/kg",Ib,"The irreversibility in case b is")
```

Scilab code Exa 8.18 Energy calculation of steam through turbine

```
h1 = 3230.9; s1 = 6.69212; V1 = 160; T1 = 273+400;
h2 = 2676.1; s2 = 7.3549; V2 = 100; T2 = 273+100;
T0 = 298; W = 540; Tb = 500;
Q = (h1-h2)+((V1^2-V2^2)/2)*1e-03-W;
I = 151.84-Q*(0.404);
AF = W + Q*(1-(T0/Tb)) + I; // AF = af1-af2
n2 = W/AF;
```

```
disp("kJ/kg",I,"Irreversibility per unit mass is")
disp(n2,"The second law effiency of the turbine is")
```

Scilab code Exa 8.19 Availability calculations on a furnace

```
T0 = 300; T = 1500;
Q = -8.5; W = 8.5;
// Case (a)
I = Q*(1-T0/T) + W;
R = Q*(1-T0/T);
disp("kW",I,"and",R,"Rate of availability transfer with heat and the irreversibility rate are")
// Case (b)
T1 = 500;
Ib = - Q*(1-T0/T) + Q*(1-T0/T1);
disp("kW",Ib,"Rate of availability in case b is")
```

Scilab code Exa 8.20 Energy calculation of air through compressor

```
P1 = 1; T1 = 273+30;
P2 = 3.5; T2 = 141+273 ; V = 90;
T0 = 303;
V2 = 100;
// Part (a)
g = 1.4;
T2s = T1*((P2/P1)^((g-1)/g));
disp("As T2s&gt; T2 so the process must be polytropic")
// Part (b)
p = log(P2/P1); q = log(T2/T1);
n = p/(p-q);
disp(n,"The polytropic index is")
// Part (c)
```

```
cp = 1.0035; R = 0.287;
Wa = cp*(T1-T2)-(V2^2/2)*1e-03 ;
Wt = -R*T0*log(P2/P1)-(V2^2/2)*1e-03;
Nt = Wt/Wa;
disp(Nt,"The isothermal effiency is")
// Part (d)
f12 = cp*(T1-T2) + T0*((R*log(P2/P1))-(cp*log(T2/T1)
    )) - (V2^2/2)*1e-03 ;
I = f12-Wa ;
disp("kW respectively",I,"and",f12,"The minimum work
    input and irreversibility are")
// Part (e)
n2 = (f12/Wa);
disp(n2,"Second law efficiency is")
```

Chapter 9

Properties of pure substances

Scilab code Exa 9.1 Calculations on vapourization of steam

```
// At 1 MPa
tsat = 179.91;
vf = 0.001127;
vg = 0.19444;
vfg = vg-vf;
sf = 2.1387;
sg = 6.5865;
sfg = sg-sf;
disp("degree",tsat,"At 1 Mpa saturation temperature
   is")
disp("m3/kg",vfg,"Changes in specific volume is")
disp("kJ/kg K",sfg,"Change in entropy during
   evaporation is")
```

Scilab code Exa 9.3 Finding the entropy and enthalpy of steam

```
v = 0.09; vf = 0.001177; vg = 0.09963;
x = (v-vf)/(vg-vf);
```

```
hf = 908.79; hfg = 1890.7;
sf = 2.4474; sfg = 3.8935;
h = hf+(x*hfg);
s = sf+(x*sfg);
disp("kJ/kg and kJ/kg K respectively",s,"and",h,"The
    enthalpy and entropy og the system are")
```

Scilab code Exa 9.4 Finding the entropy and enthalpyand volume of steam

```
// for T = 350 degree
T1 = 350; v1 = 0.2003; h1 = 3149.5; s1 = 7.1369;
// for T = 400 degree
T2 = 400; v2 = 0.2178; h2 = 3257.5; s2 = 7.3026;
// Interpolation for T = 380;
T = [T1 T2];
v = [v1 v2];
h = [h1 h2];
s = [s1 s2];
v3 = interpln([T;v],380);
h3 = interpln([T;h],380);
s3 = interpln([T;s],380);
disp("m3/kg respectively",v3,"kJ/kg",h3,"kJ/kg K",s3
    ,"The entropy, enthalpy and volume of stem at 1.4
    MPa and 380 degree is")
```

Scilab code Exa 9.5 Calculations of thermodynamics properties of mixture of air an

```
Psat = 3.973e06;
vf = 0.0012512; vg = 0.05013;
hf = 1085.36; hfg = 1716.2;
sf = 2.7927; sfg = 3.2802;
mf = 9; V = 0.04;
Vf = mf*vf;
```

```
Vg = V-Vf;
mg = Vg/vg;
m = mf+mg;
x = mg/m;
v = vf+x*(vg-vf);
h = hf+x*hfg;
s = sf+(x*sfg);
u = h-Psat*v*1e-03;
// at T = 250
uf = 1080.39; ufg = 1522;
u_ = uf+x*ufg;
disp("Pa",Psat,"The pressure is")
disp("kg",m,"The mass is")
disp("m3/kg",v,"Specific volume is")
disp("kJ/kg",h,"Enthalpy is")
disp("kJ/kg K",s,"The entropy is")
disp("kJ/kg",u,"The interal energy is")
```

Scilab code Exa 9.6 energy calculation on cooling of steam

```
// Part (a)
vg1_ = 0.8919; T1_ = 120;
vg2_ = 0.77076; T2_ = 125;
vg_ = [vg1_ vg2_]; T_ = [T1_ T2_];
v1 = 0.7964;
h1 = 2967.6;
P1 = 0.3e03; // in Kpa
T1 = interpln([vg_;T_],v1);
disp("degree",T1,"The steam become saturated at ")
// Part (b)
vf = 0.001029; vg = 3.407;
hf = 334.91; hfg = 2308.8;
Psat = 47.39; // In kPa
v2 = v1;
x2 = (v1-vf)/(vg-vf);
```

```
h2 = hf+x2*hfg;
P2 = Psat;
Q12 = (h2-h1)+v1*(P1-P2);
disp(x2,"The quality factor at t  =80 degree is")
disp("kJ/kg",Q12,"The heat transfered per kg of steam in cooling from 250 degree to 80 degree")
```

Scilab code Exa 9.7 `energy calculation on expansion of steam`

```
// At T = 40 degree
Psat = 7.384e06;
sf = 0.5725; sfg = 7.6845;
hf = 167.57; hfg = 2406.7;
//
s1 = 6.9189; h1 = 3037.6;
x2 = (s1-sf)/sfg ;
h2 = hf+(x2*hfg);
W = h1-h2;
disp("kJ/Kg",W,"The ideal work output of the turbine is")
```

Scilab code Exa 9.8 `Determination of velocity of steam leaving through steam`

```
w3 = 2.3; w1 = 1.0;
w2 = w3-w1;
h1 = 2950.0;
// At 0.8MPa, 0.95 dry
x = 0.95;
hf = 721.11; hfg = 2048;
h2 = hf + (x*hfg);
h3 = ((w1*h1)+(w2*h2))/w3;
// Interpolation
H = [2769.1 2839.3];
```

```
T = [170.43 200];
t3 = interpln([H;T],2790);
s3 = 6.7087;
s4 = s3;
x4 = (s3-1.7766)/5.1193;
h4 = 604.74+(x4*2133.8);
V4 = sqrt(2000*(h3-h4));
disp("degree",t3-T(1),"The condition of superheat
    after mixing")
disp("m/sec",V4,"The velocity of steam leaving the
    nozzle is")
```

Scilab code Exa 9.9 Calculation of moisture of steam

```
h2 = 2716.2; hf = 844.89; hfg = 1947.3;
x1 = (h2-hf)/hfg;
h3 = 2685.5;
x4 = (h3-hf)/hfg;
disp(x1,"The quality of steam in pipe line is")
disp("%",100-(x4*100),"Maximum moisture is")
```

Scilab code Exa 9.10 Finding the quantity of steam in pipeline

```
// At 0.1Mpa, 110 degree
h2 = 2696.2; hf = 844.89; hfg = 1947.3;
x2 = (h2-hf)/hfg;
vf = 0.001023; // at T = 70 degree
V = 0.000150; // In m3
m1 = V/vf;
m2 = 3.24;
x1 = (x2*m2)/(m1+m2);
disp(x1,"The quality of the steam in the pipe line
    is")
```

Scilab code Exa 9.11 Calculation of heat transferred in a steam bolier

```
// P = 1MPa
vf = 0.001127; vg = 0.1944;
hg = 2778.1; uf = 761.68;
ug = 2583.6; ufg = 1822;
// Initial anf final mass
Vis = 5; Viw = 5;
Vfs = 6 ; Vfw = 4 ;
//
ms = ((Viw/vf)+(Vis/vg)) - ((Vfw/vf)+(Vfs/vg)) ;
U1 =  ((Viw*uf/vf)+(Vis*ug/vg));
Uf =  ((Vfw*uf/vf)+(Vfs*ug/vg));
Q = Uf-U1+(ms*hg)
disp("kJ",Q,"The heat transfer during the process is
   ")
```

Scilab code Exa 9.12 Calculations on heat transfer in a cylinder and piston system

```
m = 0.02; d = 0.28; l = 0.305;
P1 = 0.6e06; P2 = 0.12e06;
// At 0.6MPa, t = 200 degree
v1 = 0.352; h1 = 2850.1;
V1 = m*v1;
Vd = (%pi/4)*d^2*l;
V2 = V1+Vd ;
n = log(P1/P2)/log(V2/V1);
W12 = ((P1*V1)-(P2*V2))/(n-1);
disp(n,"The value of n is");
disp("J",W12,"The work done by the steam is")
v2 = V2/m;
```

```
vf = 0.0010476; vfg = 1.4271;
x2 = (v2-vf)/vfg ;
// At 0.12MPa
uf = 439.3; ug = 2512.0;
u2 = uf + (x2*(ug-uf));
u1 = h1-(P1*v1*1e-03);
Q12 = m*(u2-u1)+ (W12/1000);
disp("kJ",Q12,"The heat transfer is")
```

Scilab code Exa 9.13 Energy calculations in an insulated vessel

```
x1 = 1; x2 = 0.8;
// at 0.2MPa
vg = 0.8857; v1 = vg; hg = 2706.7; h1 = hg;
m1 = 5 ; V1 = m1*v1;
// at 0.5MPa
m2 = 10;
hf = 640.23; hfg = 2108.5
vf = 0.001093; vfg = 0.3749;
v2 = vf+(x2*vfg);
V2 = m2*v2;
//
Vm = V1+V2;
m = m1+m2;
vm = Vm/m;
u1 = h1;
h2 = hf+(x2*hfg);
u2 = h2;
m3 = m;
h3 = ((m1*u1)+(m2*u2))/m3;
u3 = h3;
v3 = vm;
// From mollier diagram
x3 = 0.870; p3 = 3.5; s3 = 6.29;
s1 = 7.1271;
```

```
sf = 1.8607; sfg = 4.9606;
s2 = sf+(x2*sfg);
E = m3*s3-((m1*s1)+(m2*s2));
disp("bar",p3,"Final pressure is")
disp(x3,"Steam quality is")
disp("kJ/K",E,"Entropy change during the process is"
    )
```

Scilab code Exa 9.14 Energy calculation on steam passing through turbine

```
// At 6 MPa, 400 degree
h1 = 3177.2; s1 = 6.5408;
// At 20 degree
h0= 83.96; s0 = 0.2966;
T0 = 293;
f1 = (h1-h0)-T0*(s1-s0);
// By interpolation
t2 = 273 + 393;
s2 = 6.63;
h2 = h1;
f2 = (h2-h0)-T0*(s2-s0);
df = f1-f2;
x3s = (s2-1.5301)/(7.1271-1.5301);
h3s = 504.7+(x3s*2201.9);
eis = 0.82;
h3 = h2-eis*(h1-h3s);
x3 = (h3-504.7)/2201.7;
s3 = 1.5301+(x3*5.597);
f3 = (h3-h0)-T0*(s3-s0);
disp("kJ/kg",f1,"The availability of the steam
    before the throttle valve")
disp("kJ/kg",f2,"The availability of the steam after
     the throttle valve")
disp("kJ/kg",f3,"The availability of the steam at
    the turbine exhaust")
```

```
disp("kJ/kg",h2-h3,"The specific work output from
    the turbine is")
```

Scilab code Exa 9.15 Energy calculation on a steam turbine

```
// At 25 bar, 350 degree
h1 = 3125.87; s1 = 6.8481;
// 30 degree
h0 = 125.79; s0 = 0.4369;
// At 3 bar, 200 degree
h2 = 2865.5; s2 = 7.3115;
// At 0.2 bar 0.95 dry
hf = 251.4; hfg = 2358.3;
sf = 0.8320; sg = 7.0765;
h3 = hf+0.92*hfg;
s3 = sf+(0.92*sg);
// Part (a)
T0 = 303;
f1 = (h1-h0)-(T0*(s1-s0));
f2 = (h2-h0)-(T0*(s2-s0));
f3 = (h3-h0)-(T0*(s3-s0));
disp("kJ/kg",f1,"Availability of steam entering at
    state 1")
disp("kJ/kg",f2,"Availability of steam leaving  at
    state 2")
disp("kJ/kg",f3,"Availability of steam leaving  at
    state 3")
// Part (b)
m2m1 = 0.25; m3m1 = 0.75;
Wrev = f1-(m2m1*f2)-(m3m1*f3);
disp("kJ/kg",Wrev,"Maximum work is")
// Part (c)
w1 = 600; w2 = 150; w3 = 450;
Q = -10*3600;  // For 1 hour
I = T0*(w2*s2+w3*s3-w1*s1)-Q;
```

```
disp("kJ/h",I,"Irreversibility is")
```

Scilab code Exa 9.16 Determination of energy of different phases of water

```
// At dead state of 1 bar, 300K
u0 = 113.1; h0 = 113.2;
v0 = 0.001005; s0 = 0.0395;
T0 = 300; P0 = 100;
K = h0-(T0*s0);
// Part (a)
u = 376.9; h = 377;
v = 0.001035; s = 1.193;
m = 3;
fi = m*(h-(T0*s)-K); // As P = P0 = 1 bar
disp("kJ",fi,"Energy of system in Part (a) is")
// Part (b)
u = 3099.8; h = 3446.3; v = 0.08637; s = 7.090; //
    At P = 4 Mpa, t = 500 degree
m = 0.2;
fib = m*(u+P0*v-T0*s-K);
disp("kJ",fib,"Energy of system in Part (b) is")
// Part (c)
m = 0.4;
x = 0.85; // Quality
u = 192+x*2245;
h = 192+x*2392;
s = 0.649+x*7.499;
v = 0.001010+x*14.67;
fic = m*(u+P0*v-T0*s-K);
disp("kJ",fic,"Energy of system in Part (c) is")
// Part (d)
m = 3;
h = -354.1; s = -1.298; // at 1000kPa, -10 degree
fid = m*((h-h0)-T0*(s-s0));
disp("kJ",fid,"Energy of system in Part (d) is")
```

Scilab code Exa 9.17 Calculations on a heat exchanger

```
// Given
th1 = 90+273;
tc1 = 25+273;
tc2 = 50+273;
mc = 1; T0 = 300;
th2p = 60+273; // Parallel
th2c = 35+273; // Counter
mhp = (tc2-tc1)/(th1-th2p); // Parallel
mhc = (tc2-tc1)/(th1-th2c); // Counter
h0 = 113.2; s0 = 0.395; T0 = 300; // At 300 K
h1 = 376.92; s1 = 1.1925; // At 90 degree
af1 = mhp*((h1-h0)-T0*(s1-s0));
// Parallel Flow
h2 = 251.13; s2 =0.8312; // At 60 degree
h3 = 104.89; s3 = 0.3674; // At 25 degree
h4 = 209.33; s4 = 0.7038; // At 50 degree
REG = mc*((h4-h3)-T0*(s4-s3)); // Rate of energy
    gain
REL = mhp*((h1-h2)-T0*(s1-s2)); // Rate of energy
    loss
Ia = REL-REG; // Energy destruction
n2a = REG/REL; // Second law efficiency
disp("In parallel flow")
disp("kW",Ia,"The rate of irreversibility is")
disp("%",n2a*100,"The Second law efficiency is")
// Counter flow
h2 = 146.68; s2 = 0.5053; // At 35 degree
REG_b = REG; // Rate of energy gain by hot water is
    same in both flows
REL_b = mhc*((h1-h2)-T0*(s1-s2));
Ib = REL_b-REG_b; // Energy destruction
n2b = REG_b/REL_b; // Second law efficiency
```

```
disp("In Counter flow")
disp("kW",Ib,"The rate of irreversibility is")
disp("%",n2b*100,"The Second law efficiency is")
```

Scilab code Exa 9.18 Estimation of max cooling rate of a system

```
m = 50 ; // in kg/h
Th = 23+273; // Home temperature
// State 1
T1 = 150+273;
h1 = 2746.4;
s1 = 6.8387;
// State 2
h2 = 419.0;
s2 = 1.3071;
T0 = 318;
//
b1 = h1-(T0*s1);
b2 = h2-(T0*s2);
Q_max = m*(b1-b2)/(T0/Th-1);
disp("kW",Q_max/3600,"The maximum cooling rate is")
```

Chapter 10

Properties of gases and gas mixture

Scilab code Exa 10.1 Finding the final temperature and heat transferred in a fluid

```
// Part (a)
P1 = 100; P2 = 50;
T1 = 273+300;
T2 = (P2/P1)*T1;
R = 0.287; cv = 0.718;
V1 = 0.8;
m = (P1*V1)/(R*T1);
Q = m*cv*(T2-T1);
disp("If the fluid is in the air")
disp("K",T2,"The final temperature is ")
disp("kJ/kg",Q,"The heat transferred is")
// Part (b)
t2 = 273+81.33; vf = 0.00103; vg = 3.24;
v1 = 2.6388; u1 = 2810.4;
x2 = (v1-vf)/(vg-vf);
u2 = 340.42+(x2*2143.4);
m_ = V1/v1;
Q_ = m_*(u2-u1);
disp("If the fluid is in the steam")
```

```
disp("K",t2,"The final temperature is ")
disp("kJ/kg",Q_,"The heat transferred is")
```

Scilab code Exa 10.2 Finding the final temperature and heat transferred in a fluid

```
// Part (a)
R = 0.287; T1 = 273+150; v1 = 0.96; v2 = 1.55; Cp =
    1.005;
P = (R*T1)/v1;
W = P*(v2-v1);
T2 = (v2/v1)*T1;
Q = Cp*(T2-T1);
disp("If the fluid is in the air")
disp("K",T2,"The final temperature is ")
disp("kJ",Q,"The heat transferred is")
disp("kJ",W,"Work done is")
// Part (b)
vg = 0.3928;
P1 = 200e03;
P2 = P1;
h1 = 2768.8;
t2 = 273+400; h2 = 3276.5;
Q_ = h2-h1;
W_ = P1*(v2-v1);
disp("If the fluid is in the steam")
disp("K",t2,"The final temperature is ")
disp("kJ",Q_,"The heat transferred is")
disp("J",W_,"Work done is")
```

Scilab code Exa 10.3 Heat calculation on a fluid

```
// Part (a)
v = 16 ; // v = v1/v2
```

```
P1 = 300e03;
P2 = P1*v;
R = 0.287; T1 = 300+273;
W12 = R*T1*log(1/v);
disp("If the fluid is in the air")
disp("Pa",P2,"The final pressure is ")
disp("kJ",0,"The change in internal energy is")
disp("kJ",W12,"Work done is")
// Part (b)
v1 = 0.7664; u1 = 2728.7;
v2 = v1/16;
x2 = (v2-0.00125)/(0.05013);
s2 = 2.7927+(x2*3.2802);
s1 = 7.5165;
u2 = 1080.37+(x2*1522.0);
du = u2-u1;
T = 250+273;
Q12 = T*(s2-s1)
disp("If the fluid is in the steam")
disp("K",T,"The final temperature is ")
disp("kJ/kg",Q12,"The heat transferred is")
disp("kJ/kg  ",du,"The change in internal energy is"
  )
```

Scilab code Exa 10.4 Heat calculation for a reversible adiabatic process

