

Scilab Textbook Companion for
Engineering Thermodynamics
by P. K. Nag¹

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 1

Introduction

Scilab code Exa 1.1 Calculating gas pressure

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

Scilab code Exa 1.2 Calculating inlet and exhaust pressure in pascals

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

```

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

```

Scilab code Exa 1.3 Converting various readings of pressure in kPa

```

1 z = 0.760; // Barometer reading in m
2 // Part (a)
3 h1 = 40e-02; // Mercury height in vaccume in m
4 d_r = 13.6e03; // Density of mercury in kg/m3
5 g = 9.80; // Acceleration due to gravity in m/s2
6 Patm = z*d_r*g; // Atmospheric pressure in Pas
7 Pv = h1*d_r*g; // Pressue in vaccume in Pa
8 Pabs = Patm-Pv; // Absolute pressure in Pa
9 disp("Pa",Pabs," 40cmHg vaccume is")
10 // Part (b)
11 h2 = 90e-02; // Mercury height in gauge in m
12 Pg = h2*d_r*g; // Gauge Pressure in Pa
13 Pabs1 = Patm + Pg ; // Absolute pressure in Pa
14 disp("Pa",Pabs1,"90cmHg gauge is")
15 // Part(c)
16 d_w = 1e03 ; // Density of water in kg/m3
17 h3 = 1.2 ; // Gauge Pressure water height in m
18 Pga = d_w*h3*g; // Gauge Pressure in Pa
19 Pabs3 = Patm + Pga ; // Absolute pressure in Pa
20 disp("Pa",Pabs3,"1.2 m H2O gauge is")

```

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

```

1 Pr = 1.033e05; // Required Pressure in bar
2 function y = pressure(p)
3     y = p^(-0.714);
4 endfunction;

```

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

Scilab code Exa 1.5 Determining net upward force experienced by astronaut

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

Chapter 2

Temperature

Scilab code Exa 2.1 Calculations on straight bore thermometer

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

Scilab code Exa 2.2 Calculation of thermometer reading

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

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

Scilab code Exa 2.3 Calculating temperature for given resistance

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

Chapter 3

Work and heat transfer

Scilab code Exa 3.1 Calculation of magnitude of velocity

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

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

```
1 dV = 0.5; // Change in volume in m3
2 P = 101.325e03; // Atmospheric pressure in N/m2
3 Wd = P*dV; // Work done in J
4 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

```

1 dV = 0.6; // Change in volume in m3
2 P = 101.325e03; // Atmospheric pressure in N/m2
3 Wd = P*dV; // Work done in J
4 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

```

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

```

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

```

```

8 Pm = (ad/ld)*k; // Effective pressure
9 W1 = Pm*L*A*w; // Work done in 1 minute
10 W = (12*W1)/60; // The rate of work transfer gas to
    the piston in MJ/s
11 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

```

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

```

Scilab code Exa 3.7 Calculations on alluminium furnace

```

1 SH = 0.9; // Specific heat of alluminium in solid
    state

```

```

2 L = 390; // Latent heat
3 aw = 27; // Atomic weight
4 D = 2400; // Density in molten state
5 Tf = 700+273; // Final temperature
6 Tm = 660+273; // Melting point of aluminium
7 Ti = 15+273; // Intial temperature
8 HR = SH*(Tm-Ti)+L+(29.93/27)*(Tf-Tm); // Heat
    requires
9 HS = HR/0.7 ; // Heat supplied
10 RM = 217*1000*3600/HS ; // From the data of problem
    3.7
11 V = 2.18; // Volume
12 M = V*D;
13 disp("tonnes",M*0.001,"Mass of alluminium that can
    be melted is")
14 disp("kg/h",RM,"Rate at which alluminium can be
    melted is")

```

Scilab code Exa 3.8 Calculation on work required for automization

```

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

```

Scilab code Exa 3.9 Calculation on electric motor

```

1 dc = 40e-02;
2 L = 30e-02;
3 P = 1e05; // Pressure in Pascal
4 I = 0.5;
5 V = 24;
6 t = 15*60; // in seconds
7 Wm = V*I*t;
8 Ws = 0.9*Wm;
9 W = P*(%pi/4)*dc^2*L;
10 disp("J",Wm,"Work input to the motor is")
11 disp("J",Ws,"Work input to the stirrer is")
12 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

```

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

```

Scilab code Exa 3.11 Calculation of work done in PV cycle

```

1 P1 = 20*1.01325e05;
2 V1 = 0.04; V2 = 2*V1;
3 n = 1.45;
4 P2 = (V1/V2)^n*P1;
5 W12 = ((P1*V1)-(P2*V2))/(n-1);
6 W23 = P2*(V2-V1);
7 Wc = W12-W23;

```

```
8 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

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

Scilab code Exa 4.2 Calculations on PV cycle

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

```

8 // Part (b)
9 Wb_a = -21e03;
10 Uab = - Uba;
11 Qb_a = Uab+Wb_a;
12 disp("J",Qb_a,"The heat liberated along the path b-a
      is")
13 // Part (c)
14 Wdb = 0; // Constant volume
15 Wad = 10.4e03;
16 Wadb = Wdb-Wad;
17 Ud = 42e03;
18 Ua = 0;
19 Qad = Ud-Ua+Wad;
20 Qdb = Qadb-Qad;
21 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 cylinder machine

```

1 // Process a-b
2 Qab = 0;
3 Wab = 2170; // in KJ/min
4 Eab = Qab-Wab;
5 // Process b-c
6 Qbc = 21000;
7 Wbc = 0;
8 Ebc = Qbc-Wbc;
9 // Process c-d
10 Qcd = -2100;
11 Ecd = -36600;
12 Wcd = Qcd-Ecd;
13 // Process d-a
14 Q = -17000; // Total heat transfer
15 Qda = Q-Qab-Qbc-Qcd;

```



```

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

```

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

```

1 // Part (a)
2 m = 3;
3 V1 = 0.22;
4 P1 = 500e03;
5 P2 = 100e03;
6 V2 = V1*(P1/P2)^(1/1.2);
7 dU = 3.56*(P2*V2-P1*V1);
8 gama = 1.2;
9 W = (P2*V2-P1*V1)/(1-gama);
10 Q = dU+W;
11 disp("J respectively",dU,W,Q,"Q,W and dU of the
      quasi static process are")
12 // Part (b)
13 Qb = 30e03;
14 Wb = Qb-dU;
15 disp("Joule",Wb,"Work transfer for the process is")
16 // Part (c)
17 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 energy function

```

1 V1 = 0.03;

```

```

2 P1 = 170e03;
3 P2 = 400e03;
4 V2 = 0.06;
5 U = 3.15*(P2*V2-P1*V1);
6 B = [P1 P2]';
7 A = [1 V1; 1 V2];
8 x = inv(A)*B;
9 a = x(1); b = x(2);
10 function P = pressure(V)
11     P = a+b*V;
12 endfunction;
13 W = intg(V1,V2,pressure);
14 Q = U+W;
15 disp("J",W,"The work done by the system is")
16 disp("J",U,"The internal energy change of the system
    is")
17 disp("J",Q,"The heat flow into the system is")

```

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

```

1 // Process 1-2
2 Q12 = 235; // in KJ/Kg
3 W12 = 0 ;
4 U12 = Q12-W12;
5 // Process 2-3
6 Q23 = 0;
7 U23 = -70 ;
8 W23 = Q23-U23;
9 // Process 3-1
10 Q31 = - 200;
11 U31 = -U12-U23;
12 W31 = Q31-U31;
13 //
14 W = W12 + W23 + W31;
15 Q = Q12 + Q23 + Q31;

```

```
16 disp("KJ/Kg",Q,"Heat trasfer in the cycle is")
17 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

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

Scilab code Exa 5.2 Calculations across a control volume

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

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

```
1 P1 = 4e06;
2 t1 = 400;
3 h1 = 3213e03;
4 V1 = 0.073;
5 P2 = 3.5e06;
6 t2 = 392;
7 h2 = 3202e03;
8 V2 = 0.084;
9 Q = -8.5e03;
10 v1 = sqrt((2*(h1-h2+Q))/(1.15^2-1));
11 A1 = (%pi/4)*0.2^2;
12 w = (A1*v1)/V1;
```

```
13 disp("Kg/s",w,"The stean flow rate is")
```

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

```
1 h1 = 313.93;
2 h2 = 2676;
3 h3 = 419;
4 w1 = 4.2;
5 w = poly(0, 'w') // w = w2
6 P = w1*h1 + w*h2 - h3*(4.2+w)
7 function [x] = stress(a,b,f)
8     N = 100;
9     eps = 1e-5;
10    if((f(a)*f(b))>0) then
11        error('no root possible f(a)*f(b)>0');
12        abort;
13    end;
14    if(abs(f(a))<eps) then
15        error('solution at a');
16        abort;
17    end
18    if(abs(f(b))<eps) then
19        error('solution at b');
20        abort;
21    end
22    while(N>0)
23        c = (a+b)/2
24        if(abs(f(c))<eps) then
25            x = c ;
26            x;
27            return;
28        end;
29        if((f(a)*f(c))<0 ) then
30            b = c ;
31        else
```

```

32     a = c ;
33     end
34     N = N-1;
35     end
36     error('no convergence');
37     abort;
38 endfunction
39
40 deff(' [y]=p(w)', ['y = - 441.294 + 2257*w '])
41 w = stress(0.1,0.2,p);
42 disp("Kg/h",w*3600,"The amount of heat that should
    be supplied is")

```

Scilab code Exa 5.5 Calculations across a heat exchanger

```

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

```

Scilab code Exa 5.6 Calculations on a gas turbine

```

1 w = 5;
2 h1 = 900e03;

```

```

3 h2 = 400e03;
4 v1 = 50; v2 = 150;
5 Q = -25*5; // Q = dQ/dt for w = 5kg
6 W = w*( (h1-h2) + ((v1^2-v2^2)/2) ) + Q; // W = dW/
    dt
7 disp("kW",W/1000,"The power output of the turbine is
    ")
8 R = 285; T1 = 300; P1 = 100e03;
9 V = (w*R*T1)/P1; // V = dV/dt
10 A1 = V/v1;
11 D1 = sqrt((4*A1)/%pi);
12 disp("m",D1,"The diameter of the inlet pipe is")

```

Scilab code Exa 5.7 Calculation of velocity of exhaust jet

```

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

```

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

```

1 u0 = 0.718*273*1e03;
2 t = poly(0, 't');
3 u = u0+718*t; // in SI unit

```



```
4 hp = u + 285*(t+273); // ""
5 h = horner(hp,150); // h = hp(150)
6 W = 100; // W = dW/dt
7 m = W/h;
8 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 engine

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

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

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

```
7
8 // There is a calculation mistake in the book
```

Scilab code Exa 6.4 Calculations on a carnot engine

```
1 Q1 = 200;
2 T1 = 373.15;
3 T2 = 273.16;
4 Q2 = Q1*(T2/T1);
5 W = Q1-Q2;
6 e = W/Q1;
7 disp("respectively",e,"J",W,"J",Q2,"The heat
      rejected , the work done and the thermal efficiency
      of the engine is")
```

Scilab code Exa 6.5 Calculations on reversible heat engine

```
1 T1 = 873;
2 T2 = 313;
3 T3 = 253;
4 Q1 = 2000e03; // In joule
5 W = 360e03; // in joule
6 // Part (a)
7 e_max = 1-(T2/T1);
8 W1 = e_max*Q1;
9 COP = T3/(T2-T3);
10 W2 = W1-W;
11 Q4 = COP*W2;
12 Q3 = Q4+W2;
13 Q2 = Q1-W1;
14 disp("J",Q2+Q3,"The heat rejection to the 40 degree
      reservior is")
15 // Part (b)
```

```

16 e_max_ = 0.4*e_max;
17 W1_ = e_max_*Q1;
18 W2_ = W1_-W;
19 COP_ = 0.4*COP;
20 Q4_ = COP_*W2_;
21 Q3_ = Q4_+W2_;
22 Q2_ = Q1-W1_;
23 disp("J",Q2_+Q3_,"The heat rejection to the 40
      degree reservior is")

```

Scilab code Exa 6.7 Determination of heat multiplication factor

```

1 T1 = 473;
2 T2 = 293;
3 T3 = 273;
4 MF = (T2*(T1-T3))/(T1*(T2-T3));
5 disp(MF," The multiplication factor is ")

```

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

```

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

```

Scilab code Exa 6.9 Determination of minimum solar panel area

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

Chapter 7

Entropy

Scilab code Exa 7.1 Calculation of entropy change of water

```
1 T1 = 37+273;  
2 T2 = 35+273;  
3 m = 1 ;  
4 cv = 4.187;  
5 S = m*cv*log(T2/T1); // S = S2-S1  
6 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

```
1 // Part (a)  
2 T1 = 273;  
3 T2 = 373;  
4 m = 1 ;  
5 cv = 4.187;  
6 Ss = m*cv*log(T2/T1); // S = S2-S1  
7 Q = m*cv*(T2-T1);
```

```

8 Sr = -(Q/T2);
9 S = Ss+Sr;
10 disp("kJ/K",S,"The entropy change of the universe is
    ")
11 // Part (b)
12 T3 = 323;
13 Sw = m*cv*(log(T3/T1)+log(T2/T3));
14 Sr1 = -m*cv*(T3-T1)/T3;
15 Sr2 = -m*cv*(T2-T3)/T2;
16 Su = Sw+Sr1+Sr2;
17 disp("kJ/K",Su,"The entropy change of the universe
    is")

```

Scilab code Exa 7.3 Entropy change calculations between ice and universe

```

1 // Part (a)
2 m = 1;
3 T1 = -5+273;
4 T2 = 20+273;
5 T0 = 0+273;
6 cp = 2.093;
7 cv = 4.187;
8 lf = 333.3;
9 Q = m*cp*(T0-T1)+1*333.3+m*cv*(T2-T0);
10 Sa = -Q/T2;
11 Ss1 = m*cp*log(T0/T1);
12 Ss2 = lf/T0;
13 Ss3 = m*cv*log(T2/T0);
14 St = Ss1+Ss2+Ss3;
15 Su = St+Sa;
16 disp("kJ/K",Su,"The entropy change of the universe
    is")
17 // Part (b)
18 S = 1.5549; // S = S4-S1
19 Wmin = T2*(S)-Q;

```

