

Scilab Textbook Companion for  
Engineering Thermodynamics  
by O. Singh<sup>1</sup>

Created by  
Prateek Jain  
Bachelor of Technology  
Mechanical Engineering  
National Institute Of Technology Hamirpur  
College Teacher  
None  
Cross-Checked by  
Bhavani Jalkrish

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# **Book Description**

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

**Exa** Example (Solved example)

**Eqn** Equation (Particular equation of the above book)

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

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

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# Chapter 1

## Fundamental Concepts And Definitions

**Scilab code Exa 1.1** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
     Chapter 1,Example 1")
8 h=30*10^-2; //manometer deflection of mercury in m
9 g=9.78; //acceleration due to gravity in m/s^2
10 rho=13550; //density of mercury at room temperature
    in kg/m^3
11 disp("pressure difference(p) in pa")
12 disp("p=rho*g*h")
13 p=rho*g*h
```

---

**Scilab code Exa 1.2** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 2

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 2")
8 d=30*10^-2; //diameter of cylindrical vessel in m
9 h=76*10^-2; //atmospheric pressure in m of mercury
10 g=9.78; //acceleration due to gravity in m/s^2
11 rho=13550; //density of mercury at room temperature
               in kg/m^3
12 disp("effort required for lifting the lid (E) in N")
13 disp("E=(rho*g*h)*(3.14*d^2)/4")
14 E=(rho*g*h)*(3.14*d^2)/4
```

---

**Scilab code Exa 1.3** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 3

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 3")
8 h=30*10^-2; // pressure of compressed air in m of
               mercury
9 Patm=101*10^3; //atmospheric pressure in pa
10 g=9.78; //acceleration due to gravity in m/s^2
```

```

11 rho=13550; //density of mercury at room temperature
   in kg/m^3
12 disp("pressure measured by manometer is gauge
   pressure (Pg) in kpa")
13 disp("Pg=rho*g*h/10^3")
14 Pg=rho*g*h/10^3
15 disp("actual pressure of the air (P) in kpa")
16 disp("P=Pg+Patm/10^3")
17 P=Pg+Patm/10^3

```

---

**Scilab code Exa 1.4** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
   Chapter 1, Example 4")
8 h=1; //depth of oil tank in m
9 sg=0.8; //specific gravity of oil
10 RHOw=1000; //density of water in kg/m^3
11 g=9.81; //acceleration due to gravity in m/s^2
12 disp("density of oil (RHOoil) in kg/m^3")
13 disp("RHOoil=sg*RHOw")
14 RHOoil=sg*RHOw
15 disp("gauge pressure (Pg) in kpa")
16 disp("Pg=RHOoil*g*h/10^3")
17 Pg=RHOoil*g*h/10^3

```

---

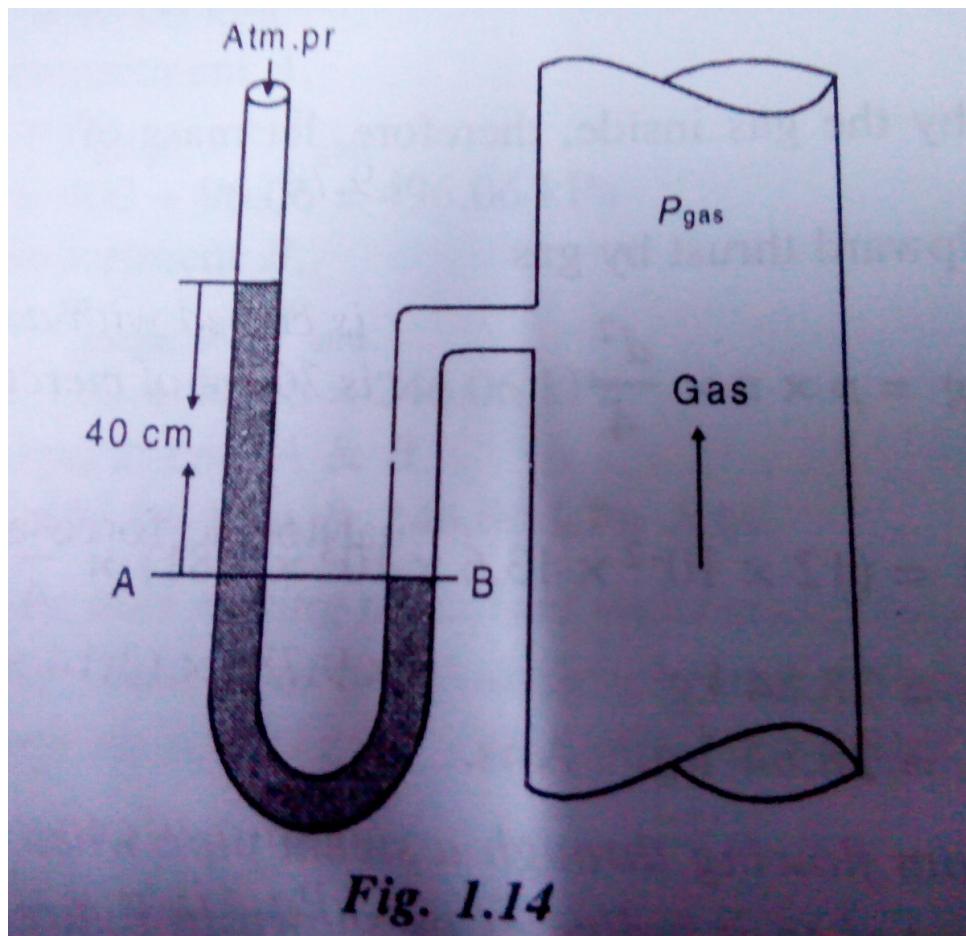


Figure 1.1: Engineering Thermodynamics by Onkar Singh Chapter 1 Example 5

**Scilab code Exa 1.5** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 5

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 5")
8 rho=13.6*10^3;//density of mercury in kg/m^3
9 g=9.81;//acceleration due to gravity in m/s^2
10 h1=40*10^-2;//difference of height in mercury column
    in m as shown in figure
11 h2=76*10^-2;//barometer reading of mercury in m
12 disp("atmospheric pressure(Patm) in kpa")
13 disp("Patm=rho*g*h2/10^3")
14 Patm=rho*g*h2/10^3
15 disp("pressure due to mercury column at AB(Pab) in
    kpa")
16 disp("Pab=rho*g*h1/10^3")
17 Pab=rho*g*h1/10^3
18 disp("pressure exerted by gas(Pgas) in kpa")
19 disp("Pgas=Patm+Pab")
20 Pgas=Patm+Pab
```

---

**Scilab code Exa 1.6** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 6

```
1 // Display mode
2 mode(0);
```

```

3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 6")
8 m=1; //mass of water in kg
9 h=1000; //height from which water fall in m
10 Cp=1; //specific heat of water in kcal/kg k
11 g=9.81; //acceleration due to gravity in m/s^2
12 disp("by law of conservation of energy")
13 disp(" potential energy(m*g*h)in joule = heat
      required for heating water(m*Cp*deltaT *1000*4.18)
      in joule")
14 disp("so m*g*h = m*Cp*deltaT *4.18*1000")
15 disp("change in temperature of water(deltaT) in
      degree celcius")
16 disp("deltaT=(g*h)/(4.18*1000*Cp)")
17 deltaT=(g*h)/(4.18*1000*Cp)

```

---

**Scilab code Exa 1.7** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 7")
8 w1=100; //weight of object at standard gravitational
      acceleration in N
9 g1=9.81;//acceleration due to gravity in m/s^2
10 g2=8.5; //gravitational acceleration at some location

```

```

11 disp(" mass of object (m) in kg")
12 disp("m=w1/g1")
13 m=w1/g1
14 disp(" spring balance reading=gravitational force in
      mass (F) in N")
15 disp("F=m*g2")
16 F=m*g2

```

---

**Scilab code Exa 1.8** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 8

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 8")
8 d=15*10^-2; //diameter of cylinder in m
9 h=12*10^-2; //manometer height difference in m of
      mercury
10 rho=13.6*10^3; //density of mercury in kg/m^3
11 g=9.81; //acceleration due to gravity in m/s^2
12 disp("pressure measured by manometer(P) in pa")
13 disp("p=rho*g*h")
14 p=rho*g*h
15 disp("now weight of piston(m*g) = upward thrust by
      gas(p*%pi*d^2/4)")
16 disp("mass of piston(m) in kg")
17 disp("so m=(p*%pi*d^2)/(4*g)")
18 m=(p*%pi*d^2)/(4*g)

```

---

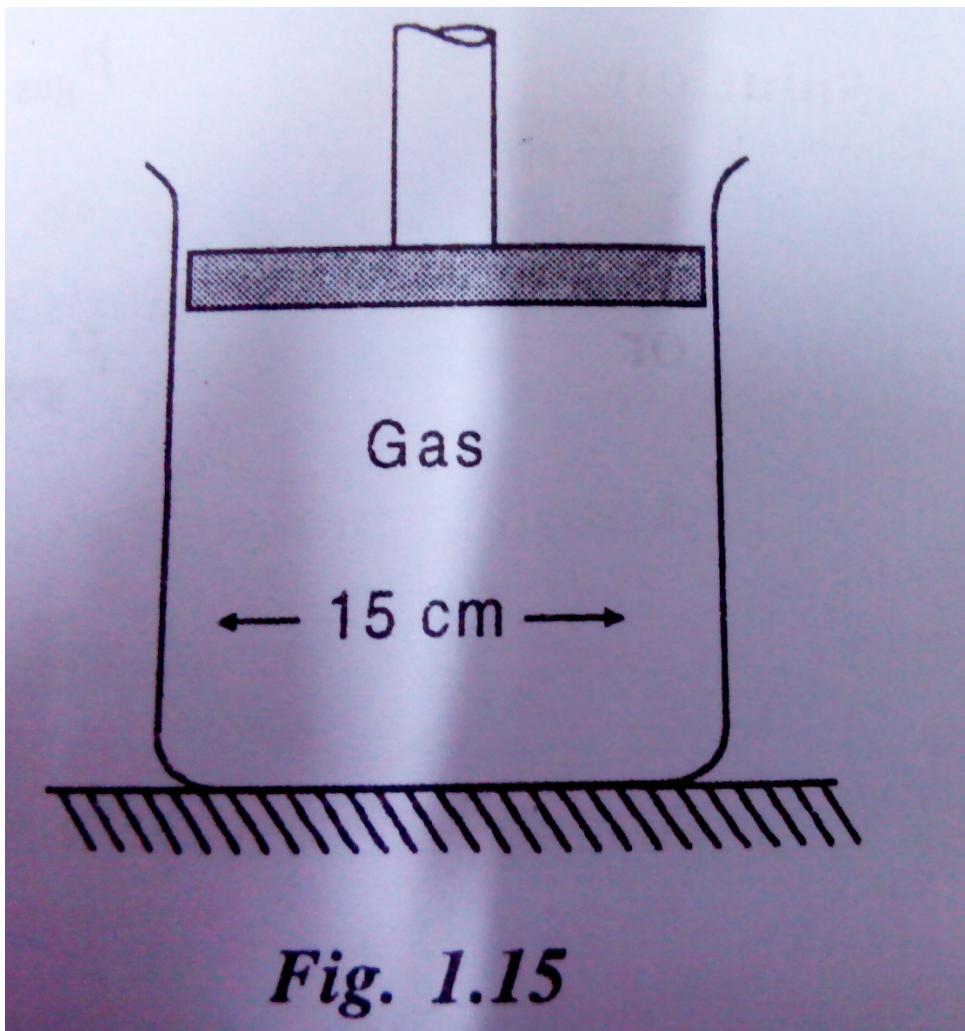


Figure 1.2: Engineering Thermodynamics by Onkar Singh Chapter 1 Example 8

**Scilab code Exa 1.9** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 9

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 9")
8 RH0m=13.6*10^3; //density of mercury in kg/m^3
9 RH0w=1000; //density of water in kg/m^3
10 h1=76*10^-2; //barometer reading in m of mercury
11 h2=2*10^-2; //height raised by water in manometer
    tube in m
12 h3=10*10^-2; //height raised by mercury in manometer
    tube in m
13 g=9.81; //acceleration due to gravity in m/s^2
14 disp("balancing pressure at plane BC in figure we
get")
15 disp("Psteam+Pwater=Patm+Pmercury")
16 disp("now 1. atmospheric pressure (Patm) in pa")
17 disp("Patm=RH0m*g*h1")
18 Patm=RH0m*g*h1
19 disp("2. pressure due to water (Pwater) in pa")
20 disp("Pwater=RH0w*g*h2")
21 Pwater=RH0w*g*h2
22 disp("3. pressure due to mercury (Pmercury) in pa")
23 disp("Pmercury=RH0m*g*h3")
24 Pmercury=RH0m*g*h3
25 disp("using balancing equation")
```