```
// Part (a)
P1 = 10; P2 = 1;
T1 = 273+300;
g = 1.4;
T2 = T1*((P2/P1)^((g-1)/g));
R = 0.287;
W12 = ((R*T1)/(1-g))*(T2/T1-1);
v2 = (R*T2)/(100*P2);
disp("If the fluid is in the air")
```

```
disp("m3/kg",v2,"The specific volume is")
disp("kJ",W12,"The work done per kg of the fluid is")
// Part (b)
u1 = 2793.2; v1 = 0.2579; s1 = 7.1228;
x2 = (7.1228-1.3025)/6.0568;
u2 = 417.33+(x2*2088.7);
v2 = 0.001043+(0.96*1.693);
W12 = u1-u2;
disp("If the fluid is in the steam")
disp("m3/kg",v2,"The specific volume is")
disp("kJ",W12,"The work done per kg of the fluid is")
```

Scilab code Exa 10.5 Heat calculations on a reversible polytropic process

```
// Part (a)
P1 = 10; P2 = 1;
T1 = 273+200; n = 1.15; R = 0.287;
v2 = ((R*T1)/(P1*100))*((P1/P2)^(1/1.15));
v1 = ((R*T1)/(P1*100));
T2 = T1*(P2/P1)*(v2/v1);
cv = 0.716;
Q = (cv+(R/(1-n)))*(T2-T1);
disp("If the fluid is in the air")
disp("m3/kg",v2,"The specific volume is")
disp("K",T2,"The final temperature is ")
disp("kJ",Q,"Heat transferred per kg is")
// Part (b)
v1 = 0.20596; u1 = 2621.9;
v2 = v1*(P1/P2)^(1/n);
x2 = (v2-0.001043)/(1.694-0.001043);
t2 = 99.62+273;
u2 = 417.33+(x2*2088.7);
W = ((P1*100*v1)-(P2*100*v2))/(n-1);
```

```
Q = u2-u1+W;
disp("If the fluid is in the steam")
disp("m3/kg",v2,"The specific volume is")
disp("K",t2,"The final temperature is ")
disp("kJ",Q,"Heat transferred per kg is")
```

Scilab code Exa 10.6 Calculation on PV cycle of ideal monoatomic gas

```
P0 = 1000;
T0 = 3;
V0 = 0.001;
R = 287;
n = (P0*V0)/(R*T0); // Number of moles
// Process ab
Wab = 0;
cv = (3/2)*R;
Ta = T0; Tb = 300;
Qab = n*cv*(Tb-Ta);
Ua = 0; // Given internal energy
Ub = Qab+Ua;
Uab = Ub-Ua;
// Process bc
Qbc = 0; Uc = 0; Ubc = Uc-Ub;
Wbc = -Ubc;
// Process ca
Tc = Ta;
g = 5/3; // gamma
Vcb = (Tb/Tc)^(3/2); // Vc/Vb
Wca = -n*R*Tc*log(Vcb);
Qca = Wca ;
Uca = 0;
//
disp("J",Wab+Wbc+Wca,"Work done in the cycle is")
disp("J",Uab+Ubc+Uca,"Internal energy change in the
   cycle is")
```

```
disp("J",Qab+Qbc+Qca,"Heat transfer in the cycle is"
    )
// Part (b)
e = (Qab+Qca)/Qab;
disp("%",e*100,"Thermal efficiency of the system is"
    )
```

Scilab code Exa 10.7 Pressure calculation in a system of two vessels

```
Pa = 1.5; Ta = 273+50; ca = 0.5;
Pb = 0.6; Tb = 20+273; mb = 2.5;
R = 8.3143;
Va = (ca*R*Ta)/(Pa*1e03);
ma = ca*28;
Rn = R/28;
Vb = (mb*Rn*Tb)/(Pb*1e03);
V = Va + Vb ;
m = ma + mb ;
Tf = 27+273;
P = (m*Rn*Tf)/V;
g = 1.4;
cv  = Rn/(g-1);
U1 = cv*(ma*Ta+mb*Tb);
U2 = m*cv*Tf;
Q = U2-U1;
disp("KPa",P,"The final equillibrium pressure is")
disp("kJ",Q,"The amount of heat transferred to the
    surrounding is")
T_ = (ma*Ta+mb*Tb)/m ;
P_ = (m*Rn*T_)/V;
disp("If the vessele is perfectly inslulated")
disp("K",T_,"The final temperature is")
disp("KPa",P_,"The final pressure is")
```

Scilab code Exa 10.8 Heat calculation on a gas in constant volume chamber

```
cp = 1.968; cv = 1.507;
R_ = 8.314;
V = 0.3; m = 2;
T1 = 5+273; T2 = 100+273;
R = cp-cv;
mu = R_/R;
Q12 = m*cv*(T2-T1);
W12 = 0 ;
U21 = Q12;
H21= m*cp*(T2-T1);
S21 = m*cv*log(T2/T1);
disp("kJ/kg K",R,"kg/kg mol and",mu,"Molecular
    weight and the gas constant of the gas are")
disp("kJ",0,"Work done")
disp("kJ",Q12,"The heat transferred")
disp("kJ",U21,"The change in internal energy ")
disp("kJ",S21,"entropy")
disp("kJ/K",H21,"enthalpy")
```

Scilab code Exa 10.9 Calculation of work done in expansion of a gas

```
m = 1.5;
P1 = 5.6; V1 = 0.06;
T2 = 273+240;
a = 0.946; b = 0.662;
k = 0.0001;
// Part (b)
R = a-b;
T1 = (P1*1e03*V1)/(m*R);
W12 = -integrate('m*(b+k*T)','T',T1,T2);
```

```
disp("kJ",W12,"The work done in the expansion is")
```

Chapter 11

Introduction

Scilab code Exa 1.1 Calculting gas pressure

```
d_r = 13640; // Density of mercury in kg/m3
g = 9.79; // Acceleration due to gravity in m/s2
z = 562e-03; // Difference in height in m
z0 = 761e-03; // Reading of barometer in m
P = (d_r*g*(z+z0))*(0.987/1e05); // Gas Pressure in
    bar
disp("bar",P,"Gas Pressure is ")
```

Scilab code Exa 1.2 Calculating inlet and exhaust pressure in pascals

```
d_r = 13.6e03; // Density of mercury in kg/m3
g = 9.81; // Acceleration due to gravity in m/s2
z = 710e-03; // Stean flow pressure in m
z0 = 772e-03; // Reading of barometer in m
P = 1.4e06; // Gauge pressure of applied steam in Pa
P0 = d_r*g*z0; // Atmospheric pressure in Pa
Pi = P+P0 ; // Inlet steam pressure in Pa
Pc = d_r*g*(z0-z); // Condenser pressure in Pa
```

```
disp("Pa",Pi,"Inlet steam pressure is")
disp("Pa",Pc,"Condenser pressure is")
```

Scilab code Exa 1.3 Converting various readings of pressure in kPa

```
z = 0.760; // Barometer reading in m
// Part (a)
h1 = 40e-02; // Mercury height in vaccume in m
d_r = 13.6e03; // Density of mercury in kg/m3
g = 9.80; // Acceleration due to gravity in m/s2
Patm = z*d_r*g; // Atmospheric pressure in Pas
Pv = h1*d_r*g; // Pressure in vaccume in Pa
Pabs = Patm-Pv; // Absolute pressure in Pa
disp("Pa",Pabs," 40cmHg vaccume is")
// Part (b)
h2 = 90e-02; // Mercury height in gauge in m
Pg = h2*d_r*g; // Gauge Pressure in Pa
Pabs1 = Patm + Pg ; // Absolute pressure in Pa
disp("Pa",Pabs1,"90cmHg gauge is")
// Part(c)
d_w = 1e03 ; // Density of water in kg/m3
h3 = 1.2 ; // Gauge Pressure water height in m
Pga = d_w*h3*g; // Gauge Pressure in Pa
Pabs3 = Patm + Pga ; // Absolute pressure in Pa
disp("Pa",Pabs3,"1.2 m H2O gauge is")
```

Scilab code Exa 1.4 Calculating the depth of earth atmosphere required to produce

```
Pr = 1.033e05; // Required Pressure in bar
function y = pressure(p)
  y = p^(-0.714);
endfunction;
g = 9.81; // Acceleration due to gravity in m/s2
```

```
H = ((2.5e05^0.714)/g)*intg(0,Pr,pressure); // Depth
    of atmosphere required in m
disp("Km",H/1000,"The depth of atmosphere required
    is ")
```

Scilab code Exa 1.5 Determining net upward force experienced by astrounaut

```
m = 68 ; // Astronaut mass in Kg
g = 9.806; // Acceleration due to gravity in m/s2
a = 10*g ; // Lift off acceleration in m/s2
F = m*a; // Net vertical force in N
disp("N",F,"Net vertical force experienced by
    astronaut is")
```

Chapter 12

Temperature

Scilab code Exa 2.1 Calculations on straight bore thermometer

```
d = 1; l = 1; // Assuming
A_ACDB = (%pi/4)*(1/3)*((1.05*d)^2)*10.5*l - (%pi/4)
    *(1/3)*d^2*10*l ; // Area of ABCD
A_AEFB = (%pi/4)*(1/3)*((1.1*d)^2)*11*l - (%pi/4)
    *(1/3)*d^2*10*l;
t = 100*(A_ACDB/A_AEFB);
disp("degree Celcius",t,"The straight bore
    thermometer reading would e")
```

Scilab code Exa 2.2 Calculation of thermometer reading

```
t = poly(0,'t');
e = (0.2*t)-(5e-04*t^2); // e.m.f. as a function of
    temperature in mV
e0 = horner(e, 0); // e.m.f. at t = 0 degree
e100 = horner(e, 100); // e.m.f. at t = 100 degree
e50 = horner(e, 50); // e.m.f. at t = 50 degreer
r = (100/e100)*e50; // Reading of thermocouple at t
    = 50degree
```

```
disp("degree",r,"Reading of thermocouple at t = 50
    degree is")
```

Scilab code Exa 2.3 Calculting temperature for given resistance

```
R0 = 2.8; // Resistence at t=0 degree in ohm
R100 = 3.8; // Resistence at t = 100 degree in ohm
a = (R100/R0 - 1)*0.01; // alpha
R = 5.8; // Indicated ressistace in ohm
t = (R/R0 - 1)/a; // Temperature in degree
disp("degree",t,"The temperature when indicated
    resistance is 5.8 ohm is ")
```

Chapter 13

Work and heat transfer

Scilab code Exa 3.1 Calculation of magnitude of velocity

```
V1 = 100; // Initial velocity in m/s
g = 9.81; // Acceleration due to gravity in m/s2
z1 = 100; // Initial elevation in m
V = sqrt((2*g*z1)+(V1)^2); // Final velocity in m/s2
disp("m/s",V,"The velocity of the object just before
    ir hits the ground is")
```

Scilab code Exa 3.2 Calculation of work done on atmosphere by balloon

```
dV = 0.5; // Change in volume in m3
P = 101.325e03; // Atmospheric pressure in N/m2
Wd = P*dV; // Work done in J
disp("KJ",Wd/1000,"The amount of work done upon the
   atmosphere by the ballon is")
```

Scilab code Exa 3.3 Calculation of work done by atmosphere

```
dV = 0.6; // Change in volume in m3
P = 101.325e03; // Atmospheric pressure in N/m2
Wd = P*dV; // Work done in J
disp("KJ",Wd/1000,"The displacement work done by the
    air is")
```

Scilab code Exa 3.4 Calculation of net work transfer for the system

```
T = 1.275e-03; // Torque acting against the fluid in
    N
N = 10000; // Number of revolutions
W1 = 2*%pi*T*N; // Work done by stirring device upon
    the system
P = 101.325e03; // Atmospheric pressure in N/m2
d = 0.6; // Piston diameter in m
A = (%pi/4)*(d)^2; // Piston area in m
L = 0.80; // Displacement of diameter in m
W2 = (P*A*L)/1000; // Work done by the system on the
    surroundings i KJ
W = -W1+W2; // Net work tranfer for the system
disp("KJ",W,"The Net work tranfer for the system is"
    )
```

Scilab code Exa 3.5 Calculation of net rate of work transfer from the gas to pisto

```
ad = 5.5e-04; // Area of indicator diagram
ld = 0.06; // Length of diagram
k = 147e06; // Spring constant in MPa/m
w = 150; // Speed of engine
L = 1.2 ; // Stroke of piston
d = 0.8; // Diameter of the cylinder in m
A = (%pi/4)*(0.8^2); // Area of cylinder
Pm = (ad/ld)*k; // Effective pressure
```

```
W1 = Pm*L*A*w; // Work done in 1 minute
W = (12*W1)/60; // The rate of work transfer gas to
    the piston in MJ/s
disp("kW",W/1000,"The rate of work transfer gas to
    the piston is")
```

Scilab code Exa 3.6 Calculation of dimension of cylindrical furnace

```
Tm = 1535; // Melting point of iron on degree
Ti = 15; // Initial temperature
Tf = 1650; // Final temperature
Lh = 270e03; // Latent heat of iron in J/Kg
ml = 29.93; // Atomic weight of iron in liquid state
m = 56; // Atomoc weight of iron
sh = 0.502e03; // Specific heat of iron in J/Kg
d = 6900; // Density of molten metal in kg/m3
H = (Tm-Ti)*sh + Lh + (ml/m)*(Tf-Tm)*1000; // Heat
    required
Mr = 5e03; // Melting rate in Kg/h
Hr = H*Mr ; // Rate of heat suppy
HrA = Hr/(0.7*3600) // Actual rate of heat supply
disp("W",HrA,"Rating of furnace would be")
V = (3*Mr)/d; // Volume required in m3
d = ((V/2)*(4/%pi))*(1/3); // Diameter of cylinder
    of furnace in m
l = 2*d; // Length of cylinder of furnace in m
disp("m",l," Length of cylinder of furnace is")
```

Scilab code Exa 3.7 Calculations on alluminium furnace

```
SH = 0.9; // Specific heat of alluminium in solid
    state
L = 390; // Latent heat
```

```
aw = 27; // Atomic weight
D = 2400; // Density in molten state
Tf = 700+273; // Final temperature
Tm = 660+273; // Melting point of aluminium
Ti = 15+273; // Intial temperature
HR = SH*(Tm-Ti)+L+(29.93/27)*(Tf-Tm); // Heat
    requires
HS = HR/0.7 ; // Heat supplied
RM = 217*1000*3600/HS ; // From the data of problem
    3.7
V = 2.18; // Volume
M = V*D;
disp("tonnes",M*0.001,"Mass of alluminium that can
    be melted is")
disp("kg/h",RM,"Rate at which alluminium can be
    melted is")
```

Scilab code Exa 3.8 Calculation on work required for automization

```
dd = 60e-06;
mw = 1;
st = 0.07;
dw = 1000;
dp = 15e-03;
N = (mw*6)/(%pi*dd^3*dw);
Af = %pi*dd^2*N;
S_L = 4/(dp*dw);
W = st*(100-S_L);
disp("J",W,"Work done during automization is")
```

Scilab code Exa 3.9 Calcultion on electric motor

```
dc = 40e-02;
```

```
L = 30e-02;
P = 1e05; // Pressure in Pascal
I = 0.5;
V = 24;
t = 15*60; // in seconds
Wm = V*I*t;
Ws = 0.9*Wm;
W = P*(%pi/4)*dc^2*L;
disp("J",Wm,"Work input to the motor is")
disp("J",Ws,"Work input to the stirrer is")
disp("J",W,"Work done by the fluid on the atmosphere
    is")
```

Scilab code Exa 3.10 Calculation of work done by piston cylinder system

```
P1 = 100; P2 = 37.9; P3 = 14.4;
V1 = 0.1; V2 = 0.2; V3 = 0.4;
n1 = (log(P1/P2))/(log(V2/V1));
n2 = (log(P2/P3))/(log(V3/V2));
// n1 = n2
W = ((P1*V1)-(P3*V3))/(n1-1);
disp("kJ",W,"Work done by the system is")
```

Scilab code Exa 3.11 Calculation of work done in PV cycle

```
P1 = 20*1.01325e05;
V1 = 0.04; V2 = 2*V1;
n = 1.45;
P2 = (V1/V2)^n*P1;
W12 = ((P1*V1)-(P2*V2))/(n-1);
W23 = P2*(V2-V1);
Wc = W12-W23;
disp("J",Wc,"Work done in the cycle is")
```

Chapter 14

First law of thermodynamics

Scilab code Exa 4.1 `Calculation of change in internal energy of gas`

```
V1 = 0.3; // Initial volume in m3
V2 = 0.15; // Final volume in m3
P = 0.105e06; // Pressure in Pa
Q = -37.6e03; // Heat tranferred in J
W = P*(V2-V1); // Work done
U = Q-W; // Internal energy change
disp("Joule",U,"Change in the internal energy of the
    system is")
```

Scilab code Exa 4.2 `Calculations on PV cycle`

```
Qacb = 84e03;
Wacb = 32e03;
Uba = Qacb-Wacb; // Ub-Ua
// Part (a)
Wadb = 10.5e03;
Qadb = Uba+Wadb;
disp("J",Qadb,"The heat flow into the system along
   the path adb");
```

```
// Part (b)
Wb_a = -21e03;
Uab = - Uba;
Qb_a = Uab+Wb_a;
disp("J",Qb_a,"The heat liberated along the path b−a
    is")
// Part (c)
Wdb = 0; // Constant volume
Wad = 10.4e03;
Wadb = Wdb-Wad;
Ud = 42e03;
Ua = 0;
Qad = Ud-Ua+Wad;
Qdb = Qadb-Qad;
disp("J",Qdb,"and",Qad,"The heat absorbed in the
   path ad and db are")
```

Scilab code Exa 4.3 Calculation of net rate of work output in a piston and cylinde

```
// Process a−b
Qab = 0;
Wab = 2170; // in KJ/min
Eab = Qab-Wab;
// Process b−c
Qbc = 21000;
Wbc = 0;
Ebc = Qbc-Wbc;
// Process c−d
Qcd = -2100;
Ecd = -36600;
Wcd = Qcd-Ecd;
// Process d−a
Q = -17000; // Total heat transfer
Qda = Q-Qab-Qbc-Qcd;
Eda = -Eab-Ebc-Ecd;
```

```
Wda = Qda-Eda;
M = [Qab Wab Eab ; Qbc Wbc Ebc; Qcd Wcd Ecd; Qda Wda Eda];
disp(M,"The completed table is")
```

Scilab code Exa 4.4 Thermodynamics calculations of a substance with given internal

```
// Part (a)
m = 3;
V1 = 0.22;
P1 = 500e03;
P2 = 100e03;
V2 = V1*(P1/P2)^(1/1.2);
dU = 3.56*(P2*V2-P1*V1);
gama = 1.2;
W = (P2*V2-P1*V1)/(1-gama);
Q = dU+W;
disp("J respectively",dU,W,Q,"Q,W and dU of the quasi static process are")
// Part (b)
Qb = 30e03;
Wb = Qb-dU;
disp("Joule",Wb,"Work transfer for the process is")
// Part (c)
disp("Wb is not equal to integral(p*dv) since the process is not quasi static")
```

Scilab code Exa 4.5 Thermodynamics calculations of a cylinder with given internal

```
V1 = 0.03;
P1 = 170e03;
P2 = 400e03;
V2 = 0.06;
```

```
U = 3.15*(P2*V2-P1*V1);
B = [P1 P2]';
A = [1 V1; 1 V2];
x = inv(A)*B;
a = x(1); b = x(2);
function P = pressure(V)
  P = a+b*V;
endfunction;
W = intg(V1,V2,pressure);
Q = U+W;
disp("J",W,"The work done by the system is")
disp("J",U,"The internal energy change of the system
    is")
disp("J",Q,"The heat flow into the system is")
```

Scilab code Exa 4.6 Calculation on PV cycle of a stationary fluid system

```
// Process 1-2
Q12 = 235; // in KJ/Kg
W12 = 0 ;
U12 = Q12-W12;
// Process 2-3
Q23 = 0;
U23 = -70 ;
W23 = Q23-U23;
// Process 3-1
Q31 = - 200;
U31 = -U12-U23;
W31 = Q31-U31;
//
W = W12 + W23 + W31;
Q = Q12 + Q23 + Q31;
disp("KJ/Kg",Q,"Heat trasfer in the cycle is")
disp("KJ/Kg",W,"Work done during the the cycle is")
```

Chapter 15

First law applied to flow processes

Scilab code Exa 5.1 Calculation on an air compressor