```
20 disp("kJ",Wmin,"The minimum risk required is")
```

Scilab code Exa 7.5 Calculation of entropy change for a gas

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

Scilab code Exa 7.8 Calculation of highest temperature in three body system of constant heat capacity

```
1 T = poly(0, 'T'); // T = Tf
2 Tf_ = 700-2*T; // Tf_ = Tf'
3 // Bisection method to solve for the polynomial
4 function [x] = Temperature(a,b,f)
5     N = 100;
6     eps = 1e-5;
7     if((f(a)*f(b))>0) then
8         error('no root possible f(a)*f(b)>0');
9         abort;
10    end;
11    if(abs(f(a))<eps) then
12        error('solution at a');
13        abort;
14    end
15    if(abs(f(b))<eps) then
16        error('solution at b');
17        abort;
```



```

18  end
19  while(N>0)
20      c = (a+b)/2
21      if(abs(f(c))<eps) then
22          x = c ;
23          x;
24          return;
25      end;
26      if((f(a)*f(c))<0 ) then
27          b = c ;
28      else
29          a = c ;
30      end
31      N = N-1;
32  end
33  error('no convergence');
34  abort;
35  endfunction
36  defp(' [y]=p(T) ', ['y = 2*T^3-700*T^2+9000000 '])
37  T = Temperature(100,200,p);
38
39  Tf_ = horner(Tf_,T);
40  disp("K",Tf_,"The final temperature of the body C is
    ")

```

Scilab code Exa 7.9 Calculation of maximum amount of work for a system with given heat capacity

```

1  T1 = 200;
2  T2 = 100;
3  A = 0.042;
4  Q1 = integrate('A*T^2', 'T', T1, T2);
5  S = integrate('A*T^2/T', 'T', T1, T2);
6  W = poly(0, 'W');
7  Z = (-Q1-W)/T2 + S; // Polynomial to be solved for W

```

```

8 // Bisection method to solve for the Work
9 function [x] = Work(a,b,f)
10     N = 100;
11     eps = 1e-5;
12     if((f(a)*f(b))>0) then
13         error('no root possible f(a)*f(b)>0');
14         abort;
15     end;
16     if(abs(f(a))<eps) then
17         error('solution at a');
18         abort;
19     end
20     if(abs(f(b))<eps) then
21         error('solution at b');
22         abort;
23     end
24     while(N>0)
25         c = (a+b)/2
26         if(abs(f(c))<eps) then
27             x = c ;
28             x;
29             return;
30         end;
31         if((f(a)*f(c))<0 ) then
32             b = c ;
33         else
34             a = c ;
35         end
36         N = N-1;
37     end
38     error('no convergence');
39     abort;
40 endfunction
41 deff(' [y]=p(W) ', ['y = 350-0.01*W '])
42 W = Work(34000,36000,p);
43
44 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

```
1 P1 = 0.5e06;
2 V1 = 0.2; V2 = 0.05;
3 n = 1.3
4 P2 = P1*(V1/V2)^n;
5 function y = H(p)
6   y = ((P1*V1^n)/p)^(1/n);
7 endfunction
8 H = integrate('H','p',P1,P2); // H = H2-H1
9 U = H-(P2*V2-P1*V1);
10 W12 = -U;
11 disp("kJ",H/1000,"Change in enthalpy is")
12 disp("kJ",U/1000,"Change in internal energy is")
13 disp("kJ",0,"and",0,"The change in entropy and heat
    transfer are")
14 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

```
1 Pa = 130e03; Pb = 100e03;
2 Ta = 50+273; Tb = 13+273;
3 cp = 1.005;
4 Ss = integrate('cp/T','T',Ta,Tb)-integrate('0.287/p',
    'p',Pa,Pb);
5 Ssy = 0;
6 Su = Ss+Ssy;
7 disp("kJ/Kg K",Su,"Change in the entropy of the
    universe is")
```

```
8 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 thermodynamically

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

Scilab code Exa 7.13 Calculation of heat transfer through a room

```
1 A = 5*7;
2 k = 0.71;
3 L = 0.32;
4 Ti = 21+273;
5 To = 6+273;
6 Q = k*A*(Ti-To)/L ;
7 disp("W",Q,"The rate of heat transfer through the
    wall is")
8 Sgen_wall = Q/To - Q/Ti;
9 disp("W/K",Sgen_wall,"The rate of entropy through
    the wall is")
10 Tr = 27+273;
11 Ts = 2+273;
```

```
12 Sgen_total = Q/Ts-Q/Tr;  
13 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

```
1 T0 = 308;
2 T1 = 693;
3 T1_ = 523; // T1_ = T1'
4 T1_ = 523; // ""
5 f = (T0*(T1-T1_))/(T1_*(T1-T0));
6 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

```
1 lhw = 1858.5; // Latent heat of water
2 Tew = 220+273;
3 Sw = lhw/Tew;
```

```

4 Tfg = 1100; // Initial temperature of the gas
5 Tfg = 550; // Final "
6 k = 1*lhv/(Tfg-Tfg); // k = mg_dot*cpg
7 Tg2 = 823; Tg1 = 1373
8 Sg = integrate('k/T', 'T', Tg1, Tg2)
9 St = Sg+Sv;
10 disp("kJ/K", St, "Total change in entropy is ")
11 T0 = 303;
12 disp("kJ", T0*St, "Increase in unavailable energy is")

```

Scilab code Exa 8.3 Calculation of available energy in water

```

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

```

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

```

1 Ts = 273+15;
2 Tw1 = 95+273;
3 Tw2 = 35+273;
4 m1 = 25; m2 = 35;
5 cp = 4.2;
6 AE25 = integrate('m1*cp*(1-(Ts/T))', 'T', Ts, Tw1);
7 AE35 = integrate('m2*cp*(1-(Ts/T))', 'T', Ts, Tw2);
8 AEt = AE25 + AE35;

```

```

9 Tm = (m1*Tw1+m2*Tw2)/(m1+m2); // Temperature after
    mixing
10 AE60 = integrate( '(m1+m2)*cp*(1-(Ts/T)) ', 'T', Ts, Tm);
11 AE = AEt - AE60;
12 disp("kJ", AE, "The decrease in the totla energy is")

```

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

```

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

```

Scilab code Exa 8.6 Energy calculations on air

```

1 T1 = 353; T2 = 278;
2 V2 = 2; V1 = 1;
3 P0 = 100; P1 = 500;
4 R = 0.287; cv = 0.718;
5 m = 2;
6 S = integrate( '(m*cv)/T', 'T', T1, T2) + integrate( '(m*
    R)/V', 'V', V1, V2); // S = S1-S2
7 U = m*cv*(T1-T2);
8 Wmax = U-(T2*(-S));

```



```

9 V1_ = (m*R*T1)/P1;
10 CA = Wmax-P0*(V1_); // Change in availability
11 I = T2*S;
12 disp("kJ",Wmax,"The maximum work is")
13 disp("kJ",CA,"Change in availability is")
14 disp("kJ",I,"Irreversibility is")

```

Scilab code Exa 8.7 Energy calculation of air through a turbine

```

1 P1 = 500; P2 = 100;
2 T1 = 793; T2 = 573;
3 cp = 1.005; T0 = 293; R = 0.287;
4 S21 = (R*log(P2/P1))-(cp*log(T2/T1))
5 CA = cp*(T1-T2)-T0*S21; // Change in v=availability
6 disp("kJ/kg",CA,"The decrease in availability is")
7 Wmax = CA;
8 disp("kJ/kg",Wmax,"The maximum work is")
9 Q = -10;
10 W = cp*(T1-T2)+Q ;
11 I = Wmax-W;
12 disp("kJ/kg",I,"The irreversibility is")
13 // Alternatively
14 Ssystem = -Q/T0;
15 Ssurr = -S21;
16 I1 = T0*(Ssystem+Ssurr);

```

Scilab code Exa 8.8 Energy calculation on a air preheater

```

1 T0 = 300;
2 Tg1 = 573; Tg2 = 473;
3 Ta1 = 313;
4 cpg = 1.09; cpa = 1.005;
5 mg = 12.5; ma = 11.15;

```

```

6 f1 = cpg*(Tg1-T0)-T0*cpg*(log(Tg1/T0));
7 f2 = cpg*(Tg2-T0)-T0*cpg*(log(Tg2/T0));
8 disp("kJ/Kg respectively",f2,"and",f1,"The initial
    and final availability of the products are")
9 // Part (b)
10 Dfg = f1-f2;
11 Ta2 = Ta1 + (mg/ma)*(cpg/cpa)*(Tg1-Tg2);
12 Ifa = cpa*(Ta2-Ta1)-T0*cpa*(log(Ta2/Ta1));
13 I = mg*Dfg-ma*Ifa;
14 disp("kW",I,"The irreversibility of the process is")
15 // Part (c)
16 Ta2_ = Ta1*(%e^(-(mg/ma)*(cpg/cpa)*log(Tg2/Tg1)));
17 Q1 = mg*cpg*(Tg1-Tg2);
18 Q2 = ma*cpa*(Ta2_-Ta1);
19 W = Q1-Q2;
20 disp("kW",W,"Tota power generated by the heat engine
    ")

```

Scilab code Exa 8.9 Calculation of rate of energy degradation of gas flowing through a pipe

```

1 T2 = 1063;
2 T1 = 1073;
3 m = 2; cp = 1.1;
4 I = m*cp*((T1-T2)-T0*(log(T1/T2)));
5 disp("kW",I,"The irrevesibility rate is")
6 // At lower temperature
7 T1_ = 353; T2_ = 343;
8 I_ = m*cp*((T1_-T2_-T0*(log(T1_/T2_)));
9 disp("kW",I_,"The irrevesibility rate at lower
    temperature is")

```

Scilab code Exa 8.10 Calculation of rate of energy loss of gas flowing through a pipe

```
1 m = 3; R = 0.287;
2 T0 = 300; k = 0.10; // k = dP/P1
3 Sgen = m*R*k;
4 I = Sgen*T0;
5 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

```
1 m1 = 2; // m1_dot
2 m2 = 1;
3 T1 = 90+273;
4 T2 = 30+273;
5 T0 = 300;
6 m = m1+m2;
7 x = m1/m;
8 t = T2/T1; // Tau
9 cp = 4.187;
10 Sgen = m*cp*log((x+t*(1-x))/(t^(1-x)));
11 I = T0*Sgen;
12 disp("kW/K",Sgen,"The rate of entropy generation is"
    )
13 disp("kW",I,"The rate of energy loss due to mixing
    is")
14 // Alternatively
15 T = (m1*T1+m2*T2)/(m1+m2); // equilibrium
    temperature
16 Sgen1 = m1*cp*log(T/T1)+m2*cp*log(T/T2);
17 I1 = T0*Sgen1;
```

Scilab code Exa 8.12 Calculations on efficiency of burning of fuel

```
1 Qr = 500; // Heat release in kW
2 Tr = 2000;
3 T0 = 300;
4 // Part (a)
5 Qa = 480; Ta = 1000;
6 n1a = (Qa/Qr);
7 n2a = n1a*(1-(T0/Ta))/(1-(T0/Tr));
8 disp("PART (A)")
9 disp("%",n1a*100,"The first law efficiency is")
10 disp("%",n2a*100,"The Second law efficiency is")
11 // Part (b)
12 Qb = 450; Tb = 500;
13 n1b = (Qb/Qr);
14 n2b = n1b*(1-(T0/Tb))/(1-(T0/Tr));
15 disp("PART (B)")
16 disp("%",n1b*100,"The first law efficiency is")
17 disp("%",n2b*100,"The Second law efficiency is")
18 // Part (c)
19 Qc = 300; Tc = 320;
20 n1c = (Qc/Qr);
21 n2c = n1c*(1-(T0/Tc))/(1-(T0/Tr));
22 disp("PART (C)")
23 disp("%",n1c*100,"The first law efficiency is")
24 disp("%",n2c*100,"The Second law efficiency is")
25 // Part (d)
26 Qd = 450;
27 n1d = (Qd/Qr);
28 n2a_ = n1d*(1-(T0/Ta))/(1-(T0/Tr));
29 n2b_ = n1d*(1-(T0/Tb))/(1-(T0/Tr));
30 n2c_ = n1d*(1-(T0/Tc))/(1-(T0/Tr));
31 disp("Part (D)")
32 disp("%",n1d*100,"The first law efficiency is")
33 disp("%",n2a_*100,"The Second law efficiency of part
(a) is")
34 disp("%",n2b_*100,"The Second law efficiency of part
(b) is")
```

```
35 disp("%",n2c_*100,"The Second law efficiency of part  
(c) is")
```

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

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

Scilab code Exa 8.15 Determination of energy of vaccume

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

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

```

1 m = 1000; T0 = 300; P0 = 1;
2 T1 = 300;
3 T2 = 273-20; Tf = 273-2.2;
4 Cb = 1.7; Ca = 3.2;
5 Lh = 235;
6 H12 = m*((Cb*(Tf-T2))+Lh+(Ca*(T1-Tf)));
7 H21 = -H12;
8 S12 = m*((Cb*log(Tf/T2))+(Lh/Tf)+(Ca*log(T1/Tf)));
9 S21 = -S12;
10 E = H21-T0*S21;
11 disp("kJ",E,"Energy produced is")

```

Scilab code Exa 8.17 Thermodynamic calculation on air

```

1 cv = 0.718; T2 = 500; T1 = 300;
2 m = 1; T0 = 300;
3 // Case (a)
4 Sua = cv*log(T2/T1);
5 Ia = T0*Sua;
6 disp("kJ/kg",Ia,"The irreversibility in case a is")
7 // Case (b)
8 Q = m*cv*(T2-T1);
9 T = 600;
10 Sub = Sua-(Q/T);
11 Ib = T0*Sub;
12 disp("kJ/kg",Ib,"The irreversibility in case b is")

```

Scilab code Exa 8.18 Energy calculation of steam through turbine

```

1 h1 = 3230.9; s1 = 6.69212; V1 = 160; T1 = 273+400;
2 h2 = 2676.1; s2 = 7.3549; V2 = 100; T2 = 273+100;
3 T0 = 298; W = 540; Tb = 500;
4 Q = (h1-h2)+((V1^2-V2^2)/2)*1e-03-W;

```