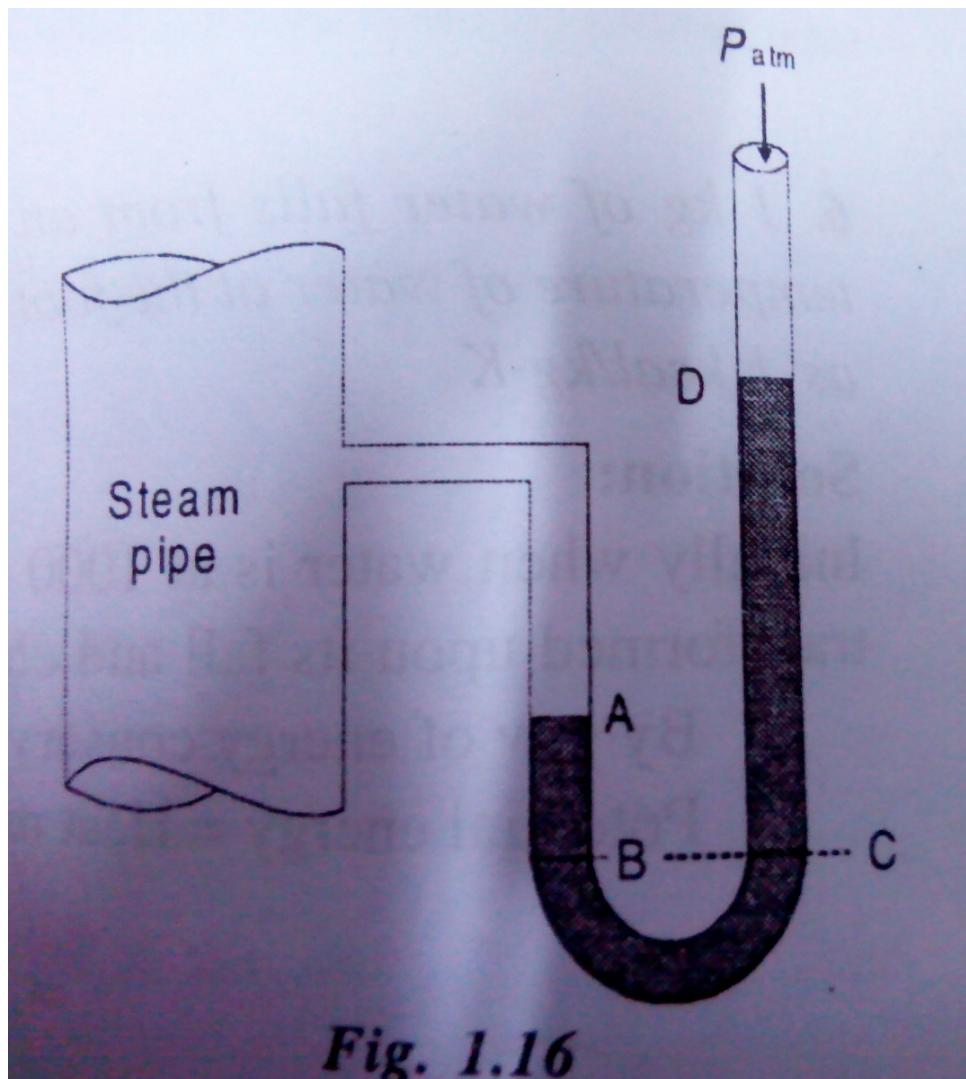
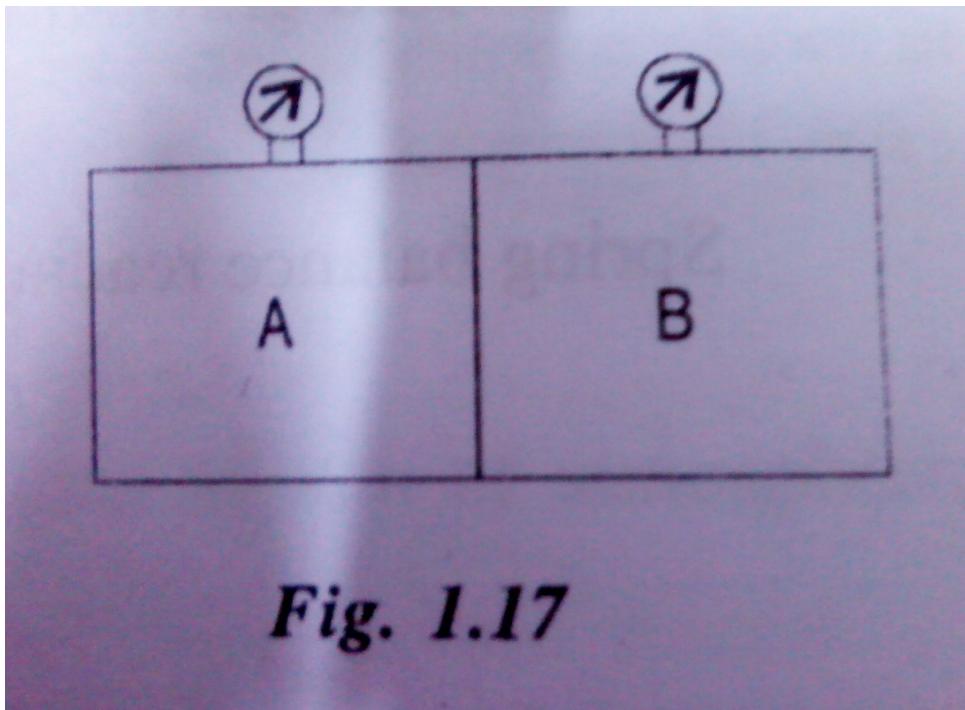


Figure 1.3: Engineering Thermodynamics by Onkar Singh Chapter 1 Example 9



**Fig. 1.17**

Figure 1.4: Engineering Thermodynamics by Onkar Singh Chapter 1 Example 10

```
26 disp("Psteam=Patm+Pmercury-Pwater")
27 disp("so pressure of steam(Psteam) in kpa")
28 disp("Psteam=(Patm+Pmercury-Pwater)/1000")
29 Psteam=(Patm+Pmercury-Pwater)/1000
```

---

**Scilab code Exa 1.10** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 10

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 10")
8 h=720*10^-3; //barometer reading in m of Hg
9 Pga=400; //gauge pressure in compartment A in kpa
10 Pgb=150; //gauge pressure in compartment B in kpa
11 rho=13.6*10^3; //density of mercury in kg/m^3
12 g=9.81; //acceleration due to gravity in m/s^2
13 disp("atmospheric pressure(Patm) in kpa")
14 Patm=(rho*g*h)/1000
15 disp("absolute temperature in compartment A(Pa) in
kpa")
16 disp("Paa=Pga+Patm")
17 Pa=Pga+Patm
18 disp("absolute temperature in compartment B(Pb) in
kpa")
19 disp("Pb=Pgb+Patm")
20 Pb=Pgb+Patm
21 disp("absolute pressure in compartments in A & B
=496.06 kpa & 246.06 kpa")

```

---

**Scilab code Exa 1.11** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 11

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,

```

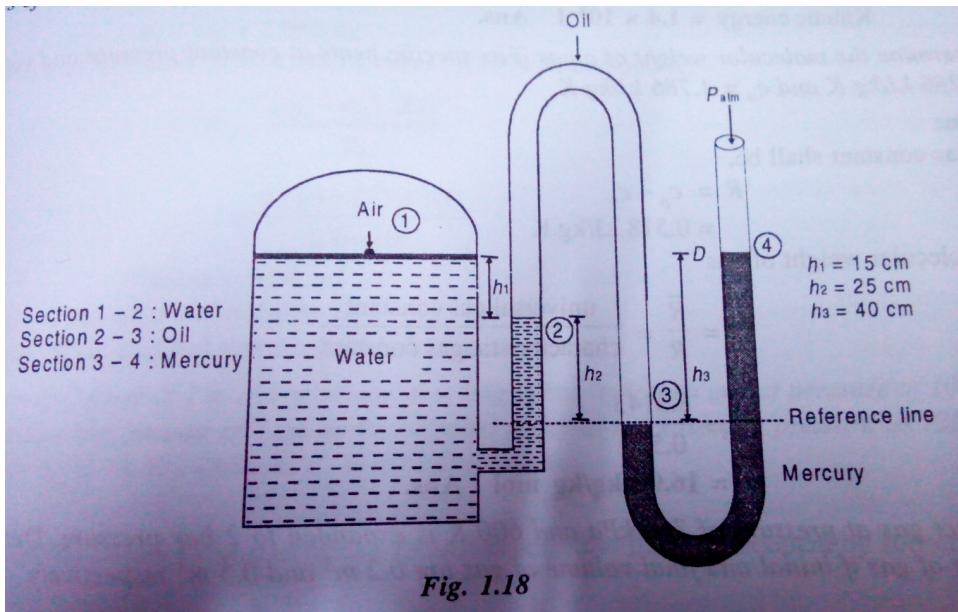


Figure 1.5: Engineering Thermodynamics by Onkar Singh Chapter 1 Example 11

Chapter 1 , Example 11”)

```

8 Patm=90*10^3; //atmospheric pressure in pa
9 RH0w=1000; //density of water in kg/m^3
10 RH0m=13600; //density of mercury in kg/m^3
11 RH0o=850; //density of oil in kg/m^3
12 g=9.81; //acceleration due to gravity in m/s^2
13 h1=.15; //height difference between water column in m
14 h2=.25; //height difference between oil column in m
15 h3=.4; //height difference between mercury column in
           m
16 disp("the pressure of air in air tank can be
          obtained by equalising pressures at some
          reference line")
17 disp("P1+RH0w*g*h1+RH0o*g*h2 = Patm+RH0m*g*h3")
18 disp("so P1 = Patm+RH0m*g*h3-RH0w*g*h1-RH0o*g*h2")
19 disp("air pressure(P1) in kpa")
20 P1=(Patm+RH0m*g*h3-RH0w*g*h1-RH0o*g*h2)/1000

```

---

**Scilab code Exa 1.12** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 12

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 12")
8 v=750; //relative velocity of object with respect to
earth in m/sec
9 F=4000; //gravitational force in N
10 g=8; //acceleration due to gravity in m/s^2
11 disp("mass of object(m) in kg")
12 disp("m=F/g")
13 m=F/g
14 disp("kinetic energy(E) in J is given by")
15 disp("E=m*v^2/2")
16 E=m*v^2/2
```

---

**Scilab code Exa 1.13** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 13

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
```

```

7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 13")
8 Cp=2.286; //specific heat at constant pressure in kJ/
kg k
9 Cv=1.786; //specific heat at constant volume in kJ/kg
k
10 R1=8.3143; //universal gas constant in kJ/kg k
11 disp(" characteristics gas constant (R2) in kJ/kg k")
12 R2=Cp-Cv
13 disp("molecular weight of gas (m) in kg/kg mol")
14 m=R1/R2
15 disp("NOTE=>Their is some calculation mistake while
calaulating gas constant in book ,which is
corrected above hence answer may vary.")

```

---

**Scilab code Exa 1.14** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 14

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 14")
8 P1=750*10^3; //initial pressure of gas in pa
9 V1=0.2; //initial volume of gas in m^3
10 T1=600; //initial temperature of gas in k
11 P2=2*10^5; //final pressure of gas i pa
12 V2=0.5; //final volume of gas in m^3
13 disp("using perfect gas equation")
14 disp("P1*V1/T1 = P2*V2/T2")
15 disp("=>T2=(P2*V2*T1)/(P1*V1)")
16 disp("so final temperature of gas (T2) in k")

```

```
17 T2=(P2*V2*T1)/(P1*V1)
18 disp("or final temperature of gas (T2) in degree
      celcius")
19 T2=T2-273
```

---

**Scilab code Exa 1.15** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 15

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 15")
8 P1=100*10^3; //initial pressure of air in pa
9 V1=5; //initial volume of air in m^3
10 T1=300; //initial temperature of gas in k
11 P2=50*10^3; //final pressure of air in pa
12 V2=5; //final volume of air in m^3
13 T2=(7+273); //final temperature of air in K
14 R=287; //gas constant on J/kg k
15 disp("from perfect gas equation we get")
16 disp("initial mass of air(m1 in kg)=(P1*V1)/(R*T1)")
17 m1=(P1*V1)/(R*T1)
18 disp("final mass of air(m2 in kg)=(P2*V2)/(R*T2)")
19 m2=(P2*V2)/(R*T2)
20 disp("mass of air removed(m) in kg")
21 m=m1-m2
22 disp("volume of this mass of air(V) at initial
      states in m^3")
23 V=m*R*T1/P1
```

---

**Scilab code Exa 1.16** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 16

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 16")
8 d=1; //diameter of cylinder in m
9 l=4; //length of cylinder in m
10 P1=100*10^3; //initial pressureof hydrogen gas in pa
11 T1=(27+273); //initial temperature of hydrogen gas in
k
12 P2=125*10^3; //final pressureof hydrogen gas in pa
13 Cp=14.307; //specific heat at constant pressure in KJ
/kg k
14 Cv=10.183; //specific heat at constant volume in KJ/
kg k
15 disp(" here V1=V2")
16 disp(" so P1/T1=P2/T2")
17 disp(" final temperature of hydrogen gas (T2) in k")
18 disp("=>T2=P2*T1/P1")
19 T2=P2*T1/P1
20 disp("now R=(Cp-Cv) in KJ/kg k")
21 R=Cp-Cv
22 disp("And volume of cylinder (V1) in m^3")
23 disp("V1=(%pi*d^2*l)/4")
24 V1=(%pi*d^2*l)/4
25 disp("mass of hydrogen gas (m) in kg")
26 disp("m=(P1*V1)/(1000*R*T1)")
27 m=(P1*V1)/(1000*R*T1)
```

```
28 disp("now heat supplied (Q) in KJ")
29 disp("Q=m*Cv*(T2-T1)")
30 Q=m*Cv*(T2-T1)
```

---

**Scilab code Exa 1.17** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 17

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 17")
8 V1=2; //volume of first cylinder in m^3
9 V2=2; //volume of second cylinder in m^3
10 T=(27+273); //temperature of system in k
11 m1=20; //mass of air in first vessel in kg
12 m2=4; //mass of air in second vessel in kg
13 R=287; //gas constant J/kg k
14 disp("final total volume(V) in m^3")
15 disp("V=V1*V2")
16 V=V1*V2
17 disp("total mass of air (m) in kg")
18 disp("m=m1+m2")
19 m=m1+m2
20 disp("final pressure of air (P) in kpa")
21 disp("using perfect gas equation")
22 disp("P=(m*R*T)/(1000*V)")
23 P=(m*R*T)/(1000*V)
```

---

**Scilab code Exa 1.18** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 18

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 18")
8 m=5; //mass of CO2 in kg
9 V=2; //volume of vessel in m^3
10 T=(27+273); //temperature of vessel in k
11 R=8.314*10^3; //universal gas constant in J/kg k
12 M=44.01; //molecular weight of CO2
13 disp(" 1.By considering it as a PERFECT GAS")
14 disp("gas constant for CO2(Rco2)") 
15 disp("Rco2=R/M")
16 Rco2=R/M
17 disp("Also P*V=M*Rco2*T")
18 disp("pressure of CO2 as perfect ga(P) in N/m^2")
19 disp("P=(m*Rco2*T)/V ")
20 P=(m*Rco2*T)/V
21 disp(" 2.By considering as a REAL GAS")
22 disp("values of vanderwaal constants a,b can be seen
      from the table which are")
23 disp("a=3628.5*10^2 N m^4/(kg mol)^2 ")
24 disp("b=3.14*10^-2 m^3/kg mol")
25 a=3628.5*10^2; //vanderwall constant in N m^4/(kg mol
                  )^2
26 b=3.14*10^-2; // vanderwall constant in m^3/kg mol
27 disp("now specific volume(v) in m^3/kg mol")
28 disp("v=V*M/m")
29 v=V*M/m
30 disp("now substituting the value of all variables in
      vanderwaal equation")
31 disp("(P+(a/v^2))*(v-b)=R*T")
```

```
32 disp(" pressure of CO2 as real gas(P) in N/m^2")
33 disp("P=((R*T)/(v-b))-(a/v^2)")
34 P=((R*T)/(v-b))-(a/v^2)
```

---

**Scilab code Exa 1.19** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 19

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 19")
8 P=17672; //pressure of steam on kpa
9 T=712; //temperature of steam in k
10 Pc=22.09; //critical pressure of steam in Mpa
11 Tc=647.3; //critical temperature of steam in k
12 R=0.4615; //gas constant for steam in KJ/kg k
13 disp(" 1.considering as perfect gas")
14 disp(" specific volume(V) in m^3/kg")
15 disp("V=R*T/P")
16 V=R*T/P
17 disp(" 2.considering compressibility effects")
18 disp(" reduced pressure(P) in pa")
19 disp("p=P/(Pc*1000)")
20 p=P/(Pc*1000)
21 disp(" reduced temperature(t) in k")
22 disp(" t=T/Tc")
23 t=T/Tc
24 disp("from generalised compressibility chart ,
      compressibility factor(Z)can be seen for reduced
      pressure and reduced temperatures of 0.8 and 1.1"
    )
```

```

25 disp("we get Z=0.785")
26 Z=0.785; // compressibility factor
27 disp("now actual specific volume(v) in m^3/kg")
28 disp("v=Z*V")
29 v=Z*V

