

Scilab Textbook Companion for
Basic Engineering Thermodynamics
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June 1, 2016

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

Book Description

Title: Basic Engineering Thermodynamics

Author: A. Venkatesh

Publisher: Universities Press, Hyderabad

Edition: 1

Year: 2009

ISBN: 978-81-7371-587-7

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes	4
1 Fundamental Concepts and Definitions	6
2 Work	11
3 Temperature and Heat	20
4 The First Law of Thermodynamics for Systems Pure Substances	24
5 First Law of Thermodynamics for Control Volumes	28
6 Heat Engines The Second Law of Thermodynamics	37
7 Reversibility and the Thermodynamics Temperature Scale	40
8 Entropy Available and Unavailable Energy	44
9 Ideal Gas and Ideal Gas Mixtures	53
10 Properties of Pure Substance Water	69
11 Real Gas	80
12 Fuels and Combustion	87

List of Scilab Codes

Exa 1.1	Find velocity of a body	6
Exa 1.2	Find the force acting on the body	7
Exa 1.3	Find the weight of body	7
Exa 1.4	Find the steam pressures in kPa	8
Exa 1.5	Find specific volume and density	9
Exa 1.6	Find equivalent temperature in Kelvin scale	9
Exa 1.7	Find corresponding temperature in degree Celsius	10
Exa 2.1	Find the work done by the force	11
Exa 2.2	Find magnitude and direction of work	12
Exa 2.3	Identify interaction between battery and resistor	12
Exa 2.4	Calculate magnitude and direction of work	13
Exa 2.5	Find the work interaction	14
Exa 2.6	Find the work of compression for air	15
Exa 2.7	Find the mep and indicated power	16
Exa 2.8	Find the mechanical efficiency of engine	17
Exa 2.9	Compute net work for battery and motor	18
Exa 3.1	Temperature in degree Celsius and Fahrenheit	20
Exa 3.2	Find temperature in Kelvin	21
Exa 3.3	Find temperature in degree Celsius	21
Exa 3.4	Determine what A reads when B reads 30	21
Exa 3.5	Find the temperature attained by the coil	22
Exa 3.6	Find thermometer reading when gas thermometer reads 50 degree C	23
Exa 4.1	Find the magnitude and direction of the fourth work interaction	24
Exa 4.2	Find the change in energy of the system and find the magnitude and direction of work done during B	25
Exa 4.3	Evaluate total energy of the system	26

Exa 4.4	Find Cv and Cp	26
Exa 4.5	Show that work done on system is equal to increase in enthalpy	27
Exa 5.1	Find work output	28
Exa 5.2	Find the change in enthalpy across the turbine	29
Exa 5.3	Determine the temperature at the inlet and power developed	30
Exa 5.4	Find the inlet and exit velocities	31
Exa 5.5	Find the temperature of air after throttling	32
Exa 5.6	Calculate the work input to the compressor	33
Exa 5.7	Find the mass flow rate of cooling water	33
Exa 5.8	Find the mass flow rate of cooling water if the heat loss to surrounding is 10 percent of heat transferred from steam to cooling water	34
Exa 5.9	Find the inlet air temperature	35
Exa 5.10	Find the mass of air entering and the final temperature of the air in the vessel	35
Exa 5.11	Show relation between mass and pressure ratios	36
Exa 6.1	Find the heat rejected at the condenser and the thermal efficiency of the plant	37
Exa 6.2	Find the rate of heat transfer power input and COP	38
Exa 6.3	Find savings in the monthly electricity bill	39
Exa 7.1	Fiind the work output of the engine and the magnitude of heat interaction	40
Exa 7.2	Evaluate validity of claim	41
Exa 7.3	Comment on internal and external reversibility	42
Exa 7.4	Find efficiency	42
Exa 7.5	Find COP	43
Exa 8.1	Clausius inequality	44
Exa 8.2	Find change in entropy	44
Exa 8.3	Find change in entropy if reservoir temperature is 100 degree Celsius	45
Exa 8.4	Find the change in entropy for paddle stirred gas	46
Exa 8.5	Identify possible and impossible processes	46
Exa 8.6	Identify processes as reversible irreversible or impossible	46
Exa 8.7	State whether entropy change of the universe is positive negative or zero	47
Exa 8.8	Determine the change in entropy	47

Exa 8.9	Find the change in entropy	47
Exa 8.10	Find the change in entropy during melting process . .	48
Exa 8.11	Can system undergo isentropic process	48
Exa 8.12	Find direction of flow of air	48
Exa 8.13	Find the change in entropy	49
Exa 8.14	Find the available and unavailable parts of 100 kJ heat	50
Exa 8.15	Evaluate the increase in unavailable energy	51
Exa 8.16	What are the available and unavailable energies	52
Exa 9.1	What is the volume occupied by Nitrogen	53
Exa 9.2	Find the final volume	53
Exa 9.3	Find internal energy and enthalpy	54
Exa 9.4	Calculate the value of Cp for air	55
Exa 9.5	Calculate the increase in specific enthalpy and change in enthalpy	55
Exa 9.6	Find the final temperature of air	56
Exa 9.7	Find the enthalpy entropy and internal energy of Nitro- gen	58
Exa 9.8	Calculate work per kilogram of air and change in entropy	60
Exa 9.9	Find the molar mass and the gas constant of the mixture	61
Exa 9.10	Find the molar mass and gas constant for the mixture and mole fractions partial pressures and partial volumes of the constituents	62
Exa 9.11	Evaluate the mass fraction and volume fractions of ni- trogen and hydrogen in the mixture	63
Exa 9.12	Determine specific heat internal energy enthalpy and entropy change	64
Exa 9.13	Calculate magnitude and direction of heat transfer and pressure of the mixture	66
Exa 9.14	Determine mixture temperature and rate of entropy gen- eration	67
Exa 10.1	Find dryness fraction of mixture	69
Exa 10.2	Find ratio of mass of saturated liquid to saturated steam	69
Exa 10.3	Find volume enthalpy internal energy and entropy per kg water	70
Exa 10.4	Find temperature and all other specific properties . . .	71
Exa 10.5	Find other properties of water	71
Exa 10.6	Find all other properties of steam	72
Exa 10.7	Find all other thermodynamic properties	73

Exa 10.8	Find all other thermodynamic properties of steam . . .	74
Exa 10.9	Find the all other thermodynamic properties of steam	74
Exa 10.10	Find the temperature of steam	75
Exa 10.11	Find the heat rejected from steam	76
Exa 10.12	Find work and heat interaction during expansion process	77
Exa 10.13	Find the exit area of the nozzle	78
Exa 10.14	Find the flow rate of feed water	79
Exa 11.1	Calculate the specific volume of propane	80
Exa 11.2	Find the reduced properties of air	81
Exa 11.3	At what temperature and pressure steam be similar to air	81
Exa 11.4	Find Z for air	82
Exa 11.5	Calculate specific volume of gaseous propane	82
Exa 11.6	Determine the pressure exerted by Carbon dioxide . . .	83
Exa 11.7	Determine the pressure in rigid vessel	84
Exa 12.1	Find the gravimetric and ultimate analysis	87
Exa 12.2	Find the stoichiometric air	88
Exa 12.3	Find the stoichiometric air	89
Exa 12.4	Find the excess air and percent theoretical air	90
Exa 12.5	Find the Orsat analysis	91
Exa 12.6	Find the volume fraction and mass fraction of the prod- ucts of combustion	92
Exa 12.7	Find the actual air excess air theoretical air mass frac- tion and dew point temperature	93
Exa 12.8	Find the actual air and excess air	95
Exa 12.9	Find the heat transfer from the combustor	96
Exa 12.10	Find the enthalpy of reaction	97
Exa 12.11	Find the standard change in enthalpy for the reaction	97
Exa 12.12	Frind the heat transferred from the combustor	98
Exa 12.13	Find the adiabatic combustion temperature	99
Exa 12.14	Find the LCV and HCV of gaseous hexane	99

List of Figures

9.1 Find the final temperature of air	57
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Chapter 1

Fundamental Concepts and Definitions

Scilab code Exa 1.1 Find velocity of a body

```
1 clc
2 clear
3 printf("Example 1.1 | Page number 5 \n\n");
4 //find velocity of a body.
5
6 //Given Data
7 distanceTravelled = 80 * 1000 //in meters
8 timeOfTravel = 2 * 3600 //in seconds
9 printf("Distance of travel = %.2f m \n",
    distanceTravelled);
10 printf("Time of travel = %.2f s \n\n",timeOfTravel);
11
12 //Solution
13 Velocity = distanceTravelled / timeOfTravel //in
    meter/second
14 printf("Velocity = %.2f m/s \n",Velocity);
```

Scilab code Exa 1.2 Find the force acting on the body

```
1 clc
2 clear
3 printf("Example 1.2 | Page number 6 \n\n");
4 //find the force.
5
6 //Given Data
7 mass = 120 //in kg
8 acceleration = 10 //in m/s^2
9 printf("Mass = %.2f kg \n",mass);
10 printf(" Acceleration = %.2f m/s^2 \n\n",acceleration
    );
11
12 //Solution
13 force = mass * acceleration * 0.001 //in kN
14 printf("Force = %.2f kN \n",force);
```

Scilab code Exa 1.3 Find the weight of body

```
1 clc
2 clear
3 printf("Example 1.3 | Page number 6 \n\n");
4 //find the weight of a body.
5
6 //Given Data
7 mass = 60 //in kg
8 accelerationDueToGravity = 9.8 //in m/s^2
9 printf("Mass = %.2f kg \n",mass);
10 printf("Acceleration due to gravity = %.2f m/s^2 \n\
    n",accelerationDueToGravity);
11
12 //Solution
13 weight = mass * accelerationDueToGravity //in N
14 printf("Weight = %.2f N \n",weight);
```

Scilab code Exa 1.4 Find the steam pressures in kPa

```
1  clc
2  clear
3  printf("Example 1.4 | Page number 10 \n\n");
4  //find the steam pressure.
5
6  //Given Data
7  Pg = 12E5 //in N/m^2 //inlet gauge pressure
8  Pvac = 75 / 1000 //in m Hg //exit gauge pressure
9  atmosphericPressure = 760 / 1000 //in m Hg //
    atmospheric pressure
10 density = 13.6 * 10^3 //kg/m^3 //density of mercury
11 g = 9.805 //in m/s^2 //acceleration due to gravity
12
13 printf("At inlet to the turbine , Pg = %.3f N/m^2 \n"
    ,Pg);
14 printf("At the exit , Pvac = %.3f m Hg \n",Pvac);
15 printf("Atmospheric pressure = %.3f m Hg \n",
    atmosphericPressure);
16 printf("Density of mercury = %.3f kg/m^3 \n",density
    );
17 printf("Acceleration due to gravity = %.3f m/s^2 \n\
    n",g);
18
19 //Solution
20 Pvac = density*g*Pvac //Pvac in N/m^2
21 atmosphericPressure = density*g*atmosphericPressure
    //atmospheric pressure in N/m^2
22 PabsInlet = atmosphericPressure + Pg //in N/m^2 //
    absolute inlet pressure
23 PabsExit = atmosphericPressure - Pvac //in N/m^2 //
    absolute exit pressure
24 printf("At the inlet , absolute pressure = %.3f kPa \
```

```
    n",PabsInlet*.001);
25 printf("At the exit , absolute pressure = %.3f kPa \n
    ",PabsExit*.001);
```

Scilab code Exa 1.5 Find specific volume and density

```
1 clc
2 clear
3 printf("Example 1.5 | Page number 12 \n\n");
4 //find the specific volume and density.
5
6 //Given Data
7 mass = 50 * .001 //in kg
8 volume = 0.04 //in m^3
9 printf("Mass = %.2f kg \n",mass);
10 printf("Volume = %.2f m^3 \n\n",volume);
11
12 //Solution
13 specificVolume = volume / mass //in m^3/kg
14 density = 1/specificVolume //in kg/m^3
15 printf("Specific density = %.2f m^3/kg \n",
    specificVolume);
16 printf("Density = %.2f kg/m^3 \n",density);
```

Scilab code Exa 1.6 Find equivalent temperature in Kelvin scale

```
1 clc
2 clear
3 printf("Example 1.6 | Page number 12 \n\n");
4 //find the equivalent temperature in Kelvin scale.
5
6 //Given Data
7 temp = 100; //in degree Celsius
```

```
8 printf("Temperature in degree Celsius = %.2f degree
    C \n\n",temp);
9
10 //Solution
11 TEMP = temp + 273.15;
12 printf("Temperature in Kelvin = %.2f K",TEMP);
```

Scilab code Exa 1.7 Find corresponding temperature in degree Celsius

```
1 clc
2 clear
3 printf("Example 1.7 | Page number 12 \n\n");
4 //find the equivalent temperature in Celsius scale.
5
6 //Given Data
7 TEMP = 263.15; //in Kelvin
8 printf("Temperature in Kelvin = %.2f K \n\n",TEMP);
9
10 //Solution
11 temp = TEMP - 273.15;
12 printf("Temperature in degree Celsius = %.2f degree
    C",temp);
```

Chapter 2

Work

Scilab code Exa 2.1 Find the work done by the force

```
1  clc
2  clear
3  printf("Example 2.1 | Page number 28 \n\n");
4  //find work done.
5
6  //Given Data
7  Force = 180 //in N //horizontal force
8  theta = 30 //in degrees //angle of inclination
9  distance = 12 //in m //distance moved by block along
    inclined plane.
10
11 printf("Horizontal force acting on block = %.2f N \n
    ",Force);
12 printf("Angle of inclination = %.2f degrees \n",
    theta);
13 printf("Distance moved by block = %.2f m \n\n",
    distance);
14
15
16 //Solution
17 Work = Force * (distance * cosd(theta)) //in J //
```

```

    Work done
18 Work = 0.001 * Work // Work done in KJ
19 printf("Work done by block = %.4f KJ",Work);

```

Scilab code Exa 2.2 Find magnitude and direction of work

```

1  clc
2  clear
3  printf("Example 2.2 | Page number 31 \n\n");
4  //find the magnitude and direction of work for
   systems agent and body.
5
6  //Given Data
7  mass_body = 2 //in kg //mass of body
8  L = 5 //in m //vertical distance
9  g = 9.8 //in m/s^2 //acceleration due to gravity
10
11 printf("Mass of body = %.2f kg \n",mass_body);
12 printf("Vertical distance = %.2f m \n",L);
13 printf("Acceleration due to gravity = %.2f m/s^2 \n\
   n",g);
14
15
16 //Solution
17 Work_done_by_agent = mass_body * g * L //in Nm //
   work done by agent
18 Work_done_by_body = -1*Work_done_by_agent
19 printf("Work done by agent = %.2f Nm\n",
   Work_done_by_agent);
20 printf("Work done by body = %.2f Nm",
   Work_done_by_body);

```

Scilab code Exa 2.3 Identify interaction between battery and resistor


```

1 clc
2 clear
3 printf("Example 2.3 | Page number 32 \n\n");
4 //Identify interaction between battery and resistor
5
6 //This example has a theoretical solution please
  refer to the textbook.
7 printf("This example has a theoretical solution
  please refer to the textbook.");

```

Scilab code Exa 2.4 Calculate magnitude and direction of work

```

1 clc
2 clear
3 printf("Example 2.4 | Page number 39 \n\n");
4 //(a) Calculate the magnitude and direction of work
  for air inside the balloon
5 //(b) Find the magnitude and direction of work for
  the atmosphere and the balloon
6
7 //Given Data
8 p1 = 1.5 * 10^(5) //N/m^2 //initial pressure in
  ballon
9 d1 = 0.25 //m //initial diameter of balloon
10 d2 = 0.3 //m //final diameter of balloon
11 p_atm = 10^(5) //N/m^2 //atmospheric pressure
12 printf("Initial pressure in ballon = %.2f N/m^2\n",
  p1);
13 printf("Initial diameter of ballon = %.2f m\n",d1);
14 printf("Final diameter of ballon = %.2f m\n",d2);
15 printf("Atmospheric pressure = %.2f N/m^2\n\n",p_atm
  );
16
17 //Solution
18