```

5 I = 151.84-Q*(0.404);
6 AF = W + Q*(1-(T0/Tb)) + I; // AF = af1-af2
7 n2 = W/AF;
8 disp("kJ/kg",I,"Irreversibility per unit mass is")
9 disp(n2,"The second law efficiency of the turbine is")

```

Scilab code Exa 8.19 Availability calculations on a furnace

```

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

```

Scilab code Exa 8.20 Energy calculation of air through compressor

```

1 P1 = 1; T1 = 273+30;
2 P2 = 3.5; T2 = 141+273 ; V = 90;
3 T0 = 303;
4 // Part (a)
5 g = 1.4;
6 T2s = T1*((P2/P1)^((g-1)/g));
7 disp("As T2s> T2 so the process must be polytropic")
8 // Part (b)
9 p = log(P2/P1); q = log(T2/T1);
10 n = p/(p-q);
11 disp(n,"The polytropic index is")

```

```

12 // Part (c)
13 cp = 1.0035; R = 0.287;
14 Wa = cp*(T1-T2)-(V2^2/2)*1e-03 ;
15 Wt = -R*T0*log(P2/P1)-(V2^2/2)*1e-03;
16 Nt = Wt/Wa;
17 disp(Nt,"The isothermal efficiency is")
18 // Part (d)
19 f12 = cp*(T1-T2) + T0*((R*log(P2/P1))-(cp*log(T2/T1)
    )) - (V2^2/2)*1e-03 ;
20 I = f12-Wa ;
21 disp("kW respectively",I,"and",f12,"The minimum work
    input and irreversibility are")
22 // Part (e)
23 n2 = (f12/Wa);
24 disp(n2,"Second law efficiency is")

```

Chapter 9

Properties of pure substances

Scilab code Exa 9.1 Calculations on vapourization of steam

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

Scilab code Exa 9.3 Finding the entropy and enthalpy of steam

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

```

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

```

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

```

1 // for T = 350 degree
2 T1 = 350; v1 = 0.2003; h1 = 3149.5; s1 = 7.1369;
3 // for T = 400 degree
4 T2 = 400; v2 = 0.2178; h2 = 3257.5; s2 = 7.3026;
5 // Interpolation for T = 380;
6 T = [T1 T2];
7 v = [v1 v2];
8 h = [h1 h2];
9 s = [s1 s2];
10 v3 = interpvn([T;v],380);
11 h3 = interpvn([T;h],380);
12 s3 = interpvn([T;s],380);
13 disp("m3/kg respectively",v3,"kJ/kg",h3,"kJ/kg K",s3
      ,"The entropy, enthalpy and volume of steam at 1.4
      MPa and 380 degree is")

```

Scilab code Exa 9.5 Calculations of thermodynamics properties of mixture of air and steam

```

1 Psat = 3.973e06;
2 vf = 0.0012512; vg = 0.05013;
3 hf = 1085.36; hfg = 1716.2;
4 sf = 2.7927; sfg = 3.2802;
5 mf = 9; V = 0.04;

```

```

6 Vf = mf*vf;
7 Vg = V-Vf;
8 mg = Vg/vg;
9 m = mf+mg;
10 x = mg/m;
11 v = vf+x*(vg-vf);
12 h = hf+x*hfg;
13 s = sf+(x*sfg);
14 u = h-Psat*v*1e-03;
15 // at T = 250
16 uf = 1080.39; ufg = 1522;
17 u_ = uf+x*ufg;
18 disp("Pa",Psat,"The pressure is")
19 disp("kg",m,"The mass is")
20 disp("m3/kg",v,"Specific volume is")
21 disp("kJ/kg",h,"Enthalpy is")
22 disp("kJ/kg K",s,"The entropy is")
23 disp("kJ/kg",u,"The interal energy is")

```

Scilab code Exa 9.6 energy calculation on cooling of steam

```

1 // Part (a)
2 vg1_ = 0.8919; T1_ = 120;
3 vg2_ = 0.77076; T2_ = 125;
4 vg_ = [vg1_ vg2_]; T_ = [T1 T2];
5 v1 = 0.7964;
6 h1 = 2967.6;
7 P1 = 0.3e03; // in Kpa
8 T1 = interpln([vg_;T_],v1);
9 disp("degree",T3,"The steam become saturated at ")
10 // Part (b)
11 vf = 0.001029; vg = 3.407;
12 hf = 334.91; hfg = 2308.8;
13 Psat = 47.39; // In kPa
14 v2 = v1;

```

```

15 x2 = (v1-vf)/(vg-vf);
16 h2 = hf+x2*hfg;
17 P2 = Psat;
18 Q12 = (h2-h1)+v1*(P1-P2);
19 disp(x2,"The quality factor at t =80 degree is")
20 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

```

1 // At T = 40 degree
2 Psat = 7.384e06;
3 sf = 0.5725; sfg = 7.6845;
4 hf = 167.57; hfg = 2406.7;
5 //
6 s1 = 6.9189; h1 = 3037.6;
7 x2 = (s1-sf)/sfg ;
8 h2 = hf+(x2*hfg);
9 W = h1-h2;
10 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

```

1 w3 = 2.3; w1 = 1.0;
2 w2 = w3-w1;
3 h1 = 2950.0;
4 // At 0.8MPa, 0.95 dry
5 x = 0.95;
6 hf = 721.11; hfg = 2048;
7 h2 = hf + (x*hfg);
8 h3 = ((w1*h1)+(w2*h2))/w3;

```

```

9 // Interpolation
10 H = [2769.1 2839.3];
11 T = [170.43 200];
12 t3 = interp1n([H;T],2790);
13 s3 = 6.7087;
14 s4 = s3;
15 x4 = (s3-1.7766)/5.1193;
16 h4 = 604.74+(x4*2133.8);
17 V4 = sqrt(2000*(h3-h4));
18 disp("degree",t3-T(1),"The condition of superheat
    after mixing")
19 disp("m/sec",V4,"The velocity of steam leaving the
    nozzle is")

```

Scilab code Exa 9.9 Calculation of moisture of steam

```

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

```

Scilab code Exa 9.10 Finding the quantity of steam in pipeline

```

1 // At 0.1Mpa, 110 degree
2 h2 = 2696.2; hf = 844.89; hfg = 1947.3;
3 x2 = (h2-hf)/hfg;
4 vf = 0.001023; // at T = 70 degree
5 V = 0.000150; // In m3
6 m1 = V/vf;
7 m2 = 3.24;
8 x1 = (x2*m2)/(m1+m2);

```

```
9 disp(x1,"The quality of the steam in the pipe line
   is")
```

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

```
1 // P = 1MPa
2 vf = 0.001127; vg = 0.1944;
3 hg = 2778.1; uf = 761.68;
4 ug = 2583.6; ufg = 1822;
5 // Initial and final mass
6 Vis = 5; Viw = 5;
7 Vfs = 6 ; Vfw = 4 ;
8 //
9 ms = ((Viw/vf)+(Vis/vg)) - ((Vfw/vf)+(Vfs/vg)) ;
10 U1 = ((Viw*uf/vf)+(Vis*ug/vg));
11 Uf = ((Vfw*uf/vf)+(Vfs*ug/vg));
12 Q = Uf-U1+(ms*hg)
13 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

```
1 m = 0.02; d = 0.28; l = 0.305;
2 P1 = 0.6e06; P2 = 0.12e06;
3 // At 0.6MPa, t = 200 degree
4 v1 = 0.352; h1 = 2850.1;
5 V1 = m*v1;
6 Vd = (%pi/4)*d^2*l;
7 V2 = V1+Vd ;
8 n = log(P1/P2)/log(V2/V1);
9 W12 = ((P1*V1)-(P2*V2))/(n-1);
10 disp(n,"The value of n is");
```

```

11 disp("J",W12,"The work done by the steam is")
12 v2 = V2/m;
13 vf = 0.0010476; vfg = 1.4271;
14 x2 = (v2-vf)/vfg ;
15 // At 0.12MPa
16 uf = 439.3; ug = 2512.0;
17 u2 = uf + (x2*(ug-uf));
18 u1 = h1-(P1*v1*1e-03);
19 Q12 = m*(u2-u1)+ (W12/1000);
20 disp("kJ",Q12,"The heat transfer is")

```

Scilab code Exa 9.13 Energy calculations in an insulated vessel

```

1 x1 = 1; x2 = 0.8;
2 // at 0.2MPa
3 vg = 0.8857; v1 = vg; hg = 2706.7; h1 = hg;
4 m1 = 5 ; V1 = m1*v1;
5 // at 0.5MPa
6 m2 = 10;
7 hf = 640.23; hfg = 2108.5
8 vf = 0.001093; vfg = 0.3749;
9 v2 = vf+(x2*vfg);
10 V2 = m2*v2;
11 //
12 Vm = V1+V2;
13 m = m1+m2;
14 vm = Vm/m;
15 u1 = h1;
16 h2 = hf+(x2*hfg);
17 u2 = h2;
18 m3 = m;
19 h3 = ((m1*u1)+(m2*u2))/m3;
20 u3 = h3;
21 v3 = vm;
22 // From mollier diagram

```

```

23 x3 = 0.870; p3 = 3.5; s3 = 6.29;
24 s1 = 7.1271;
25 sf = 1.8607; sfg = 4.9606;
26 s2 = sf+(x2*sfg);
27 E = m3*s3-((m1*s1)+(m2*s2));
28 disp("bar",p3,"Final pressure is")
29 disp(x3,"Steam quality is")
30 disp("kJ/K",E,"Entropy change during the process is"
    )

```

Scilab code Exa 9.14 Energy calculation on steam passing through turbine

```

1 // At 6 MPa, 400 degree
2 h1 = 3177.2; s1 = 6.5408;
3 // At 20 degree
4 h0= 83.96; s0 = 0.2966;
5 T0 = 293;
6 f1 = (h1-h0)-T0*(s1-s0);
7 // By interpolation
8 t2 = 273 + 393;
9 s2 = 6.63;
10 h2 = h1;
11 f2 = (h2-h0)-T0*(s2-s0);
12 df = f1-f2;
13 x3s = (s2-1.5301)/(7.1271-1.5301);
14 h3s = 504.7+(x3s*2201.9);
15 eis = 0.82;
16 h3 = h2-eis*(h1-h3s);
17 x3 = (h3-504.7)/2201.7;
18 s3 = 1.5301+(x3*5.597);
19 f3 = (h3-h0)-T0*(s3-s0);
20 disp("kJ/kg",f1,"The availability of the steam
    before the throttle valve")
21 disp("kJ/kg",f2,"The availability of the steam after

```



```

    the throttle valve")
22 disp("kJ/kg",f3,"The availability of the steam at
    the turbine exhaust")
23 disp("kJ/kg",h2-h3,"The specific work output from
    the turbine is")

```

Scilab code Exa 9.15 Energy calculation on a steam turbine

```

1 // At 25 bar , 350 degree
2 h1 = 3125.87; s1 = 6.8481;
3 // 30 degree
4 h0 = 125.79; s0 = 0.4369;
5 // At 3 bar , 200 degree
6 h2 = 2865.5; s2 = 7.3115;
7 // At 0.2 bar 0.95 dry
8 hf = 251.4; hfg = 2358.3;
9 sf = 0.8320; sg = 7.0765;
10 h3 = hf+0.92*hfg;
11 s3 = sf+(0.92*sg);
12 // Part (a)
13 T0 = 303;
14 f1 = (h1-h0)-(T0*(s1-s0));
15 f2 = (h2-h0)-(T0*(s2-s0));
16 f3 = (h3-h0)-(T0*(s3-s0));
17 disp("kJ/kg",f1,"Availability of steam entering at
    state 1")
18 disp("kJ/kg",f2,"Availability of steam leaving at
    state 2")
19 disp("kJ/kg",f3,"Availability of steam leaving at
    state 3")
20 // Part (b)
21 m2m1 = 0.25; m3m1 = 0.75;
22 Wrev = f1-(m2m1*f2)-(m3m1*f3);
23 disp("kJ/kg",Wrev,"Maximum work is")
24 // Part (c)

```

```

25 w1 = 600; w2 = 150; w3 = 450;
26 Q = -10*3600; // For 1 hour
27 I = T0*(w2*s2+w3*s3-w1*s1)-Q;
28 disp("kJ/h",I,"Irreversibility is")

```

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

```

1 // At dead state of 1 bar, 300K
2 u0 = 113.1; h0 = 113.2;
3 v0 = 0.001005; s0 = 0.0395;
4 T0 = 300; P0 = 100;
5 K = h0-(T0*s0);
6 // Part (a)
7 u = 376.9; h = 377;
8 v = 0.001035; s = 1.193;
9 m = 3;
10 fi = m*(h-(T0*s)-K); // As P = P0 = 1 bar
11 disp("kJ",fi,"Energy of system in Part (a) is")
12 // Part (b)
13 u = 3099.8; h = 3446.3; v = 0.08637; s = 7.090; //
    At P = 4 Mpa, t = 500 degree
14 m = 0.2;
15 fib = m*(u+P0*v-T0*s-K);
16 disp("kJ",fib,"Energy of system in Part (b) is")
17 // Part (c)
18 m = 0.4;
19 x = 0.85; // Quality
20 u = 192+x*2245;
21 h = 192+x*2392;
22 s = 0.649+x*7.499;
23 v = 0.001010+x*14.67;
24 fic = m*(u+P0*v-T0*s-K);
25 disp("kJ",fic,"Energy of system in Part (c) is")
26 // Part (d)
27 m = 3;

```

```

28 h = -354.1; s = -1.298; // at 1000kPa, -10 degree
29 fid = m*((h-h0)-T0*(s-s0));
30 disp("kJ",fid,"Energy of system in Part (d) is")