```

---

**Scilab code Exa 1.20** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 20

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 20")
8 d=5; //diameter of ballon in m
9 T1=(27+273); //temperature of hydrogen in k
10 P=1.013*10^5; //atmospheric pressure in pa
11 T2=(17+273); //temperature of surrounding air in k
12 R=8.314*10^3; //gas constant in J/kg k
13 disp("volume of ballon(V1)in m^3")
14 disp("V1=(4/3)*%pi*(d/2)^3")
15 V1=(4/3)*%pi*(d/2)^3
16 disp("molecular mass of hydrogen(M)")
17 disp("M=2")
18 M=2; //molecular mass of hydrogen
19 disp("gas constant for H2(R1)in J/kg k")
20 disp("R1=R/M")
21 R1=R/M
22 disp("mass of H2 in ballon(m1)in kg")
23 disp("m1=(P*V1)/(R1*T1)")
24 m1=(P*V1)/(R1*T1)
25 disp("volume of air displaced(V2)=volume of ballon (

```

```

        V1)") )
26 disp("mass of air displaced (m2) in kg")
27 disp("m2=(P*V1)/(R2*T2)")
28 disp("gas constant for air (R2)=0.287 KJ/kg k")
29 R2=0.287*1000; //gas constant for air in J/kg k
30 m2=(P*V1)/(R2*T2)
31 disp("load lifting capacity due to buoyant force(m)
      in kg")
32 disp("m=m2-m1")
33 m=m2-m1

```

---

**Scilab code Exa 1.21** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 21

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 21")
8 v=0.25; //volume sucking rate of pump in m^3/min
9 V=20; //volume of air vessel in m^3
10 disp("let initial receiver pressure(p1)=1 in pa")
11 p1=1; //initial receiver pressure in pa
12 disp("so final receiver pressure(p2)=p1/4 in pa")
13 p2=p1/4
14 disp("perfect gas equation ,p*V*m=m*R*T")
15 disp("differentiating and then integrating equation
      w.r.t to time(t) ")
16 disp("we get t=-(V/v)*log(p2/p1)")
17 disp("so time(t) in min")
18 t=-(V/v)*log(p2/p1)

```

---

**Scilab code Exa 1.22** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 22

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 22")
8 m=5; //mass of mixture of gas in kg
9 P=1.013*10^5; //pressure of mixture in pa
10 T=300; //temperature of mixture in k
11 M1=28; //molecular weight of nitrogen(N2)
12 M2=32; //molecular weight of oxygen(O2)
13 M3=44; //molecular weight of carbon dioxide(CO2)
14 f1=0.8; //fraction of N2 in mixture
15 f2=0.18; //fraction of O2 in mixture
16 f3=0.02; //fraction of CO2 in mixture
17 k1=1.4; //ratio of specific heat capacities for N2
18 k2=1.4; //ratio of specific heat capacities for O2
19 k3=1.3; //ratio of specific heat capacities for CO2
20 R=8314; //universal gas constant in J/kg k
21 disp("first calculate gas constants for different
gases in j/kg k")
22 disp("for nitrogen ,R1=R/M1")
23 R1=R/M1
24 disp("for oxygen ,R2=R/M2")
25 R2=R/M2
26 disp("for carbon dioxide ,R3=R/M3")
27 R3=R/M3
28 disp("so the gas constant for mixture (Rm) in j /kg k")
29 disp("Rm=f1*R1+f2*R2+f3*R3")
```

```

30 Rm=f1*R1+f2*R2+f3*R3
31 disp("now the specific heat at constant pressure for
       constituent gases in KJ/kg k")
32 disp(" for nitrogen ,Cp1=((k1/(k1-1))*R1)/1000")
33 Cp1=((k1/(k1-1))*R1)/1000
34 disp(" for oxygen ,Cp2=((k2/(k2-1))*R2)/1000")
35 Cp2=((k2/(k2-1))*R2)/1000
36 disp(" for carbon dioxide ,Cp3=((k3/(k3-1))*R3)/1000")
37 Cp3=((k3/(k3-1))*R3)/1000
38 disp("so the specific heat at constant pressure for
       mixture(Cpm)in KJ/kg k")
39 disp("Cpm=f1*Cp1+f2*Cp2+f3*Cp3")
40 Cpm=f1*Cp1+f2*Cp2+f3*Cp3
41 disp("now no. of moles of constituents gases")
42 disp("for nitrogen ,n1=m1/M1 in mol, where m1=f1*m in
       kg")
43 m1=f1*m
44 n1=m1/M1
45 disp("for oxygen ,n2=m2/M2 in mol, where m2=f2*m in kg
       ")
46 m2=f2*m
47 n2=m2/M2
48 disp("for carbon dioxide ,n=m3/M3 in mol, where m3=f3*
       m in kg")
49 m3=f3*m
50 n3=m3/M3
51 disp("total no. of moles in mixture in mol")
52 disp("n=n1+n2+n3")
53 n=n1+n2+n3
54 disp("now mole fraction of constituent gases")
55 disp("for nitrogen ,x1=n1/n")
56 x1=n1/n
57 disp("for oxygen ,x2=n2/n")
58 x2=n2/n
59 disp("for carbon dioxide ,x3=n3/n")
60 x3=n3/n
61 disp("now the molecular weight of mixture(Mm) in kg/
       kmol")

```

```
62 disp("Mm=M1*x1+M2*x2+M3*x3")
63 Mm=M1*x1+M2*x2+M3*x3
```

---

**Scilab code Exa 1.23** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 23

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 1,Example 23")
8 V1=0.18;//volume fraction of O2 in m^3
9 V2=0.75;//volume fraction of N2 in m^3
10 V3=0.07;//volume fraction of CO2 in m^3
11 P=0.5;//pressure of mixture in Mpa
12 T=(107+273);//temperature of mixture in k
13 M1=32;//molar mass of O2
14 M2=28;//molar mass of N2
15 M3=44;//molar mass of CO2
16 disp("mole fraction of constituent gases")
17 disp("x=(ni/n)=(Vi/V)")
18 disp("take volume of mixture(V)=1 m^3")
19 V=1;// volume of mixture in m^3
20 disp("mole fraction of O2(x1)")
21 disp("x1=V1/V")
22 x1=V1/V
23 disp("mole fraction of N2(x2)")
24 disp("x2=V2/V")
25 x2=V2/V
26 disp("mole fraction of CO2(x3)")
27 disp("x3=V3/V")
28 x3=V3/V
```

```

29 disp("now molecular weight of mixture = molar mass(m
   )")
30 disp("m=x1*M1+x2*M2+x3*M3")
31 m=x1*M1+x2*M2+x3*M3
32 disp("now gravimetric analysis refers to the mass
   fraction analysis")
33 disp("mass fraction of constituents")
34 disp("y=xi*Mi/m")
35 disp("mole fraction of O2")
36 disp("y1=x1*M1/m")
37 y1=x1*M1/m
38 disp("mole fraction of N2")
39 disp("y2=x2*M2/m")
40 y2=x2*M2/m
41 disp("mole fraction of CO2")
42 disp("y3=x3*M3/m")
43 y3=x3*M3/m
44 disp("now partial pressure of constituents = volume
   fraction * pressure of mixture")
45 disp("Pi=xi*P")
46 disp("partial pressure of O2(P1) in Mpa")
47 disp("P1=x1*P")
48 p1=x1*P
49 disp("partial pressure of N2(P2) in Mpa")
50 disp("P2=x2*P")
51 P2=x2*P
52 disp("partial pressure of CO2(P3) in Mpa")
53 disp("P3=x3*P")
54 P3=x3*P
55 disp("NOTE=>Their is some calculation mistake for
   partial pressure of CO2(i.e 0.35Mpa) which is
   given wrong in book so it is corrected above
   hence answers may vary.")

```

---

**Scilab code Exa 1.24** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 24

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 24")
8 V=6; //volume of tank in m^3
9 P1=800*10^3; //pressure of N2 gas tank in pa
10 T1=480; //temperature of N2 gas tank in k
11 P2=400*10^3; //pressure of CO2 gas tank in pa
12 T2=390; //temperature of CO2 gas tank in k
13 k1=1.4; //ratio of specific heat capacity for N2
14 k2=1.3; //ratio of specific heat capacity for CO2
15 R=8314; //universal gas constant in J/kg k
16 M1=28; //molecular weight of N2
17 M2=44; //molecular weight of CO2
18 disp("volume of tank of N2(V1) in m^3")
19 V1=V/2
20 disp("volume of tank of CO2(V2) in m^3")
21 V2=V/2
22 disp("taking the adiabatic condition")
23 disp("no. of moles of N2(n1)")
24 disp("n1=(P1*V1)/(R*T1)")
25 n1=(P1*V1)/(R*T1)
26 disp("no. of moles of CO2(n2)")
27 disp("n2=(P2*V2)/(R*T2)")
28 n2=(P2*V2)/(R*T2)
29 disp("total no. of moles of mixture(n) in mol")
30 disp("n=n1+n2")
31 n=n1+n2
32 disp("gas constant for N2(R1) in J/kg k")
33 disp("R1=R/M1")
34 R1=R/M1
```

```

35 disp(" gas constant for CO2(R2) in J/kg k")
36 disp("R2=R/M2")
37 R2=R/M2
38 disp(" specific heat of N2 at constant volume (Cv1)
      in J/kg k")
39 disp("Cv1=R1/(k1-1")
40 Cv1=R1/(k1-1)
41 disp(" specific heat of CO2 at constant volume (Cv2)
      in J/kg k")
42 disp("Cv2=R2/(k2-1")
43 Cv2=R2/(k2-1)
44 disp(" mass of N2(m1) in kg")
45 disp("m1=n1*M1")
46 m1=n1*M1
47 disp(" mass of CO2(m2) in kg")
48 disp("m2=n2*M2")
49 m2=n2*M2
50 disp(" let us consider the equilibrium temperature of
      mixture after adiabatic mixing at T")
51 disp(" applying energy conservation principle")
52 disp("m1*Cv1*(T-T1) = m2*Cv2*(T-T2")
53 disp(" equilibrium temperature(T) in k")
54 disp("=>T=((m1*Cv1*T1)+(m2*Cv2*T2)) / ((m1*Cv1)+(m2*
      Cv2))")
55 T=((m1*Cv1*T1)+(m2*Cv2*T2)) / ((m1*Cv1)+(m2*Cv2))
56 disp(" so the equilibrium pressure(P) in kpa")
57 disp("P=(n*R*T)/(1000*V")
58 P=(n*R*T)/(1000*V)

```

---

**Scilab code Exa 1.25** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 25

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
    Chapter 1,Example 25")
8 m1=2; //mass of H2 in kg
9 m2=3; //mass of He in kg
10 T=100; //temperature of container in k
11 Cp1=11.23; //specific heat at constant pressure for
    H2 in KJ/kg k
12 Cp2=5.193; //specific heat at constant pressure for
    He in KJ/kg k
13 disp("since two gases are non reacting therefore
    specific heat of final mixture(Cp)in KJ/kg k can
    be obtained by following for adiabatic mixing")
14 disp("so the specific heat at constant pressure(Cp)
    in KJ/kg k")
15 disp("Cp=((Cp1*m1)+Cp2*m2)/(m1+m2") )
16 Cp=((Cp1*m1)+Cp2*m2)/(m1+m2)

```

---

**Scilab code Exa 1.26** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 26

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
    Chapter 1,Example 26")
8 m1=18; //mass of hydrogen(H2) in kg
9 m2=10; //mass of nitrogen(N2) in kg
10 m3=2; //mass of carbon dioxide(CO2) in kg
11 R=8.314; //universal gas constant in KJ/kg k

```

```

12 Pi=101.325; //atmospheric pressure in kpa
13 T=(27+273.15); //ambient temperature in k
14 M1=2; //molar mass of H2
15 M2=28; //molar mass of N2
16 M3=44; //molar mass of CO2
17 disp("gas constant for H2(R1) in KJ/kg k")
18 disp("R1=R/M1")
19 R1=R/M1
20 disp("gas constant for N2(R2) in KJ/kg k")
21 disp("R2=R/M2")
22 R2=R/M2
23 disp("gas constant for CO2(R3) in KJ/kg k")
24 disp("R3=R/M3")
25 R3=R/M3
26 disp("so now gas constant for mixture(Rm) in KJ/kg k")
27 disp("Rm=(m1*R1+m2*R2+m3*R3)/(m1+m2+m3)")
28 Rm=(m1*R1+m2*R2+m3*R3)/(m1+m2+m3)
29 disp("considering gas to be perfect gas")
30 disp("total mass of mixture(m) in kg")
31 disp("m=m1+m2+m3")
32 m=m1+m2+m3
33 disp("capacity of vessel(V) in m^3")
34 disp("V=(m*Rm*T)/Pi")
35 V=(m*Rm*T)/Pi
36 disp("now final temperature(Tf) is twice of initial
      temperature(Ti)")
37 disp("so take k=Tf/Ti=2")
38 k=2; //ratio of initial to final temperature
39 disp("for constant volume heating , final pressure(Pf)
      in kpa shall be")
40 disp("Pf=Pi*k")
41 Pf=Pi*k

```

---

**Scilab code Exa 1.27** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 27

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 1,Example 27")
8 T1=(27+273); //initial temperature of air in k
9 T2=500; //final temperature of air in k
10 disp("let inlet state be 1 and exit state be 2")
11 disp("by charles law volume and temperature can be
      related as")
12 disp("(V1/T1)=(V2/T2)")
13 disp("(V2/V1)=(T2/T1)")
14 disp("or (((%pi*D2^2)/4)*V2) /(((%pi*D1^2)/4)*V1)=T2/
      T1")
15 disp("since K.E=0")
16 disp("so (D2^2/D1^2)=T2/T1")
17 disp("D2/D1=sqrt(T2/T1)")
18 disp("say(D2/D1)=k")
19 disp("so exit to inlet diameter ratio(k)")
20 k=sqrt(T2/T1)
```