```

```

19 //Part (a)
20 printf("Part (a)\n");
21 printf("As p is proportional to d, p = k*d, where k
    is proportionality constant\n");
22 printf("Therefore,\n");
23
24 k = p1/d1;
25 printf("p1 = k*d1 => k = (p1/d1) = (%.2 f/%.2 f) = %.2
    f N/m^3\n",p1,d1,k);
26
27 p2 = k*d2; //N/m^2 //final pressure in balloon
28 printf("p2 = k*d2 = (%.2 f*%.2 f) = %.2 f N/m^2\n\n",k,
    d2,p2);
29
30 W_air = integrate('k*(%pi/2)*(d^3)', 'd', d1, d2) //Nm
    //Work done by air on the balloon
31 printf("Work done by balloon on air = %.2 f Nm\n\n",
    W_air);
32
33 //Part (b)
34 printf("Part (b)\n");
35 W_atm = integrate('p_atm*(0.5*%pi*(d^2))', 'd', d2, d1)
    ; //Nm //Work done by atmosphere on balloon
36 printf("Work done by atmosphere on balloon = %.2 f Nm
    \n", W_atm);
37 W_balloon = -1*(W_air+W_atm);
38 printf("Work done by balloon = -(Work done by air +
    Work done by atmosphere) = -(%.2 f*%.2 f) = %.2 f Nm\
    n", W_air, W_atm, W_balloon);

```

Scilab code Exa 2.5 Find the work interaction

```

1 clc
2 clear
3 printf("Example 2.5 | Page number 40 \n\n");

```

```

4 //Find the work interaction for pure substance.
5 //Given Data
6 p1 = 10 //bar //initial pressure
7 V1 = 0.1 //m^3 //initial volume
8 p2 = 2 //bar //final pressure
9 V2 = 0.35 //m^3 //final volume
10
11 printf("Initial pressure = %.2f bar\n",p1);
12 printf("initial volume = %.2f m^3\n",V1);
13 printf("Final pressure = %.2f bar\n",p2);
14 printf("Final volume = %.2f m^3\n",V2);
15
16 //Solution
17 printf("\nLet the expansion process follow the path
    pV^(n) = constant\n");
18 printf("Therefore ,\n");
19 n = (log(p1/p2))/(log(V2/V1));
20 printf("n = (ln(p1/p2))/(ln(V2/V1)) = (ln(%.2f/%.2f)
    )/(ln(%.2f/%.2f)) = %.4f\n",p1,p2,V2,V1,n);
21 W_d = (p1*V1 - p2*V2)*10^5/(n-1) //J //Work
    interaction for pure substance
22 printf("Work interaction for pure substance = (p1V1
    - p2V2)/(n-1) = %.2f kJ",W_d*.001)

```

Scilab code Exa 2.6 Find the work of compression for air

```

1 clc
2 clear
3 printf("Example 2.6 | Page number 41 \n\n");
4 //(a)Find the work of compression of air.
5 //(b)What would be the work done on air.
6
7 //Given Data
8 p1 = 1.0 //bar //initial pressure
9 V1 = 0.1 //m^3 //initial volume

```

```

10 p2 = 6    //bar //final pressure
11         //and p1*(V1^1.4) = p2*(V2^1.4)
12
13 printf("Initial pressure = %.2f bar\n",p1);
14 printf("inital volume = %.2f m^3\n",V1);
15 printf("Final pressure = %.2f bar\n\n",p2);
16
17
18 //Solution
19 //Part (a)
20 printf("Part (a)\n");
21 V2 = V1*(p1/p2)^(1/1.4) //m^3 //final volume
22 printf("Final Volume = %.4f m^3\n",V2);
23
24 W_d = (10^5)*(p1*V1 - p2*V2)/(1.4-1); //J //Work of
      compression for air
25 printf("Work of compression for air = %.1f KJ\n\n",
      W_d*.001);
26
27 //Part (b)
28 printf("Part (b)\n");
29 V2 = (p1/p2)*V1; //m^3 //final volume
30 printf("Final Volume = %.4f m^3\n",V2);
31
32 W_d = (10^5)*p1*V1*log(V2/V1); //J //Work done on
      air
33 printf("Work done on air = %.1f KJ\n\n",W_d*.001);

```

Scilab code Exa 2.7 Find the mep and indicated power

```

1 clc
2 clear
3 printf("Example 2.7 | Page number 41 \n\n");
4 //Find the mep, in kPa, and the indicated power in
      kW.

```

```

5
6 //Given Data
7 //four-stroke engine
8 x = 3 //number of cylinders
9 y = 1 //engine is single-acting
10 n = 500 //rev/min
11 N = n/2 //cycles/min
12 D = 0.075 //m //bore length
13 L = 0.1 //m //stroke length
14 a = 6*10^(-4) //m2 //area
15 l = 0.05 //m //length
16 S = 2*10^8 //N/m3 //spring constant
17
18 //Solution
19 p_m = (a/l)*S //Pa //mep
20
21 printf("Mean effective pressure , mep{Pm} = %.2 f kPa\
      n",p_m*.001)
22 A = (%pi/4)*D2 //m2
23
24 printf("Indicated power{P_ind} = %.2 f kW" ,(x*y)*(p_m
      *L*A*N)/60000)

```

Scilab code Exa 2.8 Find the mechanical efficiency of engine

```

1 clc
2 clear
3 printf("Example 2.8 | Page number 45 \n\n");
4 //Find the mechanical efficiency of the engine
5
6 //Given Data
7 N = poly([0 .5], 'n', 'c') //n is engine speed
8 x = 6 //six cylinders
9 y = 1 //assumed
10 d = 0.1 //m //bore length

```

```

11 A = %pi*(0.1)^2/4 //m^2 //Area
12 L = 0.15 //m //stroke length
13 P_shaft = 24.78 //KW //Power of shaft
14 T = 474.9 //Nm //Torque in the crank shaft
15 l = 0.05 //m //length of indicator diagram
16 a = 9.37*10^(-4) //cm^2 //area of indicator diagram
17 S = 0.5*(10^8) //N/m^3 //spring constant
18
19 //Solution
20 p_m = a*S/l //mean pressure difference
21 printf("Mean pressure difference = %.2f N/m^2\n",p_m
    );
22
23 P_ind = (x*y)*p_m*(L*A*N/60000) //indicated power
24 C = coeff(P_ind)
25 printf("Indicated Power = %.6f n kW\n",C(2));
26
27 P_shaft = 2*%pi*poly([0 1], 'n', 'c')*T/60000 //shaft
    power output
28 C = coeff(P_shaft)
29 printf("Shaft power output (in KW)= %.5f n kW\n",C
    (2));
30
31 Mechanical_efficiency = coeff(P_shaft,1)/coeff(P_ind
    ,1)*100
32 printf("Mechanical Efficiency = %.0f %%",
    Mechanical_efficiency(1));

```

Scilab code Exa 2.9 Compute net work for battery and motor

```

1 clc
2 clear
3 printf("Example 2.9 | Page number 46 \n\n");
4 //(a) Compute the torque in the driving shaft and
    shaft power output of the motor.

```

```

5 // (b) Compute the net work for battery and motor.
6
7 // Given Data
8 d = 0.4 //m //cylinder diameter
9 t = 10 //min //Time taken for stirring
10 L = 0.49 //m //distance moved by the piston
11 p_atm = 1 //bar //atmospheric pressure
12 W_net = -1965 //Nm //net work done
13 n = 750 //rev/min //rotational velocity of electric
    motor
14 I = 0.9 //A //current
15 V = 24 //V //voltage
16
17 // Solution
18 // Part (a)
19 printf("Part (a)\n");
20 W_d = 10^5 * p_atm * (%pi/4) * d^2 * L; //Nm //work
    done by fluid on piston
21 printf("Work done by fluid on the piston = %.1f Nm\n
    ", W_d);
22 W_str = W_net - W_d; //Nm //Work done by stirrer
23 printf("Work done by stirrer on the fluid = %.1f Nm\
    n", W_str);
24 P_shaft = abs(W_str)/(t*60); //W //shaft power
    output
25 printf("Shaft power output = %.2f W\n", P_shaft);
26 T = (P_shaft*60)/(2*%pi*n); //Nm //Torque in the
    driving shaft
27 printf("Torque in the driving shaft = %.3f Nm\n", T)
    ;
28
29 // Part (b)
30 printf("\nPart (b)\n");
31 W_bat = I*V*t*60; //Nm //work done by battery
32 printf("Work done by battery = %.1f Nm\n", W_bat);
33 W_motor = -1*(W_bat+W_str) //Nm //work done by motor
34 printf("Work done by motor = %.1f Nm", W_motor);

```

Chapter 3

Temperature and Heat

Scilab code Exa 3.1 Temperature in degree Celsius and Fahrenheit

```
1  clc
2  clear
3  printf("Example 3.1 | Page number 73 \n\n");
4  //(a) Average human temperature in C
5  //(b) Annual average temperature in peninsular India
    in F
6
7  //Solution
8  //Part(a)
9  printf("Part (a)\n")
10 tf = 98.6 // F //average temperature Human Body in
    C
11 tc = (tf - 32)/1.8 // C
12 printf("Average human temperature in C = %.1f C \n\n",tc);
13
14
15 //Part(b)
16 printf("Part (b)\n")
17 tc = 27 // C //Annual average temperature in
    peninsular India in C
```



```
18 tf = 1.8*tc+32 //Annual average temperature in
    peninsular India in F
19 printf("Annual average temperature in peninsular
    India in F = %.1f F\n\n",tf);
```

Scilab code Exa 3.2 Find temperature in Kelvin

```
1 clc
2 clear
3 printf("Example 3.2 | Page number 73 \n\n");
4 //find temperature in kelvin
5
6 t = 27 // C
7 T = t + 273.15 //K
8 printf("Temperature in Kelvin = %.2f K",T)
```

Scilab code Exa 3.3 Find temperature in degree Celsius

```
1 clc
2 clear
3 printf("Example 3.3 | Page number 74 \n\n");
4 //find temperature in C
5
6 T = 250 //K
7 t = T - 273.15 // C
8 printf("Temperature in C = %.2f C",t)
```

Scilab code Exa 3.4 Determine what A reads when B reads 30

```
1 clc
```

```

2 clear
3 printf("Example 3.4 | Page number 77 \n\n");
4 //Part(a) Determine what A reads when B reads 30
5 printf("Part (a)\n");
6 //t_A and t_B are readings two Celsius thermometers
   A and B
7 //t_A = p + q*t_B + r*(t_B)^2
8 //p, q and r are constants.
9 X = [1, 0, 0; 1, 100, 100^2; 1, 50, 50^2]\[0; 100;
   51]
10 p = X(1);
11 q = X(2);
12 r = X(3);
13
14 deff('y = t_A(t_B)', ['y = q*t_B + r*(t_B^2)'])
15 t_B = 30;
16
17 printf("When thermometer B reads %0.1 f C then
   thermometer A reads , t_B = %.02 f C \n", t_B, t_A(
   t_B));
18 //Part(b)
19 printf("\nPart (b)\n");
20 printf("This part is theoretical question , book
   shall be referred for solution.");

```

Scilab code Exa 3.5 Find the temperature attained by the coil

```

1 clc
2 clear
3 printf("Example 3.5 | Page number 79 \n\n");
4 //Find the temperature attained by the coil during
   full load.
5 Rt = 80
6 t = 25
7 //Substituting Rt and t in Rt = Ro(1+0.00395t)

```

```

8 Ro = 80/(1+0.00395*25)
9 printf("Ro {Resistance at 0 C} = %.2f ohm\n",Ro)
10 //Full load condition
11 Rt = 95
12 //temperature at full load condition
13 printf("t {Temperature at full load condition} = %.2
    f C",((Rt/Ro)-1)/0.00395);

```

Scilab code Exa 3.6 Find thermometer reading when gas thermometer reads 50 degree C

```

1 clc
2 clear
3 printf("Example 3.6 | Page number 80 \n\n");
4 //What will be thermometer read in place where gas
    thermometer reads 50 C
5 deff('y = e(t)', ['y = 0.0367*t + 1.33 * 10^(-4)*t^2'
    ])
6
7 printf("Thermometer read in place where gas
    thermometer reads 50 C = %.2f C",e(50)/(e(100)
    /100))

```

Chapter 4

The First Law of Thermodynamics for Systems Pure Substances

Scilab code Exa 4.1 Find the magnitude and direction of the fourth work interaction

```
1  clc
2  clear
3  printf("Example 4.1 | Page number 93 \n\n");
4  //Find magnitude and direction of W_4
5  //Given Data
6  //four heat transfer
7  Q_1 = 900 //J
8  Q_2 = 80 //J
9  Q_3 = -800 //J
10 Q_4 = 150 //J
11 //four work interactions
12 W_1 = 200 //J
13 W_2 = 150 //J
14 W_3 = 300 //J
15 //W_4
16 //Solution
```

```

17 W_4 = Q_1 +Q_2 +Q_3 +Q_4 -W_1 -W_2 -W_3
18 printf("Magnitude and Direction of the fourth work
    interaction , W4 = %.2f J",W_4)

```

Scilab code Exa 4.2 Find the change in energy of the system and find the magnitude and direction of work done during B

```

1  clc
2  clear
3  printf("Example 4.2 | Page number 94 \n\n");
4  //Part (a) Find change in energy of the system
5  //Part (b) Find the magnitude and direction of work
    during B
6  //Given Data
7  Q_a = -50 //KJ //heat transferred from the system
    along path A
8  W_a = -65 //KJ //work done along path A
9  Q_b = 0 //KJ //heat transferred from the system
    along path B
10 //W_b work done along path B
11
12 //Solution
13
14 //Part(a)
15 printf("Part (a)\n");
16 delE_a = Q_a - W_a //KJ //Change in energy along
    path A
17 printf("Change in energy of the system = %.2f KJ\n\n
    ",delE_a);
18
19 //Part(b)
20 printf("Part (b)\n");
21 delE_b = -1*delE_a //KJ //Change in energy along
    path B
22 W_b = delE_b - Q_b //KJ //work done along path B

```

```
23 printf("Magnitude and direction of work done during
    B, W_b = %.2f KJ",W_b)
```

Scilab code Exa 4.3 Evaluate total energy of the system

```
1 clc
2 clear
3 printf("Example 4.3 | Page number 99 \n\n");
4 //Find the total energy of the system with respect
    to an observer at rest at sea level.
5 //Given data
6 m = 2.3 //kg //mass of substance
7 u = 21 * 10^3 //J/kg //internal energy
8 V = 110 //m/s //velocity
9 z = 1500 //m //elevation above sea level
10 g = 9.81 //m/s^2 //acceleration due to gravity
11
12
13 //Solution
14 E = m*(g*z + V^2/2 + u) //J/kg //Total energy of the
    system
15 printf("The total energy of the system with respect
    to an observer at rest at sea level , E = %.4f KJ"
    ,0.001*E);
```

Scilab code Exa 4.4 Find Cv and Cp

```
1 clc
2 clear
3 printf("Example 4.4 | Page number 103 \n\n");
4 //find Cv and Cp
5 //Given data
6 t = poly(0, 't'); // C //Temperature in C
```

```

7 u = 196 + .718*t; //KJ/kg //specific internal energy
8 pv = 287*(t+273); //Nm/kg //p is pressure and v =
    specific volume
9
10 //Solution
11 Cv = coeff(derivat(u));
12 printf(" Specific heat at constant volume ,Cv = %.3 f
    kJ/kgK\n", Cv(1));
13
14 h = u + pv*.001 //KJ/kg //enthalpy
15 Cp = coeff(derivat(h));
16 printf(" Specific heat at constant pressure ,Cp = %.3 f
    kJ/kgK", Cp(1));

```

Scilab code Exa 4.5 Show that work done on system is equal to increase in enthalpy

```

1 clc
2 clear
3 printf("Example 4.5 | Page number 103 \n\n");
4 //This question is theoretical. Refer textbook for
    solution
5 printf("This is a theoretical question. Refer
    textbook for solution.")