```
// Part(a)
V1 = 0.95;
P1 = 100e03;
v1 = 7;
V2 = 0.19;
P2 = 700e03;
v2 = 5;
w = 0.5;
u21 = 90e03; // u21 = u2-u1
Q = -58e03; // As heat is added Q = dQ/dt
W =  - w*( u21 + (P2*V2-P1*V1) + ((v2^2-v1^2)/2) ) +
    Q; // W = dW/dt
disp("Watt",W,"The rate of work input is")
// Part (b)
A = (v2/v1)*(V1/V2); // A = A1/A2
d = sqrt(A); // d = d1/d2
disp(d,"The ratio of the inlet pipe diameter and
   outer pipe diameter is")
```

Scilab code Exa 5.2 Calculations across a control volume

```
V1 = 0.37;
P1 = 600e03;
v1 = 16;
V2 = 0.62;
P2 = 100e03;
v2 = 270;
Z1 = 32;
Z2 = 0;
g = 9.81;
Q = -9e03; // heat loss Q = dQ/dt
W = 135e03; // Work done W = dW/dt
U12 = (P2*V2-P1*V1) + ((v2^2-v1^2)/2) + (Z2-Z1)*g +
    W - Q; // U12 = U1-U2
disp("Joule",U12,"The internal energy decreases by")
```

Scilab code Exa 5.3 Calculation of steam flow rate between a boiler and turbine

```
P1 = 4e06;
t1 = 400;
h1 = 3213e03;
V1 = 0.073;
P2 = 3.5e06;
t2 = 392;
h2 = 3202e03;
V2 = 0.084;
Q = -8.5e03;
v1 = sqrt((2*(h1-h2+Q))/(1.15^2-1));
A1 = (%pi/4)*0.2^2;
w = (A1*v1)/V1;
disp("Kg/s",w,"The stean flow rate is")
```

Scilab code Exa 5.4 Calculation of quantity of steam supplied to a heater

```
h1 = 313.93;
h2 = 2676;
h3 = 419;
w1 = 4.2;
w = poly(0,'w') // w = w2
P = w1*h1 + w*h2 - h3*(4.2+w)
function [x] = stress(a,b,f)
  N = 100;
  eps = 1e-5;
  if((f(a)*f(b))>0) then
    error('no root possible f(a)*f(b)>0');
    abort;
  end;
  if(abs(f(a))<eps) then
    error('solution at a');
    abort;
  end
  if(abs(f(b))<eps) then
    error('solution at b');
    abort;
  end
  while(N>0)
    c = (a+b)/2
    if(abs(f(c))<eps) then
      x = c ;
      x;
      return;
    end;
    if((f(a)*f(c))<0 ) then
      b = c ;
    else
      a = c ;
```

```
    end
    N = N-1;
  end
  error('no convergence');
  abort;
endfunction

deff('[y]=p(w)',['y = - 441.294 + 2257*w '])
w = stress(0.1,0.2,p);
disp("Kg/h",w*3600,"The amount of heat that should
   be supplied is")
```

Scilab code Exa 5.5 `Calculations across a heat exchanger`

```
t1 = 15; t2 = 800; t3 = 650; t4 = 500;
v1 = 30; v2 = 30 ; v3 = 60;
w = 2;
cp = 1005;
Q1_2 = w*cp*(t2-t1);
disp("KJ/s",Q1_2/1000,"The rate of heat transfer to
   the air in the heat exchanger is")
W_T = w*( ((v2^2-v3^2)/2) + cp*(t2-t3));
disp("KW",W_T/1000,"The power output from the
   turbine assuming no heat loss")
v4 = sqrt( (v3^2) + (2*cp*(t3-t4)) );
disp("m/s",v4,"The velocity at the exit of the
   nozzle is")
```

Scilab code Exa 5.6 `Calculations on a gas turbine`

```
w = 5;
h1 = 900e03;
h2 = 400e03;
```

```
v1 = 50; v2 = 150;
Q = -25*5; // Q = dQ/dt for w = 5kg
W = w*( (h1-h2) + ((v1^2-v2^2)/2) ) + Q; // W = dW/dt
disp("kW",W/1000,"The power output of the turbine is")
R = 285; T1 = 300; P1 = 100e03;
V = (w*R*T1)/P1; // V = dV/dt
A1 = V/v1;
D1 = sqrt((4*A1)/%pi);
disp("m",D1,"The diameter of the inlet pipe is")
```

Scilab code Exa 5.7 Calculation of velocity of exhaust jet

```
ha = 260; // Enthalpy of air
hg = 912; // Enthalpy of gas
Va = 270; // Velocity of air
f = 0.0190; // Fuel to air ratio wf/wa
Ef = 44500; // Chemical energy of fuel in kJ/kg
Q = 21; // Heat loss from the engine
Eg = 0.05*f*Ef/(1+f); // As 5% of chemical energy is not released in reaction
Vg = sqrt(2000*(((ha+(Va^2*0.001)/2+(f*Ef)-Q)/(1+f))-hg-Eg));
disp("m/s",Vg,"Velocity of exhaust gas is")
```

Scilab code Exa 5.9 Thermodynamics calculations of air with given internal energy

```
u0 = 0.718*273*1e03;
t = poly(0,'t');
u = u0+718*t; // in SI unit
hp = u + 285*(t+273); // ""
h = horner(hp,150); // h = hp(150)
```

```
W = 100; // W = dW/dt
m = W/h;
disp("kg/h",m*3600,"The rate at which air flows out
    of the tank")
```

Chapter 16

Second law of thermodynamics

Scilab code Exa 6.1 Calculation of least rate of heat rejection by a cyclic heat e

```
T1 = 800;
T2 = 30;
e_max = 1-((T2+273)/(T1+273));
Wnet = 1; // in kW
Q1 = Wnet/e_max;
Q2 = Q1-Wnet;
disp("KW",Q2,"Least rate of heat rejection is")
```

Scilab code Exa 6.2 Calculation of least power for a domestic food freezer

```
T1 = -15+273;
T2 = 30+273;
Q2 = 1.75; // in kJ/sec
Q1 = (T1/T2)*Q2;
W = Q1-Q2;
disp("kW",W,"Least Power necessary to pump the heat
   out is")

// There is a calculation mistake in the book
```

Scilab code Exa 6.4 Calculations on a carnot engine

```
Q1 = 200;
T1 = 373.15;
T2 = 273.16;
Q2 = Q1*(T2/T1);
W = Q1-Q2;
e = W/Q1;
disp("respectively",e,"J",W,"J",Q2,"The heat
    rejected , the work done and the thermal effiency
    of the engine is")
```

Scilab code Exa 6.5 Calculations on reversible heat engine

```
T1 = 873;
T2 = 313;
T3 = 253;
Q1 = 2000e03; // In joule
W = 360e03; // in joule
// Part (a)
e_max = 1-(T2/T1);
W1 = e_max*Q1;
COP = T3/(T2-T3);
W2 = W1-W;
Q4 = COP*W2;
Q3 = Q4+W2;
Q2 = Q1-W1;
disp("J",Q2+Q3,"The heat rejection to the 40 degree
    reservior is")
// Part (b)
e_max_ = 0.4*e_max;
```

```
W1_ = e_max_*Q1;
W2_ = W1_-W;
COP_ = 0.4*COP;
Q4_ = COP_*W2_;
Q3_ = Q4_+W2_;
Q2_ = Q1-W1_;
disp("J",Q2_+Q3_,"The heat rejection to the 40
   degree reservior is")
```

Scilab code Exa 6.7 Determination of heat multiplication factor

```
T1 = 473;
T2 = 293;
T3 = 273;
MF = (T2*(T1-T3))/(T1*(T2-T3));
disp(MF," The multiplication factor is ")
```

Scilab code Exa 6.8 Estimation of minimum collector area of solar area

```
T1 = 363;
T2 = 293;
W = 1; // Kj/s
e_max = 1-(T2/T1);
Qmin = W/e_max ;
Qmin_ = Qmin*3600;
E = 1880; // in kJ/m2 h
Amin = Qmin_/E ;
disp("m2",Amin,"Minimum area required for the
   collector plate")
```

Scilab code Exa 6.9 Determination of minimum solar panel area

```
T1 = 1000;
W = 1000; // in W
K = 5.67e-08;
Amin = (256*W)/(27*K*T1^4);
disp("m2",Amin,"Area of the panel")
```

Chapter 17

Entropy

Scilab code Exa 7.1 Calculation of entropy change of water

```
T1 = 37+273;
T2 = 35+273;
m = 1 ;
cv = 4.187;
S = m*cv*log(T2/T1); // S = S2-S1
disp("KJ/K",S,"Change in the entropy of the water is
   ")
```

Scilab code Exa 7.2 Entropy change calculations of a heat reservoir and universe

```
// Part (a)
T1 = 273;
T2 = 373;
m = 1 ;
cv = 4.187;
Ss = m*cv*log(T2/T1); // S = S2-S1
Q = m*cv*(T2-T1);
Sr = -(Q/T2);
```

```
S = Ss+Sr;
disp("kJ/K",S,"The entropy change of the universe is
   ")
// Part (b)
T3 = 323;
Sw = m*cv*(log(T3/T1)+log(T2/T3));
Sr1 = -m*cv*(T3-T1)/T3;
Sr2 = -m*cv*(T2-T3)/T2;
Su = Sw+Sr1+Sr2;
disp("kJ/K",Su,"The entropy change of the universe
   is")
```

Scilab code Exa 7.3 Entropy change calculations between ice and universe

```
// Part (a)
m = 1;
T1 = -5+273;
T2 = 20+273;
T0 = 0+273;
cp = 2.093;
cv = 4.187;
lf = 333.3;
Q = m*cp*(T0-T1)+1*333.3+m*cv*(T2-T0);
Sa = -Q/T2;
Ss1 = m*cp*log(T0/T1);
Ss2 = lf/T0;
Ss3 = m*cv*log(T2/T0);
St = Ss1+Ss2+Ss3;
Su = St+Sa;
disp("kJ/K",Su,"The entropy change of the universe
   is")
// Part (b)
S = 1.5549; // S = S4-S1
Wmin = T2*(S)-Q;
disp("kJ",Wmin,"The minimum risk required is")
```

Scilab code Exa 7.5 Calculation of entropy change for a gas

```
Vo = 8.4;
Vh = 14;
n1 = Vo/22.4; n2 = Vh/22.4;
R = 8.31;
x1 = n1/(n1+n2);
x2 = n2/(n1+n2);
S = -R*(n1*log(x1)+n2*log(x2));
disp("J/K",S,"Entropy change for the process is")
```

Scilab code Exa 7.8 Calculation of highest temperature in three body system of con

```
T = poly(0,'T'); // T = Tf
Tf_ = 700-2*T; // Tf_ = Tf'
// Bisection method to solve for the polynomial
function [x] = Temperature(a,b,f)
  N = 100;
  eps = 1e-5;
  if((f(a)*f(b))>0) then
    error('no root possible f(a)*f(b)>0');
    abort;
  end;
  if(abs(f(a))<eps) then
    error('solution at a');
    abort;
  end
  if(abs(f(b))<eps) then
    error('solution at b');
    abort;
  end
```

```
  while(N>0)
    c = (a+b)/2
    if(abs(f(c))<eps) then
      x = c ;
      x;
      return;
    end;
    if((f(a)*f(c))<0 ) then
      b = c ;
    else
      a = c ;
    end
    N = N-1;
  end
  error('no convergence');
  abort;
endfunction
deff('[y]=p(T)',['y = 2*T^3-700*T^2+9000000 '])
T = Temperature(100,200,p);

Tf_ = horner(Tf_,T);
disp("K",Tf_,"The final temperature of the body C is ")
```

Scilab code Exa 7.9 Calculation of mxaximum amount of work for a system with given

```
T1 = 200;
T2 = 100;
A = 0.042;
Q1 = integrate('A*T^2','T',T1,T2);
S =  integrate('A*T^2/T','T',T1,T2);
W = poly(0,'W');
Z = (-Q1-W)/T2 + S; // Polynomial to be solved for W
// Bisection method to solve for the Work
function [x] = Work(a,b,f)
```

```
  N = 100;
  eps = 1e-5;
  if((f(a)*f(b))>0) then
    error('no root possible f(a)*f(b)>0');
    abort;
  end;
  if(abs(f(a))<eps) then
    error('solution at a');
    abort;
  end
  if(abs(f(b))<eps) then
    error('solution at b');
    abort;
  end
  while(N>0)
    c = (a+b)/2
    if(abs(f(c))<eps) then
      x = c ;
      x;
      return;
    end;
    if((f(a)*f(c))<0 ) then
      b = c ;
    else
      a = c ;
    end
    N = N-1;
  end
  error('no convergence');
  abort;
endfunction
deff('[y]=p(W)',['y = 350-0.01*W '])
W = Work(34000,36000,p);

disp("kJ",W/1000,"The maximum work that can be
    recovered is")
```

Scilab code Exa 7.10 Heat calculation for a reversible adiabatic compression cycle

```
P1 = 0.5e06;
V1 = 0.2; V2 = 0.05;
n = 1.3
P2 = P1*(V1/V2)^n;
function y = H(p)
  y = ((P1*V1^n)/p)^(1/n);
endfunction
H = integrate('H','p',P1,P2); // H = H2-H1
U = H-(P2*V2-P1*V1);
W12 = -U;
disp("kJ",H/1000,"Change in enthalpy is")
disp("kJ",U/1000,"Change in internal energy is")
disp("kJ",0,"and",0,"The change in entropy and heat
   transfer are")
disp("kJ",W12/1000,"The work transfer during the
   process is ")
```

Scilab code Exa 7.11 Establishment of direction of flow in a insulated duct

```
Pa = 130e03; Pb = 100e03;
Ta = 50+273; Tb = 13+273;
cp = 1.005;
Ss = integrate('cp/T','T',Ta,Tb)-integrate('0.287/p'
   ,'p',Pa,Pb);
Ssy = 0;
Su = Ss+Ssy;
disp("kJ/Kg K",Su,"Change in the entropy of the
   universe is")
disp("As the change in entropy of the universe in
   the process A-B is negative so the flow must be
```

```
   from B–A")
```

Scilab code Exa 7.12 Determination of possibility of a hypothetical device thermod

```
T1 = 300; T2 = 330; T3 = 270;
P1 = 4; P2 =1 ; P3 =1 ;
cp = 1.0005; R = 0.287;
S21 = cp*log(T2/T1)-R*log(P2/P1); // S21 = S2−S1
S31 = cp*log(T3/T1)-R*log(P3/P1); // S31 = S3−S1
Sgen = 1*S21 + 1*S31;
disp("kW/K",Sgen,"The entropy generated during the
   process is")
disp("As the entropy generated is positive so such
   device is possible")
```

Scilab code Exa 7.13 Calculation of heat transfer through a room

```
A = 5*7;
k = 0.71;
L = 0.32;
Ti = 21+273;
To = 6+273;
Q = k*A*(Ti-To)/L ;
disp("W",Q,"The rate of heat transfer through the
   wall is")
Sgen_wall = Q/To - Q/Ti;
disp("W/K",Sgen_wall,"The rate of entropy through
   the wall is")
Tr = 27+273;
Ts = 2+273;
Sgen_total = Q/Ts-Q/Tr;
disp("W/K",Sgen_total,"The rate of total entropy
   generation with this heat transfer process is")
```

Chapter 18

Available energy Availability and irreversibility

Scilab code Exa 8.1 `Calculation of fraction of available energy in heat transfer`

```
T0 = 308;
T1 = 693;
T1_ = 523; // T1_ = T1'
T1_ = 523; // ""
f = (T0*(T1-T1_))/(T1_*(T1-T0));
disp(f,"The fraction of energy that becomes
   unavailable due to irreversible heat transfer is"
   )
```

Scilab code Exa 8.2 `Calculation of increase in available energy in a steam boiler`

```
lhw = 1858.5; // Latent heat of water
Tew = 220+273;
Sw = lhw/Tew;
Tig = 1100; // Initial temperature of the gas
Tfg = 550; // Final ""
```

```
k = 1*lhw/(Tig-Tfg); // k = mg_dot*cpg
Tg2 = 823; Tg1 = 1373
Sg = integrate('k/T','T',Tg1,Tg2)
St = Sg+Sw;
disp("kJ/K",St,"Total change in entropy is ")
T0 = 303;
disp("kJ",T0*St,"Increase in unavailable energy is")
```

Scilab code Exa 8.3 Calculation of available energy in water

```
Tw = 75+273;
Ts = 5+273; // Ts = T0
m = 40;
cp = 4.2;
W = integrate('m*cp*(1-(Ts/T))','T',Ts,Tw);
Q1 = m*cp*(Tw-Ts);
UE = Q1-W;
disp("kJ",W,"Total work")
disp("kJ",Q1,"Heat released")
disp("kJ",UE,"Internal energy change")
```

Scilab code Exa 8.4 Calculation of decrease in available energy in water

```
Ts = 273+15;
Tw1 = 95+273;
Tw2 = 35+273;
m1 = 25; m2 = 35;
cp = 4.2;
AE25 = integrate('m1*cp*(1-(Ts/T))','T',Ts,Tw1);
AE35 = integrate('m2*cp*(1-(Ts/T))','T',Ts,Tw2);
AEt = AE25 + AE35;
Tm = (m1*Tw1+m2*Tw2)/(m1+m2); // Temperature after
    mixing
```

```
AE60 = integrate('(m1+m2)*cp*(1-(Ts/T))','T',Ts,Tm);
AE = AEt - AE60;
disp("kJ",AE,"The decrease in the totla energy is")
```

Scilab code Exa 8.5 Calculation of the final RPM of the flywheel

```
N1 = 3000;
w1 = (2*%pi*N1)/60;
I = 0.54;
Ei = 0.5*I*w1^2;
ti = 15+273;
m = 2;
dt = Ei/(1000*2*4.187);
tf = ti+dt;
AE = integrate('m*4.187*(1-(ti/T))','T',ti,tf);
UE = Ei/1000 - AE;
w2 = sqrt(AE*1000*2/I);
N2 = (w2*60)/(2*%pi);
disp(N2,"The final RPM of the flywheel would be")
```

Scilab code Exa 8.6 Energy calculations on air

```
T1 = 353; T2 = 278;
V2 = 2; V1 = 1;
P0 = 100; P1 = 500;
R = 0.287; cv = 0.718;
m = 2;
S = integrate('(m*cv)/T','T',T1,T2) + integrate('(m*
   R)/V','V',V1,V2); // S = S1-S2
U = m*cv*(T1-T2);
Wmax = U-(T2*(-S));
V1_ = (m*R*T1)/P1;
CA = Wmax-P0*(V1_); // Change in availability
```

```
I = T2*S;
disp("kJ",Wmax,"The maximum work is")
disp("kJ",CA,"Change in availability is")
disp("kJ",I,"Irreversibility is")
```

Scilab code Exa 8.7 Energy calculation of air through a turbine

```
P1 = 500; P2 = 100;
T1 = 793; T2 = 573;
cp = 1.005; T0 = 293; R = 0.287;
S21 = (R*log(P2/P1))-(cp*log(T2/T1))
CA = cp*(T1-T2)-T0*S21; // Change in v=availability
disp("kJ/kg",CA,"The decrease in availability is")
Wmax = CA;
disp("kJ/kg",Wmax,"The maximum work is")
Q = -10;
W = cp*(T1-T2)+Q ;
I = Wmax-W;
disp("kJ/kg",I,"The irreversibility is")
// Altenatively
Ssystem = -Q/T0;
Ssurr = -S21;
I1 = T0*(Ssystem+Ssurr);
```

Scilab code Exa 8.8 Energy calculation on a air preheater

```
T0 = 300;
Tg1 = 573; Tg2 = 473;
Ta1 = 313;
cpg = 1.09; cpa = 1.005;
mg = 12.5; ma = 11.15;
f1 = cpg*(Tg1-T0)-T0*cpg*(log(Tg1/T0));
f2 = cpg*(Tg2-T0)-T0*cpg*(log(Tg2/T0));
```