---

**Scilab code Exa 1.28** Engineering Thermodynamics by Onkar Singh Chapter 1 Example 28

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
```

```

6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh ,
    Chapter 1,Example 29")
8 V=2; //volume of vessel in m^3
9 P1=76; //initial pressure or atmospheric pressure in
    cm of Hg
10 T=(27+273.15); //temperature of vessel in k
11 p=70; //final pressure in cm of Hg vaccum
12 R=8.314; //universal gas constant in KJ/kg k
13 M=2; //molecular weight of H2
14 disp("gas constant for H2(R1)in KJ/kg k")
15 disp("R1=R/M")
16 R1=R/M
17 disp("say initial and final ststes are given by 1
    and 2")
18 disp("mass of hydrogen pumped out shall be
    difference of initial and final mass inside
    vessel")
19 disp("final pressure of hydrogen(P2)in cm of Hg")
20 disp("P2=P1-p")
21 P2=P1-p
22 disp("therefore pressure difference(P)in kpa")
23 disp("P=((P1-P2)*101.325)/76")
24 P=((P1-P2)*101.325)/76
25 disp("mass pumped out(m)in kg")
26 disp("m=((P1*V1)/(R1*T1))-((P2*V2)/(R1*T2))")
27 disp(" here V1=V2=V and T1=T2=T")
28 disp(" so m=(V*(P1-P2))/(R1*T)")
29 m=(V*P)/(R1*T)
30 disp("now during cooling upto 10 degree celcius ,the
    process may be consider as constant volume
    process")
31 disp("say state before and after cooling are denoted
    by suffix 2 and 3")
32 T3=(10+273.15); //final temperature after cooling in
    k
33 disp(" final pressure after cooling(P3)in kpa")
34 disp("P3=(T3/T)*P2*(101.325/76)")
```

35 P3=(T3/T)\*P2\*(101.325/76)

---

# Chapter 2

## Zeroth Law Of Thermodynamics

**Scilab code Exa 2.1** Engineering Thermodynamics by Onkar Singh Chapter 2 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
     Chapter 2,Example 1")
8 Tf=98.6;//temperature of body in farenheit
9 disp("degree celcius and farenheit are related as
     follows")
10 disp("Tc=(Tf-32)/1.8")
11 disp("so temperature of body in degree celcius")
12 Tc=(Tf-32)/1.8
```

---

**Scilab code Exa 2.2** Engineering Thermodynamics by Onkar Singh Chapter 2 Example 2

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
      Chapter 2,Example 2")
8 t1=0; //ice point temperature in degree celcius
9 p1=3; //thermometric property for ice point
10 t2=100; //steam point temperature in degree celcius
11 p2=8; //thermometric property for steam point
12 p3=6.5; //thermometric property for any temperature
13 disp("using thermometric relation")
14 disp("t=a*log(p)+(b/2)")
15 disp("for ice point ,b/a=")
16 b=2*log(p1)
17 disp("so b=2.1972*a")
18 disp("for steam point")
19 a=t2/(log(p2)-(2.1972/2))
20 disp("and b=")
21 b=2.1972*a
22 disp("thus , t=a*log(p3)+(b/2) in degree celcius")
23 t=a*log(p3)+(b/2)
24 disp("so for thermodynamic property of 6.5 ,t=302.83
      degree celcius")
```

---

**Scilab code Exa 2.3** Engineering Thermodynamics by Onkar Singh Chapter 2 Example 3

```
1 // Display mode
2 mode(0);
```

```

3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
    Chapter 2,Example 3")
8 disp("emf equation")
9 disp("E=(0.003*t)-((5*10^-7)*t^2)+(0.5*10^-3)")
10 disp("using emf equation at ice point ,E_0 in volts")
11 t=0; //ice point temperature in degree celcius
12 disp("E_0=(0.003*t)-((5*10^-7)*t^2)+(0.5*10^-3)")
13 E_0=(0.003*t)-((5*10^-7)*t^2)+(0.5*10^-3)
14 disp("using emf equation at steam point ,E_100 in
    volts")
15 t=100; //steam point temperature in degree celcius
16 disp("E_100=(0.003*t)-((5*10^-7)*t^2)+(0.5*10^-3)")
17 E_100=(0.003*t)-((5*10^-7)*t^2)+(0.5*10^-3)
18 disp("now emf at 30 degree celcius using emf
    equation (E_30)in volts")
19 t=30; //temperature of substance in degree celcius
20 E_30=(0.003*t)-((5*10^-7)*t^2)+(0.5*10^-3)
21 disp("now the temperature(T) shown by this
    thermometer")
22 disp("T=((E_30-E_0)/(E_100-E_0))*(T_100-T_0) in
    degree celcius")
23 T_100=100; //steam point temperature in degree
    celcius
24 T_0=0; //ice point temperature in degree celcius
25 T=((E_30-E_0)/(E_100-E_0))*(T_100-T_0)
26 disp("NOTE=>In this question ,values of emf at 100
    and 30 degree celcius is calculated wrong in book
    so it is corrected above so the answers may vary
    .")

```

---

**Scilab code Exa 2.4** Engineering Thermodynamics by Onkar Singh Chapter 2 Example 4

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 2,Example 4")
8 t1=0; //temperature at ice point
9 t2=100; //temperature at steam point
10 t3=50; //temperature of gas
11 disp("emf equation ,e=0.18*t -5.2*10^-4*t ^2 in
millivolts")
12 disp("as ice point and steam points are two
reference points ,so")
13 disp("at ice point ,emf(e1)in mV")
14 e1=0.18*t1-5.2*10^-4*t1^2
15 disp("at steam point ,emf(e2)in mV")
16 e2=0.18*t2-5.2*10^-4*t2^2
17 disp("at gas temperature ,emf(e3)in mV")
18 e3=0.18*t3-5.2*10^-4*t3^2
19 disp("since emf variation is linear so ,temperature(t
)in degree celcius at emf of 7.7 mV")
20 t=((t2-t1)/(e2-e1))*e3
21 disp("temperature of gas using thermocouple=60.16
degree celcius")
22 disp("% variation in temperature reading with
respect to gas thermometer reading of 50 degree
celcius")
23 variation=((t-t3)/t3)*100
```

---

**Scilab code Exa 2.5** Engineering Thermodynamics by Onkar Singh Chapter 2 Example 5

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh ,
Chapter 2,Example 5")
8 disp("let the conversion relation be X=aC+b")
9 disp("where C is temperature in degree celcius ,a&b
are constants and X is temperature in X degree ")
10 disp("at freezing point ,temperature=0 degree celcius
,0 degree X")
11 disp("so by equation X=aC+b")
12 X=0; //temperature in degree X
13 C=0; //temperature in degree celcius
14 disp("we get b=0")
15 b=0;
16 disp("at boiling point ,temperature=100 degree
celcius ,1000 degree X")
17 X=1000; //temperature in degree X
18 C=100; //temperature in degree celcius
19 a=(X-b)/C
20 disp("conversion relation")
21 disp("X=10*C")
22 disp("absolute zero temperature in degree celcius
=-273.15")
23 disp("absolute zero temperature in degree X=")
24 10*-273.15
```

---

# Chapter 3

## First Law Of Thermodynamics

**Scilab code Exa 3.1** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
          Chapter 3 Example 1")
8 p=689; //pressure of gas in cylinder in kpa
9 v1=0.04; //initial volume of fluid in m^3
10 v2=0.045; //final volume of fluid in m^3
11 W_paddle=-4.88; //paddle work done on the system in
          KJ
12 disp("a> work done on piston (W_piston) in KJ can be
          obtained as")
13 disp("W_piston=pdv")
14 function y = f(v), y=p, endfunction
15 W_piston=intg(v1,v2,f)
```

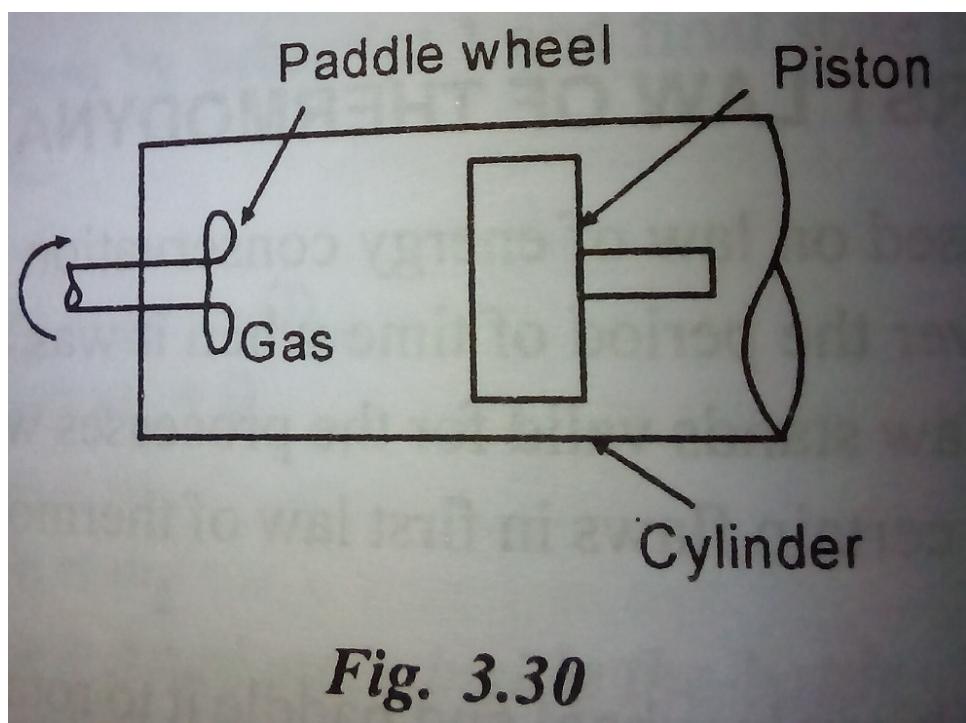


Figure 3.1: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 1

```
16 disp("b> paddle work done on the system(W_paddle)
      =-4.88 KJ")
17 disp(" net work done of system(W_net) in KJ")
18 disp("W_net=W_piston+W_paddle")
19 W_net=W_piston+W_paddle
20 disp("so work done on system(W_net)=1.435 KJ")
```

---

**Scilab code Exa 3.2** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 2

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 2")
8 m=0.5; //mass of gas in kg
9 u1=26.6; //internal energy of gas at 200 degree
            celcius
10 u2=37.8; //internal energy of gas at 400 degree
              celcius
11 W=0; //work done by vessel in KJ
12 disp("as the vessel is rigid therefore work done
      shall be zero")
13 disp("W=0")
14 disp("from first law of thermodynamics , heat required
      (Q) in KJ")
15 disp("Q=U2-U1+W=Q=m(u2-u1)+W")
16 Q=m*(u2-u1)+W
17 disp("so heat required =5.6 KJ")
```

---

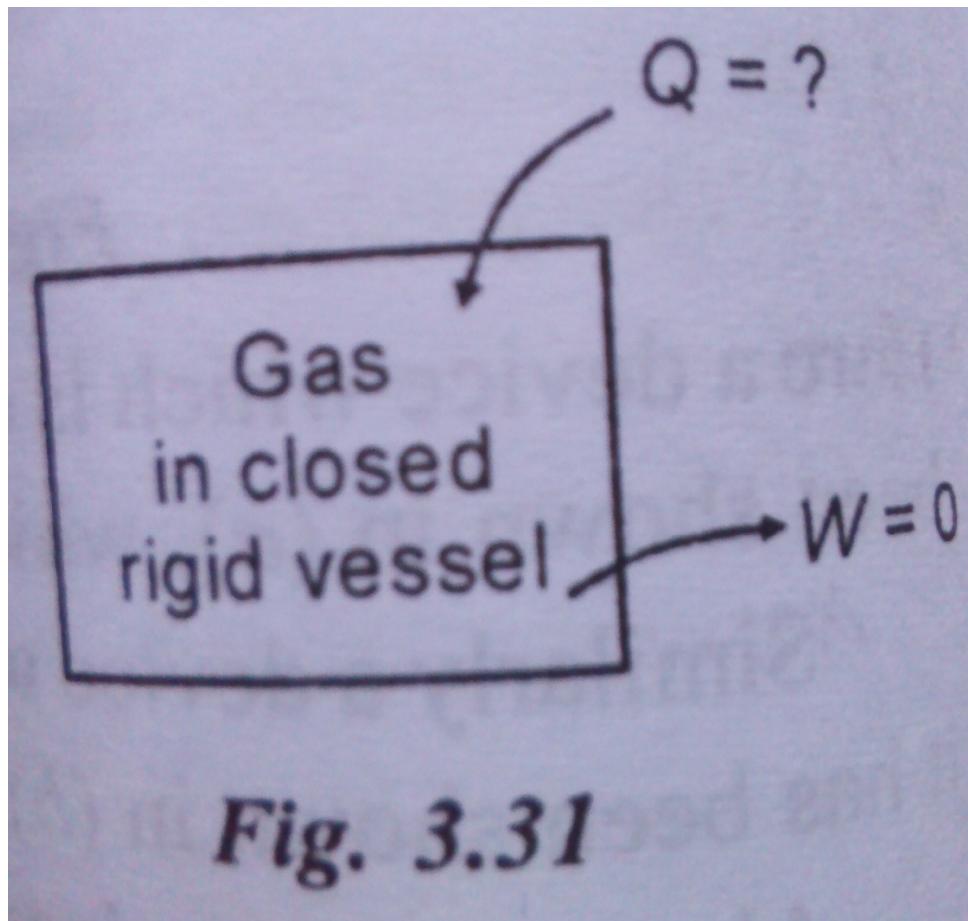


Figure 3.2: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 2

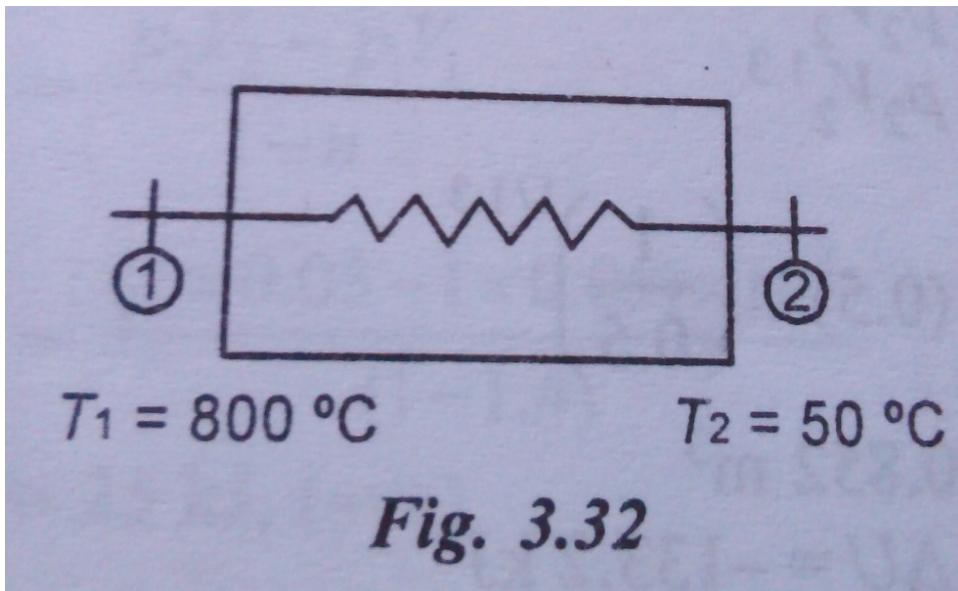


Figure 3.3: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 3

**Scilab code Exa 3.3** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 3

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 3")
8 m=50; //rate at which carbon dioxide passing through
heat exchanger in kg/hr