```

Scilab code Exa 9.17 Calculations on a heat exchanger

```

1 // Given
2 th1 = 90+273;
3 tc1 = 25+273;
4 tc2 = 50+273;
5 mc = 1; T0 = 300;
6 th2p = 60+273; // Parallel
7 th2c = 35+273; // Counter
8 mhp = (tc2-tc1)/(th1-th2p); // Parallel
9 mhc = (tc2-tc1)/(th1-th2c); // Counter
10 h0 = 113.2; s0 = 0.395; T0 = 300; // At 300 K
11 h1 = 376.92; s1 = 1.1925; // At 90 degree
12 af1 = mhp*((h1-h0)-T0*(s1-s0));
13 // Parallel Flow
14 h2 = 251.13; s2 = 0.8312; // At 60 degree
15 h3 = 104.89; s3 = 0.3674; // At 25 degree
16 h4 = 209.33; s4 = 0.7038; // At 50 degree
17 REG = mc*((h4-h3)-T0*(s4-s3)); // Rate of energy
    gain
18 REL = mhp*((h1-h2)-T0*(s1-s2)); // Rate of energy
    loss
19 Ia = REL-REG; // Energy destruction
20 n2a = REG/REL; // Second law efficiency
21 disp("In parallel flow")
22 disp("kW",Ia,"The rate of irreversibility is")
23 disp("%",n2a*100,"The Second law efficiency is")
24 // Counter flow
25 h2 = 146.68; s2 = 0.5053; // At 35 degree
26 REG_b = REG; // Rate of energy gain by hot water is
    same in both flows

```

```

27 REL_b = mhc*((h1-h2)-T0*(s1-s2));
28 Ib = REL_b-REG_b; // Energy destruction
29 n2b = REG_b/REL_b; // Second law efficiency
30 disp("In Counter flow")
31 disp("kW",Ib,"The rate of irreversibility is")
32 disp("%",n2b*100,"The Second law efficiency is")

```

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

```

1 m = 50 ; // in kg/h
2 Th = 23+273; // Home temperature
3 // State 1
4 T1 = 150+273;
5 h1 = 2746.4;
6 s1 = 6.8387;
7 // State 2
8 h2 = 419.0;
9 s2 = 1.3071;
10 T0 = 318;
11 //
12 b1 = h1-(T0*s1);
13 b2 = h2-(T0*s2);
14 Q_max = m*(b1-b2)/(T0/Th-1);
15 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

```
1 // Part (a)
2 P1 = 100; P2 = 50;
3 T1 = 273+300;
4 T2 = (P2/P1)*T1;
5 R = 0.287; cv = 0.718;
6 V1 = 0.8;
7 m = (P1*V1)/(R*T1);
8 Q = m*cv*(T2-T1);
9 disp("If the fluid is in the air")
10 disp("K",T2,"The final temperature is ")
11 disp("kJ/kg",Q,"The heat transferred is")
12 // Part (b)
13 t2 = 273+81.33; vf = 0.00103; vg = 3.24;
14 v1 = 2.6388; u1 = 2810.4;
15 x2 = (v1-vf)/(vg-vf);
16 u2 = 340.42+(x2*2143.4);
17 m_ = V1/v1;
18 Q_ = m_*(u2-u1);
```

```
19 disp(" If the fluid is in the steam")
20 disp("K",t2,"The final temperature is ")
21 disp("kJ/kg",Q_,"The heat transferred is")
```

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

```
1 // Part (a)
2 R = 0.287; T1 = 273+150; v1 = 0.96; v2 = 1.55; Cp =
   1.005;
3 P = (R*T1)/v1;
4 W = P*(v2-v1);
5 T2 = (v2/v1)*T1;
6 Q = Cp*(T2-T1);
7 disp(" If the fluid is in the air")
8 disp("K",T2,"The final temperature is ")
9 disp("kJ",Q,"The heat transferred is")
10 disp("kJ",W,"Work done is")
11 // Part (b)
12 vg = 0.3928;
13 P1 = 200e03;
14 P2 = P1;
15 h1 = 2768.8;
16 t2 = 273+400; h2 = 3276.5;
17 Q_ = h2-h1;
18 W_ = P1*(v2-v1);
19 disp(" If the fluid is in the steam")
20 disp("K",t2,"The final temperature is ")
21 disp("kJ",Q_,"The heat transferred is")
22 disp("J",W_,"Work done is")
```

Scilab code Exa 10.3 Heat calculation on a fluid

```

1 // Part (a)
2 v = 16 ; // v = v1/v2
3 P1 = 300e03;
4 P2 = P1*v;
5 R = 0.287; T1 = 300+273;
6 W12 = R*T1*log(1/v);
7 disp(" If the fluid is in the air")
8 disp("Pa",P2,"The final pressure is ")
9 disp("kJ",0,"The change in internal energy is")
10 disp("kJ",W12,"Work done is")
11 // Part (b)
12 v1 = 0.7664; u1 = 2728.7;
13 v2 = v1/16;
14 x2 = (v2-0.00125)/(0.05013);
15 s2 = 2.7927+(x2*3.2802);
16 u2 = 1080.37+(x2*1522.0);
17 du = u2-u1;
18 T = 250+273;
19 Q12 = T*(s2-s1)
20 disp(" If the fluid is in the steam")
21 disp("K",T,"The final temperature is ")
22 disp("kJ/kg",Q12,"The heat transferred is")
23 disp("kJ/kg ",du,"The change in internal energy is"
    )

```

Scilab code Exa 10.4 Heat calculation for a reversible adiabatic process

```

1 // Part (a)
2 P1 = 10; P2 = 1;
3 T1 = 273+300;
4 g = 1.4;
5 T2 = T1*((P2/P1)^((g-1)/g));
6 R = 0.287;
7 W12 = ((R*T1)/(1-g))*(T2/T1-1);
8 v2 = (R*T2)/(100*P2);

```

```

 9 disp(" If the fluid is in the air")
10 disp("m3/kg",v2,"The specific volume is")
11 disp("kJ",W12,"The work done per kg of the fluid is"
    )
12 // Part (b)
13 u1 = 2793.2; v1 = 0.2579; s1 = 7.1228;
14 x2 = (7.1228-1.3025)/6.0568;
15 u2 = 417.33+(x2*2088.7);
16 v2 = 0.001043+(0.96*1.693);
17 W12 = u1-u2;
18 disp(" If the fluid is in the steam")
19 disp("m3/kg",v2,"The specific volume is")
20 disp("kJ",W12,"The work done per kg of the fluid is"
    )

```

Scilab code Exa 10.5 Heat calculations on a reversible polytropic process

```

 1 // Part (a)
 2 P1 = 10; P2 = 1;
 3 T1 = 273+200; n = 1.15; R = 0.287;
 4 v2 = ((R*T1)/(P1*100))*((P1/P2)^(1/1.15));
 5 v1 = ((R*T1)/(P1*100));
 6 T2 = T1*(P2/P1)*(v2/v1);
 7 cv = 0.716;
 8 Q = (cv+(R/(1-n)))*(T2-T1);
 9 disp(" If the fluid is in the air")
10 disp("m3/kg",v2,"The specific volume is")
11 disp("K",T2,"The final temperature is ")
12 disp("kJ",Q,"Heat transferred per kg is")
13 // Part (b)
14 v1 = 0.20596; u1 = 2621.9;
15 v2 = v1*(P1/P2)^(1/n);
16 x2 = (v2-0.001043)/(1.694-0.001043);
17 t2 = 99.62+273;
18 u2 = 417.33+(x2*2088.7);

```



```

19 W = ((P1*100*v1)-(P2*100*v2))/(n-1);
20 Q = u2-u1+W;
21 disp("If the fluid is in the steam")
22 disp("m3/kg",v2,"The specific volume is")
23 disp("K",t2,"The final temperature is ")
24 disp("kJ",Q,"Heat transferred per kg is")

```

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

```

1 P0 = 1000;
2 T0 = 3;
3 V0 = 0.001;
4 R = 287;
5 n = (P0*V0)/(R*T0); // Number of moles
6 // Process ab
7 Wab = 0;
8 cv = (3/2)*R;
9 Ta = T0; Tb = 300;
10 Qab = n*cv*(Tb-Ta);
11 Ua = 0; // Given internal energy
12 Ub = Qab+Ua;
13 Uab = Ub-Ua;
14 // Process bc
15 Qbc = 0; Uc = 0; Ubc = Uc-Ub;
16 Wbc = -Ubc;
17 // Process ca
18 Tc = Ta;
19 g = 5/3; // gamma
20 Vcb = (Tb/Tc)^(3/2); // Vc/Vb
21 Wca = -n*R*Tc*log(Vcb);
22 Qca = Wca ;
23 Uca = 0;
24 //
25 disp("J",Wab+Wbc+Wca,"Work done in the cycle is")
26 disp("J",Uab+Ubc+Uca,"Internal energy change in the

```

```

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

```

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

```

1 Pa = 1.5; Ta = 273+50; ca = 0.5;
2 Pb = 0.6; Tb = 20+273; mb = 2.5;
3 R = 8.3143;
4 Va = (ca*R*Ta)/(Pa*1e03);
5 ma = ca*28;
6 Rn = R/28;
7 Vb = (mb*Rn*Tb)/(Pb*1e03);
8 V = Va + Vb ;
9 m = ma + mb ;
10 Tf = 27+273;
11 P = (m*Rn*Tf)/V;
12 g = 1.4;
13 cv = Rn/(g-1);
14 U1 = cv*(ma*Ta+mb*Tb);
15 U2 = m*cv*Tf;
16 Q = U2-U1;
17 disp("KPa",P,"The final equilibrium pressure is")
18 disp("kJ",Q,"The amount of heat transferred to the
    surrounding is")
19 T_ = (ma*Ta+mb*Tb)/m ;
20 P_ = (m*Rn*T_)/V;
21 disp("If the vessele is perfectly inslulated")
22 disp("K",T_,"The final temperature is")
23 disp("KPa",P_,"The final pressure is")

```

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

```
1 cp = 1.968; cv = 1.507;
2 R_ = 8.314;
3 V = 0.3; m = 2;
4 T1 = 5+273; T2 = 100+273;
5 R = cp-cv;
6 mu = R_/R;
7 Q12 = m*cv*(T2-T1);
8 W12 = 0 ;
9 U21 = Q12;
10 H21= m*cp*(T2-T1);
11 S21 = m*cv*log(T2/T1);
12 disp("kJ/kg K",R,"kg/kg mol and",mu,"Molecular
      weight and the gas constant of the gas are")
13 disp("kJ",0,"Work done")
14 disp("kJ",Q12,"The heat transferred")
15 disp("kJ",U21,"The change in internal energy ")
16 disp("kJ",S21,"entropy")
17 disp("kJ/K",H21,"enthalpy")
```

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

```
1 m = 1.5;
2 P1 = 5.6; V1 = 0.06;
3 T2 = 273+240;
4 a = 0.946; b = 0.662;
5 k = 0.0001;
6 // Part (b)
7 R = a-b;
8 T1 = (P1*1e03*V1)/(m*R);
```

```

9 W12 = -integrate('m*(b+k*T)', 'T', T1, T2);
10 disp("kJ", W12, "The work done in the expansion is")

```

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

```

1 m = 0.5;
2 P1 = 80e03; T1 = 273+60;
3 P2 = 0.4e06;
4 R = 0.287;
5 V1 = (m*R*T1)/P1 ;
6 g = 1.4; // Gamma
7 T2 = T1*(P2/P1)^((g-1)/g);
8 W12 = (m*R*(T1-T2))/(g-1);
9 V2 = V1*((P1/P2)^(1/g));
10 W23 = P2*(V1-V2);
11 W = W12+W23;
12 V3 = V1;
13 T3 = T2*(V3/V2);
14 cp = 1.005;
15 Q = m*cp*(T3-T2);
16 disp("kJ", W, "The work transfer for the whole path is
    ")
17 disp("kJ", Q, "The heat transfer for the whole path")

```

Scilab code Exa 10.12 Heat calculations over a cycle

```

1 P1 = 700e03; T1 = 273+260; T3 = T1;
2 V1 = 0.028; V2 = 0.084;
3 R = 0.287;
4 m = (P1*V1)/(R*T1);
5 P2 = P1;
6 T2 = T1*((P2*V2)/(P1*V1));
7 n = 1.5;

```

```

8 P3 = P2*((T3/T2)^(n/(n-1)));
9 cp = 1.005; cv = 0.718;
10 Q12 = m*cp*(T2-T1);
11 Q23 = m*cv*(T3-T2) + (m*R*(T2-T3))/(n-1);
12 Q31 = m*R*T1*log(P3/P1);
13 Q1 = Q12;
14 Q2 = -(Q23+Q31);
15 e = 1-(Q2/Q1);
16 disp("J",Q1,"The heat received in the cycle is")
17 disp("J",Q2,"The heat rejected in the cycle")
18 disp(e,"The efficiency of the cycle is")

```

Scilab code Exa 10.13 Heat calculations on an ideal gas

```

1 P1 = 300e03; V1 = 0.07;
2 m = 0.25; T1 = 80+273;
3 R = (P1*V1)/(1000*m*T1);
4 P2 = P1;
5 V2 = 0.1;
6 T2 = (P2*V2)/(1000*m*R);
7 W = -25;
8 cv = -W/(m*(T2-T1));
9 cp = R+cv;
10 S21 = m*cp*log(V2/V1); // S21 = S2-S1
11 disp("kJ/kg K",cv,"cv of the gas is")
12 disp("kJ/kg K",cp,"cp of the gas is")
13 disp("kJ/kg K",S21,"Increase in the entropy of the
    gas is")

```

Scilab code Exa 10.14 Calculations on internal combustion engine

```

1 P1 = 1;
2 P2 = 15;

```

```

3 V1 = 800e-06;
4 V2 = V1/8;
5 cv = 0.718; g = 1.4;
6 n = (log(P2/P1))/(log(V1/V2))
7 T1 = 348; R = 0.287;
8 m = (P1*100*V1)/(R*T1);
9 T2 = T1*((P2*V2)/(P1*V1));
10 P3 = 50;
11 T3 = T2*(P3/P2);
12 S21 = m*(cv*log(T2/T1)+R*log(V2/V1));
13 S32 = m*cv*log(T3/T2);
14 Q = (m*cv*(g-n)*(T2-T1))/(1-n);
15 disp(n,"The index of compression process is")
16 disp("kJ/K",S21,"S2-S1 is")
17 disp("kJ/K",S32,"S3-S2 is")
18 disp("kJ",Q,"The heat exchange is")

```

Scilab code Exa 10.15 Calculations on a mixture of ideal gases