```

Chapter 5

First Law of Thermodynamics for Control Volumes

Scilab code Exa 5.1 Find work output

```
1  clc
2  clear
3  printf("Example 5.1 | Page number 119 \n\n");
4  //Find the work output in KJ/kg
5  //Given data
6  Q = -24; //KJ/kg
7
8  p1 = 5e5; //N/m^2
9  t1 = 227; // C
10 V1 = 50; //m/s
11 v1 = 0.78; //m^3/kg
12
13 p2 = 1e5; //N/m^2
14 t2 = 57; // C
15 V2 = 100; //m/s
16 v2 = 0.97; //m^3/kg
17
18 g = 9.81; //m/s^2 //acceleration due to gravity
19
```



```

20 delta_z = -5; //m
21 Cv = 0.7; //KJ/kg
22 delta_u = Cv*(t2 - t1); //KJ/kg //change in internal
    energy //u2-u1
23
24 //Solution
25 delta_h = delta_u + (p2*v2 - p1*v1)*.001; //KJ/kg //
    change in enthalpy //h2-h1
26
27 W_x = Q - (delta_h + (V2^2 - V1^2)/2*.001 + g*
    delta_z*.001); //kJ/kg //Work Output
28
29 printf("Work output = %.2f KJ/kg",W_x);

```

Scilab code Exa 5.2 Find the change in enthalpy across the turbine

```

1  clc
2  clear
3  printf("Example 5.2 | Page number 120 \n\n");
4  //Part (a) Find the change in enthalpy across
    turbine, if inlet velocity is negligible
5  //Part (b) Find the change in enthalpy across
    turbine, if inlet velocity is 60m/s
6
7  //Given Data
8  m = 5000/3600 // kg/s // flow rate
9  W_x = 550 // KJ/s //power developed by turbine
10 Q = 0 //Heat loss is negligible
11
12 //Solution
13 //Part (a)
14 printf("Part(a)\n\n")
15 V1 = 0 // m/s //inlet velocity
16 V2 = 360 // m/s //exit velocity
17 g = 9.81 // m/s^2

```

```

18 delta_z = 0 //m //z2-z1
19
20 delta_h = ((Q-W_x)/m)-g*delta_z*.001-((V2^2-V1^2)
    /2000) //KJ/Kg //change in enthalpy
21 printf("Change in enthalpy = %.2f KJ/kg\n",delta_h)
22
23 //Part (a)
24 printf("\nPart(b)\n\n")
25 V1 = 60 // m/s //inlet velocity
26 V2 = 360 // m/s //exit velocity
27 g = 9.81 // m/s^2
28 delta_z = 0 //m //z2-z1
29
30 delta_h = ((Q-W_x)/m)-g*delta_z*.001-((V2^2-V1^2)
    /2000) //KJ/Kg //change in enthalpy
31 printf("Change in enthalpy = %.2f KJ/kg\n",delta_h)

```

Scilab code Exa 5.3 Determine the temperature at the inlet and power developed

```

1 clc
2 clear
3 printf("Example 5.3 | Page number 122 \n\n");
4 //Part(a) Determine the temperature of air at inlet
    to the turbine
5 //PART(b) Determine power developed by turbine
6
7 //Given Data
8 mA = 0.8 // kg/s //flow rate of stream A
9 pA = 15e5 // N/m^2 //Pressure of stream A
10 tA = 250 // C //temperature of stream A
11
12
13 mB = 0.5 // kg/s //flow rate of stream B
14 pB = 15e5 // N/m^2 //Pressure of stream B

```

```

15 tB = 200 // C //temperature of stream B
16
17 Q = 0 //No heat loss
18
19 p1 = 10e5 // N/m^2 //pressure supply of chamber
20 t2 = 30 // C //exhaust air temperature from turbine
21
22 Cv = 0.718 // KJ/kgK //heat capacity at constant
    volume
23 Cp = 1 // KJ/kgK //heat capacity at constant
    pressure
24
25 //solution
26 //Part(a)
27 printf("Part (a)\n")
28 t1 = ((mA*Cp*tA)+(mB*Cp*tB))/((mA*Cp)+(mB*Cp)) //
    C //the temperature of air at inlet to the
    turbine
29 printf("The temperature of air at inlet to the
    turbine = %.2f C\n",t1);
30 //Part(b)
31 printf("\nPart (b)\n")
32 WT = -1*(mA+mB)*Cp*(t2-t1) // kW //power developed
    by turbine
33 printf("Power developed by turbine = %.2f kW",WT);

```

Scilab code Exa 5.4 Find the inlet and exit velocities

```

1 clc
2 clear
3 printf("Example 5.4 | Page number 123 \n\n");
4 //Find inlet and exit velocities
5
6 //Given Data
7 d1 = 0.15 //m //inlet diameter

```

```

8 m = 4000/3600 // kg/s //flow rate
9 v1 = 0.285 //m^3/kg //specific volume at entry
10 d2 = 0.25 //m //exit diameter
11 v2 = 15 // m^3/kg //specific volume at exit
12
13 //Solution
14
15 A1 = %pi*d1^2/4 //m^2 //inlet cross sectional area
16 A2 = %pi*d2^2/4 // m^2 // exit cross sectional area
17 printf("Inlet cross sectional area (A1)= %.5f m^2\n",
    ,A1);
18 printf("Exit cross sectional area (A2)= %.5f m^2\n",
    A2);
19
20 V1 = m*v1/A1 //m/s //inlet velocity
21 V2 = m*v2/A2 //m/s //exit velocity
22
23 printf("\nInlet velocity = %.1f m/s",V1);
24 printf("\nExit velocity = %.1f m/s",V2);

```

Scilab code Exa 5.5 Find the temperature of air after throttling

```

1 clc
2 clear
3 printf("Example 5.5 | Page number 125 \n\n");
4 //Find air temperature after throttling
5
6 //Given Data
7 p1 = 10//bar //inlet pressure
8 t1 = 300 // C //inlet temperature
9
10 p2 = 0.1 //bar //exit pressure
11 Cp = 1 //kJ/kgK // heat capacity at constant
    pressure
12 //Solution

```

```

13 //Adiabatic process
14 delta_h = 0 //change in enthalpy
15 t2 = delta_h/Cp + t1
16 printf("Temperature of air after throttling = %.1f
        C ",t1)

```

Scilab code Exa 5.6 Calculate the work input to the compressor

```

1 clc
2 clear
3 printf("Example 5.6 | Page number 126 \n\n");
4 // Calculate work input to compressor
5
6 //Given Data
7 p1 = 1e5 // N/m^2 //inlet pressure
8 v1 = 0.08 //m^3/kg // specific volume at inlet
9 p2 = 7e5 // N/m^2 //exit pressure
10 v2 = 0.016 // m^3/kg //specific volume at exit
11 u1 = 48 // kJ/kg // internal energy at inlet
12 u2 = 200 // kJ/kg // internal energy at exit
13 Q = -120 // kJ/kg // heat loss
14 //Solution
15 Wc = ((u2 - u1) + (p2*v2 - p1*v1)*.001 - Q)*-1 // kJ
        /kg // work input to compressor
16 printf("Work input to compressor (Wc) = %.1f kJ/kg",
        Wc)

```

Scilab code Exa 5.7 Find the mass flow rate of cooling water

```

1 clc
2 clear
3 printf("Example 5.7 | Page number 128 \n\n");
4 //Find mass flow rate of cooling water

```

```

5 mh = 9.45 // kg/s // flow rate of steam
6 h_h2 = 140 // kJ/kg // enthalpy of condensate
7 h_h1 = 2570 // kJ/kg // inlet enthalpy of steam
8 t1 = 25 // C //inlet temperature of cooling water
9 t2 = 36 // C //exit temperature of cooling water
10 c = 4.189 // kJ/kg deg // specific heat of water
11 //Solution
12 mc = -1*(mh*(h_h2-h_h1))/(c*(t2-t1)) // kg/s //mass
    flow rate of cooling water
13 printf("Mass flow rate of cooling water = %.2f kg/s"
    ,mc)

```

Scilab code Exa 5.8 Find the mass flow rate of cooling water if the heat loss to surrounding is 10 percent of heat transferred from steam to cooling water

```

1 clc
2 clear
3 printf("Example 5.8 | Page number 129 \n\n");
4 //Redo example 5.7 for heat loss 10% of heat
    transferred
5 mh = 9.45 // kg/s // flow rate of steam
6 h_h2 = 140 // kJ/kg // enthalpy of condensate
7 h_h1 = 2570 // kJ/kg // inlet enthalpy of steam
8 t1 = 25 // C //inlet temperature of cooling water
9 t2 = 36 // C //exit temperature of cooling water
10 c = 4.189 // kJ/kg deg // specific heat of water
11 fractionalheatloss = 0.1 // fractional heat loss
12 //Solution
13 mc = -1*((1-fractionalheatloss)*mh*(h_h2-h_h1))/(c*(
    t2-t1)) // kg/s //mass flow rate of cooling water
14 printf("Mass flow rate of cooling water = %.1f kg/s"
    ,mc)

```

Scilab code Exa 5.9 Find the inlet air temperature

```
1 clc
2 clear
3 printf("Example 5.9 | Page number 130 \n\n");
4 //Find inlet air temperature
5 V1 = 300 //m/s //inlet air velocity
6 t2 = 100 // C //exit air temperature
7 V2 = 15 //m/s //exit air velocity
8 //Solution
9 t1 = t2 + .001*(V2^2 - V1^2)/2 // C //inlet air
    temperature
10 printf("Inlet air temperature = %.1f C",t1)
```

Scilab code Exa 5.10 Find the mass of air entering and the final temperature of the air in the vessel

```
1 clc
2 clear
3 printf("Example 5.10 | Page number 131 \n\n");
4 //Find the mass of air entering and temperature of
    air in vessel
5
6 //Given Data
7 m1 = 0.8 //kg //initial mass of air
8 p1 = 150 //kPa //initial pressure of air
9 T1 = 300 //K //initial temperature of air
10 p_p = 600 //kPa //pressure of air in pipe
11 T_p = 330 //K // temperature of air in pipe
12
13 //Solution
14 m2T2 = (p_p/p1)*T1*m1
```

```
15 m2 = ((0.718*(m2T2/m1-T1))/(331.65)*m1)+m1 //kg //  
    final mass of air  
16 printf("Mass of air entering in vessel = %.4f kg\n",  
    m2-m1)  
17 T2 = m2T2/m2 //K //Temperature of air in vessel  
18 printf("Temperature of air in vessel = %.1f K",T2)
```

Scilab code Exa 5.11 Show relation between mass and pressure ratios

```
1 clc  
2 clear  
3 printf("Example 5.11 | Page number 133 \n\n");  
4 //This is a theoretical question. Refer textbook for  
    solution.  
5 printf("This is a theoretical question. Refer  
    textbook for solution.")
```

Chapter 6

Heat Engines The Second Law of Thermodynamics

Scilab code Exa 6.1 Find the heat rejected at the condenser and the thermal efficiency of the plant

```
1  clc
2  clear
3  printf("Example 6.1 | Page number 148 \n\n");
4  //Find the heat rejected at the condenser and
   thermal efficiency of the plant
5
6  //Given Data
7  Q1 = 300 //kJ //heat supplied at the boiler
8  Wt = 100 //kJ //work output of turbine
9  Wp = 0.5 //kJ //work input to pump
10
11 //Solution
12 Q2 = Q1 - (Wt - Wp) //kJ //heat rejected at the
   condensor
13 printf("Heat rejected at the condensor = %.1f kJ\n",
   Q2);
14 efficiency = 1 - (Q2/Q1)
15 printf("The thermal efficiency of plant = %.2f ",
```

efficiency)

Scilab code Exa 6.2 Find the rate of heat transfer power input and COP

```
1  clc
2  clear
3  printf("Example 6.2 | Page number 153 \n\n");
4  //Part(a)Find the rate of heat transfer in the
   evaporator and the power input to the compressor.
5  //Part(b)Calculate COP if refrigerator were to
   operate as heat pump
6
7  //Given Data
8  COP_ref = 4 //COP of refrigerator
9  Q1 = 0.5 //kJ/s //rate of heat transfer at the
   condensor
10
11 //Solution
12 //Part(a)
13 printf("Part(a)\n");
14 Wc = Q1/(COP_ref+1) //kJ/s //Power input to
   compressor
15 Q2 = COP_ref*Wc //kJ/s //Rate of heat transfer in
   evaporator
16 printf("Rate of heat transfer in evaporator = %.1f
   kJ/s\n",Q2)
17 printf("Power input to compressor = %.1f kJ/s\n\n",
   Wc)
18
19 //Part(b)
20 printf("Part(b)\n");
21 COP_hp = 1 + COP_ref //COP of heat pump
22 printf("COP of heat pump = %.1f",COP_hp)
```

Scilab code Exa 6.3 Find savings in the monthly electricity bill

```
1  clc
2  clear
3  printf("Example 6.3 | Page number 154 \n\n");
4  //Part(a)Find the additional monthly electricity
   bill
5  //Part(b)What would be the saving in monthly
   electricity bill
6
7  //Part(a)
8  printf("Part(a)\n");
9  I = 4.5 //Amp //Current drawn
10 V = 220 //V
11 Electricity_consumption = I*V //Watts
12 ElectricityUnitPerDay = Electricity_consumption
   /1000*8 //kWh
13 MonthlyBill_part_a = ElectricityUnitPerDay * 5 * 30
14 printf("The additional monthly electricity bill = Rs
   . %.2f\n\n",MonthlyBill_part_a);
15
16 //Part(b)
17 printf("Part(b)\n");
18 Q1 = Electricity_consumption*.001 //kW //Rate of
   heat transfer from heat pump
19 COP_hp = 4 //COP of heat pump
20 W = Q1/COP_hp //kW //rate at which energy is
   consumed
21 ElectricityUnitPerDay = W*8
22 MonthlyBill_part_b = ElectricityUnitPerDay * 5 * 30
23 printf("Saving in monthly electricity bill = Rs. %.2
   f",MonthlyBill_part_a - MonthlyBill_part_b)
```

Chapter 7

Reversibility and the Thermodynamics Temperature Scale

Scilab code Exa 7.1 Find the work output of the engine and the magnitude of heat interaction

```
1  clc
2  clear
3  printf("Example 7.1 | Page Number 174 \n\n");
4  //Part(a) Find the work output of the engine
5  //Part(b) Find the magnitude of heat interaction
    with the reservoir at t2 and work input to the
    heat pump.
6
7  //Part(a)
8  printf("Part (a)\n");
9  //Given Data
10 Q1 = 500 //kJ //Heat transfer from reservoir at t1
11 Q2 = 187.5 //kJ //Heat transfer from reservoir at t2
12
13 //Solution
14 nr = 1-(Q2/Q1) //Efficiency
```

```

15 W = nr*Q1 //kJ //Work output of the engine
16 printf("Work output of the engine = %.1f kJ\n\n",W);
17
18 //Part(b)
19 printf("Part (b)\n");
20 //Given Data
21 Q1 = 500 //kJ //Heat transfer from reservoir at t1
22 //Solution
23 COP_hp = 1/nr
24 W = Q1/COP_hp //kJ //Work input to heat pump
25 Q2 = Q1-W //kJ //heat ineraction with reservoir at
    t2
26 printf("Heat ineraction with reservoir at t2 = %.1f
    kJ\n",Q2);
27 printf("Work input to the heat pump = %.1f kJ\n",W);