```

```

9 T2=800; // initial temperature of carbon dioxide in
degree celcius
10 T1=50; //final temperature of carbon dioxide in
degree celcius
11 Cp=1.08;// specific heat at constant pressure in KJ/
kg K
12 disp("by steady flow energy equation")
13 disp("q+h1+C1^2/2+g*z1=h2+C2^2/2+g*z2+w")
14 disp(" let us assume changes in kinetic and potential
energy is negligible ,during flow the work
interaction shall be zero")
15 disp("q=h2-h1")
16 disp(" rate of heat removal(Q) in KJ/hr")
17 disp("Q=m(h2-h1)=m*Cp*(T2-T1)")
18 Q=m*Cp*(T2-T1)
19 disp("heat should be removed at the rate of 40500 KJ
/hr")

```

---

**Scilab code Exa 3.4** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 4")
8 v=0.78; //volume of cylinder in m^3
9 p=101.325; //atmospheric pressure in kPa
10 disp("total work done by the air at atmospheric
pressure of 101.325 kPa")
11 disp("W=(pdv)cylinder+(pdv)air")
12 disp("0+p*(delta v)")

```

```

13 disp(" work done by air (W)=-p*v in KJ")
14 W=-p*v
15 disp("so work done by surrounding on system =79.03
      KJ")

```

---

**Scilab code Exa 3.5** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 5")
8 m=5; //mass of gas in kg
9 p1=1*10^3; //initial pressure of gas in KPa
10 V1=0.5; //initial volume of gas in m^3
11 p2=0.5*10^3; //final pressure of gas in KPa
12 n=1.3; //expansion constant
13 disp(" given p*v^1.3=constant")
14 disp("assuming expansion to be quasi-static ,the work
      may be given as")
15 disp("W=m(p*dv)=(p2*V2-p1*V1)/(1-n)")
16 disp("from internal energy relation ,change in
      specific internal energy")
17 disp(" delta u=u2-u1=1.8*(p2*v2-p1*v1) in KJ/kg")
18 disp(" total change ,delta U=1.8*m*(p2*v2-p1*v1)=1.8*(
      p2*V2-p1*V1) in KJ")
19 disp(" using p1*V1^1.3=p2*V2^1.3")
20 disp(" V2=V1*(p1/p2)^(1/1.3) in m^3")
21 V2=V1*(p1/p2)^(1/1.3)
22 disp(" take V2=.852 m^3")
23 V2=0.852; //final volume of gas in m^3

```

```

24 disp(" so deltaU in KJ")
25 deltaU=1.8*(p2*v2-p1*v1)
26 disp(" and W in KJ")
27 W=(p2*v2-p1*v1)/(1-n)
28 disp(" from first law")
29 disp(" deltaQ=deltaU+W in KJ")
30 deltaQ=deltaU+W
31 disp(" heat interaction=113.5 KJ")
32 disp(" work interaction=246.7 KJ")
33 disp(" change in internal energy=-113.2 KJ")

```

---

**Scilab code Exa 3.6** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 6

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 6")
8 p1=1; // initial pressure of gas in MPa
9 v1=0.05; // initial volume of gas in m^3
10 p2=2; // final pressure of gas in MPa
11 n=1.4; // expansion constant
12 disp(" final state volume(v2) in m^3")
13 disp(" v2=((p1/p2)^(1/1.4))*v1")
14 v2=((p1/p2)^(1/1.4))*v1
15 disp(" take v2=0.03 m^3")
16 v2=0.03; // final volume of gas in m^3
17 disp(" now internal energy of gas is given by U=7.5*p
*v-425")
18 disp(" change in internal energy(deltaU) in KJ")
19 disp(" deltaU=U2-U1=7.5*p2*v2-7.5*p1*v1")

```

```

20 disp("deltaU=7.5*10^3*(p2*v2-p1*v1)") )
21 deltaU=7.5*10^3*(p2*v2-p1*v1)
22 disp("for quasi-static process")
23 disp("work(W) in KJ,W=p*dv")
24 disp("W=(p2*v2-p1*v1)/(1-n)")
25 W=((p2*v2-p1*v1)/(1-n))*10^3
26 disp("from first law of thermodynamics ,")
27 disp("heat interaction (deltaQ)=deltaU+W")
28 deltaQ=deltaU+W
29 disp("heat=50 KJ")
30 disp("work=25 KJ(-ve)")
31 disp("internal energy change=75 KJ")
32 disp("if 180 KJ heat transfer takes place ,then from
      1st law ,")
33 disp("deltaQ=deltaU+W")
34 disp("since end states remain same , therefore deltaU
      i.e change in internal energy remains unaltered .")
35 disp("W=180-75")
36 W=180-75
37 disp("W=105 KJ")

```

---

### Scilab code Exa 3.7 Engineering Thermodynamics by Onkar Singh Chapter 3 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 7")
8 M=16; //molecular weight of gas
9 p1=101.3; //initial pressure of gas in KPa

```

```

10 p2=600; // final pressure of gas in KPa
11 T1=(273+20); // initial temperature of gas in K
12 R1=8.3143*10^3; // universal gas constant in J/kg K
13 Cp=1.7; // specific heat at constant pressure in KJ/kg
   K
14 n=1.3; // expansion constant
15 T2=((p2/p1)^(n-1/n))
16 disp(" characteristics gas constant (R) in J/kg K")
17 disp("R=R1/M")
18 R=R1/M
19 disp(" take R=0.520 ,KJ/kg K")
20 R=0.520; // characteristics gas constant in KJ/kg K
21 disp("Cv=Cp-R, in KJ/kg K")
22 Cv=Cp-R
23 disp("y=Cp/Cv")
24 y=Cp/Cv
25 y=1.44; // ratio of specific heat at constant pressure
   to constant volume
26 disp(" for polytropic process ,v2=((p1/p2)^(1/n))*v1
   in m^3")
27 disp(" now ,T2=T1*((p2/p1)^((n-1)/n)), in K")
28 T2=T1*((p2/p1)^((n-1)/n))
29 disp(" work (W) in KJ/kg")
30 disp("W=R*((T1-T2)/(n-1))")
31 W=R*((T1-T2)/(n-1))
32 W=257.78034; // work done in KJ/kg
33 disp(" for polytropic process ,heat (Q) in KJ/K")
34 disp("Q=((y-n)/(y-1))*W")
35 Q=((y-n)/(y-1))*W

```

---

**Scilab code Exa 3.8** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 8

```

1 // Display mode
2 mode(0);

```

```

3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 8")
8 T1=(627+273); //initial temperature of air in nozzle
                  in K
9 T2=(27+273); //temperature at which air leaves nozzle
                  in K
10 Cp=1.005*10^3; //specific heat at constant pressure
                   in J/kg K
11 disp("applying steady flow energy equation with
       inlet and exit states as 1,2 with no heat and
       work interaction and no change in potential
       energy")
12 disp("h1+C1^2/2=h2+C2^2/2")
13 disp("given that C1=0, negligible inlet velocity")
14 disp("so C2=sqrt(2(h1-h2))=sqrt(2*Cp*(T1-T2))")
15 disp("exit velocity(C2) in m/s")
16 C2=sqrt(2*Cp*(T1-T2))
17 disp("so exit velocity=1098.2 m/s")

```

---

**Scilab code Exa 3.9** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 9

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 9")
8 W=-200; //shaft work in KJ/kg of air

```

```

9  deltah=100; // increase in enthalpy in KJ/kg of air
10 Q1=-90; //heat transferred to water in KJ/kg of air
11 disp("work interaction ,W=-200 KJ/kg of air")
12 disp("increase in enthalpy of air=100 KJ/kg of air")
13 disp(" total heat interaction ,Q=heat transferred to
      water + heat transferred to atmosphere")
14 disp(" writing steady flow energy equation on
      compressor ,for unit mass of air entering at 1 and
      leaving at 2")
15 disp("h1+C1^2/2+g*z1+Q=h2+C2^2/2+g*z2+W")
16 disp("assuming no change in potential energy and
      kinetic energy")
17 disp("deltaK.E=deltaP.=0")
18 disp("total heat interaction (Q) in KJ/kg of air")
19 disp("Q=deltah+W")
20 Q=deltah+W
21 disp("Q=heat transferred to water + heat transferred
      to atmosphere=Q1+Q2")
22 disp("so heat transferred to atmosphere(Q2) in KJ/kg
      of air")
23 Q2=Q-Q1

```

---

**Scilab code Exa 3.10** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 10

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 10")
8 n=500; //total number of persons
9 q=50; //heat requirement per person in kcal/hr

```

```

10 h1=80; //enthalpy of hot water enter in pipe in kcal/
    kg
11 h2=45; //enthalpy of hot water leaves the pipe in
    kcal/kg
12 g=9.81; //acceleartion due to gravity in m/s^2
13 deltax=10; //difference in elevation of inlet and
    exit pipe in m
14 disp("above problem can be solved using steady flow
    energy equations upon hot water flow")
15 disp("Q+m1*(h1+C1^2/2+g*z1)=W+m2*(h2+C2^2/2+g*z2)")
16 disp("here total heat to be supplied(Q) in kcal/hr")
17 Q=n*q
18 disp("so heat lost by water(-ve),Q=-25000 kcal/hr")
19 Q=-25000//heat loss by water in kcal/hr
20 disp("there shall be no work interaction and change
    in kinetic energy ,so ,steady flow energy equation
    shall be ,")
21 disp("Q+m*(h1+g*z1)=m*(h2+g*z2)")
22 disp("so water circulation rate(m) in kg/hr")
23 disp("so m=Q*10^3*4.18/(g*deltaz-(h1-h2)*10^3*4.18")
24 m=Q*10^3*4.18/(g*deltaz-(h1-h2)*10^3*4.18)
25 disp("water circulation rate(m) in kg/min")
26 m=m/60

```

---

**Scilab code Exa 3.11** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 11

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;

```

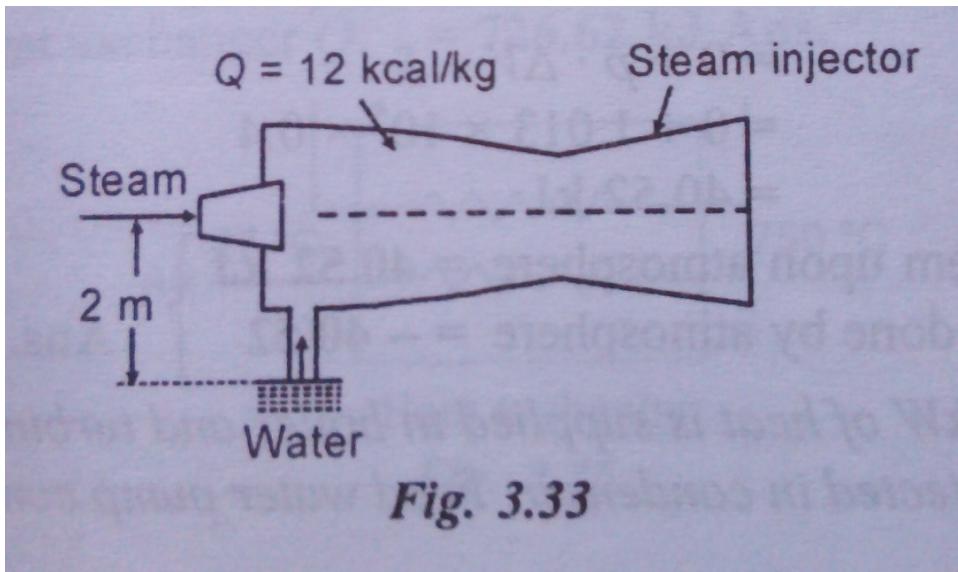


Figure 3.4: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 11

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 11")
8 v1=50; //velocity of steam entering injector in m/s
9 v2=25; //velocity of mixture leave injector in m/s
10 h1=720; //enthalpy of steam entering injector in kcal
/kg
11 h2=24.6; //enthalpy of water entering injector in
kcal/kg
12 h3=100; //enthalpy of steam leaving injector in kcal/
kg
13 h4=100; //enthalpy of water leaving injector in kcal/
kg
14 deltax=2; //depth from axis of injector in m
15 q=12; //heat loss from injector to surrounding
through injector
16 g=9.81; //acceleration due to gravity in m/s^2
17 disp("let mass of steam to be supplied per kg of
water lifted be(m) kg . applying law of energy
conservation upon steam injector , for unit mass of
steam

```

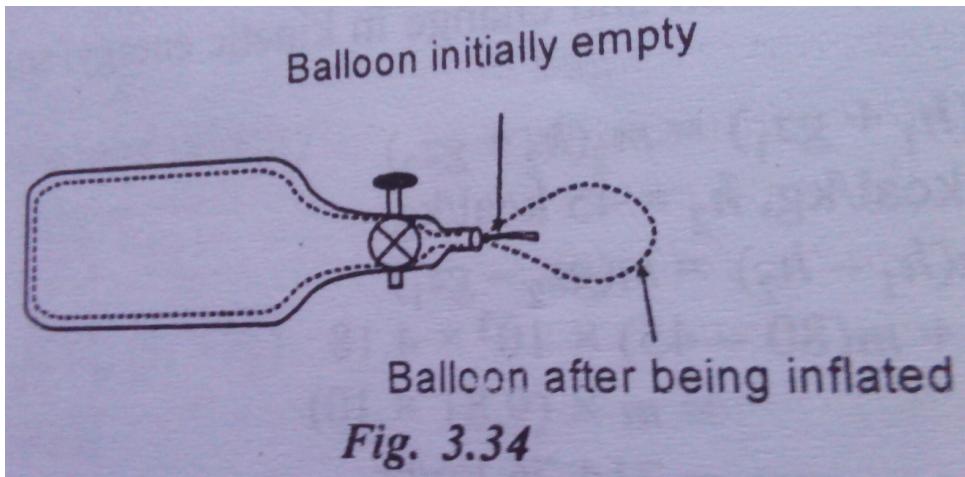


Figure 3.5: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 12

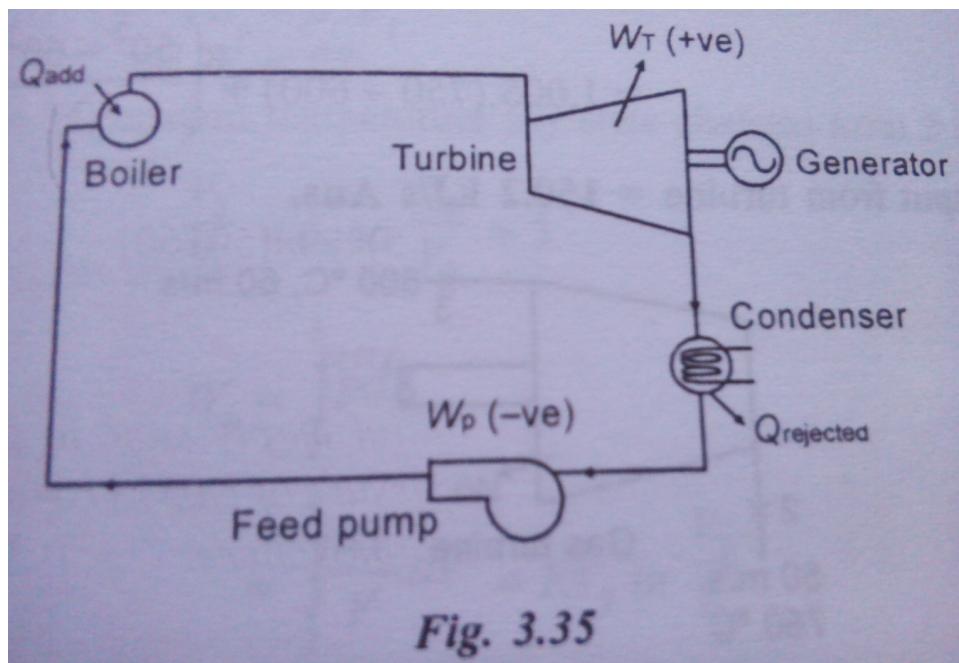
- water lifted")
- 18 **disp**("energy with steam entering + energy with water entering = energy with mixture leaving + heat loss to surrounding")
- 19 **disp**(" $m*(v1^2/2+h1*10^3*4.18)+h2*10^3*4.18+g*\delta z = (1+m)*(h3*10^3*4.18+v2^2/2)+m*q*10^3*4.18$ ")
- 20 **disp**("so steam supplying rate(m) in kg/s per kg of water")
- 21 **disp**(" $m=((h3*10^3*4.18+v2^2/2)-(h2*10^3*4.18+g*\delta z))/((v1^2/2+h1*10^3*4.18)-(h3*10^3*4.18+v2^2/2)-(q*10^3*4.18))$ ")
- 22  $m=((h3*10^3*4.18+v2^2/2)-(h2*10^3*4.18+g*\delta z))/((v1^2/2+h1*10^3*4.18)-(h3*10^3*4.18+v2^2/2)-(q*10^3*4.18))$
- 23 **disp**("NOTE=>here enthalpy of steam entering injector ( $h_1$ ) should be taken 720 kcal/kg instead of 72 kcal/kg otherwise the steam supplying rate comes wrong.")
-