```

1 mn = 3; // Mass of nitrogen in kg
2 mc = 5; // mass of CO2 in kg
3 an = 28; // Atomic weight of nitrogen
4 ac = 44; // Atomic weight of CO2
5 // Part (a)
6 xn = (mn/an)/((mn/an)+(mc/ac));
7 xc = (mc/ac)/((mn/an)+(mc/ac));
8 disp(xn,"Mole fraction of N2 is")
9 disp(xc,"Mole fraction of CO2 is")
10 // Part (b)
11 M = xn*an+xc*ac;
12 disp("kg",M,"Equivalent molecular weight of mixture
    is")
13 // Part (c)
14 R = 8.314;
15 Req = ((mn*R/an)+(mc*R/ac))/(mn+mc);

```

```

16 disp("kJ/kg K",Req,"The equivalent gas constant of
    the mixture is")
17 // Part (d)
18 P = 300; // Pressure in kPa
19 T = 20+273;
20 Pn = xn*P; // Partial pressure of Nitrogen
21 Pc = xc*P; // Partial pressure of CO2
22 Vn = (mn*R*T)/(P*an); // Volume of nitrogen
23 Vc = (mc*R*T)/(P*ac); // Volume of CO2
24 disp("kPa respectively",Pc,"and",Pn,"Partial
    pressures of nitrogen and CO2 are")
25 disp("m3 respectively",Vc,"and",Vn,"Partial volume
    of nitrogen and CO2 are")
26 // Part (e)
27 V = (mn+mc)*Req*T/P; // Total volume
28 rho = (mn+mc)/V;
29 disp("m3",V,"Volume of mixture is")
30 disp("kg/m3",rho,"Density of mixture is")
31 // Part (f)
32 gn = 1.4; // Gamma
33 gc = 1.286;
34 cvn = R/((gn-1)*an); // cp and cv of N2
35 cpn = gn*cvn;
36 cvc = R/((gc-1)*ac); // cp and cv of CO2
37 cpc = gc*cvc;
38 cp = (mn*cpn+mc*cpc)/(mn+mc) ; // of mixture
39 cv = (mn*cvn+mc*cvc)/(mn+mc) ;
40 disp("kJ/kg K respectively",cv,"and",cp,"cp and cv
    of mixture are")
41 T1 = T; T2 = 40+273;
42 U21 = (mn+mc)*cv*(T2-T1);
43 H21 = (mn+mc)*cp*(T2-T1);
44 S21v = (mn+mc)*cv*log(T2/T1); // If heated at
    constant volume
45 disp("kJ",U21,"Change in internal energy of the
    system heated at constant volume is")
46 disp("kJ",H21,"Change in enthalpy of the system
    heated at constant volume is")

```

```

47 disp("kJ/kg K",S21v,"Change in entropy of the system
      heated at constant volume is")
48 S21p = (mn+mc)*cp*log(T2/T1); // If heated at
      constant Pressure
49 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

```

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

```

Scilab code Exa 10.17 Calculations os specific properties of neon

```

1 an = 20.183; // molecular weight of neon
2 Pc = 2.73; // Critical pressure
3 Tc = 44.5;
4 Vc = 0.0416;
5 Pr = 2; // Reduced Pressure
6 Tr = 1.3;
7 Z = 0.7;
8 P = Pr*Pc;
9 T = Tr*Tc;
10 R = 8.314;
11 v = (Z*R*T)/(P*1000*an);

```



```
12 vr = (v*an)/Vc ;
13 disp("m3/kg",v," Specific volume is")
14 disp("K",T," Specific temperature is")
15 disp("kPa",P," Specific pressure is")
16 disp(vr," Reduced volume is")
```

Chapter 11

Thermodynamic relations Equilibrium and stability

Scilab code Exa 11.3 Finding the vapour pressure of benzene

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

Scilab code Exa 11.4 Calculations on vapours of benzene

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

```

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

```

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

```

1 R = 8.314;
2 N1 = 0.5e-03; N2 = 0.75e-03; // Mole number of
   system 1 and 2 in kg/mol
3 T1 = 200; T2 = 300;
4 V = 0.02;
5 Tf = ((N1*T1)+(N2*T2))/(N1+N2); // Final temperature
6 Uf1 = (3/2)*R*N1*Tf;
7 Uf2 = (3/2)*R*N2*Tf;
8 Pf = (R*Tf*(N1+N2))/V;
9 Vf1 = (R*N1*Tf)/Pf;
10 Vf2 = V - Vf1;
11 disp("System 1")
12 disp("m3",Vf1,"Volume is")
13 disp("kJ",Uf1,"Energy is")
14 disp("System 2")
15 disp("m3",Vf2,"Volume is")
16 disp("kJ",Uf2,"Energy is")
17 disp("K",Tf,"Final temperature is")
18 disp("kPa",Pf,"Final Pressure is")

```

Chapter 12

Vapour power cycle

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

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

Scilab code Exa 12.2 Calculations on steam on a cycle

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

```

2 h3 = 173.88; s3 = 0.5926; sfp2 = s3; hfp2 = h3;
3 hfgp2 = 2403.1; sgp2 = 8.2287;
4 vfp2 = 0.001008; sfgp2 = 7.6361;
5 x2s = (s1-sfp2)/(sfgp2);
6 h2s = hfp2+(x2s*hfgp2);
7 // Part (a)
8 P1 = 20e02; P2 = 0.08e02;
9 h4s = vfp2*(P1-P2)+h3 ;
10 Wp = h4s-h3;
11 Wt = h1-h2s;
12 Wnet = Wt-Wp;
13 Q1 = h1-h4s;
14 n_cycle = Wnet/Q1;
15 disp("kJ/kg",Wnet,"Net work per kg of steam is")
16 disp(n_cycle,"Cycle efficiency is")
17 // Part (b)
18 n_p = 0.8; n_t = 0.8;
19 Wp_ = Wp/n_p;
20 Wt_ = Wt*n_t;
21 Wnet_ = Wt_-Wp_;
22 P = 100*((Wnet-Wnet_)/Wnet) ;
23 n_cycle_ = Wnet_/Q1;
24 P_ = 100*((n_cycle-n_cycle_)/n_cycle);
25 disp("%",P,"Percentage reduction in net work per kg
of steam is")
26 disp("%",P_,"Percentage reduction in cycle
efficiency is")

```

Scilab code Exa 12.3 Calculation on stem power plant

```

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

```

```

6 h1 = 3165.54;
7 h2s = 173.88 + (0.85*2403.1);
8 h3 = 173.88;
9 vfp2 = 0.001;
10 h4s = h3 + (vfp2*(P2-P1)*100);
11 Q1 = h1-h4s;
12 Wt = h1-h2s;
13 Wp = h4s-h3;
14 n_cycle = 100*((Wt-Wp)/Q1);
15 Tm = (h1-h4s)/(s2s-sf);
16 disp("bar",P2,"The greatest allowable steam pressure
      at the turbine inlet is")
17 disp("%",n_cycle,"Rankine cycle efficiency is")
18 disp("K",Tm,"Mean temperature of heat addition is")

```

Scilab code Exa 12.4 Calculations on steam power plant

```

1 h1 = 3465; h2s = 3065; h3 = 3565;
2 h4s = 2300; x4s = 0.88; h5 = 191.83;
3 v = 0.001;
4 P = 150; // in bar
5 Wp = v*P*100;
6 h6s = 206.83;
7 Q1 = (h1-h6s)+(h3-h2s);
8 Wt = (h1-h2s)+(h3-h4s);
9 Wnet = Wt-Wp;
10 n_cycle = 100*Wnet/Q1;
11 sr = 3600/Wnet;
12 disp(0.88,"Quality at turbine exhaust is")
13 disp("%",n_cycle,"Cycle efficiency is")
14 disp("kg/kW h",sr,"steam rate is")

```

Scilab code Exa 12.5 Calculations on single heater regenerative cycle

```

1 h1 = 3230.9; s1 = 6.9212; s2 = s1; s3 = s1;
2 h2 = 2796; sf = 0.6493; sfg = 7.5009;
3 x3 = (s3-sf)/sfg;
4 h3 = 191.83 + x3*2392.8;
5 h4 = 191.83; h5 = h4;
6 h6 = 640.23; h7 = h6;
7 m = (h6-h5)/(h2-h5);
8 Wt = (h1-h2)+(1-m)*(h2-h3);
9 Q1 = h1-h6;
10 n_cycle = 100*Wt/Q1;
11 sr = 3600/Wt;
12 s7 = 1.8607; s4 = 0.6493;
13 Tm = (h1-h7)/(s1-s7);
14 Tm1 = (h1-h4)/(s1-s4); // With out regeneration
15 dT = Tm-Tm1;
16 Wt_ = h1-h3;
17 sr_ = 3600/Wt_;
18 dsr = sr-sr_;
19 n_cycle_ = 100*(h1-h3)/(h1-h4);
20 dn = n_cycle-n_cycle_;
21 disp("%",n_cycle,"Efficiency of the cycle is ")
22 disp("kg/kW h",sr,"Steam rate of the cycle is")
23 disp("degree centigrade",dT,"Increase in temperature
    due to regeneration is")
24 disp("kg/kW h",dsr,"Increase in steam rate due to
    regeneration is")
25 disp("%",dn,"Increase in Efficiency of the cycle due
    to regeneration is")

```

Scilab code Exa 12.6 Calculations on steam power plant

```

1 h1 = 3023.5; s1 = 6.7664; s2 = s1; s3 = s1; s4 = s1;
2 t_sat_20 = 212;
3 t_sat_1 = 46;
4 dt = t_sat_20-t_sat_1;

```

```

5 n =3; // number of heaters
6 t = dt/n;
7 t1 = t_sat_20-t;
8 t2 = t1-t;
9 // 0.1 bar
10 hf = 191.83; hfg = 2392.8; sf = 0.6493;
11 sg = 8.1502;
12 // At 100 degree
13 hf100 = 419.04; hfg100 = 2257.0; sf100 = 1.3069;
    sg100 = 7.3549;
14 // At 150 degree
15 hf150 = 632.20; hfg150 = 2114.3; sf150 = 1.8418;
    sg150 = 6.8379;
16 x2 = (s1-sf150)/4.9961;
17 h2 = hf150+(x2*hfg150);
18 x3 = (s1-sf100)/6.0480;
19 h3 = hf100+(x3*hfg100);
20 x4 = (s1-sf)/7.5010;
21 h4 = hf+(x4*hfg);
22 h5 = hf; h6 = h5;
23 h7 = hf100; h8 = h7;
24 h9 = 632.2; h10 = h9;
25 m1 = (h9-h7)/(h2-h7);
26 m2 = ((1-m1)*(h7-h6))/(h3-h6);
27 Wt = 1*(h1-h2)+(1-m1)*(h2-h3)+(1-m1-m2)*(h3-h4);
28 Q1 = h1-h9;
29 Wp = 0 ; // Pump work is neglected
30 n_cycle = 100*(Wt-Wp)/Q1;
31 sr = 3600/(Wt-Wp);
32 disp("kJ/kg",Wt,"Net work per kg os stem is")
33 disp("%",n_cycle,"Cycle efficiency is")
34 disp("kg/kW h",sr,"Stream rate is")

```

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


```

1 Ti = 2000;
2 Te = 450;
3 T0 = 300;
4 Q1_dot = 100e03; // in kW
5 cpg = 1.1;
6 wg = Q1_dot/(cpg*(Ti-Te));
7 af1 = wg*cpg*T0*((Ti/T0)-1-log(Ti/T0));
8 af2 = wg*cpg*T0*((Te/T0)-1-log(Te/T0));
9 afi = af1-af2;
10 h1 = 2801; h3 = 169; h4 = 172.8; h2 = 1890.2;
11 s1 = 6.068; s2 = s1; s3 = 0.576; s4 = s3;
12 Wt = h1-h2;
13 Wp = h4-h3;
14 Q1 = h1-h4;
15 Q2 = h2-h3;
16 Wnet = Wt-Wp;
17 ws = Q1_dot/2628;
18 afu = 38*(h1-h4-T0*(s1-s3));
19 I_dot = afi-afu;
20 Wnet_dot = ws*Wnet;
21 afc = ws*(h2-h3-T0*(s2-s3));
22 n2 = 100*Wnet_dot/af1;
23 disp("%",n2,"The second law efficiency is")

```

Scilab code Exa 12.8 Calculations on steam power plant

```

1 // Part (a)
2 h1 = 2758; h2 = 1817; h3 = 192; h4 = 200;
3 Wt = h1-h2; Wp = h4-h3;
4 Q1 = h1-h4; Wnet = Wt-Wp;
5 n1 = Wnet/Wt;
6 WR = Wnet/Wp;
7 Q1_ = 100;
8 PO = n1*Q1_;
9 cp = 1000;

```

```

10 wg = (Q1_/(833-450));
11 EIR = wg*cpg*((833-300)-300*(log(833/300)));
12 n2 = P0/EIR ;
13 disp(" Part (a)")
14 disp("%",n1*100,"n1 is")
15 disp("%",n2*100,"n2 is")
16 disp(WR,"Work ratio is")
17 // Part (b)
18 h1b = 3398; h2b = 2130; h3b = 192; h4b = 200;
19 Wtb = 1268; Wpb = 8; Q1b = 3198;
20 n1b = (Wt-Wp)/Q1;
21 WRb = (Wt-Wp)/Wt;
22 EIRb = 59.3;
23 Wnetb = Q1b*n1b;
24 n2b = Wnetb/EIRb;
25 disp(" Part (b)")
26 disp("%",n1b*100,"n1 is")
27 disp("%",n2b*100,"n2 is")
28 disp(WRb,"Work ratio is")
29 // Part (c)
30 h1c = 3398; h2c = 2761; h3c = 3482; h4c = 2522; h5c
    = 192; h6c = 200;
31 Wt1 = 637; Wt2 = 960; Wtc = Wt1+Wt2; Wpc = 8;
32 Wnetc = 1589; Q1c = 3198+721;
33 n1c = Wnetc/Q1c;
34 WRc = Wnetc/Wtc;
35 P0c = Q1_*n1c;
36 EIRc = 59.3;
37 n2c = P0c/EIRc;
38 disp(" Part (c)")
39 disp("%",n1c*100,"n1 is")
40 disp("%",n2c*100,"n2 is")
41 disp(WRc,"Work ratio is")
42 // Part (d)
43 T3 = 318.8; T1 = 568;
44 n1d = 1-(T3/T1);
45 Q1d = 2758-1316;
46 Wnet = Q1d*n1d;