```
disp("kJ/Kg respectively",f2,"and",f1,"The initial and final availbility of the products are")
// Part (b)
Dfg = f1-f2;
Ta2 = Ta1 + (mg/ma)*(cpg/cpa)*(Tg1-Tg2);
Ifa = cpa*(Ta2-Ta1)-T0*cpa*(log(Ta2/Ta1));
I = mg*Dfg-ma*Ifa;
disp("kW",I,"The irreversibility of the process is")
// Part (c)
Ta2_ = Ta1*(%e^(-(mg/ma)*(cpg/cpa)*log(Tg2/Tg1)));
Q1 = mg*cpg*(Tg1-Tg2);
Q2 = ma*cpa*(Ta2_-Ta1);
W = Q1-Q2;
disp("kW",W,"Tota power generated by the heat engine")
```

Scilab code Exa 8.9 Calculation of rate of energy degradation of gas flowing throu

```
T2 = 1063;
T1 = 1073;
T0 = 300;
m = 2; cp = 1.1;
I = m*cp*((T1-T2)-T0*(log(T1/T2)));
disp("kW",I,"The irrevesibility rate is")
// At lower temperature
T1_ = 353; T2_ = 343;
I_ = m*cp*((T1_-T2_)-T0*(log(T1_/T2_)));
disp("kW",I_,"The irrevesibility rate at lower temperature is")
```

Scilab code Exa 8.10 Calculation of rate of energy lossof gas flowing through a pi

```
m = 3; R = 0.287;
```

```
T0 = 300; k = 0.10; // k = dP/P1
Sgen = m*R*k;
I = Sgen*T0;
disp("kW",I,"The rate of energy loss because of the
    pressure drop due to friction")
```

Scilab code Exa 8.11 Energy calculation on mixing of stream of water

```
m1 = 2; // m1_dot
m2 = 1;
T1 = 90+273;
T2 = 30+273;
T0 =300;
m = m1+m2;
x = m1/m;
t = T2/T1; // Tau
cp = 4.187;
Sgen = m*cp*log((x+t*(1-x))/(t^(1-x)));
I = T0*Sgen;
disp("kW/K",Sgen,"The rate of entropy generation is"
    )
disp("kW",I,"The rate of energy loss due to mixing
    is")
// Alternatively
T  = (m1*T1+m2*T2)/(m1+m2); // euilibrium
    temperature
Sgen1 = m1*cp*log(T/T1)+m2*cp*log(T/T2);
I1 = T0*Sgen1;
```

Scilab code Exa 8.12 Calculations on efficiency of burning of fuel

```
Qr = 500; // Heat release in kW
Tr = 2000;
```

```
T0 = 300;
// Part (a)
Qa = 480; Ta = 1000;
n1a = (Qa/Qr);
n2a = n1a*(1-(T0/Ta))/(1-(T0/Tr));
disp("PART (A)")
disp("%",n1a*100,"The first law efficiency is")
disp("%",n2a*100,"The Second law efficiency is")
// Part (b)
Qb = 450; Tb = 500;
n1b = (Qb/Qr);
n2b = n1b*(1-(T0/Tb))/(1-(T0/Tr));
disp("PART (B)")
disp("%",n1b*100,"The first law efficiency is")
disp("%",n2b*100,"The Second law efficiency is")
// Part (c)
Qc = 300; Tc = 320;
n1c = (Qc/Qr);
n2c = n1c*(1-(T0/Tc))/(1-(T0/Tr));
disp("PART (C)")
disp("%",n1c*100,"The first law efficiency is")
disp("%",n2c*100,"The Second law efficiency is")
// Part (d)
Qd = 450;
n1d = (Qd/Qr);
n2a_= n1d*(1-(T0/Ta))/(1-(T0/Tr));
n2b_= n1d*(1-(T0/Tb))/(1-(T0/Tr));
n2c_= n1d*(1-(T0/Tc))/(1-(T0/Tr));
disp("Part (D)")
disp("%",n1d*100,"The first law efficiency is")
disp("%",n2a_*100,"The Second law efficiency of part
    (a) is")
disp("%",n2b_*100,"The Second law efficiency of part
    (b) is")
disp("%",n2c_*100,"The Second law efficiency of part
    (c) is")
```

Scilab code Exa 8.14 Calculation of power and efficiency in a compressor

```
cp = 1.005; T2 = 433; T1 = 298;
T0 = 298; R = 0.287; P2 = 8; P1 = 1;
Q = -100; m = 1;
W = Q + m*cp*(T1-T2);
AF = cp*(T2-T1)-T0*((cp*log(T2/T1))-(R*log(P2/P1)))
    ; // AF = af2-af1
e = AF/-W; // efficiency
disp("kW",W,"The power input is")
disp(e,"The second law efficiency of the compressor
    is")
```

Scilab code Exa 8.15 Determination of energy of vaccume

```
// Since vaccume has zero mass
U = 0; H0 = 0; S = 0;
// If the vaccume ha reduced to dead state
U0 = 0; H0 = 0 ; S0 = H0; V0 = 0;
P0 = 100; V = 1;
fi = P0*V;
disp("kJ",fi,"The energy of the complete vaccume is"
    )
```

Scilab code Exa 8.16 Calculation of energy produced in chilling process of fish

```
m = 1000; T0 = 300; P0 = 1;
T1 = 300;
T2 = 273-20; Tf = 273-2.2;
```

```
Cb = 1.7; Ca = 3.2;
Lh = 235;
H12 = m*((Cb*(Tf-T2))+Lh+(Ca*(T1-Tf)));
H21 = -H12;
S12 = m*((Cb*log(Tf/T2))+(Lh/Tf)+(Ca*log(T1/Tf)));
S21 = -S12;
E = H21-T0*S21;
disp("kJ",E,"Energy produced is")
```

Scilab code Exa 8.17 Thermodynamic calculation on air

```
cv = 0.718; T2 = 500; T1 = 300;
m = 1; T0 = 300;
// Case (a)
Sua = cv*log(T2/T1);
Ia = T0*Sua;
disp("kJ/kg",Ia,"The irreversibility in case a is")
// Case (b)
Q = m*cv*(T2-T1);
T = 600;
Sub = Sua-(Q/T);
Ib = T0*Sub;
disp("kJ/kg",Ib,"The irreversibility in case b is")
```

Scilab code Exa 8.18 Energy calculation of steam through turbine

```
h1 = 3230.9; s1 = 6.69212; V1 = 160; T1 = 273+400;
h2 = 2676.1; s2 = 7.3549; V2 = 100; T2 = 273+100;
T0 = 298; W = 540; Tb = 500;
Q = (h1-h2)+((V1^2-V2^2)/2)*1e-03-W;
I = 151.84-Q*(0.404);
AF = W + Q*(1-(T0/Tb)) + I; // AF = af1-af2
n2 = W/AF;
```

```
disp("kJ/kg",I,"Irreversibility per unit mass is")
disp(n2,"The second law effiency of the turbine is")
```

Scilab code Exa 8.19 Availability calculations on a furnace

```
T0 = 300; T = 1500;
Q = -8.5; W = 8.5;
// Case (a)
I = Q*(1-T0/T) + W;
R = Q*(1-T0/T);
disp("kW",I,"and",R,"Rate of availability transfer with heat and the irreversibility rate are")
// Case (b)
T1 = 500;
Ib = - Q*(1-T0/T) + Q*(1-T0/T1);
disp("kW",Ib,"Rate of availability in case b is")
```

Scilab code Exa 8.20 Energy calculation of air through compressor

```
P1 = 1; T1 = 273+30;
P2 = 3.5; T2 = 141+273 ; V = 90;
T0 = 303;
V2 = 100;
// Part (a)
g = 1.4;
T2s = T1*((P2/P1)^((g-1)/g));
disp("As T2s&gt; T2 so the process must be polytropic")
// Part (b)
p = log(P2/P1); q = log(T2/T1);
n = p/(p-q);
disp(n,"The polytropic index is")
// Part (c)
```

```
cp = 1.0035; R = 0.287;
Wa = cp*(T1-T2)-(V2^2/2)*1e-03 ;
Wt = -R*T0*log(P2/P1)-(V2^2/2)*1e-03;
Nt = Wt/Wa;
disp(Nt,"The isothermal effiency is")
// Part (d)
f12 = cp*(T1-T2) + T0*((R*log(P2/P1))-(cp*log(T2/T1)
   )) - (V2^2/2)*1e-03 ;
I = f12-Wa ;
disp("kW respectively",I,"and",f12,"The minimum work
    input and irreversibility are")
// Part (e)
n2 = (f12/Wa);
disp(n2,"Second law efficiency is")
```

Chapter 19

Properties of pure substances

Scilab code Exa 9.1 Calculations on vapourization of steam

```
// At 1 MPa
tsat = 179.91;
vf = 0.001127;
vg = 0.19444;
vfg = vg-vf;
sf = 2.1387;
sg = 6.5865;
sfg = sg-sf;
disp("degree",tsat,"At 1 Mpa saturation temperature
   is")
disp("m3/kg",vfg,"Changes in specific volume is")
disp("kJ/kg K",sfg,"Change in entropy during
   evaporation is")
```

Scilab code Exa 9.3 Finding the entropy and enthalpy of steam

```
v = 0.09; vf = 0.001177; vg = 0.09963;
x = (v-vf)/(vg-vf);
```

```
hf = 908.79; hfg = 1890.7;
sf = 2.4474; sfg = 3.8935;
h = hf+(x*hfg);
s = sf+(x*sfg);
disp("kJ/kg and kJ/kg K respectively",s,"and",h,"The
    enthalpy and entropy og the system are")
```

Scilab code Exa 9.4 Finding the entropy and enthalpyand volume of steam

```
// for T = 350 degree
T1 = 350; v1 = 0.2003; h1 = 3149.5; s1 = 7.1369;
// for T = 400 degree
T2 = 400; v2 = 0.2178; h2 = 3257.5; s2 = 7.3026;
// Interpolation for T = 380;
T = [T1 T2];
v = [v1 v2];
h = [h1 h2];
s = [s1 s2];
v3 = interpln([T;v],380);
h3 = interpln([T;h],380);
s3 = interpln([T;s],380);
disp("m3/kg respectively",v3,"kJ/kg",h3,"kJ/kg K",s3
   ,"The entropy, enthalpy and volume of stem at 1.4
   MPa and 380 degree is")
```

Scilab code Exa 9.5 Calculations of thermodynamics properties of mixture of air an

```
Psat = 3.973e06;
vf = 0.0012512; vg = 0.05013;
hf = 1085.36; hfg = 1716.2;
sf = 2.7927; sfg = 3.2802;
mf = 9; V = 0.04;
Vf = mf*vf;
```

```
Vg = V-Vf;
mg = Vg/vg;
m = mf+mg;
x = mg/m;
v = vf+x*(vg-vf);
h = hf+x*hfg;
s = sf+(x*sfg);
u = h-Psat*v*1e-03;
// at T = 250
uf = 1080.39; ufg = 1522;
u_ = uf+x*ufg;
disp("Pa",Psat,"The pressure is")
disp("kg",m,"The mass is")
disp("m3/kg",v,"Specific volume is")
disp("kJ/kg",h,"Enthalpy is")
disp("kJ/kg K",s,"The entropy is")
disp("kJ/kg",u,"The interal energy is")
```

Scilab code Exa 9.6 energy calculation on cooling of steam

```
// Part (a)
vg1_ = 0.8919; T1_ = 120;
vg2_ = 0.77076; T2_ = 125;
vg_ = [vg1_ vg2_]; T_ = [T1_ T2_];
v1 = 0.7964;
h1 = 2967.6;
P1 = 0.3e03; // in Kpa
T1 = interpln([vg_;T_],v1);
disp("degree",T1,"The steam become saturated at ")
// Part (b)
vf = 0.001029; vg = 3.407;
hf = 334.91; hfg = 2308.8;
Psat = 47.39; // In kPa
v2 = v1;
x2 = (v1-vf)/(vg-vf);
```

```
h2 = hf+x2*hfg;
P2 = Psat;
Q12 = (h2-h1)+v1*(P1-P2);
disp(x2,"The quality factor at t  =80 degree is")
disp("kJ/kg",Q12,"The heat transfered per kg of
   steam in cooling from 250 degree to 80 degree")
```

Scilab code Exa 9.7 energy calculation on expansion of steam

```
// At T = 40 degree
Psat = 7.384e06;
sf = 0.5725; sfg = 7.6845;
hf = 167.57; hfg = 2406.7;
//
s1 = 6.9189; h1 = 3037.6;
x2 = (s1-sf)/sfg ;
h2 = hf+(x2*hfg);
W = h1-h2;
disp("kJ/Kg",W,"The ideal work output of the turbine
    is")
```

Scilab code Exa 9.8 Determination of velocity of steam leaving through steam

```
w3 = 2.3; w1 = 1.0;
w2 = w3-w1;
h1 = 2950.0;
// At 0.8MPa, 0.95 dry
x = 0.95;
hf = 721.11; hfg = 2048;
h2 = hf + (x*hfg);
h3 = ((w1*h1)+(w2*h2))/w3;
// Interpolation
H = [2769.1 2839.3];
```

```
T = [170.43 200];
t3 = interpln([H;T],2790);
s3 = 6.7087;
s4 = s3;
x4 = (s3-1.7766)/5.1193;
h4 = 604.74+(x4*2133.8);
V4 = sqrt(2000*(h3-h4));
disp("degree",t3-T(1),"The condition of superheat
    after mixing")
disp("m/sec",V4,"The velocity of steam leaving the
    nozzle is")
```

Scilab code Exa 9.9 Calculation of moisture of steam

```
h2 = 2716.2; hf = 844.89; hfg = 1947.3;
x1 = (h2-hf)/hfg;
h3 = 2685.5;
x4 = (h3-hf)/hfg;
disp(x1,"The quality of steam in pipe line is")
disp("%",100-(x4*100),"Maximum moisture is")
```

Scilab code Exa 9.10 Finding the quantity of steam in pipeline

```
// At 0.1Mpa, 110 degree
h2 = 2696.2; hf = 844.89; hfg = 1947.3;
x2 = (h2-hf)/hfg;
vf = 0.001023; // at T = 70 degree
V = 0.000150; // In m3
m1 = V/vf;
m2 = 3.24;
x1 = (x2*m2)/(m1+m2);
disp(x1,"The quality of the steam in the pipe line
    is")
```

Scilab code Exa 9.11 Calculation of heat transferred in a steam bolier

```
// P = 1MPa
vf = 0.001127; vg = 0.1944;
hg = 2778.1; uf = 761.68;
ug = 2583.6; ufg = 1822;
// Initial anf final mass
Vis = 5; Viw = 5;
Vfs = 6 ; Vfw = 4 ;
//
ms = ((Viw/vf)+(Vis/vg)) - ((Vfw/vf)+(Vfs/vg)) ;
U1 =  ((Viw*uf/vf)+(Vis*ug/vg));
Uf =  ((Vfw*uf/vf)+(Vfs*ug/vg));
Q = Uf-U1+(ms*hg)
disp("kJ",Q,"The heat transfer during the process is
   ")
```

Scilab code Exa 9.12 Calculations on heat transfer in a cylinder and piston system

```
m = 0.02; d = 0.28; l = 0.305;
P1 = 0.6e06; P2 = 0.12e06;
// At 0.6MPa, t = 200 degree
v1 = 0.352; h1 = 2850.1;
V1 = m*v1;
Vd = (%pi/4)*d^2*l;
V2 = V1+Vd ;
n = log(P1/P2)/log(V2/V1);
W12 = ((P1*V1)-(P2*V2))/(n-1);
disp(n,"The value of n is");
disp("J",W12,"The work done by the steam is")
v2 = V2/m;
```

```
vf = 0.0010476; vfg = 1.4271;
x2 = (v2-vf)/vfg ;
// At 0.12MPa
uf = 439.3; ug = 2512.0;
u2 = uf + (x2*(ug-uf));
u1 = h1-(P1*v1*1e-03);
Q12 = m*(u2-u1)+ (W12/1000);
disp("kJ",Q12,"The heat transfer is")
```

Scilab code Exa 9.13 Energy calculations in an insulated vessel

```
x1 = 1; x2 = 0.8;
// at 0.2MPa
vg = 0.8857; v1 = vg; hg = 2706.7; h1 = hg;
m1 = 5 ; V1 = m1*v1;
// at 0.5MPa
m2 = 10;
hf = 640.23; hfg = 2108.5
vf = 0.001093; vfg = 0.3749;
v2 = vf+(x2*vfg);
V2 = m2*v2;
//
Vm = V1+V2;
m = m1+m2;
vm = Vm/m;
u1 = h1;
h2 = hf+(x2*hfg);
u2 = h2;
m3 = m;
h3 = ((m1*u1)+(m2*u2))/m3;
u3 = h3;
v3 = vm;
// From mollier diagram
x3 = 0.870; p3 = 3.5; s3 = 6.29;
s1 = 7.1271;
```

```
sf = 1.8607; sfg = 4.9606;
s2 = sf+(x2*sfg);
E = m3*s3-((m1*s1)+(m2*s2));
disp("bar",p3,"Final pressure is")
disp(x3,"Steam quality is")
disp("kJ/K",E,"Entropy change during the process is"
    )
```

Scilab code Exa 9.14 Energy calculation on steam passing through turbine

```
// At 6 MPa, 400 degree
h1 = 3177.2; s1 = 6.5408;
// At 20 degree
h0= 83.96; s0 = 0.2966;
T0 = 293;
f1 = (h1-h0)-T0*(s1-s0);
// By interpolation
t2 = 273 + 393;
s2 = 6.63;
h2 = h1;
f2 = (h2-h0)-T0*(s2-s0);
df = f1-f2;
x3s = (s2-1.5301)/(7.1271-1.5301);
h3s = 504.7+(x3s*2201.9);
eis = 0.82;
h3 = h2-eis*(h1-h3s);
x3 = (h3-504.7)/2201.7;
s3 = 1.5301+(x3*5.597);
f3 = (h3-h0)-T0*(s3-s0);
disp("kJ/kg",f1,"The availability of the steam
    before the throttle valve")
disp("kJ/kg",f2,"The availability of the steam after
     the throttle valve")
disp("kJ/kg",f3,"The availability of the steam at
    the turbine exhaust")
```

```
disp("kJ/kg",h2-h3,"The specific work output from
    the turbine is")
```

Scilab code Exa 9.15 Energy calculation on a steam turbine

```
// At 25 bar, 350 degree
h1 = 3125.87; s1 = 6.8481;
// 30 degree
h0 = 125.79; s0 = 0.4369;
// At 3 bar, 200 degree
h2 = 2865.5; s2 = 7.3115;
// At 0.2 bar 0.95 dry
hf = 251.4; hfg = 2358.3;
sf = 0.8320; sg = 7.0765;
h3 = hf+0.92*hfg;
s3 = sf+(0.92*sg);
// Part (a)
T0 = 303;
f1 = (h1-h0)-(T0*(s1-s0));
f2 = (h2-h0)-(T0*(s2-s0));
f3 = (h3-h0)-(T0*(s3-s0));
disp("kJ/kg",f1,"Availability of steam entering at
    state 1")
disp("kJ/kg",f2,"Availability of steam leaving  at
    state 2")
disp("kJ/kg",f3,"Availability of steam leaving  at
    state 3")
// Part (b)
m2m1 = 0.25; m3m1 = 0.75;
Wrev = f1-(m2m1*f2)-(m3m1*f3);
disp("kJ/kg",Wrev,"Maximum work is")
// Part (c)
w1 = 600; w2 = 150; w3 = 450;
Q = -10*3600;  // For 1 hour
I = T0*(w2*s2+w3*s3-w1*s1)-Q;
```

```
disp("kJ/h",I,"Irreversibility is")
```

Scilab code Exa 9.16 Determination of energy of different phases of water