**Scilab code Exa 3.12** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 12

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 12")
8 p=1.013*10^5; //atmospheric pressure in pa
9 deltav=0.4; //change in volume in m^3
10 disp("here let us assume that the pressure is always
equal to atmospheric pressure as balloon is
flexible ,inelastic and unstressed and no work is
done for stretching balloon during its filling
figure shows the boundary of system before and
after filling balloon by firm line and dotted line
respectively .")
11 disp("displacement work , W=(p.dv)cylinder+(p.dv)
balloon")
12 disp("(p.dv)cylinder=0,as cylinder is rigid")
13 disp("so work done by system upon atmosphere(W) in KJ
, W=(p*deltav)/1000")
14 W=(p*deltav)/1000
15 disp("and work done by atmosphere=-40.52 KJ")
```

---

**Scilab code Exa 3.13** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 13



*Fig. 3.35*

Figure 3.6: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 13

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 13")
8 Qadd=5000; //heat supplied in boiler in J/s
9 disp("work done by turbine(Wt) in J/s is 25% of heat
      added i.e")
10 disp("Wt=.25*Qadd")
11 Wt=.25*Qadd
12 disp("heat rejected by condensor (Qrejected) in J/s is
      75% of head added i.e")
13 disp("Qrejected=.75*Qadd")
14 Qrejected=.75*Qadd
15 disp("and feed water pump work(Wp) in J/s is 0.2% of
      heat added i.e")
16 disp("Wp=(-)0.002*Qadd")
17 Wp=-0.002*Qadd
18 disp("capacity of generator (W)=(Wt-Wp)/1000 in Kw")
19 W=(Wt-Wp)/1000

```

---

**Scilab code Exa 3.14** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 14

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;

```

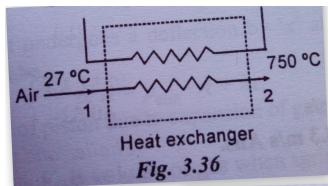


Fig. 3.36

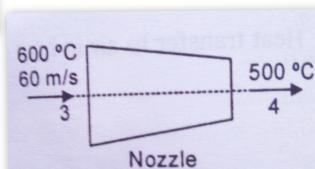
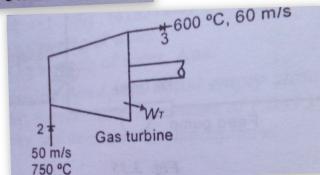


Fig. 3.38

Figure 3.7: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 14

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 14")
8 T1=(27+273); //ambient temperature in K
9 T2=(750+273); //temperature of heated air inside heat
exchanger in K
10 T3=(600+273); //temperature of hot air leaves turbine
in K
11 T4=(500+273); //temperature at which air leaves
nozzle in K
12 Cp=1.005; //specific heat at constant pressure in KJ/
kg K
13 C2=50; //velocity of hot air enter into gas turbine
in m/s
14 C3=60; //velocity of air leaving turbine enters a
nozzle in m/s
15 disp("in heat exchanger upon applying S.F.E.E with
assumption of no change in kinetic energy ,no work
interaction ,no change in potential energy , for

```

```

        unit mass flow rate of air ,")
16 disp("h1+Q1_2=h2")
17 disp("Q1_2=h2-h1")
18 disp("so heat transfer to air in heat exchanger (Q1_2
) in KJ")
19 disp("Q1_2=Cp*(T2-T1)")
20 Q1_2=Cp*(T2-T1)
21 disp("in gas turbine let us use S.F.E.E, assuming no
change in potential energy ,for unit mass flow
rate of air")
22 disp("h2+C2^2/2=h3+C3^2/2+Wt")
23 disp("Wt=(h2-h3)+(C2^2-C3^2)/2")
24 disp("so power output from turbine(Wt) in KJ/s")
25 disp("Wt=Cp*(T2-T3)+(C2^2-C3^2)*10^-3/2")
26 Wt=Cp*(T2-T3)+(C2^2-C3^2)*10^-3/2
27 disp(" applying S.F.E.E upon nozzle assuming no
change in potential energy ,no work and heat
interactions ,for unit mass flow rate ,")
28 disp("h3+C=h4+C4^2/2")
29 disp("C4^2/2=(h3-h4)+C3^2/2")
30 disp("velocity at exit of nozzle(C4) in m/s")
31 disp("C4=sqrt(2*(Cp*(T3-T4)+C3^2*10^-3/2))")
32 C4=sqrt(2*(Cp*(T3-T4)+C3^2*10^-3/2))

```

---

**Scilab code Exa 3.15** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 15

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 15")

```

```

8 T1=400; // initial temperature of gas in K
9 R=8.314; //gas constant in
10 disp("for constant pressure heating ,say state
       changes from 1 to 2")
11 disp("Wa=p1*dv")
12 disp("Wa=p1*(v2-v1)")
13 disp("it is given that v2=2v1")
14 disp("so Wa=p1*v1=R*T1")
15 disp("for subsequent expansion at constant
       temperature say state from 2 to 3")
16 disp("also given that v3/v1=6,v3/v2=3")
17 disp("so work=Wb=p*dv")
18 disp("on solving above we get Wb=R*T2*ln (v3/v2)=R*T2*
       *log3")
19 disp("temperature at 2 can be given by perfect gas
       consideration as ,")
20 disp("T2/T1=v2/v1")
21 disp("or T2=2*T1")
22 disp("now total work done by air W=Wa+Wb=R*T1+R*T2*
       log3=R*T1+2*R*T1*log3 in KJ")
23 disp("so W=R*T1+2*R*T1*log (3) in KJ")
24 W=R*T1+2*R*T1*log (3)

```

---

**Scilab code Exa 3.16** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 16

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh"

```

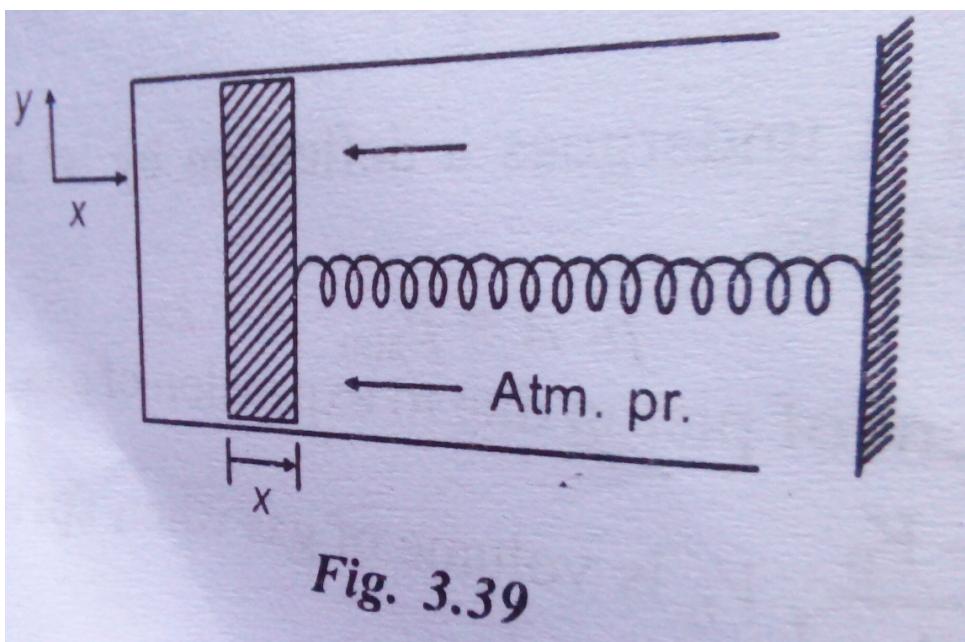


Figure 3.8: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 16

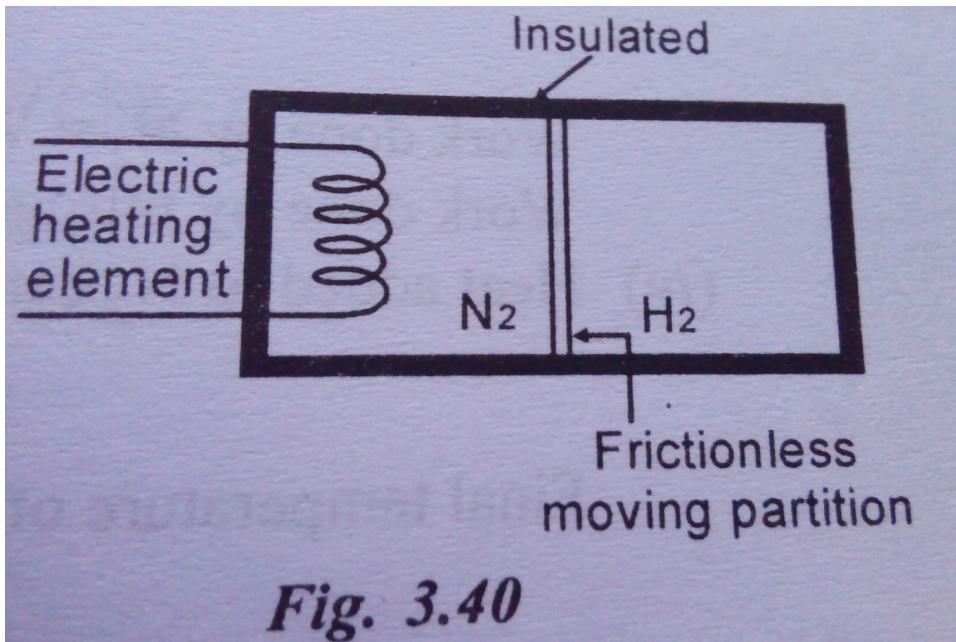


Figure 3.9: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 17

Chapter 3 Example 16")

```

8 Pi=0.5*10^6; //initial pressure of gas in pa
9 Vi=0.5; //initial volume of gas in m^3
10 Pf=1*10^6; //final pressure of gas in pa
11 disp("NOTE=>this question contain derivation which
    cannot be solve using scilab so we use the result
    of derivation to proceed further ")
12 disp("we get W=(Vf-Vi)*((Pi+Pf)/2)")
13 disp(" also final volume of gas in m^3 is Vf=3*Vi")
14 Vf=3*Vi
15 disp("now work done by gas (W) in J")
16 W=(Vf-Vi)*((Pi+Pf)/2)

```

---

**Scilab code Exa 3.17** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 17

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 3 Example 17")
8 Cp_H2=14.307; //specific heat of H2 at constant
                  pressure in KJ/kg K
9 R_H2=4.1240; //gas constant for H2 in KJ/kg K
10 Cp_N2=1.039; //specific heat of N2 at constant
                  pressure in KJ/kg K
11 R_N2=0.2968; //gas constant for N2 in KJ/kg K
12 T1=(27+273); //ambient temperature in K
13 v1=0.5; //initial volume of H2 in m^3
14 p1=0.5*10^6; //initial pressure of H2 in pa
15 v2=0.25; //final volume of H2 in m^3
16 p2=1.324*10^6; //final pressure of H2 in pa
17 disp("with the heating of N2 it will get expanded
      while H2 gets compressed simultaneously .
      compression of H2 in insulated chamber may be
      considered of adiabatic type .")
18 disp("adiabatic index of compression of H2 can be
      obtained as ,")
19 disp("Cp_H2=R_H2*(y_H2/(y_H2-1))")
20 disp("y_H2=Cp_H2/(Cp_H2-R_H2)")
21 y_H2=Cp_H2/(Cp_H2-R_H2)
22 disp("adiabatic index of expansion for N2,Cp_N2=R_N2
      *(y_N2/(y_N2-1))")
23 disp("y_N2=Cp_N2/(Cp_N2-R_N2)")
24 y_N2=Cp_N2/(Cp_N2-R_N2)
25 disp(" i>for hydrogen ,p1*v1^y=p2*v2^y")
26 disp(" so final pressure of H2(p2) in pa")
27 disp(" p2=p1*(v1/v2)^y_H2")
```