```

```

47 Wpd = 8; Wtd = 641;
48 WRd = (Wt-Wp)/Wt;
49 P0d = Q1_*0.439;
50 EIRd = (Q1_/(833-593))*cpg*((833-300)-300*(log
      (833/300)));
51 n2d = P0d/EIRd;
52 disp(" Part (d)")
53 disp("%",n1d*100,"n1 is")
54 disp("%",n2d*100,"n2 is")
55 disp(WRd,"Work ratio is")

```

Scilab code Exa 12.9 Calculations on steam in a chemical plant

```

1 hfg = 2202.6;
2 Qh = 5.83;
3 ws = Qh/hfg;
4 eg = 0.9; // efficiency of generator
5 P = 1000;
6 Wnet = 1000/0.9;
7 nbrake = 0.8;
8 h1_2s = Wnet/(ws*nbrake); // h1-h2s
9 n_internal = 0.85;
10 h12 = n_internal*h1_2s;
11 hg = 2706.3; h2 = hg;
12 h1 = h12+h2;
13 h2s = h1-h1_2s;
14 hf = 503.71;
15 x2s = (h2s-hf)/hfg;
16 sf = 1.5276; sfg = 5.6020;
17 s2s = sf+(x2s*sfg);
18 s1 = s2s;
19 P1 = 22.5; // in bar from Moiller chart
20 t1 = 360;
21 disp(" degree",t1,"Temperature of the steam is")
22 disp(" bar",P1,"Pressure of the steam is ")

```

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

```
1 h1 = 3037.3; h2 = 561+(0.96*2163.8);
2 s2 = 1.6718+(0.96*5.3201);
3 s3s = s2;
4 x3s = (s3s-0.6493)/7.5009;
5 h3s = 191.83+(x3s*2392.8);
6 h23 = 0.8*(h2-h3s); // h2-h3
7 h3 = h2-h23;
8 h5 = 561.47; h4 = 191.83;
9 Qh = 3500; // in kJ/s
10 w = Qh/(h2-h5);
11 Wt = 1500;
12 ws = (Wt+w*(h2-h3))/(h1-h3);
13 ws_ = 3600*ws ; // in kg/h
14 h6 = ((ws-w)*h4+w*h5)/ws;
15 h7 = h6;
16 n_boiler = 0.85;
17 CV = 44000; // in kJ/kg
18 wf = (1.1*ws_*(h1-h7))/(n_boiler*CV);
19 disp("kg/h",wf,"Fuel burning rate is")
```

Scilab code Exa 12.11 Calculations on a steam turbine

```
1 h1 = 3285; h2s = 3010; h3 = 3280; h4s = 3030;
2 h4 = h3-0.83*(h3-h4s);
3 h5s = 2225;
4 h5 = h4-0.83*(h4-h5s);
5 h6 = 162.7; h7 = h6;
6 h8 = 762.81;
7 h2 = h1-0.785*(h1-h2s);
```

```

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

```

Scilab code Exa 12.12 Calculations on a binary vapour cycle

```

1 // From table and graph
2 h1 = 2792.2;
3 h4 = 122.96;
4 hb = 254.88;
5 hc = 29.98;
6 ha = 355.98;
7 hd = hc;
8 h2 = 1949.27;
9 //
10 m = (h1-h4)/(hb-hc); // Amount of mercury
    circulating
11 Q1t = m*(ha-hd);
12 W1t = m*(ha-hb) + (h1-h2);
13 Nov = W1t/Q1t ;
14 disp("%",Nov*100,"Overall efficiency of the cycle")
15 S = 50000; // Stem flow rate through turbine in kg/h
16 wm = S*m;
17 disp("kg/h",wm,"Flow through the mercury turbine is"
    )
18 Wt = W1t*S/3600;
19 disp("kW",Wt,"Useful work done in binary vapour
    cycle is")
20 nm = 0.85; // Internal efficiency of mercury turbine
21 ns = 0.87; // Internal efficiency of steam turbine
22 WTm = nm*(ha-hb);
23 hb_ = ha-WTm; // hb'
24 m_ = (h1-h4)/(hb_-hc); // m'

```

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

Chapter 13

Gas power cycle

Scilab code Exa 13.1 Calculations on otto cycle

```
1 T1 = 273+35;
2 P1 = 100e03; // in kN/m2
3 Q1 = 2100;
4 R = 0.287;
5 v1 = 0.884; v2 = 0.11; v3 = v2;
6 rk = 8; g = 1.4; // gamma
7 n_cycle = 1-(1/rk^(1.4-1));
8 v12 = 8; // v1/v2
9 v1 = (R*T1)/P1;
10 v2 = v1/8;
11 T2 = T1*(v1/v2)^(g-1);
12 cv = 0.718;
13 T3 = Q1/cv + T2
14 P21 = (v1/v2)^g;
15 P2 = P21*P1;
16 P3 = P2*(T3/T2);
17 Wnet = Q1*n_cycle;
18 Pm = Wnet/(v1-v2);
19 disp("MPa",P3/1e06,"Maximum pressure is")
20 disp("K",T3,"Temperature of the cycle is")
21 disp("%",n_cycle*100,"Cycle efficiency is")
```

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

Scilab code Exa 13.2 Calculations on a diesel engine

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

Scilab code Exa 13.3 Calculations on air standard diesel cycle

```
1 rk = 16;
2 T1 = 273+15;
3 P1 = 100; // in kN/m2
4 T3 = 1480+273;
5 g = 1.4; // gamma
6 R = 0.287;
7 T2 = 288*(rk^(g-1));
8 rc = T3/T2 ;
9 cp = 1.005; cv = 0.718;
10 Q1 = cp*(T3-T2);
11 T4 = T3*((rc/rk)^(g-1));
12 Q2 = cv*(T4-T1);
13 n = 1-(Q2/Q1); // cycle efficiency
14 n_ = 1-((1/g))*(1/rk^(g-1))*((rc^(g-1))/(rc-1)); //
   cycle efficiency from another formula
15 Wnet = Q1*n;
16 v1 = (R*T1)/P1 ;
17 v2 = v1/rk;
18 Pm = Wnet/(v1-v2);
```



```

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

```

Scilab code Exa 13.4 Calculations on air standard dual cycle

```

1 T1 = 273+50;
2 rk = 16;
3 g = 1.4; // gamma
4 P3 = 70; cv = 0.718; cp = 1.005; R = 0.287;
5 T2 = T1*((rk^(g-1)));
6 P1 = 1; // in bar
7 P2 = P1*(rk)^g;
8 T3 = T2*(P3/P2);
9 Q23 = cv*(T3-T2);
10 T4 = (Q23/cp)+T3;
11 v43 = T4/T3; // v4/v3
12 v54 = rk/v43; // v5/v4 = (v1/v2)*(v3/v4)
13 T5 = T4*(1/v54)^(g-1);
14 P5 = P1*(T5/T1);
15 Q1 = cv*(T3-T2)+cp*(T4-T3);
16 Q2 = cv*(T5-T1);
17 n_cycle = 1-(Q2/Q1);
18 v1 = (R*T1)/P1;
19 v12 = (15/16)*v1; // v1-v2
20 Wnet = Q1*n1;
21 Pm = Wnet/(v12);
22 disp("%",n*100,"Efficiency of the cycle is")
23 disp("bar",Pm,"Mean effective pressure is")

```

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

```

1 P1 = 0.1e06;
2 T1 = 303;
3 T3 = 1173;
4 PR = 6; // Pressure ratio
5 rp = 6; nt = 0.8; nc = 0.8;
6 g = 1.4; cv = 0.718; cp = 1.005; R = 0.287;
7 j = (PR)^((g-1)/g);
8 T2s = j*T1;
9 T4s = T3/j;
10 T21 = (T2s-T1)/nc ; // T2-T1
11 T34 = nt*(T3-T4s); // T3-T4
12 Wt = cp*T34;
13 Wc = cp*T21;
14 T2 = T21+T1;
15 Q1 = cp*(T3-T2);
16 n = (Wt-Wc)/Q1;
17 T4 = T3-375;
18 T6 = 0.75*(T4-T2) + T2 ;
19 Q1_ = cp*(T3-T6);
20 n_ = (Wt-Wc)/Q1_;
21 I = (n_-n)/n ;
22 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

```

1 cp = 1.005;
2 Tmax = 1073; Tmin = 300;
3 Wnet_max = cp*(sqrt(Tmax)-sqrt(Tmin))^2;
4 n_cycle = 1-sqrt(Tmin/Tmax);
5 n_carnot = 1-(Tmin/Tmax);
6 r = n_cycle/n_carnot;
7 disp("kJ/kg",Wnet_max,"Maximum work done per kg of
    air is")

```

```

8 disp("%",n_cycle*100,"cycle efficiency is")
9 disp(r,"ratio of brayton and carnot efficiency is")

```

Scilab code Exa 13.7 Calculations on an ideal bryton cycle

```

1 rp = 6;
2 g = 1.4; cv = 0.718; cp = 1.005; R = 0.287;
3 T1 = 300; T3 = 1100; T0 = 300;
4 n_cycle = 1-(1/rp^((g-1)/g));
5 j = rp^((g-1)/g);
6 T2 = T1*j;
7 T4 = T3/j;
8 Wc = cp*(T2-T1);
9 Wt = cp*(T3-T4);
10 WR = (Wt-Wc)/Wt;
11 Q1 = 100; // in MW
12 P0 = n_cycle*Q1;
13 m_dot = (Q1*1e06)/(cp*(T3-T2));
14 R = m_dot*cp*T0*((T4/T0)-1-log(T4/T0));
15 disp("%",n_cycle*100,"The thermal efficiency of the
    cycle is")
16 disp(WR,"Work ratio is")
17 disp("MW",P0,"Power output is")
18 disp("MW",R/1e06,"Energy flow rate of the exhaust
    gas stream is")

```

Scilab code Exa 13.8 Calculations on stationary gas turbine

```

1 nc = 0.87; nt = 0.9; T1 = 311;
2 rp = 8; // P2/P1
3 P1 = 1; P2 = 8; P3 = 0.95*P2; P4 = 1;
4 g = 1.4; cv = 0.718; cp = 1.005; R = 0.287;
5 // With no cooling

```

```

6 T2s = T1*((P2/P1)^((g-1)/g));
7 T2 = T1 + (T2s-T1)/0.87;
8 T4s = T3*(P4/P3)^((g-1)/g);
9 n = (((T3-T4s)*nt)-((T2s-T1)/nc))/(T3-T2);
10 // With cooling
11 n_cycle = n-0.05;
12 x = 0.13;
13 r = 0.13/1.13;
14 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 aircraft

```

1 T1 = 233; V1 = 300; cp = 1.005; g = 1.4;
2 T2 = T1+((V1^2)/(2*cp))*1e-03 ;
3 P1 = 35;
4 P2 = P1*(T2/T1)^(g/(g-1));
5 rp = 10; // Pressure ratio
6 P3 = rp*P2;
7 T3 = T2*(P3/P2)^((g-1)/g);
8 T4 = 1373;
9 T5 = T4-T3+T2;
10 P4 = P3;
11 P5 = P4*(T5/T4)^(g/(g-1));
12 disp("K",T5,"Temperature at the turbine exit is")
13 disp("kPa",P5,"Pressure at the turbine exit is")
14 P6 = P1;
15 T6 = T5*(P6/P5)^((g-1)/g);
16 V6 = (2*cp*1000*(T5-T6))^0.5 ;
17 disp("m/s",V6,"Velocity of the gas at the nozzle
    exit is")
18 w = 50;
19 Ve = V6; Vi = 300;
20 Wp_dot = w*Vi*(Ve-Vi);

```

```

21 h4 = 1373; h3 = 536.66;
22 Q1 = w*cp*(h4-h3); // in kJ/kg
23 np = Wp_dot/(Q1*1000);
24 disp("%",np*100,"The propulsive efficiency of the
    cycle is")

```

Scilab code Exa 13.11 Calculations on a combined GT ST plant

```

1 Ta = 288;
2 rp = 8; // Pb/Pa
3 g = 1.33; g1 = 1.44; cv = 0.718; cpa = 1.005; cpg =
    1.11; R = 0.287;
4 Tb = Ta*(rp)^((g1-1)/g1);
5 Tc = 1073; Tm = 800+273; Tmin = 100+273;
6 Td = Tc/(rp^((g-1)/g));
7 Wgt = cpg*(Tc-Td)-cpa*(Tb-Ta);
8 Q1 = cpg*(Tc-Tb);
9 Q1_ = cpg*(Tc-Td);
10 h1 = 3775; h2 = 2183; h3 = 138; h4 = h3;
11 Q1_st = h1-h3; // Q1'
12 Q_fe = cpg*(Tm-Tmin);
13 was = Q1_st/Q_fe; // wa/ws
14 Wst = h1-h2;
15 PO = 190e03; // in kW
16 ws = PO/(was*Wgt+Wst);
17 wa = was*ws;
18 CV = 43300; // in kJ/kg
19 waf = CV/(Q1+Q1_);
20 FEI = (wa/waf)*CV;
21 noA = PO/FEI;
22 disp(waf,"Air fuel ratio is")
23 disp("%",noA*100,"Overall efficiency of combined
    plant is")

```

Chapter 14

Refrigeration cycle

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

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

Scilab code Exa 14.2 Heat calculations on a refrigerator

```
1 h1 = 236.04; s1 = 0.9322; s2 = s1;
2 P2 = 0.8; // in MPa
3 h2 = 272.05; h3 = 93.42; h4 = h3;
4 m = 0.06; // mass flow rate
5 Q2 = m*(h1-h4);
6 Wc = m*(h2-h1);
7 Q1 = m*(h2-h4);
8 COP = Q2/Wc;
```

```

9 disp("kW",Q2,"The rate of heat removal is")
10 disp("kW",Wc,"Power input to the compressor is")
11 disp("kW",Q1,"The heat rejection rate in the
    condenser is")
12 disp(COP,"COP is")