```
// At dead state of 1 bar, 300K
u0 = 113.1; h0 = 113.2;
v0 = 0.001005; s0 = 0.0395;
T0 = 300; P0 = 100;
K = h0-(T0*s0);
// Part (a)
u = 376.9; h = 377;
v = 0.001035; s = 1.193;
m = 3;
fi = m*(h-(T0*s)-K); // As P = P0 = 1 bar
disp("kJ",fi,"Energy of system in Part (a) is")
// Part (b)
u = 3099.8; h = 3446.3; v = 0.08637; s = 7.090; //
    At P = 4 Mpa, t = 500 degree
m = 0.2;
fib = m*(u+P0*v-T0*s-K);
disp("kJ",fib,"Energy of system in Part (b) is")
// Part (c)
m = 0.4;
x = 0.85; // Quality
u = 192+x*2245;
h = 192+x*2392;
s = 0.649+x*7.499;
v = 0.001010+x*14.67;
fic = m*(u+P0*v-T0*s-K);
disp("kJ",fic,"Energy of system in Part (c) is")
// Part (d)
m = 3;
h = -354.1; s = -1.298; // at 1000kPa, -10 degree
fid = m*((h-h0)-T0*(s-s0));
disp("kJ",fid,"Energy of system in Part (d) is")
```

Scilab code Exa 9.17 Calculations on a heat exchanger

```
// Given
th1 = 90+273;
tc1 = 25+273;
tc2 = 50+273;
mc = 1; T0 = 300;
th2p = 60+273; // Parallel
th2c = 35+273; // Counter
mhp = (tc2-tc1)/(th1-th2p); // Parallel
mhc = (tc2-tc1)/(th1-th2c); // Counter
h0 = 113.2; s0 = 0.395; T0 = 300; // At 300 K
h1 = 376.92; s1 = 1.1925; // At 90 degree
af1 = mhp*((h1-h0)-T0*(s1-s0));
// Parallel Flow
h2 = 251.13; s2 =0.8312; // At 60 degree
h3 = 104.89; s3 = 0.3674; // At 25 degree
h4 = 209.33; s4 = 0.7038; // At 50 degree
REG = mc*((h4-h3)-T0*(s4-s3)); // Rate of energy gain
REL = mhp*((h1-h2)-T0*(s1-s2)); // Rate of energy loss
Ia = REL-REG; // Energy destruction
n2a = REG/REL; // Second law efficiency
disp("In parallel flow")
disp("kW",Ia,"The rate of irreversibility is")
disp("%",n2a*100,"The Second law efficiency is")
// Counter flow
h2 = 146.68; s2 = 0.5053; // At 35 degree
REG_b = REG; // Rate of energy gain by hot water is same in both flows
REL_b = mhc*((h1-h2)-T0*(s1-s2));
Ib = REL_b-REG_b; // Energy destruction
n2b = REG_b/REL_b; // Second law efficiency
```

```
disp("In Counter flow")
disp("kW",Ib,"The rate of irreversibility is")
disp("%",n2b*100,"The Second law efficiency is")
```

Scilab code Exa 9.18 Estimation of max cooling rate of a system

```
m = 50 ; // in kg/h
Th = 23+273; // Home temperature
// State 1
T1 = 150+273;
h1 = 2746.4;
s1 = 6.8387;
// State 2
h2 = 419.0;
s2 = 1.3071;
T0 = 318;
//
b1 = h1-(T0*s1);
b2 = h2-(T0*s2);
Q_max = m*(b1-b2)/(T0/Th-1);
disp("kW",Q_max/3600,"The maximum cooling rate is")
```

Chapter 20

Properties of gases and gas mixture

Scilab code Exa 10.1 Finding the final temperature and heat transferred in a fluid

```
// Part (a)
P1 = 100; P2 = 50;
T1 = 273+300;
T2 = (P2/P1)*T1;
R = 0.287; cv = 0.718;
V1 = 0.8;
m = (P1*V1)/(R*T1);
Q = m*cv*(T2-T1);
disp("If the fluid is in the air")
disp("K",T2,"The final temperature is ")
disp("kJ/kg",Q,"The heat transferred is")
// Part (b)
t2 = 273+81.33; vf = 0.00103; vg = 3.24;
v1 = 2.6388; u1 = 2810.4;
x2 = (v1-vf)/(vg-vf);
u2 = 340.42+(x2*2143.4);
m_ = V1/v1;
Q_ = m_*(u2-u1);
disp("If the fluid is in the steam")
```

```
disp("K",t2,"The final temperature is ")
disp("kJ/kg",Q_,"The heat transferred is")
```

Scilab code Exa 10.2 Finding the final temperature and heat transferred in a fluid

```
// Part (a)
R = 0.287; T1 = 273+150; v1 = 0.96; v2 = 1.55; Cp =
   1.005;
P = (R*T1)/v1;
W = P*(v2-v1);
T2 = (v2/v1)*T1;
Q = Cp*(T2-T1);
disp("If the fluid is in the air")
disp("K",T2,"The final temperature is ")
disp("kJ",Q,"The heat transferred is")
disp("kJ",W,"Work done is")
// Part (b)
vg = 0.3928;
P1 = 200e03;
P2 = P1;
h1 = 2768.8;
t2 = 273+400; h2 = 3276.5;
Q_ = h2-h1;
W_ = P1*(v2-v1);
disp("If the fluid is in the steam")
disp("K",t2,"The final temperature is ")
disp("kJ",Q_,"The heat transferred is")
disp("J",W_,"Work done is")
```

Scilab code Exa 10.3 Heat calculation on a fluid

```
// Part (a)
v = 16 ; // v = v1/v2
```

```
P1 = 300e03;
P2 = P1*v;
R = 0.287; T1 = 300+273;
W12 = R*T1*log(1/v);
disp("If the fluid is in the air")
disp("Pa",P2,"The final pressure is ")
disp("kJ",0,"The change in internal energy is")
disp("kJ",W12,"Work done is")
// Part (b)
v1 = 0.7664; u1 = 2728.7;
v2 = v1/16;
x2 = (v2-0.00125)/(0.05013);
s2 = 2.7927+(x2*3.2802);
s1 = 7.5165;
u2 = 1080.37+(x2*1522.0);
du = u2-u1;
T = 250+273;
Q12 = T*(s2-s1)
disp("If the fluid is in the steam")
disp("K",T,"The final temperature is ")
disp("kJ/kg",Q12,"The heat transferred is")
disp("kJ/kg  ",du,"The change in internal energy is"
  )
```

Scilab code Exa 10.4 Heat calculation for a reversible adiabatic process

```
// Part (a)
P1 = 10; P2 = 1;
T1 = 273+300;
g = 1.4;
T2 = T1*((P2/P1)^((g-1)/g));
R = 0.287;
W12 = ((R*T1)/(1-g))*(T2/T1-1);
v2 = (R*T2)/(100*P2);
disp("If the fluid is in the air")
```

```
disp("m3/kg",v2,"The specific volume is")
disp("kJ",W12,"The work done per kg of the fluid is"
   )
// Part (b)
u1 = 2793.2; v1 = 0.2579; s1 = 7.1228;
x2 = (7.1228-1.3025)/6.0568;
u2 = 417.33+(x2*2088.7);
v2 = 0.001043+(0.96*1.693);
W12 = u1-u2;
disp("If the fluid is in the steam")
disp("m3/kg",v2,"The specific volume is")
disp("kJ",W12,"The work done per kg of the fluid is"
   )
```

Scilab code Exa 10.5 Heat calculations on a reversible polytropic process

```
// Part (a)
P1 = 10; P2 = 1;
T1 = 273+200; n = 1.15; R = 0.287;
v2 = ((R*T1)/(P1*100))*((P1/P2)^(1/1.15));
v1 = ((R*T1)/(P1*100));
T2 = T1*(P2/P1)*(v2/v1);
cv = 0.716;
Q = (cv+(R/(1-n)))*(T2-T1);
disp("If the fluid is in the air")
disp("m3/kg",v2,"The specific volume is")
disp("K",T2,"The final temperature is ")
disp("kJ",Q,"Heat transferred per kg is")
// Part (b)
v1 = 0.20596; u1 = 2621.9;
v2 = v1*(P1/P2)^(1/n);
x2 = (v2-0.001043)/(1.694-0.001043);
t2 = 99.62+273;
u2 = 417.33+(x2*2088.7);
W = ((P1*100*v1)-(P2*100*v2))/(n-1);
```

```
Q = u2-u1+W;
disp("If the fluid is in the steam")
disp("m3/kg",v2,"The specific volume is")
disp("K",t2,"The final temperature is ")
disp("kJ",Q,"Heat transferred per kg is")
```

Scilab code Exa 10.6 Calculation on PV cycle of ideal monoatomic gas

```
P0 = 1000;
T0 = 3;
V0 = 0.001;
R = 287;
n = (P0*V0)/(R*T0); // Number of moles
// Process ab
Wab = 0;
cv = (3/2)*R;
Ta = T0; Tb = 300;
Qab = n*cv*(Tb-Ta);
Ua = 0; // Given internal energy
Ub = Qab+Ua;
Uab = Ub-Ua;
// Process bc
Qbc = 0; Uc = 0; Ubc = Uc-Ub;
Wbc = -Ubc;
// Process ca
Tc = Ta;
g = 5/3; // gamma
Vcb = (Tb/Tc)^(3/2); // Vc/Vb
Wca = -n*R*Tc*log(Vcb);
Qca = Wca ;
Uca = 0;
//
disp("J",Wab+Wbc+Wca,"Work done in the cycle is")
disp("J",Uab+Ubc+Uca,"Internal energy change in the
   cycle is")
```

```
disp("J",Qab+Qbc+Qca,"Heat transfer in the cycle is")
// Part (b)
e = (Qab+Qca)/Qab;
disp("%",e*100,"Thermal efficiency of the system is")
```

Scilab code Exa 10.7 `Pressure calculation in a system of two vessels`

```
Pa = 1.5; Ta = 273+50; ca = 0.5;
Pb = 0.6; Tb = 20+273; mb = 2.5;
R = 8.3143;
Va = (ca*R*Ta)/(Pa*1e03);
ma = ca*28;
Rn = R/28;
Vb = (mb*Rn*Tb)/(Pb*1e03);
V = Va + Vb ;
m = ma + mb ;
Tf = 27+273;
P = (m*Rn*Tf)/V;
g = 1.4;
cv  = Rn/(g-1);
U1 = cv*(ma*Ta+mb*Tb);
U2 = m*cv*Tf;
Q = U2-U1;
disp("KPa",P,"The final equillibrium pressure is")
disp("kJ",Q,"The amount of heat transferred to the surrounding is")
T_ = (ma*Ta+mb*Tb)/m ;
P_ = (m*Rn*T_)/V;
disp("If the vessele is perfectly inslulated")
disp("K",T_,"The final temperature is")
disp("KPa",P_,"The final pressure is")
```

Scilab code Exa 10.8 Heat calculation on a gas in constant volume chamber

```
cp = 1.968; cv = 1.507;
R_ = 8.314;
V = 0.3; m = 2;
T1 = 5+273; T2 = 100+273;
R = cp-cv;
mu = R_/R;
Q12 = m*cv*(T2-T1);
W12 = 0 ;
U21 = Q12;
H21= m*cp*(T2-T1);
S21 = m*cv*log(T2/T1);
disp("kJ/kg K",R,"kg/kg mol and",mu,"Molecular
   weight and the gas constant of the gas are")
disp("kJ",0,"Work done")
disp("kJ",Q12,"The heat transferred")
disp("kJ",U21,"The change in internal energy ")
disp("kJ",S21,"entropy")
disp("kJ/K",H21,"enthalpy")
```

Scilab code Exa 10.9 Calculation of work done in expansion of a gas

```
m = 1.5;
P1 = 5.6; V1 = 0.06;
T2 = 273+240;
a = 0.946; b = 0.662;
k = 0.0001;
// Part (b)
R = a-b;
T1 = (P1*1e03*V1)/(m*R);
W12 = -integrate('m*(b+k*T)','T',T1,T2);
```

```
disp("kJ",W12,"The work done in the expansion is")
```

Scilab code Exa 10.11 Calculation of work and heat transfer on a path

```
m = 0.5;
P1 = 80e03; T1 = 273+60;
P2 = 0.4e06;
R = 0.287;
V1 = (m*R*T1)/P1 ;
g = 1.4; // Gamma
T2 = T1*(P2/P1)^((g-1)/g);
W12 = (m*R*(T1-T2))/(g-1);
V2 = V1*((P1/P2)^(1/g));
W23 = P2*(V1-V2);
W = W12+W23;
V3 = V1;
T3 = T2*(V3/V2);
cp = 1.005;
Q = m*cp*(T3-T2);
disp("kJ",W,"The work transfer for the whole path is
   ")
disp("kJ",Q,"The heat transfer for the whole path")
```

Scilab code Exa 10.12 Heat calculations over a cycle

```
P1 = 700e03; T1 = 273+260; T3 = T1;
V1 = 0.028; V2 = 0.084;
R = 0.287;
m = (P1*V1)/(R*T1);
P2 = P1;
T2 = T1*((P2*V2)/(P1*V1));
n  = 1.5;
P3 = P2*((T3/T2)^(n/(n-1)));
```

```
cp = 1.005; cv = 0.718;
Q12 = m*cp*(T2-T1);
Q23 = m*cv*(T3-T2) + (m*R*(T2-T3))/(n-1);
Q31 = m*R*T1*log(P3/P1);
Q1 = Q12;
Q2 = -(Q23+Q31);
e = 1-(Q2/Q1);
disp("J",Q1,"The heat received in the cycle is")
disp("J",Q2,"The heat rejected in the cycle")
disp(e,"The efficiency of the cycle is")
```

Scilab code Exa 10.13 Heat calculations on an ideal gas

```
P1 = 300e03; V1 = 0.07;
m = 0.25; T1 = 80+273;
R = (P1*V1)/(1000*m*T1);
P2 = P1;
V2 = 0.1;
T2 = (P2*V2)/(1000*m*R);
W = -25;
cv = -W/(m*(T2-T1));
cp = R+cv;
S21 = m*cp*log(V2/V1); // S21 = S2-S1
disp("kJ/kg K",cv,"cv of the gas is")
disp("kJ/kg K",cp,"cp of the gas is")
disp("kJ/kg K",S21,"Increase in the entropy of the
   gas is")
```

Scilab code Exa 10.14 Calculations on internal combustion engine

```
P1 = 1;
P2 = 15;
V1 = 800e-06;
```

```
V2 = V1/8;
cv = 0.718; g = 1.4;
n = (log(P2/P1))/(log(V1/V2))
T1 = 348; R = 0.287;
m = (P1*100*V1)/(R*T1);
T2 = T1*((P2*V2)/(P1*V1));
P3 = 50;
T3 = T2*(P3/P2);
S21 = m*(cv*log(T2/T1)+R*log(V2/V1));
S32 = m*cv*log(T3/T2);
Q = (m*cv*(g-n)*(T2-T1))/(1-n);
disp(n,"The index of compression process is")
disp("kJ/K",S21,"S2-S1 is")
disp("kJ/K",S32,"S3-S2 is")
disp("kJ",Q,"The heat exchange is")
```

Scilab code Exa 10.15 Calculations on a mixture of ideal gases

```
mn = 3; // Mass of nitrogen in kg
mc = 5; // mass of CO2 in kg
an = 28; // Atomic weight of nitrogen
ac = 44; // Atomic weight of CO2
// Part (a)
xn = (mn/an)/((mn/an)+(mc/ac));
xc = (mc/ac)/((mn/an)+(mc/ac));
disp(xn,"Mole fraction of N2 is")
disp(xc,"Mole fraction of CO2 is")
// Part (b)
M = xn*an+xc*ac;
disp("kg",M,"Equivalant molecular weight of mixture
    is")
// Part (c)
R = 8.314;
Req = ((mn*R/an)+(mc*R/ac))/(mn+mc);
disp("kJ/kg K",Req,"The equivalent gas constant of
```

```
    the mixture is")
// Part (d)
P = 300; // Pressure in kPa
T = 20+273;
Pn = xn*P; // Partial pressure of Nitrogen
Pc = xc*P; // Partial pressure of CO2
Vn = (mn*R*T)/(P*an); // Volume of nitrogen
Vc = (mc*R*T)/(P*ac); // Volume of CO2
disp("kPa respectively",Pc,"and",Pn,"Partial
    pressures of nitrogen and CO2 are")
disp("m3 respectively",Vc,"and",Vn,"Partial volume
    of nitrogen and CO2 are")
// Part (e)
V = (mn+mc)*Req*T/P; // Total volume
rho = (mn+mc)/V;
disp("m3",V,"Volume of mixture is")
disp("kg/m3",rho,"Density of mixture is")
// Part (f)
gn = 1.4; // Gamma
gc = 1.286;
cvn = R/((gn-1)*an); // cp and cv of N2
cpn = gn*cvn;
cvc = R/((gc-1)*ac); // cp and cv of CO2
cpc = gc*cvc;
cp = (mn*cpn+mc*cpc)/(mn+mc) ; // of mixture
cv = (mn*cvn+mc*cvc)/(mn+mc) ;
disp("kJ/kg K respectively",cv,"and",cp,"cp and cv
    of mixture are")
T1 = T; T2 = 40+273;
U21 = (mn+mc)*cv*(T2-T1);
H21 = (mn+mc)*cp*(T2-T1);
S21v = (mn+mc)*cv*log(T2/T1); // If heated at
    constant volume
disp("kJ",U21,"Change in internal energy of the
    system heated at constant volume is")
disp("kJ",H21,"Change in enthalpy of the system
    heated at constant volume is")
disp("kJ/kg K",S21v,"Change in entropy of the system
```

```
heated at constant volume is")
S21p = (mn+mc)*cp*log(T2/T1); // If heated at constant Pressure
disp("kJ",S21p,"Change in entropy of the system heated at constant Pressure is")
```

Scilab code Exa 10.16 Finding the increase in entropy of gas

```
mo = 2; mn = 6;
muo = 32; mun = 28;
o = mo/muo;
n = mn/mun;
xo = o/(n+o);
xn = n/(n+o);
R = 8.314;
Ro = R/muo; Rn = R/mun;
dS = -mo*Ro*log(xo)-mn*Rn*log(xn);
disp("kJ/kg K",dS,"Increase in entropy is")
```

Scilab code Exa 10.17 Calculations os specific properties of neon

```
an = 20.183; // molecular weight of neon
Pc = 2.73; // Critical pressure
Tc = 44.5;
Vc = 0.0416;
Pr = 2; // Reduced Pressure
Tr = 1.3;
Z = 0.7;
P = Pr*Pc;
T = Tr*Tc;
R = 8.314;
v = (Z*R*T)/(P*1000*an);
vr = (v*an)/Vc ;
```

```
disp("m3/kg",v,"Specific volume is")
disp("K",T,"Specific temperature is")
disp("kPa",P,"Specific pressure is")
disp(vr,"Reduced volume is")
```

Chapter 21

Thermodynamic relations Equilibrium and stability

Scilab code Exa 11.3 Finding the vapour pressure of benzene

```
Tb = 353;
T = 303;
R = 8.3143;
P = 101.325*exp((88/R)*(1-(Tb/T)));
disp("kPa",P,"Vapour pressure of benzene is ")
```

Scilab code Exa 11.4 Calculations on vapours of benzene

```
T = (3754-3063)/(23.03-19.49);
P = exp(23.03-(3754/195.2));
R = 8.3143;
Lsub = R*3754;
Lvap = 3063*R;
Lfu = Lsub-Lvap;
disp("K",T,"Temperature of triple point is")
disp("mm Hg",P,"Pressure of triple point is")
```

```
disp("kJ/kg mol",Lsub,"Latent heat of sublimation is")
disp("kJ/kg mol",Lvap,"Latent heat of vapourization is")
disp("kJ/kg mol",Lfu,"Latent heat of fusion is")
```

Scilab code Exa 11.6 Thermodynamic calculation on a system of two simple systems