```

Scilab code Exa 7.2 Evaluate validity of claim

```

1 clc
2 clear
3 printf("Example 7.2 | Page Number 178 \n\n");
4 //Evaluate validity of claim
5 //Given Data
6 nr = 0.7 //maximum efficiency
7 W = 80 //kJ //Work
8 Q1 = 100 //kJ //heat transfered
9 //Solution
10 nx = W/Q1 //claimed efficiency
11 if nx>nr then
12     printf("Engine X is not a viable proposition
        because the claimed efficiency %.2f is
        greater than maximum efficiency %.2f",nx,nr)
13 else
14     printf("Engine X is a viable proposition because
        the claimed efficiency %.2f is less than

```

```
        maximum efficiency %.2f",nx,nr)
15 end
```

Scilab code Exa 7.3 Comment on internal and external reversibility

```
1 clc
2 clear
3 printf("Example 7.3 | Page number 185 \n\n");
4 //This is a theoretical question. Refer textbook for
  solution
5 printf("This is a theoretical question. Refer
  textbook for solution.");
```

Scilab code Exa 7.4 Find efficiency

```
1 clc
2 clear
3 printf("Example 7.4 | Page number 191 \n\n");
4 //Part(a) Find efficiency if the engine is
  reversible.
5 //Part(b) Find efficiency if the engine is
  irreversible.
6
7 //Given Data
8 T1 = (527+273) //K
9 T2 = (27+273) //K
10 //Part (a)
11 printf("Part (a)\n");
12 nr = 1 - (T2/T1) //reversible efficiency
13 printf("Reversible efficiency = %.3f \n\n",nr);
14
15 //Part(b)
16 printf("Part (b)\n");
```

```
17 printf("As the values of at least any two from among
    Q1,Q2 and W are not given \nthe efficiency of
    the engine cannot be evaluated.However, according
    to \nCarnots statement, the efficiency will be
    less than %.3f",nr)
```

Scilab code Exa 7.5 Find COP

```
1 clc
2 clear
3 printf("Example 7.5 | Page number 192 \n\n");
4 //Part(a) Find the COP of reversible heat engine as
    refrigerator.
5 //Part(b) Find the COP of reversible heat engine as
    heat pump.
6
7 //Given Data
8 T1 = 273 + 37 //K
9 T2 = 273 - 13 //K
10
11 //Part(a)
12 printf("Part (a)\n");
13 COP_ref = T2/(T1-T2) //COP of reversible heat engine
    as refrigerator.
14 printf("COP of reversible heat engine as
    refrigerator = %.1f\n\n",COP_ref)
15 //Part(b)
16 printf("Part (b)\n");
17 COP_hp = T1/(T1-T2) //COP of reversible heat engine
    as heat pump.
18 printf("COP of reversible heat engine as heat pump =
    %.1f",COP_hp)
```

Chapter 8

Entropy Available and Unavailable Energy

Scilab code Exa 8.1 Clausius inequality

```
1 clc
2 clear
3 printf("Example 8.1 | Page number 211 \n\n");
4 //This is a theoretical question.Refer textbook for
  solution
5 printf("This is a theoretical question.Refer
  textbook for solution")
```

Scilab code Exa 8.2 Find change in entropy

```
1 clc
2 clear
3 printf("Example 8.2 | Page number 211 \n\n");
4 //Evaluate delta S for the reservoir
5 //Given Data
6 Q = 10 //kJ //heat transfered from reservoir
```



```

7 T = 100+273 //K //isothermal expansion temperature
8 T_res = 300+273 //K //reservoir temperature
9 //Solution
10 delta_S_sys = (Q/T) //kJ/K //delta S for the system
11 printf("Change in entropy(Delta S) for the system =
    %.5f kJ/K\n",delta_S_sys);
12
13 delta_S_res = -1*(Q/T_res) //kJ/K //delta S for the
    reservoir
14 printf("Change in entropy(Delta S) for the reservoir
    = %.5f kJ/K\n",delta_S_res);

```

Scilab code Exa 8.3 Find change in entropy if reservoir temperature is 100 degree Celsius

```

1 clc
2 clear
3 printf("Example 8.3 | Page number 212 \n\n");
4 //Evaluate delta S for the reservoir
5 //Given Data
6 Q = 10 //kJ //heat transfered from reservoir
7 T = 100+273 //K //isothermal expansion temperature
8 T_res = 100+273 //K //reservoir temperature
9 //Solution
10 delta_S_sys = (Q/T) //kJ/K //delta S for the system
11 printf("Change in entropy(Delta S) for the system =
    %.5f kJ/K\n",delta_S_sys);
12
13 delta_S_res = -1*(Q/T_res) //kJ/K //delta S for the
    reservoir
14 printf("Change in entropy(Delta S) for the reservoir
    = %.5f kJ/K\n",delta_S_res);

```

Scilab code Exa 8.4 Find the change in entropy for paddle stirred gas

```
1 clc
2 clear
3 printf("Example 8.4 | Page number 212 \n\n");
4 //Evaluate delta S for the reservoir
5 //Given Data
6 Q = 1; //kJ //heat transfered from reservoir
7 T = 100+273; //K //isothermal expansion temperature
8 T_res = 100+273; //K //reservoir temperature
9 //Solution
10 delta_S_res = -1*(Q/T_res); //kJ/K //delta S for the
    reservoir
11 printf("Change in entropy(Delta S) for the reservoir
    = %.5f kJ/K\n",delta_S_res);
```

Scilab code Exa 8.5 Identify possible and impossible processes

```
1 clc
2 clear
3 printf("Example 8.5 | Page number 217 \n\n");
4 //This is a theoretical question.Refer textbook for
    solution
5 printf("This is a theoretical question.Refer
    textbook for solution")
```

Scilab code Exa 8.6 Identify processes as reversible irreversible or impossible

```
1 clc
2 clear
3 printf("Example 8.6 | Page number 217 \n\n");
```

```
4 //This is a theoretical question.Refer textbook for
  solution
5 printf("This is a theoretical question.Refer
  textbook for solution")
```

Scilab code Exa 8.7 State whether entropy change of the universe is positive negative or zero

```
1 clc
2 clear
3 printf("Example 8.7 | Page number 220 \n\n");
4 //This is a theoretical question.Refer textbook for
  solution
5 printf("This is a theoretical question.Refer
  textbook for solution")
```

Scilab code Exa 8.8 Determine the change in entropy

```
1 clc
2 clear
3 printf("Example 8.8 | Page number 222 \n\n");
4 //This is a theoretical question.Refer textbook for
  solution
5 printf("This is a theoretical question.Refer
  textbook for solution")
```

Scilab code Exa 8.9 Find the change in entropy

```
1 clc
2 clear
```

```
3 printf("Example 8.9 | Page number 223 \n\n");
4 //This is a theoretical question.Refer textbook for
  solution
5 printf("This is a theoretical question.Refer
  textbook for solution")
```

Scilab code Exa 8.10 Find the change in entropy during melting process

```
1 clc
2 clear
3 printf("Example 8.10 | Page number 224 \n\n");
4 //This is a theoretical question.Refer textbook for
  solution
5 printf("This is a theoretical question.Refer
  textbook for solution")
```

Scilab code Exa 8.11 Can system undergo isentropic process

```
1 clc
2 clear
3 printf("Example 8.11 | Page number 224 \n\n");
4 //This is a theoretical question.Refer textbook for
  solution
5 printf("This is a theoretical question.Refer
  textbook for solution")
```

Scilab code Exa 8.12 Find direction of flow of air

```
1 clc
2 clear
```

```

3 printf("Example 8.12 | Page number 225 \n\n");
4 //Find the direction fo air flow
5 //Given Data
6 pA = 120 //kPa //Pressure at location A
7 TA = 50+273 //K //Temperature at location A
8 VA = 150 //m/s //Velocity at location A
9
10 pB = 100 //kPa //Pressure at location B
11 TB = 30+273 //K //Temperature at location B
12 VB = 250 //m/s //Velocity at location B
13
14 Cp = 1.005 //kJ/kg
15 R = 0.287 //kJ/kgK
16 //Solution
17 delta_S_sys = (Cp*log(TB/TA))-(R*log(pB/pA)) //kJ/
    kgK //Entropy of system
18 if delta_S_sys < 0 then
19     printf("Flow is from B to A.");
20 else
21     printf("Flow is from A to B.")
22 end

```

Scilab code Exa 8.13 Find the change in entropy

```

1 clc
2 clear
3 printf("Example 8.13 | Page number 226 \n\n");
4 //Part(a)Temperature of the mixture when ice-water
    equilibrium.
5 //Change in entropy during the process for:
6 //Part(b) ice
7 //Part(c) water
8 //Part(d) universe
9
10 //Given Data

```

```

11 mi = 5 //kg //mass of ice
12 Ti = 273 - 10 //K //Temperature of ice
13 ci = 2.1 //kJ/kgK //specific heat of ice
14 L = 330 //kJ/kg //Latent heat
15 mw = 20 //kg //mass of water
16 Tw = 273+80 //K //Temperatur of water
17 cw = 4.2 //kJ/kgK //specific heat of water
18 //Part(a)
19 printf("Part (a)\n");
20 Tmix = ((mi*ci*(Ti-273))-(L*mi)+(mw*cw*Tw)+(mi*cw
      *273))/(mw*cw+mi*cw)
21 printf("Temperature of the mixture when equilibrium
      is established between ice and water = %.1f K\n\n",
      Tmix)
22 //Part (b)
23 printf("Part (b)\n");
24 delta_S_ice = mi*(ci*log(273/Ti)+L/273+cw*log(Tmix
      /273))//kJ/K //Entropy of ice
25 printf("Entropy of ice = %.2f kJ/K\n\n",delta_S_ice)
26 //Part (c)
27 printf("Part (c)\n");
28 delta_S_water = mw*(cw*log(Tmix/Tw))//kJ/K //Entropy
      of water
29 printf("Entropy of water = %.2f kJ/K\n\n",
      delta_S_water)
30 //Part (d)
31 printf("Part (d)\n");
32 delta_S_uni = delta_S_water+delta_S_ice//kJ/K //
      Entropy of universe
33 printf("Entropy of universe = %.2f kJ/K\n\n",
      delta_S_uni)

```

Scilab code Exa 8.14 Find the available and unavailable parts of 100 kJ heat

```

1  clc
2  clear
3  printf("Example 8.14 | Page number 230 \n\n");
4  //Find the available and unavailable parts of 100kJ
   of heat from
5  //Part(a) a reservoir at 1000K
6  //Part(b) a reservoir at 600K
7
8  //Given Data
9  Q1 = 100 //kJ //Heat input
10 T0 = 300 //K //Surrounding temperature
11
12 //Part(a)
13 printf("Part (a)\n");
14 T1 = 1000 //K //reservoir temperature
15 printf("Avalable enery of 100 kJ of heat from a
   reservoir at 1000K = %.1 f kJ\n",Q1*(1-(T0/T1)));
16 printf("Unvalable enery of 100 kJ of heat from a
   reservoir at 1000K = %.1 f kJ\n\n",Q1-Q1*(1-(T0/T1
   )))
17 //Part(b)
18 printf("Part (b)\n");
19 T1 = 600 //K //reservoir temperature
20 printf("Avalable enery of 100 kJ of heat from a
   reservoir at 1000K = %.1 f kJ\n",Q1*(1-(T0/T1)));
21 printf("Unvalable enery of 100 kJ of heat from a
   reservoir at 1000K = %.1 f kJ\n\n",Q1-Q1*(1-(T0/T1
   )))

```

Scilab code Exa 8.15 Evaluate the increase in unavailable energy

```

1  clc
2  clear
3  printf("Example 8.15 | Page number 231 \n\n");
4  //Evaluate the increase in unavailable energy due to

```

```

    irreversible heat transfer
5 //Given Data
6 T0 = 300 //K //Surrounding temperature
7 T1 = 1000 //K //Temperature of final reservoir
8 T2 = 600 //K //Temperature of intermediate reservoir
9 Q1 = 100 //kJ //Heat input
10 //Solution
11 printf("Increase in unavaliable energy due to
    irreversible heat transfer = %.1f kJ",Q1*(1-T0/T1
    )-Q1*(1-T0/T2))

```

Scilab code Exa 8.16 What are the available and unavailable energies

```

1 clc
2 clear
3 printf("Example 8.16 | Page number 234 \n\n");
4 //What are available and unavailable energies of Q1
5 //Given data
6 T1 = 500 //K
7 T0 = 300 //K
8 T2 = 350 //K
9 W = 250 //kJ
10 Q1 = 1000 //kJ
11 printf(" Available energy = %.1f kJ\n", (1-(T0/T1))*Q1
    );
12 printf(" Unavailable energy = %.1f kJ\n", Q1 - (1-(T0/
    T1))*Q1);

```

Chapter 9

Ideal Gas and Ideal Gas Mixtures

Scilab code Exa 9.1 What is the volume occupied by Nitrogen

```
1 clc
2 clear
3 printf("Example 9.1 | Page number 253 \n\n");
4 //Find the volume occupied
5 //Given Data
6 m = 6 //kg //mass of nitrogen
7 M = 28 //kg/kmol //molar mass of nitrogen
8 R = 8314.3 //kg/kmol
9 p = 1e5 //Pa //pressure
10 T = 27+273 //K //temperature
11 //Solution
12 V = m*R*T/(p*M)
13 printf("Volume occupied by nitrogen = %.3f m^3",V)
```

Scilab code Exa 9.2 Find the final volume

```

1  clc
2  clear
3  printf("Example 9.2 | Page number 253 \n\n");
4  //Find the final volume
5  //Given data
6  p1 = 10 //bar //inital pressure
7  T1 = 273+227 //K //inital temperature
8  v1 = 0.01 //m^3 //initial volume
9  p2 = 1 //bar //final pressure
10 T2 = 273+27 //K //final temperature
11 //Solution
12 v2 = (p1/p2)*(T2/T1)*v1 //m^3 //final volume
13 printf("Final volume = %.2f m^3",v2)

```

Scilab code Exa 9.3 Find internal energy and enthalpy

```

1  clc
2  clear
3  printf("Example 9.3 | Page number 255 \n\n");
4  //Part(a) Find internal energy
5  //Part(b) Find enthalpy and internal energy at (i)10
   bar,50 C and,(ii)0.085 m^3/kg and 50 C
6
7  //Given Data
8  p = 1 //bar //pressure
9  T = 50+273 // C //temperature
10 h = 324.6 //kJ/kg //enthalpy
11 R = 8.3143 //kJ/kmolK
12 M = 28.97 //kg/kmol
13 //Part (a)
14 printf("Part (a)\n");
15 u = h - (R/M)*T //kJ/kg //internal energy
16 printf("Internal energy = %.1f kJ/kg\n",u)
17 //Part (b)
18 printf("\nPart (b):(i)\n");

```

```

19 u = h - (R/M)*T //kJ/kg //internal energy
20 printf("Enthalpy = %.1f kJ/kg\n",h)
21 printf("Internal energy = %.1f kJ/kg\n",u)
22 printf("Part (b):( ii)\n");
23 u = h - (R/M)*T //kJ/kg //internal energy
24 printf("Enthalpy = %.1f kJ/kg\n",h)
25 printf("Internal energy = %.1f kJ/kg",u)