```

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

```

1 h1 = 183.19; h2 = 209.41; h3 = 74.59; h4 = h3;
2 T1 = 313; T2 = 263;
3 W = 70000/3600; // Plant capacity in kW
4 w = W/(h1-h4); // Refrigerant flow rate
5 v1 = 0.077;
6 VFR = w*v1;
7 T = 48; // in degree
8 P2 = 9.6066; P1 = 2.1912;
9 rp = P2/P1; // Pressure ratio
10 Q1 = w*(h2-h3);
11 hf = 26.87; hfg = 156.31;
12 x4 = (h4-hf)/hfg;
13 COP = (h1-h4)/(h2-h1);
14 PI = w*(h2-h1);
15 COP = T2/(T1-T2);
16 COP_v = 4.14;
17 r = COP_v/COP;
18 disp("kg/s",w,"Refrigerant flow rate is")
19 disp("m3/s",VFR,"Volume flow rate is")
20 disp("degree",T,"Compressor discharge temperature is
    ")
21 disp(rp,"Pressure ratio is")
22 disp("kW",Q1,"Heat rejected to the condenser is")
23 disp("%",x4*100,"Flash gas percentage is")
24 disp(COP,"COP is")
25 disp("kW",PI,"Power required to drive the compressor
    is")

```

26 `disp(r,"Ratio of COP of carnot refrigerator is")`

Scilab code Exa 14.4 Calculations on R 12 vapour compression plant

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

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


```

1 P2 = 1554.3;
2 P1 = 119.5;
3 Pi = sqrt(P1*P2);
4 h1 = 1404.6; h2 = 1574.3; h3 = 1443.5; h4 = 1628.1;
5 h5 = 371.7; h6 = h5; h7 = 181.5;
6 w = 30; // capacity of plant
7 m2_dot = (3.89*30)/(h1-h7);
8 m1_dot = m2_dot*((h2-h7)/(h3-h6));
9 Wc_dot = m2_dot*(h2-h1)+m1_dot*(h4-h3);
10 COP = w*3.89/Wc_dot;
11 // single stage
12 h1_ = 1404.6; h2_ = 1805.1;
13 h3_ = 371.1; h4_ = h3_;
14 m_dot = (3.89*30)/(h1_-h4_);
15 Wc = m_dot*(h2_-h1_);
16 COP_ = w*3.89/Wc;
17 IW = (Wc-Wc_dot)/Wc_dot;
18 ICOP = (COP-COP_)/COP_
19 disp("%",IW*100,"Increase in work of compression is"
)
20 disp("%",ICOP*100,"Increase in COP for 2 stage
compression is")

```

Scilab code Exa 14.6 Estimation of COP of refrigeration

```

1 tsat = 120.2+273; hfg = 2201.9;
2 T1 = 120.2+273;
3 T2 = 30+273;
4 Tr = -10+273;
5 COP_max = ((T1-T2)*Tr)/((T2-Tr)*T1);
6 ACOP = 0.4*COP_max;
7 Qe = (20*14000)/3600; // in KW
8 Qg = Qe/ACOP;
9 x = 0.9;
10 H = x*hfg;

```

```

11 SFR = Qg/H;
12 disp("kg/s",SFR,"Steam flow rate required is")

```

Scilab code Exa 14.7 Calculations on a aircraft cooling system

```

1 T1 = 277; T3 = 273+55;
2 rp = 3; // Pressure ratio
3 g = 1.4; cp = 1.005;
4 T2s = T1*(rp^((g-1)/g));
5 T2 = T1+(T2s-T1)/0.72
6 T4s = T3/(rp^((g-1)/g));
7 T34 = 0.78*(T3-T4s); // T3-T4
8 T4 = T3-T34;
9 COP = (T1-T4)/((T2-T1)-(T3-T4));
10 disp(COP,"COP of the refrigerator is")
11 P = (3*14000)/(COP*3600)
12 disp("kW",P,"Driving power required is")
13 m = (3*14000)/(cp*(T1-T4));
14 disp("kg/s",m/3600,"Mass flow rate is")

```

Scilab code Exa 14.8 Calculations on a vapour compression heat pump

```

1 P1 = 2.4; T1 = 0+273;
2 h1 = 188.9; s1 = 0.7177; v1 = 0.0703;
3 P2 = 9; T2 = 60+273;
4 h2 = 219.37;
5 h2s = 213.27;
6 h3 = 71.93; h4 = h3;
7 v1 = 0.0703;
8 A1V1 = 0.6/60;
9 m_dot = A1V1/0.0703;
10 Wc_dot = m_dot*(h2-h1);
11 Q1_dot = m_dot*(h2-h3);

```

```

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

```

Scilab code Exa 14.9 Calculations on air refrigeration system cycle

```

1 T1 = 275; T3 = 310;
2 P1 = 1 ; P2 = 4;
3 T2s = T1*(P2/P1);
4 nc = 0.8;
5 T2 = T1 + (T2s-T1)*nc;
6 pr = 0.1;
7 P3 = P2-0.1;
8 P4 = P1+0.08;
9 PR = P3/P4;
10 disp(PR,"Pressure ratio for the turbine is")
11 T4s = T3*(1/PR)^(0.286);
12 nt = 0.85;
13 T4 = T3-(T3-T4s)*nt;
14 COP = (T1-T4)/((T2-T3)-(T1-T4));
15 disp(COP,"COP is")

```

Chapter 15

Psychrometrics

Scilab code Exa 15.1 Calculations on atmospheric air

```
1 Ps = 0.033363; P = 1.0132;
2 W2 = (0.622*Ps)/(P-Ps);
3 hfg2 = 2439.9; hf2 = 109.1; cpa = 1.005;
4 hg = 2559.9; hw1 = hg;
5 T2 = 25+273; T1 = 32+273;
6 W1 = (cpa*(T2-T1)+(W2*hfg2))/(hw1-hf2);
7 Pw = ((W1/0.622)*P)/(1+(W1/0.622));
8 disp("kg vap./kg dry air",W1,"Specific humidity is")
9 disp("bar",Pw,"Partial pressure of water vapour is")
10 disp("degree",24.1,"Dew point temperature is") //
    saturation temperature at 0.03 bar
11 Psat = 0.048; // at 32 degree
12 fi = Pw/Psat;
13 disp("%",fi*100,"Relative humidity is")
14 mu = (Pw/Ps)*((P-Ps)/(P-Pw));
15 disp(mu,"Degree of saturation is")
16 Pa = P-Pw;
17 Ra = 0.287; Tab = T1;
18 rho_a = (Pa*100)/(Ra*Tab);
19 disp("kg/m3",rho_a,"Density of dry air is")
20 rho_w = W1*rho_a;
```

```

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

```

Scilab code Exa 15.2 Calculating the humidity of air water mixture

```

1 Ps = 2.339; P = 100;
2 W2 = (0.622*Ps)/(P-Ps);
3 hfg2 = 2454.1; hf2 = 83.96; cpa = 1.005;
4 hw1 = 2556.3;
5 T2 = 20; T1 = 30;
6 W1 = (cpa*(T2-T1)+(W2*hfg2))/(hw1-hf2);
7 Pw1 = ((W1/0.622)*P)/(1+(W1/0.622));
8 Ps1 = 4.246;
9 fi = (Pw1/Ps1);
10 disp("%",fi*100,"Relative humidity is")
11 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

```

1 Psat = 2.339;
2 fi3 = 0.50;
3 P = 101.3; cp = 1.005;
4 Pw3 = fi3*Psat;
5 Pa3 = P-Pw3;
6 W3 = 0.622*(Pw3/Pa3);
7 Psa1_1 = 0.7156;
8 Pw1 = 0.7156;
9 Pa1 = P-Pw1;
10 W1 = 0.622*(Pw1/Pa1); W2 = W1;
11 T3 = 293; Ra = 0.287; Pa3 = 100.13;

```

```

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

```

Scilab code Exa 15.4 Calculations on an air conditioning system

```

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

```

Scilab code Exa 15.5 Calculation on air mixed with RH

```

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

```

Scilab code Exa 15.7 Calculation on the airconditioning of a hall

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

Scilab code Exa 15.8 Calculations on water into a cooling tower

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

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

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

```
1 Psat1 = 0.01705; hg1 = 2528.9; // at 15 degree
2 Psat2 = 0.05628; hg2 = 2565.3; // At 35 degree
3 fi1 = 0.55;
4 Pw1 = fi1*Psat1;
5 fi2 = 1;
6 Pw2 = fi2*Psat2;
7 P = 1;
8 W1 = (0.622*Pw1)/(P-Pw1);
9 W2 = (0.622*Pw2)/(P-Pw2);
10 MW = W2-W1;
11 t2 = 35; t1 = 15;
12 m_dot = 2.78;
13 cpa = 1.005;
14 h43 = 35*4.187; // h4-h3
15 h5 = 14*4.187;
16 m_dot_w = (-(W2-W1)*h5 - W1*hg1 + W2*hg2 + cpa*(t2-
    t1))/(h43) ;
17 R = m_dot/m_dot_w ;
18 MW = (W2-W1)*R;
19 RWA = R*(1+W1);
20 R = 0.287; T = 288;
21 V_dot = (RWA*R*T)/(P*1e02) ; // Pressure is in kilo
    Pascal
22 disp("kg/s",MW,"Make up water flow rate is")
23 disp("m3/s",V_dot,"Volume flow rate of air is")
```

Chapter 16

Reactive systems

Scilab code Exa 16.2 Dissociation calculation on N2O4

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

Scilab code Exa 16.3 Determination of gubbs constant and equilibrium function

```
1 v1 = 1; v2 = v1; v3 = v2; v4 = v2;
2 e = 0.56; // Degree of reaction
3 P = 1; // Dummy
4 T = 1200; R = 8.3143;
```

```

5 x1 = (1-e)/2; x2 = (1-e)/2;
6 x3 = e/2; x4 = e/2;
7 K = (((x3^v3)*(x4^v4))/((x1^v1)*(x2^v2)))*P^(v3+v4-
      v1-v2); // Equilibrium constant
8 dG = -R*T*log(K);
9 disp(K,"Equilibrium constant is")
10 disp("J/gmol",dG,"Gibbs function change is")

```

Scilab code Exa 16.5 Calculation of equilibrium constant

```

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

```

Scilab code Exa 16.6 Estimation of Cp of H2O dissociation

```

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

```

Scilab code Exa 16.7 Calculations on combustion of unknown hydrocarbon

```

1 a = 21.89;

```

```

2 y = 18.5;
3 x = 8.9;
4 PC = 100*(x*12)/((8.9*12)+(18.5*1));
5 PH = 100-PC;
6 AFR = ((32*a)+(3.76*a*28))/((12*x)+y);
7 EAU = (8.8*32)/((21.89*32)-(8.8*32));
8 disp("%",PH," Hydrogen", "%",PC," carbon", "The
    composition of fuel is")
9 disp(AFR," Air fuel ratio is")
10 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

```

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

```

Scilab code Exa 16.9 Calculations on a gasoline engine

```

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

```

Scilab code Exa 16.10 Calculations on burning of liquid octane

```
1 Hr1 = -249952; // For octane
2 Hp1 = Hr1;
3 // Below values are calculated using value from
  table 16.4
4 T2 = 1000;
5 Hp2 = -1226577
6 T3 = 1200;
7 Hp3 = 46537;
8 T4 = 1100;
9 Hp4 = -595964;
10 Hp = [Hp2 Hp3 Hp4]
11 T = [T2 T3 T4]
12 T1 = interpln([Hp ; T],Hp1); // Interpolation to
  find temperature at Hp1
13 disp("K",T1,"the adeabatic flame temperature is")
```

Scilab code Exa 16.11 Calculations on burning of gaseous propane

```
1 // Refer table 16.4 for values
2 T0 = 298;
3 Wrev = -23316-3*(-394374)-4*(-228583);
4 Wrev_ = Wrev/44; // in kJ/kg
5 Hr = -103847;
6 T = 980; // Through trial and error
7 Sr = 270.019+20*205.142+75.2*191.611;
8 Sp = 3*268.194 + 4*231.849 + 15*242.855 +
  75.2*227.485;
9 IE = Sp-Sr; // Increase in entropy
10 I = T0*3699.67/44;
11 Si = Wrev_ - I;
```

```

12 disp("kJ/kg",Wrev_," Reversible work is")
13 disp("kJ/kg mol K",Sp-Sr,"Increase in entropy during
    combustion is")
14 disp("kJ/kg",I," Irreversibility of the process")
15 disp("kJ/kg",Si," Availability of products of
    combustion is")

```

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

```

1 T0 = 298.15; P0 = 1; R = 8.3143;
2 xn2 = 0.7567; xo2 = 0.2035; xh2o = 0.0312; xco2 =
    0.0003;
3 // Part (a)
4 g_o2 = 0; g_c = 0; g_co2 = -394380;
5 A = -g_co2 + R*T0*log(xo2/xco2);
6 disp("kJ/k mol",A,"The chemical energy of carbon is")
    )
7 // Part (b)
8 g_h2 = 0; g_h2o_g = -228590;
9 B = g_h2 + g_o2/2 - g_h2o_g + R*T0*log(xo2^0.5/xh2o)
    ;
10 disp("kJ/k mol",B,"The chemical energy of hydrogen
    is")
11 // Part (c)
12 g_ch4 = -50790;
13 C = g_ch4 + 2*g_o2 - g_co2 - 2*g_h2o_g + R*T0*log((
    xo2^2)/(xco2*xh2o));
14 disp("kJ/k mol",C,"The chemical energy of methane is
    ")
15 // Part (d)
16 g_co = -137150;
17 D = g_co + g_o2/2 - g_co2 + R*T0*log((xo2^0.5)/xco2
    );
18 disp("kJ/k mol",D,"The chemical energy of

```

```

Carbonmonoxide is")
19 // Part (e)
20 g_ch3oh = -166240;
21 E = g_ch3oh + 1.5*g_o2 - g_co2 - 2*g_h2o_g + R*T0*
    log((xo2^1.5)/(xco2*(xh2o^2)))
22 disp("kJ/k mol",E,"The chemical energy of methanol
    is")
23 // Part (f)
24 F = R*T0*log(1/xn2);
25 disp("kJ/k mol",F,"The chemical energy of nitrogen
    is")
26 // Part (g)
27 G = R*T0*log(1/xo2);
28 disp("kJ/k mol",G,"The chemical energy of Oxygen is"
    )
29 // Part (h)
30 H = R*T0*log(1/xco2);
31 disp("kJ/k mol",H,"The chemical energy of
    carbondioxide is")
32 // Part (i)
33 g_h2o_l = -237180;
34 I = g_h2o_l - g_h2o_g + R*T0*log(1/xh2o);
35 disp("kJ/k mol",I,"The chemical energy of water is")