```
R = 8.314;
N1 = 0.5e-03; N2 = 0.75e-03; // Mole number of system 1 and 2 in kg/mol
T1 = 200; T2 = 300;
V = 0.02;
Tf = ((N1*T1)+(N2*T2))/(N1+N2); // Final temperature
Uf1 = (3/2)*R*N1*Tf;
Uf2 = (3/2)*R*N2*Tf;
Pf = (R*Tf*(N1+N2))/V;
Vf1 = (R*N1*Tf)/Pf;
Vf2 = V - Vf1;
disp("System 1")
disp("m3",Vf1,"Volume is")
disp("kJ",Uf1,"Energy is")
disp("System 2")
disp("m3",Vf2,"Volume is")
disp("kJ",Uf2,"Energy is")
disp("K",Tf,"Final temperature is")
disp("kPa",Pf,"Final Pressure is")
```

Chapter 22

Vapour power cycle

Scilab code Exa 12.1 Calculation of work required for compression of steam

```
// Part (a)
P1 = 1e05;
P2 = 10e05;
vf = 0.001043;
Wrev = vf*(P1-P2);
disp("kJ/kg",Wrev/1000,"The work required in
   saturated liquid form is")
// Part (b)
h1 = 2675.5; s1 = 7.3594;
s2 = s1;
h2 = 3195.5;
Wrev1 = h1-h2;
disp("kJ/kg",Wrev1,"The work required in saturated
   vapour form is")
```

Scilab code Exa 12.2 Calculations on steam on a cycle

```
h1 = 3159.3; s1 = 6.9917;
```

```
h3 = 173.88; s3 = 0.5926; sfp2 = s3; hfp2 = h3;
hfgp2 = 2403.1; sgp2 = 8.2287;
vfp2 = 0.001008; sfgp2 = 7.6361;
x2s = (s1-sfp2)/(sfgp2);
h2s = hfp2+(x2s*hfgp2);
// Part (a)
P1 = 20e02; P2 = 0.08e02;
h4s = vfp2*(P1-P2)+h3 ;
Wp = h4s-h3;
Wt = h1-h2s;
Wnet = Wt-Wp;
Q1 = h1-h4s;
n_cycle = Wnet/Q1;
disp("kJ/kg",Wnet,"Net work per kg of steam is")
disp(n_cycle,"Cycle efficiency is")
// Part (b)
n_p = 0.8; n_t = 0.8;
Wp_ = Wp/n_p;
Wt_ = Wt*n_t;
Wnet_ = Wt_-Wp_;
P = 100*((Wnet-Wnet_)/Wnet) ;
n_cycle_ = Wnet_/Q1;
P_ = 100*((n_cycle-n_cycle_)/n_cycle);
disp("%",P,"Percentage reduction in net work per kg
    of steam is")
disp("%",P_,"Percentage reduction in cycle
    efficiency is")
```

Scilab code Exa 12.3 Calculation on stem power plant

```
P1 = 0.08; // in bar
sf = 0.5926; x2s = 0.85; sg = 8.2287;
s2s = sf+(x2s*(sg-sf));
s1 = s2s;
P2 = 16.832; // by steam table opposite to s1 in bar
```

```
h1 = 3165.54;
h2s = 173.88 + (0.85*2403.1);
h3 = 173.88;
vfp2 = 0.001;
h4s = h3 + (vfp2*(P2-P1)*100);
Q1 = h1-h4s;
Wt = h1-h2s;
Wp = h4s-h3;
n_cycle = 100*((Wt-Wp)/Q1);
Tm = (h1-h4s)/(s2s-sf);
disp("bar",P2,"The greatest allowable steam pressure
    at the turbine inlet is")
disp("%",n_cycle,"Rankine cycle efficiency is")
disp("K",Tm,"Mean temperature of heat addition is")
```

Scilab code Exa 12.4 Calculations on steam power plant

```
h1 = 3465; h2s = 3065; h3 = 3565;
h4s = 2300; x4s = 0.88; h5 = 191.83;
v = 0.001;
P = 150; // in bar
Wp = v*P*100;
h6s = 206.83;
Q1 = (h1-h6s)+(h3-h2s);
Wt = (h1-h2s)+(h3-h4s);
Wnet = Wt-Wp;
n_cycle = 100*Wnet/Q1;
sr = 3600/Wnet;
disp(0.88,"Quality at turbine exhaust is")
disp("%",n_cycle,"Cycle efficiency is")
disp("kg/kW h",sr,"steam rate is")
```

Scilab code Exa 12.5 Calculations on single heater regenerative cycle

```
h1 = 3230.9; s1 = 6.9212; s2 = s1; s3 = s1;
h2 = 2796; sf = 0.6493; sfg = 7.5009;
x3 = (s3-sf)/sfg;
h3 = 191.83 + x3*2392.8;
h4 = 191.83; h5 = h4;
h6 = 640.23; h7 = h6;
m = (h6-h5)/(h2-h5);
Wt = (h1-h2)+(1-m)*(h2-h3);
Q1 = h1-h6;
n_cycle = 100*Wt/Q1;
sr = 3600/Wt;
s7 = 1.8607; s4 = 0.6493;
Tm = (h1-h7)/(s1-s7);
Tm1 = (h1-h4)/(s1-s4); // With out regeneration
dT = Tm-Tm1;
Wt_ = h1-h3;
sr_ = 3600/Wt_;
dsr = sr-sr_;
n_cycle_ = 100*(h1-h3)/(h1-h4);
dn = n_cycle-n_cycle_;
disp("%",n_cycle,"Efficiency of the cycle is ")
disp("kg/kW h",sr,"Steam rate of the cycle is")
disp("degree centigrade",dT,"Increase in temperature
    due to regeneration is")
disp("kg/kW h",dsr,"Increase in steam rate due to
   regeneration is")
disp("%",dn,"Increase in Efficiency of the cycle due
    to regeneration is")
```

Scilab code Exa 12.6 Calculations on steam power plant

```
h1 = 3023.5; s1 = 6.7664; s2 = s1; s3 = s1; s4 = s1;
t_sat_20 = 212;
t_sat_1 = 46;
dt = t_sat_20-t_sat_1;
```

```
n =3; // number of heaters
t = dt/n;
t1 = t_sat_20-t;
t2 = t1-t;
// 0.1 bar
hf = 191.83; hfg = 2392.8; sf = 0.6493;
sg = 8.1502;
// At 100 degree
hf100 = 419.04; hfg100 = 2257.0; sf100 = 1.3069;
    sg100 = 7.3549;
// At 150 degree
hf150 = 632.20; hfg150 = 2114.3; sf150 = 1.8418;
    sg150 = 6.8379;
x2 = (s1-sf150)/4.9961;
h2 = hf150+(x2*hfg150);
x3 = (s1-sf100)/6.0480;
h3 = hf100+(x3*hfg100);
x4 = (s1-sf)/7.5010;
h4 = hf+(x4*hfg);
h5 = hf; h6 = h5;
h7 = hf100; h8 = h7;
h9 = 632.2; h10 = h9;
m1 = (h9-h7)/(h2-h7);
m2 = ((1-m1)*(h7-h6))/(h3-h6);
Wt = 1*(h1-h2)+(1-m1)*(h2-h3)+(1-m1-m2)*(h3-h4);
Q1 = h1-h9;
Wp = 0 ; // Pump work is neglected
n_cycle = 100*(Wt-Wp)/Q1;
sr = 3600/(Wt-Wp);
disp("kJ/kg",Wt,"Net work per kg os stem is")
disp("%",n_cycle,"Cycle efficiency is")
disp("kg/kW h",sr,"Stream rate is")
```

Scilab code Exa 12.7 Calculations on expansion of steam in a turbine

```
Ti = 2000;
Te = 450;
T0 = 300;
Q1_dot = 100e03; // in kW
cpg = 1.1;
wg = Q1_dot/(cpg*(Ti-Te));
af1 = wg*cpg*T0*((Ti/T0)-1-log(Ti/T0));
af2 = wg*cpg*T0*((Te/T0)-1-log(Te/T0));
afi = af1-af2;
h1 = 2801; h3 = 169; h4 = 172.8; h2 = 1890.2;
s1 = 6.068; s2 = s1; s3 = 0.576; s4 = s3;
Wt = h1-h2;
Wp = h4-h3;
Q1 = h1-h4;
Q2 = h2-h3;
Wnet = Wt-Wp;
ws = Q1_dot/2628;
afu = 38*(h1-h4-T0*(s1-s3));
I_dot = afi-afu;
Wnet_dot = ws*Wnet;
afc = ws*(h2-h3-T0*(s2-s3));
n2 = 100*Wnet_dot/af1;
disp("%",n2,"The second law efficiency is")
```

Scilab code Exa 12.8 Calculations on steam power plant

```
// Part (a)
h1 = 2758; h2 = 1817; h3 = 192; h4 = 200;
Wt = h1-h2; Wp = h4-h3;
Q1 = h1-h4; Wnet = Wt-Wp;
cpg = 1.1;
n1 = Wnet/Wt;
WR = Wnet/Wp;
Q1_ = 100;
PO = n1*Q1_;
```

```
cp = 1000;
wg = (Q1_/(833-450));
EIR = wg*cpg*((833-300)-300*(log(833/300)));
n2 = PO/EIR ;
disp("Part (a)")
disp("%",n1*100,"n1 is")
disp("%",n2*100,"n2 is")
disp(WR,"Work ratio is")
// Part (b)
h1b = 3398; h2b = 2130; h3b = 192; h4b = 200;
Wtb = 1268; Wpb = 8; Q1b = 3198;
n1b = (Wt-Wp)/Q1;
WRb = (Wt-Wp)/Wt;
EIRb = 59.3;
Wnetb = Q1b*n1b;
n2b = Wnetb/EIRb;
disp("Part (b)")
disp("%",n1b*100,"n1 is")
disp("%",n2b*100,"n2 is")
disp(WRb,"Work ratio is")
// Part (c)
h1c = 3398; h2c = 2761; h3c = 3482; h4c = 2522; h5c = 192; h6c = 200;
Wt1 = 637; Wt2 = 960; Wtc = Wt1+Wt2; Wpc = 8;
Wnetc = 1589; Q1c = 3198+721;
n1c = Wnetc/Q1c;
WRc = Wnetc/Wtc;
POc = Q1_*n1c;
EIRc = 59.3;
n2c = POc/EIRc;
disp("Part (c)")
disp("%",n1c*100,"n1 is")
disp("%",n2c*100,"n2 is")
disp(WRc,"Work ratio is")
// Part (d)
T3 = 318.8; T1 = 568;
n1d = 1-(T3/T1);
Q1d = 2758-1316;
```

```
Wnet = Q1d*n1d;
Wpd = 8; Wtd = 641;
WRd = (Wt-Wp)/Wt;
P0d = Q1_*0.439;
EIRd = (Q1_/(833-593))*cpg*((833-300)-300*(log
    (833/300)));
n2d = P0d/EIRd;
disp("Part (d)")
disp("%",n1d*100,"n1 is")
disp("%",n2d*100,"n2 is")
disp(WRd,"Work ratio is")
```

Scilab code Exa 12.9 Calculations on steam in a chemical plant

```
hfg = 2202.6;
Qh = 5.83;
ws = Qh/hfg;
eg = 0.9; // efficiency of generator
P = 1000;
Wnet = 1000/0.9;
nbrake = 0.8;
h1_2s = Wnet/(ws*nbrake); // h1-h2s
n_internal = 0.85;
h12 = n_internal*h1_2s;
hg = 2706.3; h2 = hg;
h1 = h12+h2;
h2s = h1-h1_2s;
hf = 503.71;
x2s = (h2s-hf)/hfg;
sf = 1.5276; sfg = 5.6020;
s2s = sf+(x2s*sfg);
s1 = s2s;
P1 = 22.5; // in bar from Moiller chart
t1 = 360;
disp("degree",t1,"Temperature of the steam is")
```

```
disp("bar",P1,"Pressure of the steam is ")
```

Scilab code Exa 12.10 Calculation of oil consumption per day in a factory

```
h1 = 3037.3; h2 = 561+(0.96*2163.8);
s2 = 1.6718+(0.96*5.3201);
s3s = s2;
x3s = (s3s-0.6493)/7.5009;
h3s = 191.83+(x3s*2392.8);
h23 = 0.8*(h2-h3s); // h2-h3
h3 = h2-h23;
h5 = 561.47; h4 = 191.83;
Qh = 3500; // in kJ/s
w = Qh/(h2-h5);
Wt = 1500;
ws = (Wt+w*(h2-h3))/(h1-h3);
ws_ = 3600*ws ; // in kg/h
h6 = ((ws-w)*h4+w*h5)/ws;
h7 = h6;
n_boiler = 0.85;
CV = 44000; // in kJ/kg
wf = (1.1*ws_*(h1-h7))/(n_boiler*CV);
disp("kg/h",wf,"Fuel buring rate is")
```

Scilab code Exa 12.11 Calculations on a steam turbine

```
h1 = 3285; h2s = 3010; h3 = 3280; h4s = 3030;
h4 = h3-0.83*(h3-h4s);
h5s = 2225;
h5 = h4-0.83*(h4-h5s);
h6 = 162.7; h7 = h6;
h8 = 762.81;
h2 = h1-0.785*(h1-h2s);
```

```
m = (h8-h7)/(h4-h7);
n_cycle = ((h1-h2)+(h3-h4)+(1-m)*(h4-h5))/((h1-h8)+(
    h3-h2))
disp("kg/s",m,"Steam flow at turbine inlet is")
disp("%",n_cycle*100,"cycle efficiency is")
```

Scilab code Exa 12.12 Calculations on a binary vapour cycle

```
// From table and graph
h1 = 2792.2;
h4 = 122.96;
hb = 254.88;
hc = 29.98;
ha = 355.98;
hd = hc;
h2 = 1949.27;
//
m = (h1-h4)/(hb-hc); // Amount of mercury
    circulating
Q1t = m*(ha-hd);
W1t = m*(ha-hb) + (h1-h2);
Nov = W1t/Q1t ;
disp("%",Nov*100,"Overall efficiency of the cycle")
S = 50000; // Stem flow rate through turbine in kg/h
wm = S*m;
disp("kg/h",wm,"Flow through the mercury turbine is"
    )
Wt = W1t*S/3600;
disp("kW",Wt,"Useful work done in binary vapour
    cycle is")
nm = 0.85; // Internal efficiency of mercury turbine
ns = 0.87; // Internal efficiency of steam turbine
WTm = nm*(ha-hb);
hb_ = ha-WTm; // hb'
m_ = (h1-h4)/(hb_-hc); // m'
```

```
h1_ = 3037.3; // h'
Q1t = m_*(ha-hd)+(h1_-h1);
x2_ = (6.9160-0.4226)/(8.47-0.4226);
h2_ = 121+(0.806*2432.9);
WTst = ns*(h1_-h2_);
WTt = m_*(ha-hb_)+WTst;
Nov = WTt/Q1t;
disp("%",Nov*100,"Overall efficiency is")
```

Chapter 23

Gas power cycle

Scilab code Exa 13.1 Calculations on otto cycle

```
T1 = 273+35;
P1 = 100e03; // in kN/m2
Q1 = 2100;
R = 0.287;
v1 = 0.884; v2 = 0.11; v3 = v2;
rk = 8; g = 1.4; // gamma
n_cycle = 1-(1/rk^(1.4-1));
v12 = 8; // v1/v2
v1 = (R*T1)/P1;
v2 = v1/8;
T2 = T1*(v1/v2)^(g-1);
cv = 0.718;
T3 = Q1/cv + T2
P21 = (v1/v2)^g;
P2 = P21*P1;
P3 = P2*(T3/T2);
Wnet = Q1*n_cycle;
Pm = Wnet/(v1-v2);
disp("MPa",P3/1e06,"Maximum pressure is")
disp("K",T3,"Temperature of the cycle is")
disp("%",n_cycle*100,"Cycle efficiency is")
```

```
disp("MPa",Pm/1e06,"Mean effective pressure is")
```

Scilab code Exa 13.2 Calculations on a diesel engine

```
rk = 14;
k = 0.06
rc = k*(14-1)+1;
g = 1.4;
n_diesel = 1-((1/g))*(1/rk^(g-1))*((rc^(g-1))/(rc-1));
disp("%",n_diesel*100,"Air standard efficiency is")
```

Scilab code Exa 13.3 Calculations on air standard diesel cycle

```
rk = 16;
T1 = 273+15;
P1 = 100; // in kN/m2
T3 = 1480+273;
g = 1.4; // gamma
R = 0.287;
T2 = 288*(rk^(g-1));
rc =  T3/T2 ;
cp = 1.005; cv = 0.718;
Q1 = cp*(T3-T2);
T4 = T3*((rc/rk)^(g-1));
Q2 = cv*(T4-T1);
n = 1-(Q2/Q1); // cycle efficiency
n_ = 1-((1/g))*(1/rk^(g-1))*((rc^(g-1))/(rc-1)); // cycle efficiency from another formula
Wnet = Q1*n;
v1 = (R*T1)/P1 ;
v2 = v1/rk;
Pm = Wnet/(v1-v2);
```

```
disp(rc,"cut-off ratio is")
disp("kJ/kg",Q1,"Heat supplied per kg of air is")
disp("%",n*100,"Cycle efficiency is")
disp("KPa",Pm,"Mean effective pressure is")
```

Scilab code Exa 13.4 Calculations on air standard dual cycle

```
T1 = 273+50;
rk = 16;
g = 1.4; // gamma
P3 = 70; cv = 0.718; cp = 1.005; R = 0.287;
T2 = T1*((rk^(g-1)));
P1 = 1; // in bar
P2 = P1*(rk)^g;
T3 = T2*(P3/P2);
Q23 = cv*(T3-T2);
T4 = (Q23/cp)+T3;
v43 = T4/T3; // v4/v3
v54 = rk/v43; // v5/v4 = (v1/v2)*(v3/v4)
T5 = T4*(1/v54)^(g-1);
P5 = P1*(T5/T1);
Q1 = cv*(T3-T2)+cp*(T4-T3);
Q2 = cv*(T5-T1);
n_cycle = 1-(Q2/Q1);
v1 = (R*T1)/P1;
v12 = (15/16)*v1; // v1-v2
Wnet = Q1*n_cycle;
Pm = Wnet/(v12);
disp("%",n_cycle*100,"Efficiency of the cycle is")
disp("bar",Pm,"Mean effective pressure is")
```

Scilab code Exa 13.5 finding the increase in cycle efficiency of gas turbine plant

```
P1 = 0.1e06;
T1 = 303;
T3 = 1173;
PR = 6; // Pressure ratio
rp = 6; nt = 0.8; nc = 0.8;
g = 1.4; cv = 0.718; cp = 1.005; R = 0.287;
j = (PR)^((g-1)/g);
T2s = j*T1;
T4s = T3/j;
T21 = (T2s-T1)/nc ; // T2-T1
T34 = nt*(T3-T4s); // T3-T4
Wt = cp*T34;
Wc = cp*T21;
T2 = T21+T1;
Q1 = cp*(T3-T2);
n = (Wt-Wc)/Q1;
T4 = T3-375;
T6 = 0.75*(T4-T2) + T2 ;
Q1_ = cp*(T3-T6);
n_ = (Wt-Wc)/Q1_;
I = (n_-n)/n ;
disp("%",I*100,"The percentage efficiency in cycle
    efficiency due to regeneration is")
```

Scilab code Exa 13.6 Calculations on gas turbine plant operating on bryton cycle

```
cp = 1.005;
Tmax = 1073; Tmin = 300;
Wnet_max = cp*(sqrt(Tmax)-sqrt(Tmin))^2;
n_cycle = 1-sqrt(Tmin/Tmax);
n_carnot = 1-(Tmin/Tmax);
r = n_cycle/n_carnot;
disp("kJ/kg",Wnet_max,"Maximum work done per kg of
    air is")
disp("%",n_cycle*100,"cycle efficiency is")
```

```
disp(r,"ratio of brayton and carnot efficiency is")
```

Scilab code Exa 13.7 Calculations on an ideal bryton cycle

```
rp = 6;
g = 1.4; cv = 0.718; cp = 1.005; R = 0.287;
T1 = 300; T3 = 1100; T0 = 300;
n_cycle = 1-(1/rp^((g-1)/g));
j = rp^((g-1)/g);
T2 = T1*j;
T4 = T3/j;
Wc = cp*(T2-T1);
Wt = cp*(T3-T4);
WR = (Wt-Wc)/Wt;
Q1 = 100; // in MW
PO = n_cycle*Q1;
m_dot = (Q1*1e06)/(cp*(T3-T2));
R = m_dot*cp*T0*((T4/T0)-1-log(T4/T0));
disp("%",n_cycle*100,"The thermal efficiency of the
   cycle is")
disp(WR,"Work ratio is")
disp("MW",PO,"Power output is")
disp("MW",R/1e06,"Energy flow rate of the exhaust
   gas stream is")
```

Scilab code Exa 13.8 Calculations on stationary gas turbine