```

Scilab code Exa 9.4 Calculate the value of Cp for air

```

1 clc
2 clear
3 printf("Example 9.4 | Page number 256 \n\n");
4 //Calculate Cp of air
5 //Given Data
6 Cv = 718 //J/kgK //specific at constant volume
7 M = 28.97 //kg/kmol //molar mass of air
8 R = 8314.3 //J/kmolK
9 //Solution
10 Cp = (R/M)+Cv //J/kgK //specific heat at constant
    pressure
11 printf("Specific heat at constant pressure = %.1f J/
    kg K",Cp)

```

Scilab code Exa 9.5 Calculate the increase in specific enthalpy and change in enthalpy

```

1 clc
2 clear
3 printf("Example 9.5 | Page number 258 \n\n");
4 //Part(a) Calculate increase in specific enthalpy
5 //Part(b) Calculate change in enthalpy
6

```

```

7 //Given data
8 p1 = 1 //bar //initial pressure
9 T1 = 27+273 //K //initial temperature
10 p2 = 10 //bar //final pressure
11 T2 = 327+273 //K //final temperature
12 //Solution
13 //Part(a)
14 printf("Part(a)\n");
15 delta_h = integrate('1.4-18.3*(T/100)^(-1.5)+38.3*(T
    /100)^(-2)-29.3*(T/100)^(-3)', 'T', T1, T2) //kJ/kg
    //Increase in specific enthalpy
16 printf("Increase in specific enthalpy = %.2f kJ/kg\n
    ", delta_h)
17 //Part(b)
18 printf("\nPart(b)\n");
19 delta_h = integrate('1.042 ', 'T', T1, T2) //kJ/kg //
    Increase in specific enthalpy
20 printf("Increase in specific enthalpy at (Cp = 1.042
    kJ/kgK) = %.2f kJ/kg", delta_h)

```

Scilab code Exa 9.6 Find the final temperature of air

```

1 clc
2 clear
3 printf("Example 9.6 | Page number 268 \n\n");
4 //Find the final temperature when:
5 //Part(a) V = constant
6 //Part(b) pV = constant
7 //Part(c) pV^y = constant
8 //And P-V diagram
9
10 //Given Data
11 Cp = 1005 //J/kgK //specific heat at constant

```

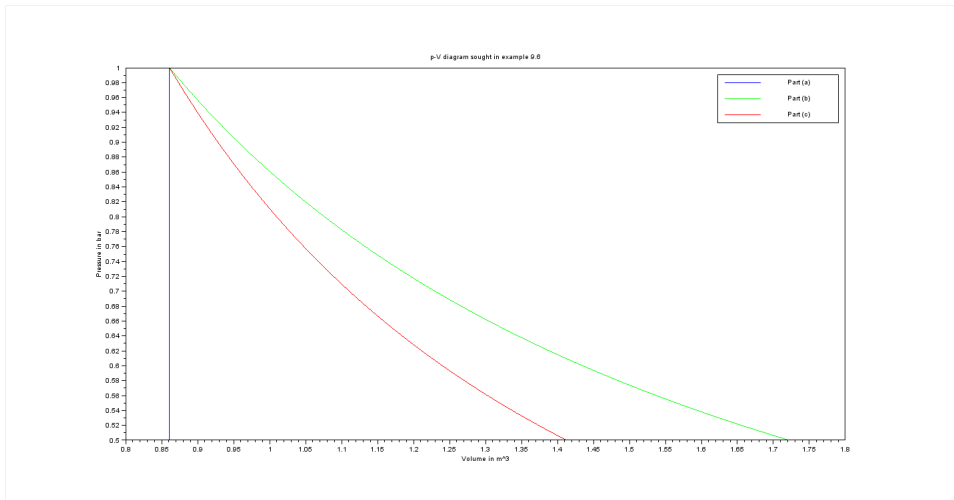


Figure 9.1: Find the final temperature of air

```

pressure
12 Cv = 718 //J/kgK //specific heat at constant volume
13 m = 1 //kg //mass of air
14 T1 = (27+273) //K //initial temperature
15 p1 = 1e5 //Pa //initial pressure
16 p2 = p1/2 //Pa //final pressure
17
18 //Solution
19 //Part(a)
20 printf("Part(a)\n");
21 R = Cp-Cv //J/kgK
22 V1_a = m*R*T1/p1 //m^3 //initial volume
23 V2_a = V1_a //m^3 //final volume
24 T2 = p2*V2_a/(m*R) //K //final temperature
25 printf("Final temperature ,T2 = %.1 f K\n\n",T2)
26
27 //Part(b)
28 printf("Part(b)\n");
29 V1_b = m*R*T1/p1 //m^3 //initial volume
30 V2_b = V1_b*(p1/p2) //m^3 //final volume
31 //Isothermal process => T1 = T2

```

```

32 printf(" Final temperature ,T2 = %.1 f K\n\n",T1)
33
34 //Part(c)
35 printf(" Part(c)\n");
36 R = Cp-Cv //J/kgK
37 y = Cp/Cv
38 V1_c = m*R*T1/p1 //m^3 //initial volume
39 V2_c = V1_c*(p1/p2)^(1/y) //m^3 //final volume
40 T2 = p2*V2_c/(m*R) //K //final temperature
41 printf(" Final temperature ,T2 = %.1 f K\n\n",T2)
42
43 //P-V diagram
44 P = [p1*1e-5 p2*1e-5]
45 V = [V1_a V1_a]
46 plot(V,P,'b') //plot for part(a)
47
48 V = linspace(V1_b,V2_b,100)
49 P = (p1*1e-5*V1_b)./V
50 plot(V,P,'g') //plot for part(b)
51
52 V = linspace(V1_c,V2_c,100)
53 P = (p1*1e-5*V1_c.^y)./V.^y
54 plot(V,P,'r') //plot for part(c)
55 xlabel('Volume in m^3')
56 ylabel('Pressure in bar')
57 title('p-V diagram sought in example 9.6')
58 legends(['Part (a)';'Part (b)';'Part (c)'],[2 3 5],
opt=1)

```

Scilab code Exa 9.7 Find the enthalpy entropy and internal energy of Nitrogen

```

1 clc
2 clear
3 printf(" Example 9.7 | Page number 270 \n\n");

```

```

4 //Part(a) How many kilograms of nitrogen are stored
   in the bottle
5 //Part(b) (i) Find temperature of nitrogen at
   maximum pressure ,(ii)increase in internal energy
   (iii)increase in enthalpy (iv)increase in entropy
   of nitrogen
6 //Given Data
7 p1 = 10e6 //N/m^2 //initial pressure
8 T1 = 273+27 //K //inital temperature
9 V1 = 50e-3 //m^3 //inital volume
10 M = 28 //g/mol //molecular mass
11 R = 8314.3/M //J/kgK
12 y = 1.4 //gamma
13
14 //Solution
15 //Part(a)
16 printf('Part(a)\n');
17 m = (p1*V1)/(R*T1)
18 printf("Mass of nitrogen stored in bottle = %.3f kg\
   n\n",m)
19
20 //Part(b):(i)
21 printf('Part(b):(i)\n');
22 p2 = 15e6 //N/m^2 //final pressure
23 V2 = V1 //m^3 //final volume
24 T2 = (p2*V2)/(m*R)
25 printf("Temperature of nitrogen at maximum permitted
   temperature = %.1f K\n\n",T2)
26
27 //Part(b):(ii)
28 printf('Part(b):(ii)\n');
29 C = [1, -1.4;1, -1]\[0;R] //J/kgK //C = [Cp;Cv]
30 delta_U = m*C(2)*(T2-T1)*.001 //kJ //Change in
   internal energy
31 printf("Change in internal energy = %.1f kJ\n\n",
   delta_U)
32
33 //Part(b):(iii)

```

```

34 printf('Part(b):(iii)\n');
35 delta_H = m*C(1)*(T2-T1)*.001 //kJ //Change in
    enthalpy
36 printf("Change in enthalpy = %.1f kJ\n\n",delta_H)
37
38 //Part(b):(iv)
39 printf('Part(b):(iv)\n');
40 delta_S = m*(C(2)*log(T2/T1)+R*log(V2/V1))*0.001 //kJ
    /K //Change in entropy
41 printf("Change in entropy = %.4f kJ/K",delta_S)

```

Scilab code Exa 9.8 Calculate work per kilogram of air and change in entropy

```

1 clc
2 clear
3 printf("Example 9.8 | Page number 271 \n\n");
4 //Calculate work per kilogram of air and change in
    entropy
5 //Given Data
6 T1 = 800 //K //initial temperature
7 p1 = 1.5e6 //N/m^2 //initial pressure
8 T2 = 540 //K //final temperature
9 T2s = 485 //K //final temperature for reversible
    process
10 Q = 0 //adiabatic process
11 y = 1.4
12 Cv = 718 //J/kgK //specific heat at constant volume
13
14 //Solution
15 delta_U = Cv*(T2-T1) //kJ/kg //change in internal
    energy
16 W = (Q-delta_U)*.001 //kJ/kg //work done per
    kilogram
17 printf("Work done per kilogram = %.1f kJ/kg\n",W);

```



```

18
19 p2 = p1*(T2s/T1)^(y/(y-1)) //N/m^2 //final pressure
20 delta_S = (y*Cv)*log(T2/T1)-(y*Cv-Cv)*log(p2/p1)
21 printf("Change in entropy = %.3f kJ/kgK",delta_S
    *.001)

```

Scilab code Exa 9.9 Find the molar mass and the gas constant of the mixture

```

1 clc
2 clear
3 printf("Example 9.9 | Page number 279 \n\n");
4 //Find molar mass and gas constant and find mass
  fractions of the constituents.
5 //Given Data
6 xCO2 = 0.1 //mole fraction of CO2
7 xO2 = .09 //mole fraction of O2
8 xCO = 0.01 //mole fraction of CO
9 xN2 = 0.8 //mole fraction of N2
10
11 //Solution
12 M = xCO2*44 + xO2*32 + xCO*28 + xN2*28 //kg/kmol //
  avg. molar mass
13 R = 8314.3/M //J/kgK //gas constant
14 yCO2 = xCO2*(44/M) //mass fraction of CO2
15 yO2 = xO2*(32/M) //mass fraction of O2
16 yCO = xCO*(28/M) //mass fraction of CO
17 yN2 = xN2*(28/M) //mass fraction of N2
18
19 printf("Molar Mass = %.2f kg/kmol\n",M);
20 printf("Gas constant = %.1f J/kgK\n",R);
21 printf("Mass fraction of CO2 = %.4f \n",yCO2);
22 printf("Mass fraction of O2 = %.4f \n",yO2);
23 printf("Mass fraction of CO = %.4f \n",yCO);
24 printf("Mass fraction of N2 = %.4f \n",yN2);

```

Scilab code Exa 9.10 Find the molar mass and gas constant for the mixture and mole fractions partial pressures and partial volumes of the constituents

```
1  clc
2  clear
3  printf("Example 9.10 | Page number 280 \n\n");
4  //Part(a) Find molar mass and gas constant
5  //Part(b) Find mole fractions , partial fractions and
    partial volumes
6  //Given
7  m = 1.9 //kg
8  T = 273+20 //K
9  p = 150e3 //Pa
10 yO2 = 0.1 //mass fraction of O2
11 yN2 = 0.75 //mass fraction of N2
12 yCO2 = 0.12 //mass fraction of CO2
13 yCO = 0.03 //mass fraction of CO
14
15 //Solution
16 //Part(a)
17 printf("Part (a)\n\n");
18 M = 1/((yO2/32)+(yN2/28)+(yCO/28)+(yCO2/44)) //kg/
    kmol //molar mass
19 printf("Molar mass = %.2 f kg/kmol \n",M)
20 R = 8314.3/M //J/kgK //Gas constant
21 printf("Gas Constant = %.2 f J/kgK \n",R)
22 V = m*R*T/p //m^3 //Volume
23
24 //Part(b)
25 printf("\nPart (b)\n")
26 xO2 = yO2*(M/32) //mole fraction O2
27 printf("\nMole fraction of O2 = %.3 f",xO2)
28 pO2 = xO2*p //partial pressure O2
```

```

29 printf("\nPartial pressure of O2 = %.2 f kPa", pO2
    *.001)
30 VO2 = xO2*V //partial volume of O2
31 printf("\nPartial volume of O2 = %.4 f m^3\n", VO2)
32
33
34 xN2 = yN2*(M/28) //mole fraction N2
35 printf("\nMole fraction of N2 = %.3 f", xN2)
36 pN2 = xN2*p //partial pressure N2
37 printf("\nPartial pressure of N2 = %.2 f kPa", pN2
    *.001)
38 VN2 = xN2*V //partial volume of N2
39 printf("\nPartial volume of N2 = %.4 f m^3\n", VN2)
40
41
42 xCO2 = yCO2*(M/44) //mole fraction CO2
43 printf("\nMole fraction of CO2 = %.3 f", xCO2)
44 pCO2 = xCO2*p //partial pressure CO2
45 printf("\nPartial pressure of CO2 = %.2 f kPa", pCO2
    *.001)
46 VCO2 = xCO2*V //partial volume of CO2
47 printf("\nPartial volume of CO2 = %.4 f m^3\n", VCO2)
48
49
50 xCO = yCO*(M/28) //mole fraction CO
51 printf("\nMole fraction of CO = %.3 f", xCO)
52 pCO = xCO*p //partial pressure CO
53 printf("\nPartial pressure of CO = %.2 f kPa", pCO
    *.001)
54 VCO = xCO*V //partial volume of CO
55 printf("\nPartial volume of CO = %.4 f m^3\n", VCO)

```

Scilab code Exa 9.11 Evaluate the mass fraction and volume fractions of nitrogen and hydrogen in the mixture

```

1  clc
2  clear
3  printf("Example 9.11 | Page number 283 \n\n");
4  //Evaluate the mass fraction and volumes fractions
   of N2 and H2 in mixture
5  //Given data
6  R = 1841 //J/kgK //Gas constant
7  Cp = 6310 //J/kgK //specific heat at constant
   pressure
8  MN = 28 //kg/kmol //molar mass N2
9  MH = 2 //kg/kmol //molar mass H2
10 CpN = 1042 //J/kgK //specific heat of N2
11 CpH = 14210 //J/kgK //specific heat of H2
12
13 //Solution
14 Y = [8314.3/MN, 8314.3/MH;CpN, CpH]\[R; Cp]
15 YN = Y(1) //mass fraction of N2
16 YH = Y(2) //mass fraction of H2
17 XN = YN*(8314.3/(R*MN)) //volume fraction of N2
18 XH = YH*(8314.3/(R*MH)) //volume fraction of H2
19 printf("Mass fraction of N2 = %.1f \n",YN)
20 printf("Mass fraction of H2 = %.1f \n",YH)
21 printf("Volume fraction of N2 = %.4f \n",XN)
22 printf("Volume fraction of H2 = %.4f \n",XH)

```

Scilab code Exa 9.12 Determine specific heat internal energy enthalpy and entropy change

```

1  clc
2  clear
3  printf("Example 9.12 | Page number 284 \n\n");
4  //Part(a) Find specific heats
5  //Part(b) Find internal energy
6  //Part(c) Find enthalpy
7  //Part(d) Find entropy