```

Scilab code Exa 16.13 Calculation on burning of liquid octane

```

1 b = 8/(0.114+0.029); // By carbon balance
2 C = 18/2; // By hydrogen balance
3 a = b*0.114 + (b/2)*0.029 + b*0.016 + C/2 ; // By
    oxygen balance
4 Wcv = 1; // Power developed by engine in kW
5 n_fuel = (0.57*1)/(3600*114.22);
6 Qcv = Wcv-n_fuel*3845872; // 5.33
7 disp("kW",Qcv,"The rate of heat transfer from the
    engine is")

```

```
8 // Part (b)
9 ach = 5407843; // chemical energy of liquid octane
10 n2 = Wcv/(n_fuel*ach);
11 disp("%",n2*100,"The second law efficiency is")
```

Chapter 17

Compressible fluid flow

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

```
1 T0 = 37+273; P = 40; g = 1.4;
2 function [x] = speed(a,b,f)
3     N = 100;
4     eps = 1e-5;
5     if((f(a)*f(b))>0) then
6         error('no root possible f(a)*f(b)>0');
7         abort;
8     end;
9     if(abs(f(a))<eps) then
10        error('solution at a');
11        abort;
12    end
13    if(abs(f(b))<eps) then
14        error('solution at b');
15        abort;
16    end
17    while(N>0)
18        c = (a+b)/2
19        if(abs(f(c))<eps) then
20            x = c ;
21            x;
```



```

22     return;
23 end;
24 if((f(a)*f(c))<0 ) then
25     b = c ;
26 else
27     a = c ;
28 end
29 N = N-1;
30 end
31 error('no convergence');
32 abort;
33 endfunction
34
35 deff(' [y]=p(x) ', ['y = x^4 + (5*(x^2)) - 3.225 '])
36 x = speed(0.5,1,p);
37 M = x; // Mach number
38 g = 1.4; // gamma
39 R = 0.287;
40 T = T0/(1+((g-1)/2)*M^2);
41 c = sqrt(g*R*T*1000);
42 V = c*M;
43 P0 = P*((T0/T)^(g/(g-1)));
44 disp(M,"Mach number is")
45 disp("m/s",V,"Velocity is")
46 disp("kPa",P0,"Stagnation pressure is")

```

Scilab code Exa 17.2 Calculations on canonical air diffuser

```

1 P1 = 0.18e03; // in Kpa
2 R = 0.287; T1 = 310; P0 = 0.1e03;
3 A1 = 0.11; V1 = 267;
4 w = (P1/(R*T1))*A1*V1;
5 g = 1.4;
6 c1 = sqrt(g*R*T1*1000);
7 M1 = V1/c1;

```

```

8 A1A_ = 1.0570; // A1/A* A* = A_
9 P1P01 = 0.68207;
10 T1T01 = 0.89644;
11 F1F_ = 1.0284;
12 A2A1 = 0.44/0.11 ; // A2A1 = A2/A1
13 A2A_ = A2A1*A1A_;
14 M2 = 0.135; P2P02 = 0.987; T2T02 = 0.996; F2F_ =
    3.46;
15 P2P1 = P2P02/P1P01;
16 T2T1 = T2T02/T1T01;
17 F2F1 = F2F_/F1F_;
18 P2 = P2P1*P1;
19 T2 = T2T1*T1;
20 A2 = A2A1*A1;
21 F1 = P1*A1*(1+g*M1^2);
22 F2 = F2F1*F1;
23 Tint = F2-F1;
24 Text = P0*(A2-A1);
25 NT = Tint - Text ;
26 disp("kN",NT,"Net thrust is")

```

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

```

1 M2 = 2.197; P2P0 = 0.0939; T2T0 = 0.5089;
2 P0 = 1000; T0 = 360; g = 1.4; R = 0.287;
3 P2 = P2P0*P0;
4 T2 = T2T0*T0;
5 c2 = sqrt(g*R*T2*1000);
6 V2 = c2*M2;
7 // for air
8 P_P0 = 0.528; T_T0 = 0.833; // T_ == T*
9 P_ = P_P0*P0; T_ = T_T0*T0;
10 rho_ = P_/(R*T_);
11 V_ = sqrt(g*R*T_*1000);

```

```

12 At = 500e-06; // throat area
13 w = At*V_*rho_;
14 disp("When divergent section act as a nozzle")
15 disp("kg/s",w,"Maximum flow rate of air is")
16 disp("K",T2,"Static temperature is")
17 disp("kPa",P2,"Static Pressure is")
18 disp("m/s",V2,"Velocity at the exit from the nozzle
    is")
19 // Part (b)
20 Mb = 0.308;
21 P2P0b = 0.936;
22 T2T0b = 0.9812;
23 P2b = P2P0b*P0;
24 T2b = T2T0b*T0;
25 c2b = sqrt(g*R*T2b*1000);
26 V2b = c2b*Mb;
27 disp("When divergent section act as a diffuser")
28 disp("kg/s",w,"Maximum flow rate of air is")
29 disp("K",T2b,"Static temperature is")
30 disp("kPa",P2b,"Static Pressure is")
31 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

```

1 Px = 16kPa; Poy = 70kPa;
2 Mx = 1.735; Pyx = 3.34; // Pyx = Py/Px
3 rho_yx = 2.25;
4 Tyx = 1.483; Poyox = 0.84; My = 0.631;
5 Tox = 573; Toy = Tox;
6 Tx = Tox/(1+((g-1)/2)*Mx^2);
7 Ty = Tyx*Tx;
8 Pox = Poy/Poyox ;
9 // From table

```

```

10 Mx = 1.735;
11 disp(Mx,"Mach number of the tunnel is")

```

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

```

1 Ax = 18.75; A_ = 12.50; // A_ = A*
2 AA_ = 1.5; // A/A*
3 Mx = 1.86; PxoX = 0.159; R = 0.287;
4 Pox = 0.21e03; // in kPa
5 Px = PxoX*Pox;
6 // from the gas table on normal shock
7 Mx = 1.86; My = 0.604; Pyx = 3.87; Poyx = 4.95;
   Poyox = 0.786;
8 Py = Pyx*Px;
9 Poy = Poyx*Px;
10 My = 0.604;
11 Ay_ = 1.183;
12 A2 = 25; Ay = 18.75;
13 A2_ = (A2/Ay)*Ay_;
14 // From isentropic table
15 M2 = 0.402;
16 P2oy = 0.895;
17 P2 = P2oy*Poy;
18 syx = -R*log(Poy/Pox); // sy-sx
19 disp(M2,"Exit mach number is M2")
20 disp("kPa",P2,"Exit pressure is")
21 disp("kPa",Pox-Poy,"Exit Stagnation pressure is")
22 disp("kJ/kg K",syx,"Entropy increase is")

```

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

```

1 g = 1.4; R = 0.287; d = 1.4; // del
2 P0 = 1.4; // in bar
3 T0 = 280; T1 = T0;
4 cp = 1.005; A2 = 0.0013
5 P_ = P0/((g+1)/2)^(d/(d-1)) ; // P_ = P*
6 P1 = P0; Pb = 1; P2 = Pb;
7 T2 = T1*(P2/P1)^((d-1)/d);
8 V2 = sqrt(2*cp*(T1-T2)*1000);
9 m_dot = (A2*V2*P2*100)/(R*T2);
10 disp("kg/s",m_dot,"Mass flow rate is")
11 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

```

1 Mx = 1.8; Pyx = 3.6133;
2 Px = 0.5; Tx = 280; Ty = 429;
3 Py = Pyx*Px; cp = 1.005;
4 disp("bar",Py,"Pressure Py is")
5 Pxox = 0.17404;
6 Pox = Px/Pxox;
7 disp("bar",Pox,"Stagnation pressure is")
8 Txox = 0.60680;
9 Tox = Tx/Txox;
10 disp("K",Tox,"Stagnation temperature is")
11 sysx = cp*log(Ty/Tx)-R*log(Py/Px);
12 disp("kJ/kg K",sysx,"The change in specific entropy
    is")

```

Chapter 18

Gas compressors

Scilab code Exa 18.1 Calculations on a single reciprocating compressor

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

Scilab code Exa 18.2 Calculations on a single reciprocating air compressor

```
1 P1 = 101.3e03; P4 = P1; // in Pa
2 P2 = 8*P1; P3 = P2;
3 T1 = 288; Vs = 2000;
4 V3 = 100; Vc = V3;
5 V1 = Vs + Vc ;
6 n = 1.25; R = 287;
7 V4 = ((P3/P4)^(1/n))*V3;
8 W = ((n*P1*(V1-V4)*1e-06)/(n-1))*(((P2/P1)^((n-1)/n)
    )-1);
9 P = (W*800*0.001)/60 ;
10 disp("kW",P,"Indicated poer is")
11 disp("%",100*(V1-V4)/Vs,"Volumetric efficiency is")
12 m = (P1*(V1-V4)*1e-06)/(R*T1);
13 m_dot = m*800;
14 disp("kg/min",m_dot,"Mass flow rate is")
15 FAD = (V1-V4)*1e-06*800;
16 disp("m3/min",FAD,"Free air delivery is")
17 Wt = P1*(V1-V4)*1e-06*log(P2/P1);
18 n_isothermal = (Wt*800*0.001)/(P*60);
19 disp("%",100*n_isothermal,"Isothermal efficiency is"
    )
20 Pi = P/0.85;
21 disp("kW",Pi,"Input power is")
```

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

```
1 P1 = 1; P3 = 9;
```

```

2 P2 = sqrt(P1*P3);
3 T1 = 300; cp = 1.005;
4 R = 0.287; n = 1.3;
5 W = ((2*n*R*T1)/(n-1))*((P2/P1)^((n-1)/n)-1);
6 T2 = T1*(P2/P1)^((n-1)/n);
7 H = cp*(T2-T1);
8 disp("kJ/kg",H,"Heat rejected to the intercooler is"
)

```

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

```

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

```

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


```

1 V12 = 0.4; // V12 = V1/V2
2 T1 = 38+273; n = 1.3; P3 = 112; // back pressure
3 m = 1.25; R = 0.287;
4 T2 = ((V12)^(n-1))*T1;
5 P1 = 700; // in kPa
6 P2 = P1*(V12)^n;
7 V2 = (m*R*T2)/P2;
8 v2 = V2/m ;
9 A = R*T1 + R*(T1-T2)/(n-1) - P3*v2; // Area of
    indicator diagram
10 IO = A*0.85*m;
11 disp("kJ",IO,"Indicated output is")

```

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

```

1 P1 = 1; P41 = 15; // P41 = P4/P1
2 P21 = (P41)^(1/3);
3 P2 = P21*P1; n = 1.3; R = 0.287;
4 P3 = P21*P2;
5 P11 = P2; P12 = P1;
6 b = 0.45; s = 0.3; // Bore and stroke of cylinder
7 Vs = (%pi/4)*b^2*s; // Swept volume of the cylinder
8 V11 = 0.05*Vs; // Clearance volume
9 V1 = V11+Vs;
10 V12 = V11*(P11/P12)^(1/n);
11 disp("m3",V1-V12,"Effective swept volume of the LP
    cylinder is")
12 T1 = 291; T3 = T1; T5 = T1;
13 P43 = P21; // P4/P3
14 T6 = T5*(P43)^((n-1)/n);
15 disp("K",T6,"Delivery temperature is")
16 P4 = 15; // Delivery pressure
17 V6_7 = (P1/P4)*(T6/T1)*(V1-V12); // V6-V7
18 disp("m3",V6_7,"Volume of the air delivered")

```

```

19 W = ((3*n*R*T1)/(n-1))*((P21)^(n-1)/n)-1);
20 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

```

1 P1 = 1.013;
2 P2 = 1.5*P1;
3 Vs = 0.03; Va = Vs;
4 WD = (P2-P1)*Vs*100;
5 Pi = (P1+P2)/2;
6 g = 1.4;
7 Aa = ((g*P1*100*Vs)/(g-1))*((Pi/P1)^((g-1)/g)-1);
8 Vb = Va *(P1/Pi)^(1/g);
9 Ab = Vb*(P2-Pi)*100;
10 WR = Aa+Ab;
11 disp("kJ/rev",WR,"Work required is")

```

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

```

1 // For Blower
2 m_dot = 1; R = 0.287; T1 = 343;
3 P1 = 100; P2 = 2*P1; g = 1.4;
4 V_dot = (m_dot*R*T1)/P1;
5 PRb = V_dot*(P2-P1);
6 disp("kW",PRb,"Power required by the blower is")
7 // For van compressor
8 P1v = 1; V21 = 0.7 // V2/V1
9 P2v = P1v*(1/V12)^g;
10 V2_dot = 0.7;
11 V1_dot = 0.7*V_dot;
12 P3v = 2;

```

```

13 PRv = ((g*P1v*100*V_dot)/(g-1))*((P2v/P1v)^((g-1)/g)
      -1) + V1_dot*100*(P3v-P2v);
14 disp("kW",PRv,"Power Required by van compressor is")

```

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

```

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

```

Scilab code Exa 18.10 Calculations on a rotary compressor

```

1 T1 = 278; P21 = 2.5; // P2/P1
2 cp = 1.005; ns = 0.84; V2 = 120;
3 T2s = T1*(P21)^((g-1)/g);
4 T2 = T1 + (T2s-T1)/ns;
5 mg = 0.04*(13+1);
6 P = mg*cp*(T2-T1);
7 T02 = T2 + V2^2/(2*cp*1000);
8 P1 = 0.6;
9 P2 = P21*0.6;
10 P02 = P2*(T02/T2)^(g/(g-1));
11 disp("kW",P,"Power required to drive the compressor
      is")
12 disp("K",T02,"Stagnation temperature is")

```

```
13 disp(" bar",P02," Stagnation pressure is")
```