```
nc = 0.87; nt = 0.9; T1 = 311; T3 = 1100;
rp = 8; // P2/P1
P1 = 1; P2 = 8; P3 = 0.95*P2; P4 = 1;
g = 1.4; cv = 0.718; cp = 1.005; R = 0.287;
// With no cooling
T2s = T1*((P2/P1)^((g-1)/g));
```

```
T2 = T1 + (T2s-T1)/0.87;
T4s = T3*(P4/P3)^((g-1)/g);
n = (((T3-T4s)*nt)-((T2s-T1)/nc))/(T3-T2);
// With cooling
n_cycle = n-0.05;
x = 0.13;
r = 0.13/1.13;
disp("%",r*100,"Percentage of air that may be taken
   from the compressor is")
```

Scilab code Exa 13.10 Calculations on air flying through the engine of a turbojet

```
T1 = 233; V1 = 300; cp = 1.005; g = 1.4;
T2 = T1+((V1^2)/(2*cp))*1e-03 ;
P1 = 35;
P2 = P1*(T2/T1)^(g/(g-1));
rp = 10; // Pressure ratio
P3 = rp*P2;
T3 = T2*(P3/P2)^((g-1)/g);
T4 = 1373;
T5 = T4-T3+T2;
P4 = P3;
P5 = P4*(T5/T4)^(g/(g-1));
disp("K",T5,"Temperature at the turbine exit is")
disp("kPa",P5,"Pressure at the turbine exit is")
P6 = P1;
T6 = T5*(P6/P5)^((g-1)/g);
V6 = (2*cp*1000*(T5-T6))^0.5 ;
disp("m/s",V6,"Velocity of the gas at the nozzle
   exit is")
w = 50;
Ve = V6; Vi = 300;
Wp_dot = w*Vi*(Ve-Vi);
h4 = 1373; h3 = 536.66;
Q1 = w*cp*(h4-h3); // in kJ/kg
```

```
np = Wp_dot/(Q1*1000);
disp("%",np*100,"The propulsive efficiency of the
    cycle is")
```

Scilab code Exa 13.11 Calculations on a combined GT ST plant

```
Ta = 288;
rp = 8; // Pb/Pa
g = 1.33; g1 = 1.44; cv = 0.718; cpa = 1.005; cpg =
    1.11; R = 0.287;
Tb = Ta*(rp)^((g1-1)/g1);
Tc = 1073; Tm = 800+273; Tmin = 100+273;
Td = Tc/(rp^((g-1)/g));
Wgt = cpg*(Tc-Td)-cpa*(Tb-Ta);
Q1 = cpg*(Tc-Tb);
Q1_ = cpg*(Tc-Td);
h1 = 3775; h2 = 2183; h3 = 138; h4 = h3;
Q1_st = h1-h3; // Q1'
Q_fe = cpg*(Tm-Tmin);
was = Q1_st/Q_fe; // wa/ws
Wst = h1-h2;
PO = 190e03; // in kW
ws = PO/(was*Wgt+Wst);
wa = was*ws;
CV = 43300; // in kJ/kg
waf = CV/(Q1+Q1_);
FEI = (wa/waf)*CV;
noA = PO/FEI;
disp(waf,"Air fuel ratio is")
disp("%",noA*100,"Overall efficiency of combined
    plant is")
```

Chapter 24

Refrigeration cycle

Scilab code Exa 14.1 Finding the power required to drive a cold storage plant

```
T2 = 268; T1 = 308;
COP = T2/(T1-T2);
ACOP = COP/3; // Actual COP
Q2 = 29; // in kW
W = Q2/ACOP;
disp("kW",W,"Power required to derive the plane is")
```

Scilab code Exa 14.2 Heat calculations on a refrigerator

```
h1 = 236.04; s1 = 0.9322; s2 = s1;
P2 = 0.8; // in MPa
h2 = 272.05; h3 = 93.42; h4 = h3;
m = 0.06; // mass flow rate
Q2 = m*(h1-h4);
Wc = m*(h2-h1);
Q1 = m*(h2-h4);
COP = Q2/Wc;
disp("kW",Q2,"The rate of heat removal is")
```

```
disp("kW",Wc,"Power input to the compressor is")
disp("kW",Q1,"The heat rejection rate in the
   condenser is")
disp(COP,"COP is")
```

Scilab code Exa 14.3 Calculations on refrigeration by a simple R 12 plant

```
h1 = 183.19; h2 = 209.41; h3 = 74.59; h4 = h3;
T1 = 313; T2 = 263;
W = 70000/3600; // Plant capacity in kW
w = W/(h1-h4); // Refrigerant flow rate
v1 = 0.077;
VFR = w*v1;
T = 48; // in degree
P2 = 9.6066; P1 = 2.1912;
rp = P2/P1; // Pressure ratio
Q1 = w*(h2-h3);
hf = 26.87; hfg = 156.31;
x4 = (h4-hf)/hfg;
COP = (h1-h4)/(h2-h1);
PI = w*(h2-h1);
COP = T2/(T1-T2);
COP_v = 4.14;
r = COP_v/COP;
disp("kg/s",w,"Refrigerant flow rate is")
disp("m3/s",VFR,"Volume flow rate is")
disp("degree",T,"Compressor discharge temperature is
   ")
disp(rp,"Pressure ratio is")
disp("kW",Q1,"Heat rejected to the condenser is")
disp("%",x4*100,"Flash gas percentage is")
disp(COP,"COP is")
disp("kW",PI,"Power required to drive the compressor
    is")
disp(r,"Ratio of COP of carnot refrigerator is")
```

Scilab code Exa 14.4 Calculations on R 12 vapour compression plant

```
h3 = 882; h2 = 1034;
h6 = 998; h1 = 1008;
v1 = 0.084;
h4 = h3-h1+h6; h5 = h4;
t4 = 25+273;
disp("kJ/kg",h6-h5,"Refrigeration effect is")
m = 10;
w = (m*14000)/((h6-h5)*3600); // in kg/s
disp("kg/s",w,"Refrigerant flow rate is")
v1 = 0.084;
VFR = w*3600*v1; // in kg/h
ve = 0.8; // volumetric efficiency
CD = VFR/(ve*60); // in m3/min
N = 900;
n = 2;
D = ((CD*4)/(%pi*1.1*N*n))^(1/3); // L = 1.1D L =
    length D = diameter
L = 1.1*D;
disp("cm",D*100,"Diameter of cylinder is")
disp("cm",L*100,"Length of cylinder is")
COP = (h6-h5)/(h2-h1);
PI = w*(h2-h1);
disp("kW",PI,"Power required to drive the compresor
    is")
disp(COP,"COP is")
```

Scilab code Exa 14.5 Calculation on work and COP of two stage refrigeration system

```
P2 = 1554.3;
```

```
P1 = 119.5;
Pi = sqrt(P1*P2);
h1 = 1404.6; h2 = 1574.3; h3 = 1443.5; h4 = 1628.1;
h5 = 371.7; h6 = h5; h7 = 181.5;
w = 30; // capacity of plant
m2_dot = (3.89*30)/(h1-h7);
m1_dot = m2_dot*((h2-h7)/(h3-h6));
Wc_dot = m2_dot*(h2-h1)+m1_dot*(h4-h3);
COP = w*3.89/Wc_dot;
// single stage
h1_ = 1404.6; h2_ = 1805.1;
h3_ = 371.1; h4_ = h3_;
m_dot = (3.89*30)/(h1_-h4_);
Wc = m_dot*(h2_-h1_);
COP_ = w*3.89/Wc;
IW = (Wc-Wc_dot)/Wc_dot;
ICOP = (COP-COP_)/COP_
disp("%",IW*100,"Increase in work of compression is")
disp("%",ICOP*100,"Increase in COP for 2 stage compression is")
```

Scilab code Exa 14.6 Estimation of COP of refrigeration

```
tsat = 120.2+273; hfg = 2201.9;
T1 = 120.2+273;
T2 = 30+273;
Tr = -10+273;
COP_max = ((T1-T2)*Tr)/((T2-Tr)*T1);
ACOP = 0.4*COP_max;
Qe = (20*14000)/3600; // in KW
Qg = Qe/ACOP;
x = 0.9;
H = x*hfg;
SFR = Qg/H;
```

```
disp("kg/s",SFR,"Steam flow rate required is")
```

Scilab code Exa 14.7 Calculations on a aircraft cooling system

```
T1 = 277; T3 = 273+55;
rp = 3; // Pressure ratio
g = 1.4; cp = 1.005;
T2s = T1*(rp^((g-1)/g));
T2 = T1+(T2s-T1)/0.72
T4s = T3/(rp^((g-1)/g));
T34 = 0.78*(T3-T4s); // T3-T4
T4 = T3-T34;
COP = (T1-T4)/((T2-T1)-(T3-T4));
disp(COP,"COP of the refrigerator is")
P = (3*14000)/(COP*3600)
disp("kW",P,"Driving power required is")
m = (3*14000)/(cp*(T1-T4));
disp("kg/s",m/3600,"Mass flow rate is")
```

Scilab code Exa 14.8 Calculations on a vapour compression heat pump

```
P1 = 2.4; T1 = 0+273;
h1 = 188.9; s1 = 0.7177; v1 = 0.0703;
P2 = 9; T2 = 60+273;
h2 = 219.37;
h2s = 213.27;
h3 = 71.93; h4 = h3;
v1 = 0.0703;
A1V1 = 0.6/60;
m_dot = A1V1/0.0703;
Wc_dot = m_dot*(h2-h1);
Q1_dot = m_dot*(h2-h3);
COP = Q1_dot/Wc_dot;
```

```
nis = (h2s-h1)/(h2-h1);
disp("kW",Wc_dot,"Power input is")
disp("kW",Q1_dot,"Heating capacity is")
disp(COP,"COP is")
disp("%",nis*100,"The isentropic compressor
    efficiency is")
```

Scilab code Exa 14.9 Calculations on air refrigeration system cycle

```
T1 = 275; T3 = 310;
P1 = 1 ; P2 = 4;
T2s = T1*(P2/P1);
nc = 0.8;
T2 = T1 + (T2s-T1)*nc;
pr = 0.1;
P3 = P2-0.1;
P4 = P1+0.08;
PR = P3/P4;
disp(PR,"Pressure ratio for the turbine is")
T4s = T3*(1/PR)^(0.286);
nt = 0.85;
T4 = T3-(T3-T4s)*nt;
COP = (T1-T4)/((T2-T3)-(T1-T4));
disp(COP,"COP is")
```

Chapter 25

Psychrometrics

Scilab code Exa 15.1 Calculations on atmospheric air

```
Ps = 0.033363; P = 1.0132;
W2 = (0.622*Ps)/(P-Ps);
hfg2 = 2439.9; hf2 = 109.1; cpa = 1.005;
hg = 2559.9; hw1 = hg;
T2 = 25+273; T1 = 32+273;
W1 = (cpa*(T2-T1)+(W2*hfg2))/(hw1-hf2);
Pw = ((W1/0.622)*P)/(1+(W1/0.622));
disp("kg vap./kg dry air",W1,"Specific humidity is")
disp("bar",Pw,"Partial pressure of water vapour is")
disp("degree",24.1,"Dew point temperature is") // saturation temperature at 0.03 bar
Psat = 0.048; // at 32 degree
fi = Pw/Psat;
disp("%",fi*100,"Relative humidity is")
mu = (Pw/Ps)*((P-Ps)/(P-Pw));
disp(mu,"Degree of saturation is")
Pa = P-Pw;
Ra = 0.287; Tab = T1;
rho_a = (Pa*100)/(Ra*Tab);
disp("kg/m3",rho_a,"Density of dry air is")
rho_w = W1*rho_a;
```

```
disp("kg/m3",rho_w,"Density of water vapour is")
ta = 32; tdb = 32; tdp = 24.1;
h = cpa*ta + W1*(hg+1.88*(tdb-tdp));
disp("kJ/kg",h,"Enthalpy of the mixture is")
```

Scilab code Exa 15.2 Calculating the humidity of air water mixture

```
Ps = 2.339; P = 100;
W2 = (0.622*Ps)/(P-Ps);
hfg2 = 2454.1; hf2 = 83.96; cpa = 1.005;
hw1 = 2556.3;
T2 = 20; T1 = 30;
W1 = (cpa*(T2-T1)+(W2*hfg2))/(hw1-hf2);
Pw1 = ((W1/0.622)*P)/(1+(W1/0.622));
Ps1 = 4.246;
fi = (Pw1/Ps1);
disp("%",fi*100,"Relative humidity is")
disp("kg vap./kg dry air",W1,"Humidity ratio of
    inlet mixture is")
```

Scilab code Exa 15.3 Calculations on air temperature and mass of water

```
Psat = 2.339;
fi3 = 0.50;
P = 101.3; cp = 1.005;
Pw3 = fi3*Psat;
Pa3 = P-Pw3;
W3 = 0.622*(Pw3/Pa3);
Psa1_1 = 0.7156;
Pw1 = 0.7156;
Pa1 = P-Pw1;
W1 = 0.622*(Pw1/Pa1); W2 = W1;
T3 = 293; Ra = 0.287; Pa3 = 100.13;
```

```
va3 = (Ra*T3)/Pa3;
SW = (W3-W1)/va3;
t3 = 20; tsat = 9.65; hg = 2518; h4 = 10;
t2 = ( W3*(hg+1.884*(t3-tsat))-W2*(hg-1.884*tsat) +
    cp*t3 - (W3-W2)*h4 )/ (cp+W2*1.884)
disp("kg moisture/m3",SW,"Mass of spray water
    required is")
disp("degree",t2,"Temperature to which air must be
    heated is")
```

Scilab code Exa 15.4 Calculations on an air conditioning system

```
h1 = 82; h2 = 52; h3 = 47; h4 = 40;
W1 = 0.020; W2 = 0.0115; W3 = W2;
v1 = 0.887;
v = 3.33; // amount of free sir circulated
G = v/v1;
CC = (G*(h1-h3)*3600)/14000; // in tonns
R = G*(W1-W3);
disp("tonnes",CC,"Capacity of the cooling coil in
    tonnes")
disp("kg/s",R,"Rate of water vapour removed is")
```

Scilab code Exa 15.5 Calculation on air mixed with RH

```
W1 = 0.0058; W2 = 0.0187;
h1 = 35; h2 = 90;
G12 = 1/2; // G12 = G1/G2
W3 = (W2+G12*W1)/(1+G12);
h3 = (2/3)*h2 + (1/3)*h1;
disp("Final condition of air is given by")
disp("kg vap./kg dry air",W3,"W3 = ")
disp("kJ/kg dry air",h3,"h3 = ")
```

Scilab code Exa 15.7 Calculation on the airconditioning of a hall

```
h1 = 57; h2 = h1;
h3 = 42;
W1 = 0.0065; W2 = 0.0088; W3 = W2;
t2 = 34.5; v1 = 0.896;
n = 1500; // seating capacity of hall
a = 0.3; // amount of out door air suplied
G = (n*a)/0.896 ; // Amount of dry air suplied
CC = (G*(h2-h3)*60)/14000; // in tonns
R = G*(W2-W1)*60;
disp("tonnes",CC,"Capacity of the cooling coil in
    tonnes")
disp("kg/h",R,"Capacity of humidifier")
```

Scilab code Exa 15.8 Calculations on water into a cooling tower

```
twb1 = 15.2; twb2 = 26.7; tw3 = 30;
h1 = 43; h2 = 83.5; hw = 84; mw = 1.15;
W1 = 0.0088; W2 = 0.0213;
hw3 = 125.8; hm = 84;
G = 1;
hw34 = (G/mw)*((h2-h1)-(W2-W1)*hw);  // hw3-hw4
tw4 = tw3-(hw34/4.19);
A = tw4-twb1;
R = tw3-tw4;
x = G*(W2-W1);
disp("degree",tw4,"Temperature of water leaving the
    tower is")
disp("kg/kg dry sir",x,"Fraction of water evoporated
     is")
```

```
disp("degree",R,"Range of cooling water is")
disp("degree",A,"Approach of cooling water is")
```

Scilab code Exa 15.9 Calculations on air flow rate into a cooling tower

```
Psat1 = 0.01705; hg1 = 2528.9; // at 15 degree
Psat2 = 0.05628; hg2 = 2565.3; // At 35 degree
fi1 = 0.55;
Pw1 = fi1*Psat1;
fi2 = 1;
Pw2 = fi2*Psat2;
P = 1;
W1 = (0.622*Pw1)/(P-Pw1);
W2 = (0.622*Pw2)/(P-Pw2);
MW = W2-W1;
t2 = 35; t1 = 15;
m_dot = 2.78;
cpa = 1.005;
h43 = 35*4.187; // h4-h3
h5 = 14*4.187;
m_dot_w = (-(W2-W1)*h5 - W1*hg1 + W2*hg2 + cpa*(t2-
    t1))/(h43) ;
R = m_dot/m_dot_w ;
MW = (W2-W1)*R;
RWA = R*(1+W1);
R = 0.287; T = 288;
V_dot = (RWA*R*T)/(P*1e02) ; // Pressure is in kilo
    Pascal
disp("kg/s",MW,"Make up water flow rate is")
disp("m3/s",V_dot,"Volume flow rate of air is")
```

Chapter 26

Reactive systems

Scilab code Exa 16.2 Dissociation calculation on N2O4

```
eps_e = 0.27; P = 1 ;
K = (4*eps_e^2*P)/(1-eps_e^2);
P1 = 100/760; // in Pa
eps_e_1 = sqrt((K/P1)/(4+(K/P1)));
T1 = 318; T2 = 298;
R = 8.3143; K1 = 0.664; K2 = 0.141;
dH = 2.30*R*((T1*T2)/(T1-T2))*(log(K1/K2));
disp("atm",K,"K is")
disp(eps_e_1,"epislon is ")
disp("kJ/kg mol",dH,"The heat of reaction is")
```

Scilab code Exa 16.3 Determination of gubbs constant and equillibrium function

```
v1 = 1; v2 = v1; v3 = v2; v4 = v2;
e = 0.56; // Degree of reaction
P = 1; // Dummy
T = 1200; R = 8.3143;
x1 = (1-e)/2; x2 = (1-e)/2;
```

```
x3 = e/2; x4 = e/2;
K = (((x3^v3)*(x4^v4))/((x1^v1)*(x2^v2)))*P^(v3+v4-
    v1-v2); // Equillibrium constant
dG = -R*T*log(K);
disp(K,"Equillibrium constant is")
disp("J/gmol",dG,"Gibbs function change is")
```

Scilab code Exa 16.5 Calculation of equillibrium constant

```
Veo = 1.777; // Ve/Vo
e = 1-Veo; // Degree of dissociation
P = 0.124; // in atm
K = (4*e^2*P)/(1-e^2);
disp("atm",K,"The value of equillibrium constant is"
    )
```

Scilab code Exa 16.6 Estimation of Cp of H2O dissociation

```
v1 = 1; v2 = 0; v3 = 1; v4 = 1/2;
dH = 250560; e = 3.2e-03;
R = 8.3143; T = 1900;
Cp = ((dH^2)*(1+e/2)*e*(1+e))/(R*T^2*(v1+v2)*(v3+v4)
    );
disp("j/gmol K",Cp,"Cp is")
```

Scilab code Exa 16.7 Calculations on combustion of unknown hydrocarbon

```
a = 21.89;
y = 18.5;
x = 8.9;
```

```
PC = 100*(x*12)/((8.9*12)+(18.5*1));
PH = 100-PC;
AFR = ((32*a)+(3.76*a*28))/((12*x)+y);
EAU = (8.8*32)/((21.89*32)-(8.8*32));
disp("%",PH,"Hydrogen","%",PC,"carbon","The
    composition of fuel is")
disp(AFR,"Air fuel ratio is")
disp("%",EAU*100,"Percentage of excess air used is")
```

Scilab code Exa 16.8 Determination of heat transfer in per kg mol of a fuel