```

```

8 //Given Data
9 m = 1.9 //kg
10 T = 273+20 //K
11 p = 150 //kPa
12 pdat = 100 //kPa //datum pressure
13 Tdat = 273 //K //datum temperature
14 yO2 = 0.1 //mass fraction of O2
15 yN2 = 0.75 //mass fraction of N2
16 yCO2 = 0.12 //mass fraction of CO2
17 yCO = 0.03 //mass fraction of CO
18 xO2 = 0.093 //mole fraction of O2
19 xN2 = 0.795 //mole fraction of N2
20 xCO2 = 0.081 //mole fraction of CO2
21 xCO = 0.031 //mole fraction of CO
22 R = 280.22 //J/kgK
23 M = 29.67 //kg/kmol //mixture molar mass
24 CpO2=0.922 //kJ/kgK
25 CpN2=1.042 //kJ/kgK
26 CpCO2=0.842 //kJ/kgK
27 CpCO=1.041 //kJ/kgK
28 //Part(a)
29 printf("Part(a)\n");
30 Cp = yN2*CpN2 + yO2*CpO2 + yCO2*CpCO2 + yCO*CpCO //
    kJ/kgK // specific heat of mixture at constant
    pressure
31 Cv = Cp - R*.001 //specific heat of mixture at
    constant volume
32 printf("Cp = %.3 f kJ/kgK\n",Cp)
33 printf("Cv = %.4 f kJ/kgK\n",Cv)
34
35 //Part(b)
36 printf("\nPart(b)\n");
37 U = m*(Cv*(T-Tdat)) //kJ //internal energy
38 printf("Internal energy = %.2 f kJ\n",U)
39
40 //Part(c)
41 printf("\nPart(c)\n")
42 H = U + m*R*T*.001 //kJ //enthalpy

```

```

43 printf("Enthalpy = %.1f kJ\n",H)
44
45 //Part(d)
46 printf("\nPart(d)\n")
47 S02 = CpO2*log(T/Tdat)-(8.3143/32)*log(xO2*(p/pdat))
    //kJ/kgK //entropy of O2
48 SN2 = CpN2*log(T/Tdat)-(8.3143/28)*log(xN2*(p/pdat))
    //kJ/kgK //entropy of N2
49 SC02 = CpCO2*log(T/Tdat)-(8.3143/44)*log(xCO2*(p/
    pdat)) //kJ/kgK //entropy of CO2
50 SC0 = CpCO*log(T/Tdat)-(8.3143/28)*log(xCO*(p/pdat))
    //kJ/kgK //entropy of CO
51
52 S = m*(yO2*S02+yN2*SN2+yCO2*SC02+yCO*SC0) //kJ/K //
    entropy
53 printf("Entropy = %.4f kJ/K",S)

```

Scilab code Exa 9.13 Calculate magnitude and direction of heat transfer and pressure of the mixture

```

1  clc
2  clear
3  printf("Example 9.13 | Page number 288 \n\n");
4  //Find magnitude and direction of heat transfer
5
6  //Given data
7  V_He = 0.3 //m^3 //volume of Helium
8  p_He = 20e5 //Pa //pressure of Helium
9  T_He = 273+30 //K //Temperature of Helium
10 V_O2 = 0.7 //m^3 //volume of O2
11 p_O2 = 6e5 //Pa //pressure of O2
12 T_O2 = 273+2 //K Temperature of O2
13 R_He = 2077 //J/kgK
14 R_O2 = 260 //J/kgK
15 Cv_He = 3116 //J/kgK

```

```

16 Cv_O2 = 662 //J/kgK
17 //Solution
18 m_He = (p_He*V_He)/(R_He*T_He) //kg //mass of Helium
19 m_O2 = (p_O2*V_O2)/(R_O2*T_O2) //kg //mass of O2
20 T_ad = (m_He*Cv_He*T_He+m_O2*Cv_O2*T_O2)/(m_He*Cv_He
      +m_O2*Cv_O2) //K //Temperature after mixing
21 T_final = 300 //K //final temperature
22 Q = (Cv_He*m_He+Cv_O2*m_O2)*(T_final-T_ad) //J //
      Magnitude of heat transfer
23 printf("Magnitude of heat transfer = %.2f kJ",Q
      *.001)

```

Scilab code Exa 9.14 Determine mixture temperature and rate of entropy generation

```

1 clc
2 clear
3 printf("Example 9.14 | Page number 289 \n\n");
4 //Part(a) Find mixture temperature
5 //Part(b) Find rate of entropy generation
6
7 //Given Data
8 T_E = (273+20) //K //temperature of ethane
9 p_E = 200 //kPa //pressure of ethane
10 T_M = 273+45 //K //temperature of methane
11 p_M = 200 //kPa //pressure of methane
12 m_E = 9 //kg/s //mass rate of ethane
13 m_M = 4.5 //kg/s //mass rate of methane
14 Cp_E = 1766 //J/kgK //specific heat of ethane
15 Cp_M = 2254 //J/kgK //specific heat of methane
16
17 //Solution
18 //Part(a)
19 printf("Part (a)\n");
20 T = (m_E*Cp_E*T_E+m_M*Cp_M*T_M)/(m_E*Cp_E+m_M*Cp_M)

```

```

//K //mixture temperature
21 printf("Mixture temperature = %.1f K\n\n",T)
22
23 //Part(b)
24 printf("Part(b)\n");
25 R_E = 8314.3/30 //J/kgK //gas constant for ethane
26 R_M = 8314.3/16 //J/kgK //gas constant for methane
27 R = (m_E/(m_E+m_M))*R_E+(m_M/(m_E+m_M))*R_M //J/kgK
//gas constant of mixture
28 M = 8314.3/R //kg/kmol //mixture molar mass
29 x_E = (m_E/(m_E+m_M))*(M/30) //mole fraction of
ethane
30 x_M = (m_M/(m_E+m_M))*(M/16) //mole fraction of
methane
31
32 delta_S_E = Cp_E*log(T/T_E) - R_E*log(x_E) //J/kgK
//change in entropy of ethane
33 delta_S_M = Cp_M*log(T/T_M) - R_M*log(x_M) //J/kgK
//change in entropy of methane
34
35 printf("Rate of entropy production = %.4f kJ/sK", (
m_E*delta_S_E+m_M*delta_S_M)*.001)

```

Chapter 10

Properties of Pure Substance Water

Scilab code Exa 10.1 Find dryness fraction of mixture

```
1 clc
2 clear
3 printf("Example 10.1 | Page number 333 \n\n");
4 //Find dryness fraction of mixture
5 //Given data
6 m = 1.5 //kg //mass of wet steam
7 mf = 0.08*m //kg //mass of liquid in wet steam
8 //Solution
9 x = (m-mf)/m //dryness fraction of mixture
10 printf("Dryness fraction of mixture = %.2f",x)
```

Scilab code Exa 10.2 Find ratio of mass of saturated liquid to saturated steam

```
1 clc
2 clear
```

```

3 printf("Example 10.2 | Page number 333 \n\n");
4 //Find the ratio of mass of saturated liquid to
  saturated steam
5 //Given Data
6 x = 0.85 //quality of steam
7 printf("The ratio of mass of saturated liquid to
  saturated steam = %.5f", (1-x)/x)

```

Scilab code Exa 10.3 Find volume enthalpy internal energy and entropy per kg water

```

1 clc
2 clear
3 printf("Example 10.3 | Page number 350 \n\n");
4 //Find volume, enthalpy, internal energy and entropy
  per kilogram of water
5 //Given Data
6 p1 = 200 //kPa //initial pressure
7 t1 = 100 // C //initial temperature
8 ts = 120.23 // C //saturated steam temperature
9
10 //Solution
11 //From steam table
12 v1 = 0.001044 //m^3/kg //volume per kilogram of
  water
13 h1 = 419 //kJ/kg //enthalpy per kilogram of water
14 s1 = 1.3068 //kJ/kg //entropy per kilogram of water
15 u1 = h1-p1*v1 //kJ/kg //internal energy per kilogram
  of water
16 printf("Volume per kilogram of water = %.6f m^3/kg\n
  ", v1)
17 printf("Enthalpy per kilogram of water = %.1f kJ/kg\
  n", h1)
18 printf("Entropy per kilogram of water = %.4f kJ/kgK\
  n", s1)

```

```
19 printf("Internal energy per kilogram of water = %.1f
    kJ/kg\n",u1)
```

Scilab code Exa 10.4 Find temperature and all other specific properties

```
1 clc
2 clear
3 printf("Example 10.4 | Page number 350 \n\n");
4 //Find temperature and all other specific properties
5 //Given data
6 p1 = 500 //kPa //initial pressure
7 s1 = 1.3625 //initial entropy
8
9 //Solution
10 //Using Method 2:
11 Ts = 424.28 //K //temperature at 500kPa
12 sf = 1.8606 //kJ/kgK //entropy at 500kPa
13 Cwat = 4.189 //kJ/kgK //specific heat of water
14 T1 = (exp((sf-s1)/Cwat)/Ts)^-1 //K
15 printf("Temperature = %.2f C\n",T1-273)
16 v1 = 0.001 //m^3/kg //volume per kg water
17 h1 = (640.21 - Cwat*(151.86-T1+273)) // kJ/kg //
    Enthalpy per kg water
18 u1 = h1 - p1*v1 //kJ/kg //internal energy per kg
    water
19 printf("Volume per kg water = %.3f m^3/kg\n",v1)
20 printf("Enthalpy per kg water = %.1f kJ/kg\n",h1)
21 printf("Internal energy per kg water = %.1f kJ/kg\n"
    ,u1)
```

Scilab code Exa 10.5 Find other properties of water

```
1 clc
```

```

2 clear
3 printf("Example 10.5 | Page number 352 \n\n");
4 //Find properties of water
5 //Given data
6 t = 50 // C //temperature of water
7 h = 209.31 //kJ/kg
8 //Solution
9 //From saturated property table
10 p = 12.35 //kPa
11 v = 0.001012 //m^3/kg
12 u = h - p*v //kJ/kg
13 s = 0.7037 //kJ/kg
14 printf("Pressure = %.2f kPa\n",p)
15 printf("Volume per kg water = %.6f m^3/kg\n",v)
16 printf("Internal energy per kg water = %.1f kJ/kg\n"
    ,u)
17 printf("Entropy per kg water = %.4f kJ/kgK",s)

```

Scilab code Exa 10.6 Find all other properties of steam

```

1 clc
2 clear
3 printf("Example 10.6 | Page number 353 \n\n");
4 //Find all properties of steam
5 //Given Data
6 p = 12 //bar //pressure of steam leaving boiler
7 h = 2705 //kJ/kg //Enthalpy of steam
8 //Solution
9 //From pressure based saturated property table, at p
    = 12bar
10 hf = 798.64 //kJ/kg
11 hg = 2784.8 //kJ/kg
12 x = (h-hf)/(hg-hf) //Dryness fraction
13 v = (1-x)*0.001139 + (x)*0.1633 //m^3/kg
14 s = (1-x)*2.2165 + (x)*6.5233 //m^3/kgK

```

```

15 u = h - p*v*100 //kJ/kg
16 printf("Volume per kg water = %.6 f m^3/kg\n",v)
17 printf("Internal energy per kg water = %.1 f kJ/kg\n"
    ,u)
18 printf("Entropy per kg water = %.4 f kJ/kgK",s)

```

Scilab code Exa 10.7 Find all other thermodynamic properties

```

1  clc
2  clear
3  printf("Example 10.7 | Page number 354 \n\n");
4  //Find all thermodynamic properties
5  //Given data
6  p = 15 //bar
7  u = 2594.5 //kJ/kg
8  //Solution
9  //From saturated steam table based on pressure at p
    = 15 bar
10 hf = 844.87 //kJ/kg
11 hg = 2792.1 //kJ/kg
12 vf = 0.001154 //m^3/kg
13 vg = 0.13177 //m^3/kg
14 uf = hf-100*p*vf //kJ/kg
15 ug = hg-100*p*vg //kJ/kg
16 if u-ug<0.1 then
17     printf("Temperature = %.2 f C\n",198.32)
18     printf("Volume per kg water = %.3 f m^3/kg\n",vg)
19     printf("Enthalpy per kg water = %.1 f kJ/kg\n",hg
    )
20     printf("Internal energy per kg water = %.1 f kJ/
    kg\n",ug)
21     printf("Entropy per kg water = %.4 f kJ/kgK"
    ,6.4448)
22
23 end

```

Scilab code Exa 10.8 Find all other thermodynamic properties of steam

```
1 clc
2 clear
3 printf("Example 10.8 | Page number 355 \n\n");
4 //Find all thermodynamic property of steam
5 //Given data
6 p = 10e6 //Pa
7 t = 550 // C
8 //Solution
9 //From superheated property table
10 v_500 = 0.03279 //m^3/kg
11 v_600 = 0.03837 //m^3/kg
12 v_550 = v_500 + (v_500-v_600)/(500-600)*(550-500) //
    m^3/kg
13 h_500 = 3373.6 //kJ/kg
14 h_600 = 3625.3 //kJ/kg
15 h_550 = h_500 + (h_500-h_600)/(500-600)*(550-500) //
    kJ/kg
16 s_500 = 6.5965 //kJ/kgK
17 s_600 = 6.9028 //kJ/kgK
18 s_550 = s_500 + (s_500-s_600)/(500-600)*(550-500) //
    kJ/kgK
19 printf("Volume per kg water = %.6f m^3/kg\n",v_550)
20 printf("Enthalpy per kg water = %.1f kJ/kg\n",h_550)
21 printf("Entropy per kg water = %.4f kJ/kgK",s_550)
```

Scilab code Exa 10.9 Find the all other thermodynamic properties of steam

```
1 clc
2 clear
```

```

3 printf("Example 10.9 | Page number 355 \n\n");
4 //Find thermodynamic properties
5 //Given data
6 t = 250 // C
7 h = 2855.8 //kJ/kg
8 //From superheated property table
9 p = 3e6 //Pa
10 v = 0.07058 //m^3/kg
11 s = 6.2871 //kJ/kgK
12 u = h - p*v*.001 //kJ/kg
13 printf("Pressure = %.1f MPa\n",p*1e-6)
14 printf("Volume per kilogram of water = %.6f m^3/kg\n
",v)
15 printf("Enthalpy per kilogram of water = %.1f kJ/kg\
n",h)
16 printf("Entropy per kilogram of water = %.4f kJ/kgK\
n",s)
17 printf("Internal energy per kilogram of water = %.1f
kJ/kg\n",u)

```

Scilab code Exa 10.10 Find the temperature of steam

```

1 clc
2 clear
3 printf("Example 10.10 | Page number 359 \n\n");
4 //Find the temperature of steam
5 p = 2 //bar
6 m = 0.16 //kg
7 V = 0.1 //m^3
8 //Solution
9 //refereing to the saturation temperature
corresponding to 2bar
10 v = V/m //m^3/kg
11 vf = 0.001061 //m^3/kg
12 vg = 0.8857 //m^3/kg

```

```

13 printf('Specific volume at saturated liquid phase (
    vf) = %.6f m^3/kg \n',vf)
14 printf('Specific volume at saturated vapor phase (vg
    ) = %.6f m^3/kg \n',vg)
15
16 if v<vg & v>vf then
17     printf('\nThe temperature of the steam must be
        equal to saturation temperature corresponding
        to 2 bar\n')
18     printf("Temperature of steam = %.2f C ",120.23)
19 end