```

28 p2=p1*(v1/v2)^y_H2
29 disp("ii>since partition remains in equilibrium
      throughout hence no work is done by partition.it
      is a case similar to free expansion ")
30 disp("partition work=0")
31 disp("iii>work done upon H2(W_H2) in J ,")
32 disp("W_H2=(p1*v1-p2*v2)/(y_H2-1)")
33 W_H2=(p1*v1-p2*v2)/(y_H2-1)
34 disp("work done upon H2(W_H2)=-2*10^5 J")
35 disp("so work done by N2(W_N2)=2*10^5 J ")
36 W_N2=2*10^5; //work done by N2 in J
37 disp("iv>heat added to N2 can be obtained using
      first law of thermodynamics as")
38 disp("Q_N2=deltaU_N2+W_N2=>Q_N2=m*Cv_N2*(T2-T1)+W_N2
      ")
39 disp("final temperature of N2 can be obtained
      considering it as perfect gas")
40 disp("therefore , T2=(p2*v2*T1)/(p1*v1)")
41 disp("here p2=final pressure of N2 which will be
      equal to that of H2 as the partition is free and
      frictionless")
42 disp("p2=1.324*10^6 pa ,v2=0.75 m^3")
43 v2=0.75; //final volume of N2 in m^3
44 disp("so now final temperature of N2(T2) in K")
45 T2=(p2*v2*T1)/(p1*v1)
46 T2=1191.6; //T2 approx. equal to 1191.6 K
47 disp("mass of N2(m) in kg=(p1*v1)/(R_N2*T1)")
48 m=(p1*v1)/(R_N2*1000*T1)
49 m=2.8; //m approx equal to 2.8 kg
50 disp("specific heat at constant volume(Cv_N2) in KJ/
      kg K, Cv_N2=Cp_N2-R_N2")
51 Cv_N2=Cp_N2-R_N2
52 disp("heat added to N2,(Q_N2) in KJ")
53 disp("Q_N2=(m*Cv_N2*1000*(T2-T1))+W_N2")
54 Q_N2=((m*Cv_N2*1000*(T2-T1))+W_N2)/1000

```

---

**Scilab code Exa 3.18** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 18

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 18")
8 p1=0.5*10^6; //initial pressure of air in pa
9 p2=1.013*10^5; //atmospheric pressure in pa
10 v1=2; //initial volume of air in m^3
11 v2=v1; //final volume of air in m^3
12 T1=375; //initial temperature of air in K
13 Cp_air=1.003; //specific heat at consatnt pressure in
KJ/kg K
14 Cv_air=0.716; //specific heat at consatnt volume in
KJ/kg K
15 R_air=0.287; //gas constant in KJ/kg K
16 y=1.4; //expansion constant for air
17 disp("let initial states and final states of air
inside cylinder be given by m1,p1,,T1 and m2,
p2,v2,T2 respectively.it is case of emptying of
cylinder")
18 disp("initial mass of air(m1)in kg")
19 disp("m1=(p1*v1)/(R_air*1000*T1)")
20 m1=(p1*v1)/(R_air*1000*T1)
21 disp("for adiabatic expansion during release of air
through valve from 0.5 Mpa to atmospheric
pressure")
22 disp("T2=T1*(p2/p1)^((y-1)/y) in K")
23 T2=T1*(p2/p1)^((y-1)/y)
```

```

24 disp(" final mass of air left in tank(m2) in kg")
25 disp("m2=(p2*v2)/(R_air*1000*T2)") )
26 m2=(p2*v2)/(R_air*1000*T2)
27 disp(" writing down energy equation for unsteady flow
    system")
28 disp("(m1-m2)*(h2+C^2/2)=(m1*u1-m2*u2)") )
29 disp(" or (m1-m2)*C^2/2=(m1*u1-m2*u2)-(m1-m2)*h2") )
30 disp(" kinetic energy available for running turbine(W
    ) in KJ")
31 disp("W=(m1*u1-m2*u2)-(m1-m2)*h2=(m1*Cv_air*1000*T1-
    m2*Cv_air*1000*T2)-(m1-m2)*Cp_air*1000*T2") )
32 disp("W=(m1*Cv_air*1000*T1-m2*Cv_air*1000*T2)-(m1-m2*
    )*Cp_air*1000*T2") )
33 W=((m1*Cv_air*1000*T1-m2*Cv_air*1000*T2)-(m1-m2)*
    Cp_air*1000*T2)/1000
34 disp(" amount of work available=482.66 KJ")

```

---

**Scilab code Exa 3.19** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 19

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
    Chapter 3 Example 19")
8 p1=0.5*10^6; //initial pressure of air in pa
9 v1=0.5; //initial volume of air in m^3
10 T1=(27+273); //initial temperature of air in K
11 p2=1*10^6; //final pressure of air in pa
12 v2=0.5; //final volume of air in m^3
13 T2=500; //final temperature of air in K
14 R=8314; //gas constant in J/kg K

```

```

15 Cv=0.716; // specific heat at constant volume in KJ/kg
    K
16 disp("using perfect gas equation for the two
        chambers having initial states as 1 and 2 and
        final states as 3")
17 disp("n1=(p1*v1)/(R*T1)")
18 n1=(p1*v1)/(R*T1)
19 disp("now n2=(p2*v2)/(R*T2)")
20 n2=(p2*v2)/(R*T2)
21 disp("for tank being insulated and rigid we can
        assume ,deltaU=0,W=0,Q=0,so writing deltaU ,")
22 deltaU=0; //change in internal energy
23 disp("deltaU=n1*Cv*(T3-T1)+n2*Cv*(T3-T2)")
24 disp("final temperature of gas (T3) in K")
25 disp("T3=(deltaU+Cv*(n1*T1+n2*T2))/(Cv*(n1+n2))")
26 T3=(deltaU+Cv*(n1*T1+n2*T2))/(Cv*(n1+n2))
27 disp("using perfect gas equation for final mixture ,"
    )
28 disp("final pressure of gas (p3) in Mpa")
29 disp("p3=((n1+n2)*R*T3)/(v1+v2)")
30 p3=((n1+n2)*R*T3)/(v1+v2)
31 disp("so final pressure and temperature =0.75 Mpa
        and 409.11 K")

```

---

**Scilab code Exa 3.20** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 20

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6clc;

```

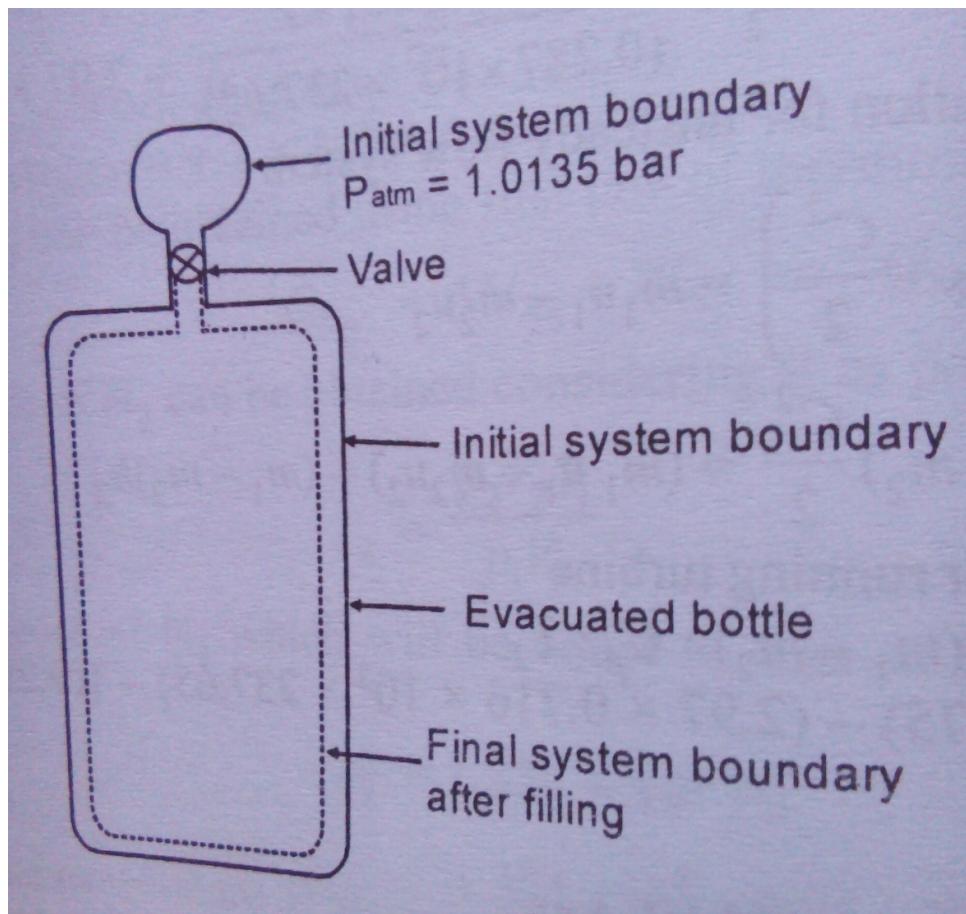


Figure 3.10: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 20

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 20")
8 v1=0; //initial volume of air inside bottle in m^3
9 v2=0.5; //final volume of air inside bottle in m^3
10 p=1.0135*10^5; //atmospheric pressure in pa
11 disp("displacement work ,W=p*(v1-v2) in N.m")
12 W=p*(v1-v2)
13 disp("so heat transfer (Q) in N.m")
14 disp("Q=W")
15 Q=-W

```

---

**Scilab code Exa 3.21** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 21

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 21")
8 p1=35*10^5; //initial pressure of air in pa
9 v1=0.3; //initial volume of air in m^3
10 T1=(40+273); //initial temperature of air in K
11 p2=1*10^5; //final pressure of air in pa
12 v2=0.3; //final volume of air in m^3
13 y=1.4; //expansion constant
14 R=0.287; //gas constant in KJ/kg K
15 Cv=0.718; //specific heat at constant volume in KJ/kg
K
16 Cp=1.005; //specific heat at constant pressure in KJ/
kg K
17 disp("here turbogenerator is fed with compressed air
from a compressed air bottle .pressure inside

```

bottle gradually decreases from 35 bar to 1 bar.  
expansion from 35 bar to 1 bar occurs  
isentropically .thus , for the initial and final  
states of pressure ,volume ,temperatureand mass  
inside bottle being given as p1,v1,T1 & m1 and p2  
,v2 ,T2 & m2 respectively .it is transient flow  
process similar to emptying of the bottle .")

```

18 disp(" (p2/p1) ^((y-1)/y)=(T2/T1)" )
19 disp(" final temperature of air(T2) in K" )
20 disp(" T2=T1*(p2/p1) ^((y-1)/y)" )
21 T2=T1*(p2/p1) ^((y-1)/y)
22 disp(" by perfect gas law ,initial mass in bottle(m1)
      in kg" )
23 disp("m1=(p1*v1)/(R*1000*T1)" )
24 m1=(p1*v1)/(R*1000*T1)
25 disp(" final mass in bottle(m2) in kg" )
26 disp("m2=(p2*v2)/(R*1000*T2)" )
27 m2=(p2*v2)/(R*1000*T2)
28 disp(" energy available for running turbo generator
      or work(W) in KJ" )
29 disp("W+(m1-m2)*h2=m1*u1-m2*u2" )
30 disp("W=(m1*Cv*T1-m2*Cv*T2)-(m1-m2)*Cp*T2" )
31 W=(m1*Cv*T1-m2*Cv*T2)-(m1-m2)*Cp*T2
32 disp(" this is maximum work that can be had from the
      emptying of compressed air bottle between given
      pressure limits" )
33 disp("turbogenerator actual output(P1)=5 KJ/s" )
34 P1=5; //turbogenerator actual output in KJ/s
35 disp("input to turbogenerator(P2) in KJ/s" )
36 P2=P1/0.6
37 disp("time duration for which turbogenerator can be
      run(deltat)in seconds" )
38 disp("deltat=W/P2" )
39 deltat=W/P2
40 disp("duration=160 seconds approx." )
```

---

**Scilab code Exa 3.22** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 22

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 22")
8 p1=1.5*10^5; //initial pressure of air in pa
9 T1=(77+273); //initial temperature of air in K
10 p2=7.5*10^5; //final pressure of air in pa
11 n=1.2; //expansion constant for process 1-2
12 R=0.287; //gas constant in KJ/kg K
13 m=3; //mass of air in kg
14 disp("different states as described in the problem
are denoted as 1,2and 3 and shown on p-V diagram")
15 disp("process 1-2 is polytropic process with index
1.2")
16 disp("(T2/T1)=(p2/p1)^((n-1)/n)")
17 disp("final temperature of air (T2) in K")
18 disp("T2=T1*(p2/p1)^((n-1)/n)")
19 T2=T1*((p2/p1)^((n-1)/n))
20 disp("at state 1,p1*v1=m*R*T1")
21 disp("initial volume of air (v1) in m^3")
22 disp("v1=(m*R*1000*T1)/p1")
23 v1=(m*R*1000*T1)/p1
24 disp("final volume of air (v2) in m^3")
25 disp("for process 1-2,v2=((p1*v1^n)/p2)^(1/n)")
```

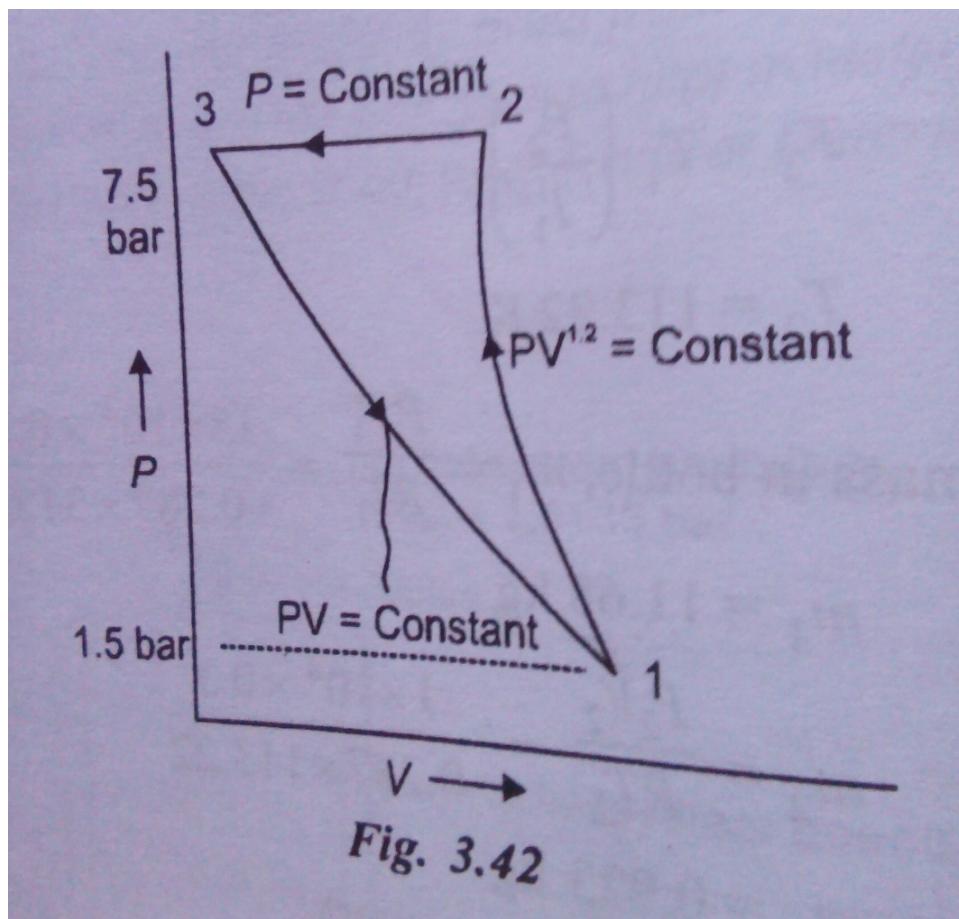


Figure 3.11: Engineering Thermodynamics by Onkar Singh Chapter 3 Example 22