```
hf_co2 = -393522;
hf_h20 = -285838;
hf_ch4 = -74874;
D = hf_co2 + (2*hf_h20);
QCV = hf_ch4;
disp("kJ",D,"Heat transfer per kg mol of fuel is")
```

Scilab code Exa 16.9 Calculations on a gasoline engine

```
// Below values are taken fron table 16.4
Hr = -249952+(18.7*560)+(70*540);
Hp = 8*(-393522+20288)+9*(-241827+16087)
    +6.25*14171+70*13491;
Wcv = 150; // Energy out put from engine in kW
Qcv = -205; // Heat transfer from engine in kW
n = (Wcv-Qcv)*3600/(Hr-Hp);
disp("kg/h",n*114,"Fuel consumption rate is")
```

Scilab code Exa 16.10 Calculations on burning of liquid octane

```
Hr1 = -249952; // For octane
Hp1 = Hr1;
// Below values are calculated using value fron
   table 16.4
T2 = 1000;
Hp2 = -1226577
T3 = 1200;
Hp3 = 46537;
T4 = 1100;
Hp4 = -595964;
Hp = [Hp2 Hp3 Hp4]
T = [T2 T3 T4]
T1 = interpln([Hp ; T],Hp1); // Interpolation to
   find temperature at Hp1
disp("K",T1,"the adeabatic flame temperature is")
```

Scilab code Exa 16.11 Calculations on burning of gaseous propane

```
// Refer table 16.4 for values
T0 = 298;
Wrev = -23316-3*(-394374)-4*(-228583);
Wrev_ = Wrev/44; // in kJ/kg
Hr = -103847;
T = 980; // Through trial and error
Sr = 270.019+20*205.142+75.2*191.611;
Sp = 3*268.194 + 4*231.849 + 15*242.855 +
   75.2*227.485;
IE = Sp-Sr; // Increase in entropy
I = T0*3699.67/44;
Si = Wrev_ - I;
disp("kJ/kg",Wrev_,"Reversible work is")
disp("kj/kg mol K",Sp-Sr,"Increase in entropy during
    combustion is")
disp("kJ/kg",I,"Irreversibility of the process")
disp("kJ/kg",Si,"Availability of products of
```

```
combustion is")
```

Scilab code Exa 16.12 Determination of chemical energy of phases of water

```
T0 = 298.15; P0 = 1; R = 8.3143;
xn2 = 0.7567; xo2 = 0.2035; xh2o = 0.0312; xco2 = 0.0003;
// Part (a)
g_o2 = 0; g_c = 0; g_co2 = -394380;
A = -g_co2 + R*T0*log(xo2/xco2);
disp("kJ/k mol",A,"The chemical energy of carbon is")
// Part (b)
g_h2 = 0; g_h2o_g = -228590;
B = g_h2 + g_o2/2 - g_h2o_g + R*T0*log(xo2^0.5/xh2o);
disp("kJ/k mol",B,"The chemical energy of hydrogen is")
// Part (c)
g_ch4 = -50790;
C = g_ch4 + 2*g_o2 - g_co2 - 2*g_h2o_g + R*T0*log((xo2^2)/(xco2*xh2o));
disp("kJ/k mol",C,"The chemical energy of methane is")
// Part (d)
g_co = -137150;
D =  g_co + g_o2/2 - g_co2 + R*T0*log((xo2^0.5)/xco2);
disp("kJ/k mol",D,"The chemical energy of Carbonmonoxide is")
// Part (e)
g_ch3oh = -166240;
E = g_ch3oh + 1.5*g_o2 - g_co2 - 2*g_h2o_g + R*T0*log((xo2^1.5)/(xco2*(xh2o^2)))
disp("kJ/k mol",E,"The chemical energy of methanol
```

```
is")
// Part (f)
F = R*T0*log(1/xn2);
disp("kJ/k mol",F,"The chemical energy of nitrogen is")
// Part (g)
G = R*T0*log(1/xo2);
disp("kJ/k mol",G,"The chemical energy of Oxygen is")
// Part (h)
H = R*T0*log(1/xco2);
disp("kJ/k mol",H,"The chemical energy of carbondioxide is")
// Part (i)
g_h2o_l = -237180;
I = g_h2o_l - g_h2o_g + R*T0*log(1/xh2o);
disp("kJ/k mol",I,"The chemical energy of water is")
```

Scilab code Exa 16.13 `Calculation on burning of liquid octane`

```
b = 8/(0.114+0.029); // By carbon balance
C = 18/2; // By hydrogen balance
a = b*0.114 + (b/2)*0.029 + b*0.016 + C/2 ; // By oxygen balance
Wcv = 1; // Power developed by engine in kW
n_fuel = (0.57*1)/(3600*114.22);
Qcv = Wcv-n_fuel*3845872; // 5.33
disp("kW",Qcv,"The rate of heat transfer from the engine is")
// Part (b)
ach = 5407843; // chemical energy of liquid octane
n2 = Wcv/(n_fuel*ach);
disp("%",n2*100,"The second law efficiency is")
```

Chapter 27

Compressible fluid flow

Scilab code Exa 17.1 Calculation s on flow of air through a duct

```
T0 = 37+273; P = 40; g = 1.4;
function [x] = speed(a,b,f)
  N = 100;
  eps = 1e-5;
  if((f(a)*f(b))>0) then
    error('no root possible f(a)*f(b)>0');
    abort;
  end;
  if(abs(f(a))<eps) then
    error('solution at a');
    abort;
  end
  if(abs(f(b))<eps) then
    error('solution at b');
    abort;
  end
  while(N>0)
    c = (a+b)/2
    if(abs(f(c))<eps) then
      x = c ;
      x;
```

```
      return;
    end;
    if((f(a)*f(c))<0 ) then
      b = c ;
    else
      a = c ;
    end
    N = N-1;
  end
  error('no convergence');
  abort;
endfunction

deff('[y]=p(x)',['y = x^4 + (5*(x^2)) - 3.225 '])
x = speed(0.5,1,p);
M = x; // Mach number
g = 1.4; // gamma
R = 0.287;
T = T0/(1+((g-1)/2)*M^2);
c = sqrt(g*R*T*1000);
V = c*M;
P0 = P*((T0/T)^(g/(g-1)));
disp(M,"Mach number is")
disp("m/s",V,"Velocity is")
disp("kPa",P0,"Stagnation pressure is")
```

Scilab code Exa 17.2 Calculations on canonical air diffuser

```
P1 = 0.18e03; // in Kpa
R = 0.287; T1 = 310; P0 = 0.1e03;
A1 = 0.11; V1 = 267;
w = (P1/(R*T1))*A1*V1;
g = 1.4;
c1 = sqrt(g*R*T1*1000);
M1 = V1/c1;
```

```
A1A_ = 1.0570; // A1/A* A* = A_
P1P01 = 0.68207;
T1T01 = 0.89644;
F1F_ = 1.0284;
A2A1 = 0.44/0.11 ; // A2A1 = A2/A1
A2A_ = A2A1*A1A_;
M2 = 0.135; P2P02 = 0.987; T2T02 = 0.996; F2F_ =
    3.46;
P2P1 = P2P02/P1P01;
T2T1 = T2T02/T1T01;
F2F1 = F2F_/F1F_;
P2 = P2P1*P1;
T2 = T2T1*T1;
A2 = A2A1*A1;
F1 = P1*A1*(1+g*M1^2);
F2 = F2F1*F1;
Tint = F2-F1;
Text = P0*(A2-A1);
NT = Tint - Text ;
disp("kN",NT,"Net thrust is")
```

Scilab code Exa 17.3 Calculations on air flow through convergent divergent nozzle

```
M2 = 2.197; P2P0 = 0.0939; T2T0 = 0.5089;
P0 = 1000; T0 = 360; g = 1.4; R = 0.287;
P2 = P2P0*P0;
T2 = T2T0*T0;
c2 = sqrt(g*R*T2*1000);
V2 = c2*M2;
// for air
P_P0 = 0.528; T_T0 = 0.833; // T_ == T*
P_ = P_P0*P0; T_ = T_T0*T0;
rho_ = P_/(R*T_);
V_ = sqrt(g*R*T_*1000);
At = 500e-06; // throat area
```

```
w = At*V_*rho_;
disp("When divergent section act as a nozzle")
disp("kg/s",w,"Maximum flow rate of air is")
disp("K",T2,"Static temperature is")
disp("kPa",P2,"Static Pressure is")
disp("m/s",V2,"Velocity at the exit from the nozzle
    is")
// Part (b)
Mb = 0.308;
P2P0b = 0.936;
T2T0b = 0.9812;
P2b = P2P0b*P0;
T2b = T2T0b*T0;
c2b = sqrt(g*R*T2b*1000);
V2b = c2b*Mb;
disp("When divergent section act as a diffuser")
disp("kg/s",w,"Maximum flow rate of air is")
disp("K",T2b,"Static temperature is")
disp("kPa",P2b,"Static Pressure is")
disp("m/s",V2b,"Velocity at the exit from the nozzle
    is")
```

Scilab code Exa 17.4 Calculations on pitot tube immersed in a supersonic flow

```
Px = 16; Poy = 70;
g  = 9.81;
Mx = 1.735; Pyx = 3.34; // Pyx = Py/Px
rho_yx = 2.25;
Tyx = 1.483; Poyox = 0.84; My = 0.631;
Tox = 573; Toy = Tox;
Tx = Tox/(1+((g-1)/2)*Mx^2);
Ty = Tyx*Tx;
Pox = Poy/Poyox ;
// From table
Mx = 1.735;
```

```
disp(Mx,"Mach number of the tunnel is")
```

Scilab code Exa 17.5 Calculations on a CD nozzle operating at off design condition

```
Ax = 18.75; A_ = 12.50; // A_= A*
AA_ = 1.5; // A/A*
Mx = 1.86; Pxox = 0.159; R = 0.287;
Pox = 0.21e03; // in kPa
Px = Pxox*Pox;
// from the gas table on normal shock
Mx = 1.86; My = 0.604; Pyx = 3.87; Poyx = 4.95;
   Poyox = 0.786;
Py = Pyx*Px;
Poy = Poyx*Px;
My = 0.604;
Ay_ = 1.183;
A2 = 25; Ay = 18.75;
A2_ = (A2/Ay)*Ay_;
// From isentropic table
M2 = 0.402;
P2oy = 0.895;
P2 = P2oy*Poy;
syx = -R*log(Poy/Pox); // sy-sx
disp(M2,"Exit mach number is M2")
disp("kPa",P2,"Exit pressure is")
disp("kPa",Pox-Poy,"Exit Stagnation pressure is")
disp("kJ/kg K",syx,"Entropy increase is")
```

Scilab code Exa 17.6 Calculations on expansion of air through a convergent nozzle

```
g = 1.4;R = 0.287;  d = 1.4; // del
P0 = 1.4; // in bar
T0 = 280; T1 = T0;
```

```
cp = 1.005; A2 = 0.0013
P_ = P0/((g+1)/2)^(d/(d-1)) ; // P_ = P*
P1 = P0; Pb = 1; P2 = Pb;
T2 = T1*(P2/P1)^((d-1)/d);
V2 = sqrt(2*cp*(T1-T2)*1000);
m_dot = (A2*V2*P2*100)/(R*T2);
disp("kg/s",m_dot,"Mass flow rate is")
disp("The mass flow rate can be increased by raising the supply pressure")
```

Scilab code Exa 17.7 Calculations on an ideal gas undergoing a normal shock

```
Mx = 1.8; Pyx = 3.6133;
Px = 0.5; Tx = 280; Ty = 429;
Py = Pyx*Px; cp = 1.005;R = 0.287;
disp("bar",Py,"Pressure Py is")
Pxox = 0.17404;
Pox = Px/Pxox;
disp("bar",Pox,"Stagnation pressure is")
Txox = 0.60680;
Tox = Tx/Txox;
disp("K",Tox,"Stagnation temperature is")
sysx = cp*log(Ty/Tx)-R*log(Py/Px);
disp("kJ/kg K",sysx,"The change in specific entropy is")
```

Chapter 28

Gas compressors

Scilab code Exa 18.1 Calculations on a single reciprocating compressor

```
T2 = 488; T1 = 298; n = 1.3; R =8314/44;
rp = (T2/T1)^(n/(n-1));
disp(rp,"Pressure ratio is")
b = 0.12; // Bore of compressor
L = 0.15; // Stroke of compressor
V1 = (%pi/4)*(b)^2*L ;
P1 = 120e03; // in kPa
W = ((n*P1*V1)/(n-1))*(((rp)^((n-1)/n))-1);
P = (W*1200*0.001)/60 ;
disp("kW",P,"Indicated power is")
disp("kW",P/0.8,"Shaft power is")
V1_dot = V1*(1200/60);
m_dot = (P1*V1_dot)/(R*T1);
disp("kg/s",m_dot,"Mass flow rate is")
rp_1 = rp^2;
disp(rp_1,"Pressure ratio when second stage is added
    is")
V2 = (1/rp)^(1/n)*V1;
disp("m3",V2,"Volume derived per cycle is V2")
d = sqrt((V2*4)/(L*%pi));
disp("mm",d*1000,"Second stage bore would be")
```

Scilab code Exa 18.2 Calculations on a single reciprocating air compressor

```
P1 = 101.3e03; P4 = P1; // in Pa
P2 = 8*P1;  P3 = P2;
T1 = 288; Vs = 2000;
V3 = 100; Vc = V3;
V1 = Vs + Vc ;
n = 1.25; R = 287;
V4 = ((P3/P4)^(1/n))*V3;
W = ((n*P1*(V1-V4)*1e-06)/(n-1))*(((P2/P1)^((n-1)/n))-1);
P = (W*800*0.001)/60 ;
disp("kW",P,"Indicated poer is")
disp("%",100*(V1-V4)/Vs,"Volumetric efficiency is")
m = (P1*(V1-V4)*1e-06)/(R*T1);
m_dot = m*800;
disp("kg/min",m_dot,"Mass flow rate is")
FAD = (V1-V4)*1e-06*800;
disp("m3/min",FAD,"Free air delivery is")
Wt = P1*(V1-V4)*1e-06*log(P2/P1);
n_isothermal = (Wt*800*0.001)/(P*60);
disp("%",100*n_isothermal,"Isothermal efficiency is")
Pi = P/0.85;
disp("kW",Pi,"Input power is")
```

Scilab code Exa 18.3 Calculations on a two stage air compressor with perfect inter

```
P1 = 1; P3 = 9;
P2 = sqrt(P1*P3);
T1 = 300; cp = 1.005;
```

```
R = 0.287; n = 1.3;
W = ((2*n*R*T1)/(n-1))*((P2/P1)^((n-1)/n)-1);
T2 = T1*(P2/P1)^((n-1)/n);
H = cp*(T2-T1);
disp("kJ/kg",H,"Heat rejected to the intercooler is"
    )
```

Scilab code Exa 18.4 Calculations on a single acting two stage air compressors

```
P1 = 1.013; P4 = 80;
P2 = sqrt(P1*P4);
V_dot = 4/60; // in m3/s
n = 1.25;
n_mech = 0.75;
W_dot = ((2*n)/(n-1))*((P1*100*V_dot)/n_mech)*((P2/
    P1)^((n-1)/n)-1);
N = 250;
L = (3*60)/(2*N); // Stroke length of piston in m
Vlp = 4/N;
n_vol = 0.8;
Dlp = sqrt((Vlp*4)/(n_vol*L*%pi));
Dhp = Dlp*sqrt(P1/P2);
disp("kW",W_dot,"Minimum power required is")
disp("cm",L*100,"Stroke of the compressor is")
disp("cm",Dhp*100,"Bore of high pressure compressure
     is")
disp("cm",Dlp*100,"Bore of lo pressure compressure
    is")
```

Scilab code Exa 18.5 Determination of out put power of an air engine

```
V12 = 0.4; // V12 = V1/V2
T1 = 38+273; n = 1.3; P3 = 112; // back pressure
```

```
m = 1.25; R = 0.287;
T2 = ((V12)^(n-1))*T1;
P1 = 700; // in kPa
P2 = P1*(V12)^n;
V2 = (m*R*T2)/P2;
v2 = V2/m ;
A = R*T1 + R*(T1-T2)/(n-1) - P3*v2; // Area of indicator diagram
IO = A*0.85*m;
disp("kJ",IO,"Indicated output is")
```

Scilab code Exa 18.6 Calculations on a three stage acting reciprocating air compre

```
P1 = 1; P41 = 15; // P41 = P4/P1
P21 = (P41)^(1/3);
P2 = P21*P1; n = 1.3; R = 0.287;
P3 = P21*P2;
P11 = P2; P12 = P1;
b = 0.45; s = 0.3; // Bore and stroke of cylinder
Vs = (%pi/4)*b^2*s; // Swept volume of the cylinder
V11 = 0.05*Vs; // Clearance volume
V1 = V11+Vs;
V12 = V11*(P11/P12)^(1/n);
disp("m3",V1-V12,"Effective swept volume of the LP cylinder is")
T1 = 291; T3 = T1; T5 = T1;
P43 = P21; // P4/P3
T6 = T5*(P43)^((n-1)/n);
disp("K",T6,"Delivery temperature is")
P4 = 15; // Delivery pressure
V6_7 = (P1/P4)*(T6/T1)*(V1-V12); // V6-V7
disp("m3",V6_7,"Volume of the air delivered")
W = ((3*n*R*T1)/(n-1))*((P21)^((n-1)/n)-1);
disp("kJ",W,"Work done per kg of the air is")
```

Scilab code Exa 18.7 Determining the work input for a vane type compressor

```
P1 = 1.013;
P2 = 1.5*P1;
Vs = 0.03; Va = Vs;
WD = (P2-P1)*Vs*100;
Pi = (P1+P2)/2;
g = 1.4;
Aa = ((g*P1*100*Vs)/(g-1))*((Pi/P1)^((g-1)/g)-1);
Vb = Va *(P1/Pi)^(1/g);
Ab = Vb*(P2-Pi)*100;
WR = Aa+Ab;
disp("kJ/rev",WR,"Work required is")
```

Scilab code Exa 18.8 Determination of power required to drive the roots blower

```
// For Blower
m_dot = 1; R = 0.287; T1 = 343;
P1 = 100; P2 = 2*P1; g = 1.4;
V_dot = (m_dot*R*T1)/P1;
PRb = V_dot*(P2-P1);
disp("kW",PRb,"Power required by the blower is")
// For van compressor
P1v = 1; V21 = 0.7 // V2/V1
P2v = P1v*(1/V21)^g;
V2_dot = 0.7;
V1_dot = 0.7*V_dot;
P3v = 2;
PRv = ((g*P1v*100*V_dot)/(g-1))*((P2v/P1v)^((g-1)/g)
    -1) + V1_dot*100*(P3v-P2v);
disp("kW",PRv,"Power Required by van compressor is")
```

Scilab code Exa 18.9 Calculations on a gas turbine utilizing a two stage centrifug

```
T1 = 283; P21 = 2.5; // P2/P1
P32 = 2.1; // P3/P2
ns = 0.85; ma = 5; cp = 1.005; g = 1.4;
T2s = T1*(P21)^((g-1)/g);
T2 = T1 + (T2s-T1)/ns;
T3 = T2-50;
T4s = T3*(P32)^((g-1)/g);
T4 = T3 + (T4s-T3)/ns;
P = ma*cp*((T2-T1)+(T4-T3));
disp("kW",P,"Total compressor power is")
```

Scilab code Exa 18.10 Calculations on a rotatry compressor

```
T1 = 278; P21 = 2.5; // P2/P1
cp = 1.005; ns = 0.84; V2 = 120; g = 1.4;
T2s = T1*(P21)^((g-1)/g);
T2 = T1 + (T2s-T1)/ns;
mg = 0.04*(13+1);
P = mg*cp*(T2-T1);
T02 = T2 + V2^2/(2*cp*1000);
P1 = 0.6;
P2 = P21*0.6;
P02 = P2*(T02/T2)^(g/(g-1));
disp("kW",P,"Power required to drive the compressor
    is")
disp("K",T02,"Stagnation temperature is")
disp("bar",P02,"Stagnation pressure is")
```