```

Scilab code Exa 10.11 Find the heat rejected from steam

```

1 clc
2 clear
3 printf("Example 10.11 | Page number 360 \n\n");
4 //Find the heat rejected from steam
5 //Given data
6 p1 = 2 //bar
7 v1 = 0.624 //m^3/kg
8 t = 120.23 // C
9 m = 0.16 //kg
10 //Solution
11 vf = 0.001061 //m^3/kg
12 vg = 0.8857 //m^3/kg
13 x1 = (v1-vf)/(vg-vf) //Dryness fraction
14 hf = 504.68 //kJ/kg
15 hg = 2706.6 //kJ/kg
16 h1 = (1-x1)*hf + x1*hg //kJ/kg
17 u1 = h1 - p1*v1*100//kJ/kg
18
19 v2 = v1 //m^3/kg
20 vf = 0.001044 //m^3/kg
21 vg = 1.673 //m^3/kg

```



```

22 x2 = (v1-vf)/(vg-vf) //Dryness fraction
23 hf = 419 //kJ/kg
24 hg = 2676 //kJ/kg
25 h2 = (1-x2)*hf + x2*hg //kJ/kg
26 p2 = 1.010325 //bar
27 u2 = h2 - p2*v2*100 //kJ/kg
28
29 printf("Heat rejected from steam = %.1f kJ",m*(u2-u1
    ))

```

Scilab code Exa 10.12 Find work and heat interaction during expansion process

```

1  clc
2  clear
3  printf("Example 10.12 | Page number 361 \n\n");
4  //Find the work and heat interactions during the
    expansion process
5  //Given data
6  m =0.1 //kg
7  p1 = 10 //bar
8  p2 = 1 //bar
9  //Solution
10 //From saturated steam table
11 v1 = 0.1944 //m^3/kg
12 v2 = (p1/p2)^(1/1.3)*v1 //m^3/kg
13 W = m*(p1*v1-p2*v2)*100/(1.3-1) //kJ
14 printf("Work during expansion process = %.2f kJ\n",W
    )
15 h1 = 2778.1 //kJ/kg
16 u1 = (h1 - p1*v1*100) //kJ/kg
17
18 vf = 0.001043 //m^3/kg
19 vg = 1.694 //m^3/kg
20 x2 = (v2-vf)/(vg-vf) //Dryness fraction

```

```

21 hf = 417.33 //kJ/kg
22 hg = 2675.5 //kJ/kg
23 h2 = (1-x2)*hf + x2*hg //kJ/kg
24 u2 = h2 - p2*v2*100 //kJ/kg
25 printf("Heat rejected from steam = %.2 f kJ",W+m*(u2-
    u1))

```

Scilab code Exa 10.13 Find the exit area of the nozzle

```

1  clc
2  clear
3  printf("Example 10.13 | Page number 361 \n\n");
4  //Find the exit area of the nozzle
5  //Given data
6  p1 = 10 //bar
7  t1 = 300 // C
8  V1 = 50 //m/s
9  p2 = 1 //bar
10 m = 1.2 //kg/s
11
12 //Solution
13 //From superheated steam table
14 h1 = 3051.2 //kJ/kg
15 s1 = 7.1228 //kJ/kgK
16 p2 = 1 //bar
17 s2 = s1 //kJ/kgK
18
19 sf = 1.3025 //kJ/kgK
20 sg = 7.3593 //kJ/kgK
21 x2 = (s2-sf)/(sg-sf) //Dryness fraction
22 hf = 417.44 //kJ/kg
23 hg = 2675.5 //kJ/kg
24 h2 = (1-x2)*hf + x2*hg //kJ/kg
25 vf = 0.001043 //m^3/kg
26 vg = 1.694 //m^3/kg

```

```

27 v2 = (1-x2)*vf + x2*vg //m^3/kg
28 V2 = (2*(1000*(h1-h2))+V1^2)^0.5 //m/s
29 A2 = m*v2/V2*10000 //cm^3
30 printf("The exit area of the nozzle = %.1f cm^2",A2)

```

Scilab code Exa 10.14 Find the flow rate of feed water

```

1 clc
2 clear
3 printf("Example 10.14 | Page number 363 \n\n");
4 //Find the flow rate of feed water into the heater.
5 //Given data
6 m1 = 0.2 //kg/s
7 p = 4 //bar
8 //Solution
9 //From superheated steam table
10 h1 = 2752.8 //kJ/kg
11 h2 = 209.31 //kJ/kg
12 h3 = 604.73 //kJ/kg
13
14 m2 = (m1*h1-m1*h3)/(h3-h2) //kg/s
15 printf("The flow rate of feed water into the heater
    = %.3f kg/s",m2)

```

Chapter 11

Real Gas

Scilab code Exa 11.1 Calculate the specific volume of propane

```
1 clc
2 clear
3 printf("Example 11.1 | Page number 394 \n\n");
4 //Calculate specific volume of propane and ideal gas
5 //Given data
6 P = 70e5 //Pa
7 T = 150 + 273 //K
8 Z = 0.55 //Compressibility factor
9 R = 8314.3/44 //J/kgK
10 //Solution
11 //For propane
12 v = Z*R*T/P //m^3/kg
13 printf(" Specific volume for propane = %.6f m^3/kg\n"
    ,v)
14 //ideal gas
15 v = R*T/P //m^3/kg
16 printf(" Specific volume for ideal gas = %.6f m^3/kg"
    ,v)
```

Scilab code Exa 11.2 Find the reduced properties of air

```
1 clc
2 clear
3 printf("Example 11.2 | Page number 396 \n\n");
4 //Find reduced properties for air at 10 bar, 27 C
5 //Given data
6 Z = 1.04 //Compressibility factor
7 pc = 3.77e6 //Pa //critical pressure
8 Tc = 132.5 //K
9 vc = 0.0883 //m^3/kmol
10 p = 10e5 //Pa
11 T = 300 //K
12 //Solution
13 R = 287 //J/kgK
14 pR = p/pc //reduced pressure
15 TR = T/Tc //reduced temperature
16 v = Z*R*T/p //m^3/kg
17 vR = v/vc //reduced volume
18
19 printf("Reduced pressure = %.5f \n",pR)
20 printf("Reduced temperature = %.5f \n",TR)
21 printf("Reduced volume = %.5f \n",vR)
```

Scilab code Exa 11.3 At what temperature and pressure steam be similar to air

```
1 clc
2 clear
3 printf("Example 11.3 | Page number 397 \n\n");
4 //Find temperature and pressure at which steam will
   behave similar to air
5 //Given Data
6 pR = 0.26525 //reduced pressure
7 TR = 2.26415 //reduced temperature
```

```

8  pc = 22.09 //bar //critical pressure of water
9  Tc = 647.3 //K //critical temperature of water
10 //Solution
11 p = pR*pc //bar
12 T = TR*Tc //K
13 printf("Temperature at which steam would behave
    similar to air at 10 bar and 27 C = %.1f K\n",T)
14
15 printf("Pressure at which steam would behave similar
    to air at 10 bar and 27 C = %.2f bar\n",p)

```

Scilab code Exa 11.4 Find Z for air

```

1  clc
2  clear
3  printf("Example 11.4 | Page number 399 \n\n");
4  //Find Z for air at 5.65 MPa and 27 C
5  //Given data
6  pc = 3.77e6 //Pa //critical pressure
7  p = 5.65e6 //Pa
8  Tc = 132.5 //K //critical temperature
9  T = 300 //K
10
11 //Solution
12 pR = p/pc //reduced pressure
13 TR = T/Tc //reduced temperature
14 //from generalized compressibility chart
15 Z =0.97
16 printf("From the generalized compressibility chart ,
    at reduced pressure of %.1f and reduced
    temperature of %.2f, Z = %.2f",pR,TR,Z)

```

Scilab code Exa 11.5 Calculate specific volume of gaseous propane

```

1  clc
2  clear
3  printf("Example 11.5 | Page number 399 \n\n");
4  //Calculate specific volume for gaseous propane
   using:
5  //(i) ideal gas equation
6  //(ii) generalized compressibility chart
7  //Given data
8  T =150+273 //K
9  p = 7e6 //Pa
10
11 //Part (i)
12 printf("Part(i)\n")
13 v = (8314.3/44)*T/p //m^3/kg
14 printf("Specific volume for gaseous propane using
   ideal gas equation = %.4f m^3/kg\n\n",v)
15
16 //Part(ii)
17 printf("Part(ii)\n")
18 pc = 4.26e6 //Pa //critical pressure
19 Tc = 370 //K //critical temperature
20
21 pR = p/pc //reduced pressure
22 TR = T/Tc //reduced temperature
23 Z = 0.56 //compressibility factor
24 printf("From the generalized compressibility chart,
   at reduced pressure of %.1f and reduced
   temperature of %.2f, Z = %.2f\n",pR,TR,Z)
25 v = Z*v
26 printf("Specific volume for gaseous propane using
   generalized compressibility chart = %.5f m^3/kg\n\n",v)

```

Scilab code Exa 11.6 Determine the pressure exerted by Carbon dioxide

```

1  clc
2  clear
3  printf("Example 11.6 | Page number 404 \n\n");
4  //Find pressure exerted using (i) ideal gas equation
   of state (ii) van der Waals equation of state
5  //Given data
6  m = 5//kg //mass of CO2
7  T = 300 //K
8  R = 8314.3/44 //J/kgK
9  V = 1.5 //m^3
10
11 //Part(i)
12 printf("Part(i)\n")
13 p = m*R*T/V
14 printf("Pressure exerted by CO2(using ideal gas
   equation) = %.2f kPa\n\n",p*.001)
15
16 //Part(ii)
17 printf("Part(ii)\n")
18 R = 8.3143 //J/kmolK
19 a = 0.3658e3 //kPam^6/kmol^2
20 b = 0.0428 //m^3.kmol
21 v = 44*V/m //m^3/kmol
22 p = T*R/(v-b) - a/v^2
23 printf("Pressure exerted by CO2(using van der Waals
   equation) = %.1f kPa\n\n",p)

```

Scilab code Exa 11.7 Determine the pressure in rigid vessel

```

1  clc
2  clear
3  printf("Example 11.7 | Page number 406 \n\n");
4  //Determine the pressure using:
5  //(i) ideal gas equation of state
6  //(ii) generalised compressibility chart

```



```

7 // (iii) van der Waals equation
8 //(iv) Redlich-Kwong equation of state
9 //(v) Bettie-Bridgeman equation
10
11 // Given Data
12 M = 28 //g/mol
13 m = 3.5 //kg
14 V = 0.015 //m^3
15 v = V/m //m^3/kg
16 T = 473 //K
17 R = 8314.3/M //J/kgK
18 //Solution
19
20 //Part(i)
21 printf("Part(i)\n")
22 p = m*R*T/V //Pa
23 printf("Pressure (using ideal gas equation of state)
      = %.2f MPa\n\n", p*(1e-6))
24
25 //Part(ii)
26 printf("Part(ii)\n")
27 pc = 3.39e6 //Pa //critical pressure
28 Tc = 126.2 //K //critical temperature
29 vc = 0.0899 //m^3/kmol //critical volume
30
31 TR = T/Tc //reduced temperature
32 vR = v/(R*Tc/pc) //reduced volume
33 Z = 1.1 //Compressibility factor
34 printf("From the generalized compressibility chart,
      at reduced volume of %.4f and reduced temperature
      of %.2f, Z = %.2f\n", vR, TR, Z)
35 p = Z*R*T/v //Pa
36 printf("Pressure (using generalised compressibility
      chart) = %.3f MPa\n\n", p*(1e-6))
37
38 //Part(iii)
39 printf("Part(iii)\n")
40 a = 0.1366e6 //Pam^5/kmol^2

```

```

41 b = 0.0386 //m^3/kmol
42 p = (8314.3*T/(v*M - b)) - a/(v*M)^2
43 printf("Pressure (using van der Waals equation) = %
      .2f MPa\n\n",p*(1e-6))
44
45 //Part(iv)
46 printf("Part(iv)\n")
47 a = (0.427*(R*M)^2*Tc^2.5/pc)
48 b = 0.0866*(R*M*Tc/pc)
49
50 p = (R*M*T/(v*M-b))-(a/(((v*M)^2 + v*M*b)*(T^0.5)))
51 printf("Pressure (using Redlich-Kwong equation of
      state) = %.2f MPa\n\n",p*(1e-6))
52
53 //---Note--- //Solution to Part(iv) in the textbook
      is 40.58 MPa which is wrong. The correct solution
      (38.13 MPa) is computed here.
54
55 //Part(v)
56 printf("Part(v)\n")
57 A0 = 136.2315
58 a = 0.02617
59 B0 = 0.05046
60 b = -0.00691
61 c = 42000
62
63 A = A0*(1 - a/(v*M))
64 B = B0*(1 - b/(v*M))
65 eps = c/(T^3 * v*M)
66 p = ((8314.3)*T*(1-eps)*(v*M+B))/(v*M)^2 - 1e3*A/(v*
      M)^2
67 printf("Pressure (using ideal gas equation of state)
      = %.2f MPa\n\n",p*(1e-6))

```

Chapter 12

Fuels and Combustion

Scilab code Exa 12.1 Find the gravimetric and ultimate analysis

```
1  clc
2  clear
3  printf("Example 12.1 | Page number 412 \n\n");
4  //Part(a) Find gravimetric analysis
5  //Part(b) Find ultimate analysis
6  //Given solution
7  xCO2 = 0.03 //mole fraction of CO2
8  xCO = 0.19 //mole fraction of CO
9  xH2 = 0.41 //mole fraction of H2
10 xCH4 = 0.25 //mole fraction of CH4
11 xC2H4 = 0.09 //mole fraction of C2H4
12 xN2 = 0.03 //mole fraction of N2
13
14 //Solution
15 //Part(a)
16 printf("Part(a)\n");
17 M = xCO2*44 + xCO*28 + xH2*2 + xC2H4*28 + xCH4*16 +
    xN2*28 //kg/mol //average molar mass
18 yCO2 = xCO2*(44/M)
19 yCO = xCO*(28/M)
20 yH2 = xH2*(2/M)
```

```

21 yCH4 = xCH4*(16/M)
22 yC2H4 = xC2H4*(28/M)
23 yN2 = xN2*(28/M)
24 printf("yCO2 = %.2f%%\n", yCO2*100)
25 printf("yCO = %.2f%%\n", yCO*100)
26 printf("yH2 = %.2f%%\n", yH2*100)
27 printf("yCH4 = %.2f%%\n", yCH4*100)
28 printf("yC2H4 = %.2f%%\n", yC2H4*100)
29 printf("yN2 = %.2f%%\n\n", yN2*100)
30
31 //Part(b)
32 printf("Part(b)\n");
33 nC = xCO2 + xCO + xCH4 + xC2H4*2 //number of moles
    of C
34 nH2 = xH2 + xCH4*2 + xC2H4*2 //number of moles of H2
35 nO2 = xCO2 + 0.5*xCO //number of moles of O2
36 nN2 = xN2 //number of moles of N2
37
38 mC = nC*12/M
39 mH2 = nH2*2/M
40 mO2 = nO2*32/M
41 mN2 = nN2*28/M
42 printf("mC = %.2f%%\n", mC*100)
43 printf("mH2 = %.2f%%\n", mH2*100)
44 printf("mO2 = %.2f%%\n", mO2*100)
45 printf("mN2 = %.2f%%\n", mN2*100)

```

Scilab code Exa 12.2 Find the stoichiometric air

```

1 clc
2 clear
3 printf("Example 12.2 | Page number 416 \n\n");
4 //Find the stoichiometric air for combustion of (a)
    Carbon (b) Hydrogen (c) Sulphur
5 //Given data

```

```

6 //Molar masses of O2,H2,N2,C and S respectively
7 M02 = 32 //g/mol
8 MH2 = 2 //g/mol
9 MN2 = 28 //g/mol
10 MC = 12 //g/mol
11 MS = 32 //g/mol
12 //Part(a)
13 printf("Part(a)\n")
14 printf("Stoichiometric air(Carbon) = %.2f kg/kg
        carbon\n\n", (M02 + 3.76*MN2)/MC)
15 //Part(b)
16 printf("Part(b)\n")
17 printf("Stoichiometric air(Hydrogen) = %.2f kg/kg
        hydrogen\n\n", 0.5*(M02 + 3.76*MN2)/MH2)
18 //Part(c)
19 printf("Part(c)\n")
20 printf("Stoichiometric air(Sulphur) = %.2f kg/kg
        sulphur\n", (M02 + 3.76*MN2)/MS)

```

Scilab code Exa 12.3 Find the stoichiometric air

```

1 clc
2 clear
3 printf("Example 12.3 | Page number 417 \n\n");
4 //Find the stoichiometric air
5 //Given data
6 xC3H8 = 0.2 //mole fraction of propane
7 xC4H10 = 0.8 //mole fraction of butane
8 //Molar masses of O2,H2,N2 & C respectively
9 M02 = 32 //g/mol
10 MH2 = 2 //g/mol
11 MN2 = 28 //g/mol
12 MC = 12 //g/mol
13
14 //Solution

```

```

15 //C balance
16 b = xC3H8*3+xC4H10*4
17 //H2 balance
18 d = xC3H8*4 + xC4H10*5
19 //O2 balance
20 a = b + d/2
21 //N2 balance
22 c = 3.76*a
23
24 Stoichiometric_air = a*(M02 + 3.76*MN2)/(xC3H8*(MC+
    M02)+xC4H10*(MC*4+MH2*5))
25 printf("Stoichiometric air = %.2f kg/kg cooking gas"
    ,Stoichiometric_air)

```

Scilab code Exa 12.4 Find the excess air and percent theoretical air

```

1 clc
2 clear
3 printf("Example 12.4 | Page number 418 \n\n");
4 //Find excess air and % theoretical air
5 //Given data
6 xC3H8 = 0.2 //mole fraction of propane
7 xC4H10 = 0.8 //mole fraction of butane
8
9 xO2 = 0.21 //mole fraction of O2
10 xN2 = 0.79 //mole fraction of N2
11 //Molar masses of O2,H2,N2 & C respectively
12 M02 = 32 //g/mol
13 MH2 = 2 //g/mol
14 MN2 = 28 //g/mol
15 MC = 12 //g/mol
16 Stoichiometric_air = 15.42 //kg/kg
17
18 //Solution
19 //C balance

```

```

20 b = xC3H8*3+xC4H10*4
21 //H2 balance
22 e = xC3H8*4 + xC4H10*5
23 //O2 balance
24 d = 40*xO2-b -0.5*e
25 //N2 balance
26 c = 40*xN2
27
28 actual_air = 40*(xO2*MO2 + xN2*MN2)/(xC3H8*(MC*3+MH2
      *4)+xC4H10*(MC*4+MH2*5)) //kg/kg gas
29
30 excess_air = (actual_air - Stoichiometric_air)/
      Stoichiometric_air*100
31 printf(" Excess air = %.1f%%\n",excess_air)
32
33 theoritical_air = 100+excess_air
34 printf(" Theoritical air = %.1f%%\n",theoritical_air)

```

Scilab code Exa 12.5 Find the Orsat analysis

```

1  clc
2  clear
3  printf("Example 12.5 | Page number 420 \n\n");
4  //Find the Orsat analysis of the combustion products
5  //Given Data
6  nCO2 = 3.8 //Number of moles of CO2
7  nN2 = 31.6 //Number of moles of N2
8  nO2 = 2.2 //Number of moles of O2
9
10 //Solution
11 n = nCO2 + nN2 + nO2
12 xCO2 = nCO2/n //mole fraction of CO2
13 xN2 = nN2/n //mole fraction of N2
14 xO2 = nO2/n //mole fraction of O2
15

```

```

16 printf("xCO2 = %.1 f %% \n", xCO2*100)
17 printf("xN2 = %.1 f %% \n", xN2*100)
18 printf("xO2 = %.1 f %% \n", xO2*100)

```

Scilab code Exa 12.6 Find the volume fraction and mass fraction of the products of combustion

```

1  clc
2  clear
3  printf("Example 12.6 | Page number 421 \n\n");
4  //Find the volume fraction and mass fraction
5  //Given Data
6  nCO2 = 3.8 //Number of moles of CO2
7  nN2 = 31.6 //Number of moles of N2
8  nO2 = 2.2 //Number of moles of O2
9  nH2O = 4.8 //Number of moles of H2O
10
11 //Solution
12 //Solution
13 n = nCO2 + nN2 + nO2 + nH2O
14 xCO2 = nCO2/n //mole fraction of CO2
15 xN2 = nN2/n //mole fraction of N2
16 xO2 = nO2/n //mole fraction of O2
17 xH2O = nH2O/n //mole fraction of H2O
18
19 printf("Volume fraction of CO2 = %.1f%%\n", xCO2*100)
20 printf("Volume fraction of N2 = %.1f%%\n", xN2*100)
21 printf("Volume fraction of O2 = %.1f%%\n", xO2*100)
22 printf("Volume fraction of H2O = %.1f%%\n\n", xH2O
    *100)
23
24 M = xCO2*44 + xN2*28 + xO2*32 + xH2O*18 //Mass of
    combustion product
25
26 yCO2 = xCO2*(44/M)

```



```

27 yH2O = xH2O*(18/M)
28 yN2 = xN2*(28/M)
29 yO2 = xO2*(32/M)
30
31 printf("Mass fraction of CO2 = %.1f%%\n", yCO2*100)
32 printf("Mass fraction of N2 = %.1f%%\n", yN2*100)
33 printf("Mass fraction of O2 = %.1f%%\n", yO2*100)
34 printf("Mass fraction of H2O = %.1f%%\n\n", yH2O*100)

```

Scilab code Exa 12.7 Find the actual air excess air theoretical air mass fraction and dew point temperature

```

1  clc
2  clear
3  printf("Example 12.7 | Page number 422 \n\n");
4  //Find
5  //(a) Actual air
6  //(b) Excess air
7  //(c) Percentage theoretical air
8  //(d) Mass fractions
9  //(e) Dew point
10
11 //Part(a)
12 printf("Part(a)\n")
13 mC = 0.65 //kg //mass of C per kg coal
14 mA = 0.15 //kg //mass of Ash per kg coal
15 CR = 0.05 //kg //mass of carbon in solid refuse per
    kg coal
16 mR = 0.2 //kg //mass of refuse per kg coal
17 m = mC- CR //kg //mass of carbon burnt per kg coal
18
19 //By C balance
20 x = (14 + 1)*(12/0.6) //kg //mass of burnt coal
21 //By H2 balance
22 b = x*(0.06/2)

```

```

23 //By O2 Balance
24 a = (14 + 0.5 + 3.5 + 4.5)-(x*0.1/32)
25 actual_air = a*(32+3.76*28)/x //kg/kg coal
26 printf("Actual air = %.3f kg/kg coal\n\n",actual_air
    )
27
28 //Part(b)
29 printf("Part(b)\n")
30 Stoichiometric_air = (0.6*11.45+0.06*34.3)
    -(0.1/0.232) //kg
31 excess_air = (actual_air - Stoichiometric_air)/
    Stoichiometric_air*100
32 printf("Excess air = %.1f%%\n\n",excess_air)
33
34 //Part(c)
35 printf("Part(c)\n");
36 printf("Percentage theoretical air = %.1f%%\n\n"
    ,100+excess_air)
37
38 //Part(d)
39 printf("Part(d)\n")
40 m = 14*44 + 1*28 +3.5*32 +81.5*28 +9*18 //kg //mass
    of combustion product
41 printf("Mass fraction of CO2 = %.2f%%\n" ,14*44/m
    *100)
42 printf("Mass fraction of CO = %.2f%%\n" ,1*28/m*100)
43 printf("Mass fraction of O2 = %.2f%%\n" ,3.5*32/m
    *100)
44 printf("Mass fraction of N2 = %.2f%%\n" ,81.5*28/m
    *100)
45 printf("Mass fraction of H2O = %.2f%%\n\n" ,9*18/m
    *100)
46
47 //Part(e)
48 printf("Part(e)\n")
49 xH2O = 9/(14+1+3.5+81.5+9) //molfraction of H2O
50 pH2O = xH2O*1e5 //Pa //partial pressure
51 //From steam table

```

```
52 tdp = 42.5 // C
53 printf("Dew point temperature = %.1f C",tdp)
```

Scilab code Exa 12.8 Find the actual air and excess air

```
1  clc
2  clear
3  printf("Example 12.8 | Page number 425 \n\n");
4  //Find actual air and excess air
5  //Given Data
6  xC02 = 9.7 //mole percent CO2
7  xC0 = 1.1 //mole percent CO
8  xO2 = 4 //mole percent O2
9  xN2 = 85.2 //mole percent N2
10
11 //Solution
12 //by C balance
13 b = 2
14 //by H2 balance
15 d = 2
16 //by O2 balance
17 a = b+d*.5
18 //by N2 balance
19 c = 3.76*a
20
21 Stoichiometric_air = a*(32+3.76*28)/28 //kg/kg
    ethylene
22
23 //by C balance
24 x = (xC02+xC0)/2 //kmol of ethylene be burnt
25 //by H2 balance
26 q = 2*x
27 //by O2 balance
28 p = xC02 + xC0/2 + xO2 + q/2
29
```

```

30 actual_air = p*(32+3.76*28)/(x*28) //kg/kg ethylene
31 excess_air = (actual_air - Stoichiometric_air)/
    Stoichiometric_air*100
32 printf("Actual air = %.1f kg/kg ethylene \n",
    actual_air)
33 printf("Excess air = %.1f%%",excess_air)

```

Scilab code Exa 12.9 Find the heat transfer from the combustor

```

1  clc
2  clear
3  printf("Example 12.9 | Page number 433 \n\n");
4  //Find the heat transfer from the combustor
5  excess_air = 10 //%
6  tR = 30 // C //temperature of reactant
7  tP = 120 // C //temperature of product
8  delta_H = -802.3*1000 //kJ/kmol CH4
9  Cp_CH4 = 36 //kJ/lmolK
10 Cp_O2 = 29.5 //kJ/lmolK
11 Cp_N2 = 29.2 //kJ/lmolK
12 Cp_CO2 = 37 //kJ/lmolK
13 Cp_H2O = 33.7 //kJ/lmolK
14 tA = 30 // C
15 tX = 25 // C
16 tY = tX // C
17 tB = 120 // C
18 //Solution
19 Q_AB = (1*Cp_CO2 + 0.2*Cp_O2 + 8.272*Cp_N2 + 2*
    Cp_H2O)*(tB-tX)+ delta_H + (1*Cp_CH4 + 2.2*Cp_O2
    +8.272*Cp_N2)*(tY-tA)
20 printf("The heat transfer from the combustor = %.1f
    kJ/kg CH4 ",Q_AB/16)

```

Scilab code Exa 12.10 Find the enthalpy of reaction

```
1 clc
2 clear
3 printf("Example 12.10 | Page number 435 \n\n");
4 //Find enthalpy of reaction
5 //Given Data
6 deltaH_gasgas = -2651.4e3 //kJ/kmol butane
7 hfg_butane = 370 //kJ/kg //enthalpies of
  vaporisation of butane
8 hfg_water = 2442 //kJ/kg //enthalpies of
  vaporisation of water
9 M_butane = 58 //g/mol
10 M_water = 18 //g/mol
11
12 //Solution
13 deltaH_liqliq = deltaH_gasgas + M_butane*hfg_butane
  - 5*M_water*hfg_water
14 printf("Enthalpy of reaction = %.1f kJ/kg",
  deltaH_liqliq/M_butane)
```

Scilab code Exa 12.11 Find the standard change in enthalpy for the reaction

```
1 clc
2 clear
3 printf("Example 12.11 | Page number 437 \n\n");
4 //Find standard delta_H for reaction
5 //Given Data
6 //Formation Enthalpies
7 hf_CO2 = -393510 //kJ/kmol
8 hf_H2O = -285838 //kJ/kmol
9 hf_C3H8 = -104680 //kJ/kmol
10 hf_O2 = 0 //kJ/kmol
11
```

```

12 //Solution
13 Hp = 3*hf_CO2 + 4*hf_H2O
14 Hr = hf_C3H8 + 5*hf_O2
15 deltaH_std = Hp-Hr
16 printf("Standard change in enthalpy for the reaction
        = %.1f kJ/kg",deltaH_std/44)

```

Scilab code Exa 12.12 Frind the heat transferred from the combustor

```

1  clc
2  clear
3  printf("Example 12.12 | Page number 438 \n\n");
4  //Find the heat transferred from the combustor per
    kg ethylene
5  //Given Data
6  Cp_C2H4 = 28*1.548 //kJ/lmolK
7  Cp_O2 = 32*0.922 //kJ/lmolK
8  Cp_N2 = 28*1.042 //kJ/lmolK
9  Cp_CO2 = 44*0.842 //kJ/lmolK
10 Cp_H2O = 18*1.86 //kJ/lmolK
11
12 //Solution
13 deltaH_BX = (2*Cp_CO2 + 2*Cp_H2O + 0.3*Cp_O2 +
    12.408*Cp_N2)*(120-25)
14 deltaH_YA = (Cp_C2H4 + 3.3*Cp_O2 + 12.408*Cp_N2)
    *(25-50)
15 hf_CO2 = -393510 //kJ/kmol
16 hf_H2O = -241820 //kJ/kmol
17 hf_C2H4 = 52283 //kJ/kmol
18 deltaH_XY = 2*hf_CO2 + 2*hf_H2O - hf_C2H4 //kJ/kmol
19 deltaH_BA = deltaH_BX + deltaH_YA + deltaH_XY //kJ/
    kmol
20
21 printf("The heat transferred from the combustor per
    kg ethylene = %.1f kJ/kg ethane",deltaH_BA/28)

```

Scilab code Exa 12.13 Find the adiabatic combustion temperature

```
1 clc
2 clear
3 printf("Example 12.13 | Page number 441 \n\n");
4 //Find adiabatic combustion temperature when methane
  is burnt
5 //Part(a) using average Cp values
6 //Part(b) using ideal gas enthalpy
7
8 //Part(a)
9 printf("Part(a)\n")
10 //Picking up various Cp values from Table 12.1
11 tB = (16*50010)
      /(44*0.842+2*18*1.86+3*32*0.922+22.56*28*1.042)
      +25
12 printf("Adiabatic combustion temperature (using
  average Cp values)= %.1 f K\n\n",tB+273)
13
14 //Part(b)
15 printf("Part(b)\n")
16 tb1 = 1000 //K //first guess temperature
17 tb2 = 1200 //K second guess temperature
18 tb = (tb1 - tb2)/(637617-836847)*(800160-836847) +
      tb2
19 printf("Adiabatic combustion temperature (using
  ideal gas enthalpy)= %.1 f K",tb)
```

Scilab code Exa 12.14 Find the LCV and HCV of gaseous hexane

```
1 clc
```

```

2 clear
3 printf("Example 12.14 | Page number 443 \n\n");
4 //Find LCV and HCV of gaseous hexane
5 //Given data
6 delta_H_std = -45101 //kJ/kg
7 hfg = 2442 //kJ/kg //enthalpy of vaporisation
8
9 //Solution
10 LCV = -1*delta_H_std // kJ/kg hexane
11 printf("LCV of gaseous hexane = %.1f kJ/kg hexane\n"
        ,LCV)
12
13 m = 7*18/86 //mass of H2O per kg hexane
14 HCV = LCV+m*hfg //kJ/kg hexane
15 printf("HCV of gaseous hexane = %.1f kJ/kg hexane",
        HCV)

```