```

26 v2=((p1*v1^n)/p2)^(1/n)
27 disp(" for process 2-3 is constant pressure process
      so p2*v2/T2=p3*v3/T3")
28 disp("v3=v2*T3/T2 in m^3")
29 disp("here process 3-1 is isothermal process so T1=
      T3")
30 T3=T1; //process 3-1 is isothermal
31 v3=v2*T3/T2
32 disp("during process 1-2 the compression work(W1_2)
      in KJ")
33 disp("W1_2=(m*R*(T2-T1)/(1-n))")
34 W1_2=(m*R*(T2-T1)/(1-n))
35 disp("work during process 2-3(W2_3) in KJ,")
36 disp("W2_3=p2*(v3-v2)/1000")
37 W2_3=p2*(v3-v2)/1000
38 disp("work during process 3-1(W3_1) in KJ")
39 disp("W3_1=p3*v3*log(v1/v3)/1000")
40 p3=p2; //pressure is constant for process 2-3
41 W3_1=p3*v3*log(v1/v3)/1000
42 disp("net work done(W_net) in KJ")
43 disp("W_net=W1_2+W2_3+W3_1")
44 W_net=W1_2+W2_3+W3_1
45 disp("net work=-71.27 KJ")
46 disp("here -ve workshows work done upon the system .
      since it is cycle ,so")
47 disp("W_net=Q_net")
48 disp("phi dW=phi dQ=-71.27 KJ")
49 disp("heat transferred from system=71.27 KJ")

```

---

**Scilab code Exa 3.23** Engineering Thermodynamics by Onkar Singh Chapter 3 Example 23

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 3 Example 23")
8 Cp=1.005; //specific heat at constant pressure in KJ/
kg K
9 Cv=0.718; //specific heat at constant volume in KJ/kg
K
10 y=1.4; //expansion constant
11 p1=40*10^5; //initial temperature of air in pa
12 v1=0.15; //initial volume of air in m^3
13 T1=(27+273); //initial temperature of air in K
14 p2=2*10^5; //final temperature of air in pa
15 v2=0.15; //final volume of air in m^3
16 R=0.287; //gas constant in KJ/kg K
17 disp("initial mass of air in bottle(m1)in kg ")
18 disp("m1=(p1*v1)/(R*1000*T1)")
19 m1=(p1*v1)/(R*1000*T1)
20 disp("now final temperature(T2)in K")
21 disp("T2=T1*(p2/p1)^((y-1)/y)")
22 T2=T1*(p2/p1)^((y-1)/y)
23 T2=127.36; //take T2=127.36 approx.
24 disp("final mass of air in bottle(m2)in kg")
25 disp("m2=(p2*v2)/(R*1000*T2)")
26 m2=(p2*v2)/(R*1000*T2)
27 m2=0.821; //take m2=0.821 approx.
28 disp("energy available for running of turbine due to
emptying of bottle(W)in KJ")
29 disp("W=(m1*Cv*T1-m2*Cv*T2)-(m1-m2)*Cp*T2")
30 W=(m1*Cv*T1-m2*Cv*T2)-(m1-m2)*Cp*T2
31 disp("work available from turbine=639.09 KJ")

```

---

# Chapter 4

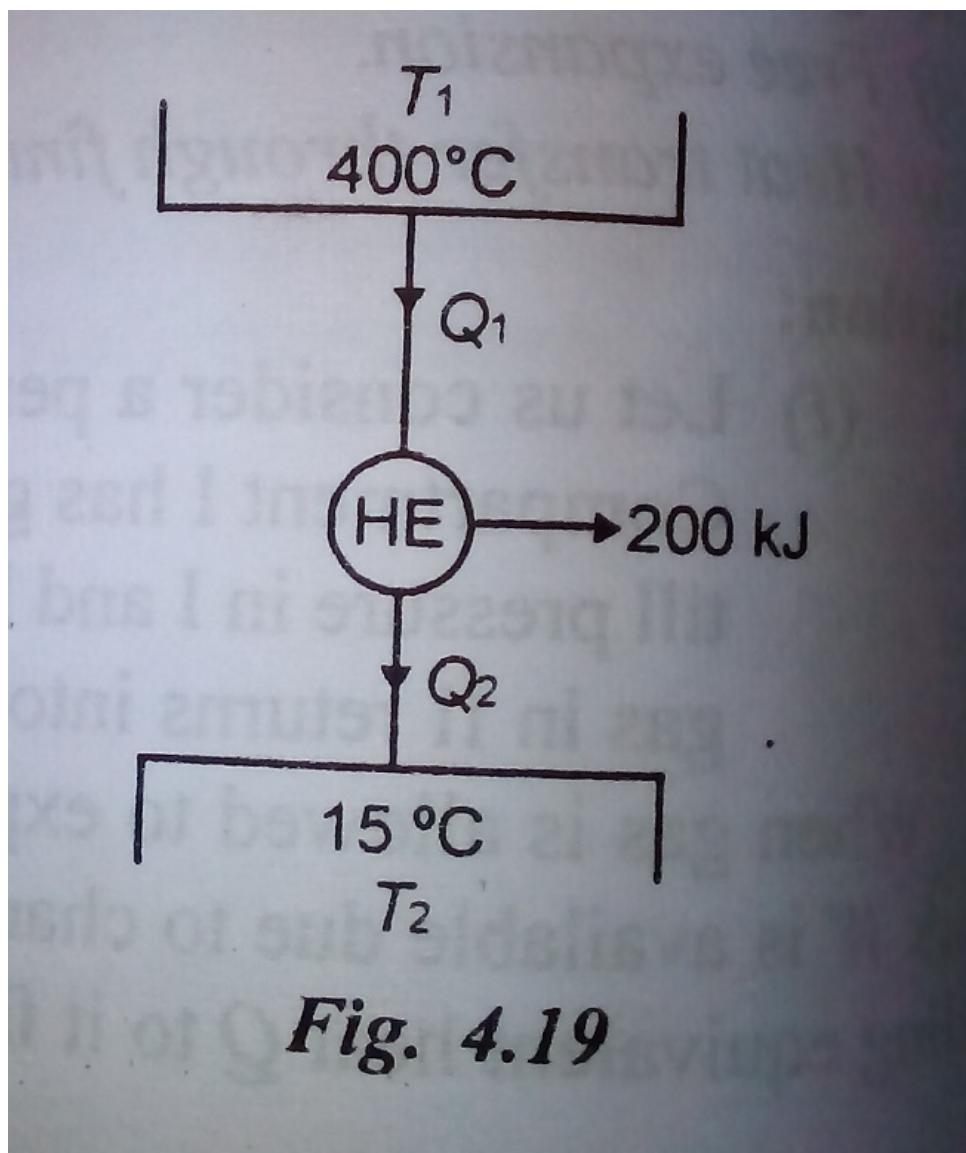
## Second Law Of Thermodynamics

**Scilab code Exa 4.1** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 1")
8 disp("NOTE=>This question is fully theoritical hence
      cannot be solve using scilab.")
```

---

**Scilab code Exa 4.2** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 2



*Fig. 4.19*

Figure 4.1: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 2")
8 T1=(400+273); //temperature of source in K
9 T2=(15+273); //temperature of sink in K
10 W=200; //work done in KJ
11 disp("in carnot engine from thermodynamics
      temperature scale")
12 disp("Q1/Q2=T1/T2")
13 disp("W=Q1-Q2=200 KJ")
14 disp("from above equations Q1 in KJ is given by")
15 disp("Q1=(200*T1)/(T1-T2)")
16 Q1=(200*T1)/(T1-T2)
17 disp("and Q2 in KJ")
18 disp("Q2=Q1-200")
19 Q2=Q1-200
20 disp("so heat supplied (Q1) in KJ")
21 Q1

```

---

**Scilab code Exa 4.3** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 3

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;

```

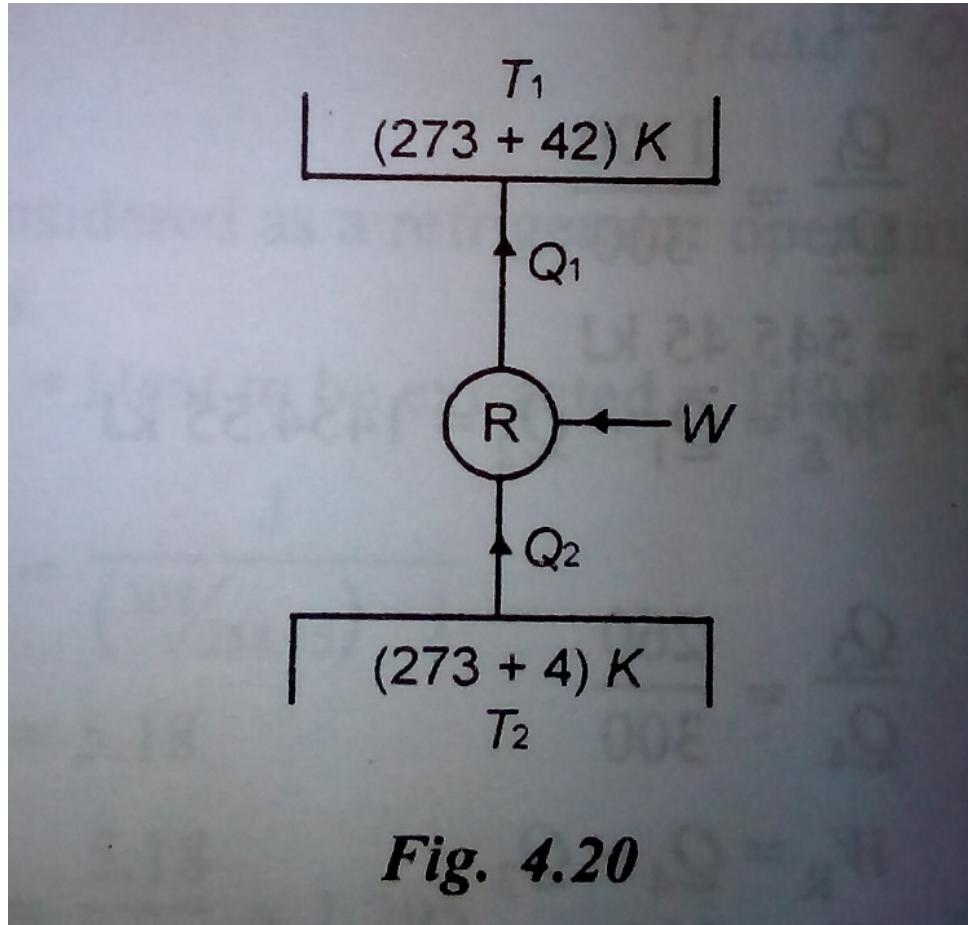


Figure 4.2: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 3

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 4 Example 3")
8 T1=315; //temperature of reservoir 1 in K
9 T2=277; //temperature of reservoir 2 in K
10 Q2=2; //heat extracted in KJ/s
11 disp("from thermodynamic temperature scale")
12 disp("Q1/Q2=T1/T2")
13 disp("so Q1=Q2*(T1/T2) in KJ/s")
14 Q1=Q2*(T1/T2)
15 disp("power/work input required (W)=Q1-Q2 in KJ/s ")
16 W=Q1-Q2
17 disp("power required for driving refrigerator=W in
KW")
18 W

```

---

**Scilab code Exa 4.4** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 4 Example 4")
8 T1=(827+273); //temperature of high temperature
reservoir in K
9 T2=(27+273); //temperature of low temperature
reservoir in K
10 T3=(-13+273); //temperature of reservoir 3 in K
11 Q1=2000; //heat ejected by reservoir 1 in KJ
12 disp("we can writefor heat engine ,Q1/Q2=T1/T2")

```

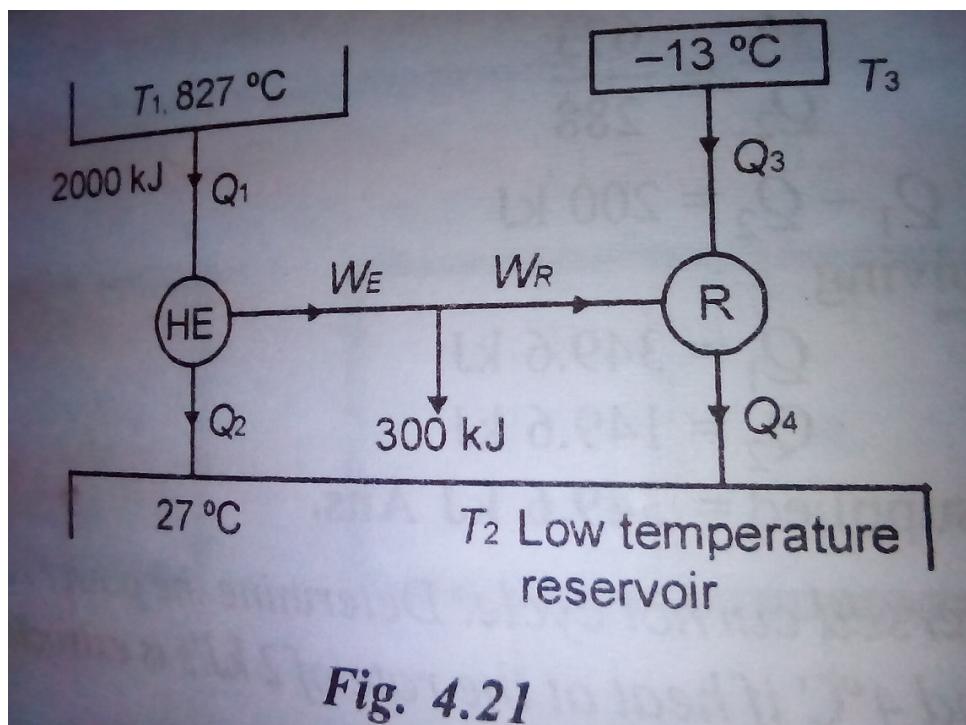


Figure 4.3: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 4

```

13 disp(" so Q2=Q1*(T2/T1) in KJ")
14 Q2=Q1*(T2/T1)
15 disp(" so We=Q1-Q2 in KJ")
16 We=Q1-Q2
17 disp(" for refrigerator ,Q3/Q4=T3/T4 eq 1")
18 T4=T2; //temperature of low temperature reservoir in
      K
19 disp("now We-Wr=300")
20 disp(" so Wr=We-300 in KJ")
21 Wr=We-300
22 disp("and Wr=Q4-Q3=1154.55 KJ eq 2 ")
23 disp(" solving eq1 and eq 2 we get")
24 disp("Q4=(1154.55*T4)/(T4-T3) in KJ")
25 Q4=(1154.55*T4)/(T4-T3)
26 disp("and Q3=Q4-Wr in KJ")
27 Q3=Q4-Wr
28 disp(" total heat transferred to low teperature
      reservoir(Q) =Q2+Q4 in KJ")
29 Q=Q2+Q4
30 disp(" hence heat transferred to refrigerant=Q3 in KJ
      ")
31 Q3
32 disp("and heat transferred to low temperature
      reservoir=Q in KJ")
33 Q

```

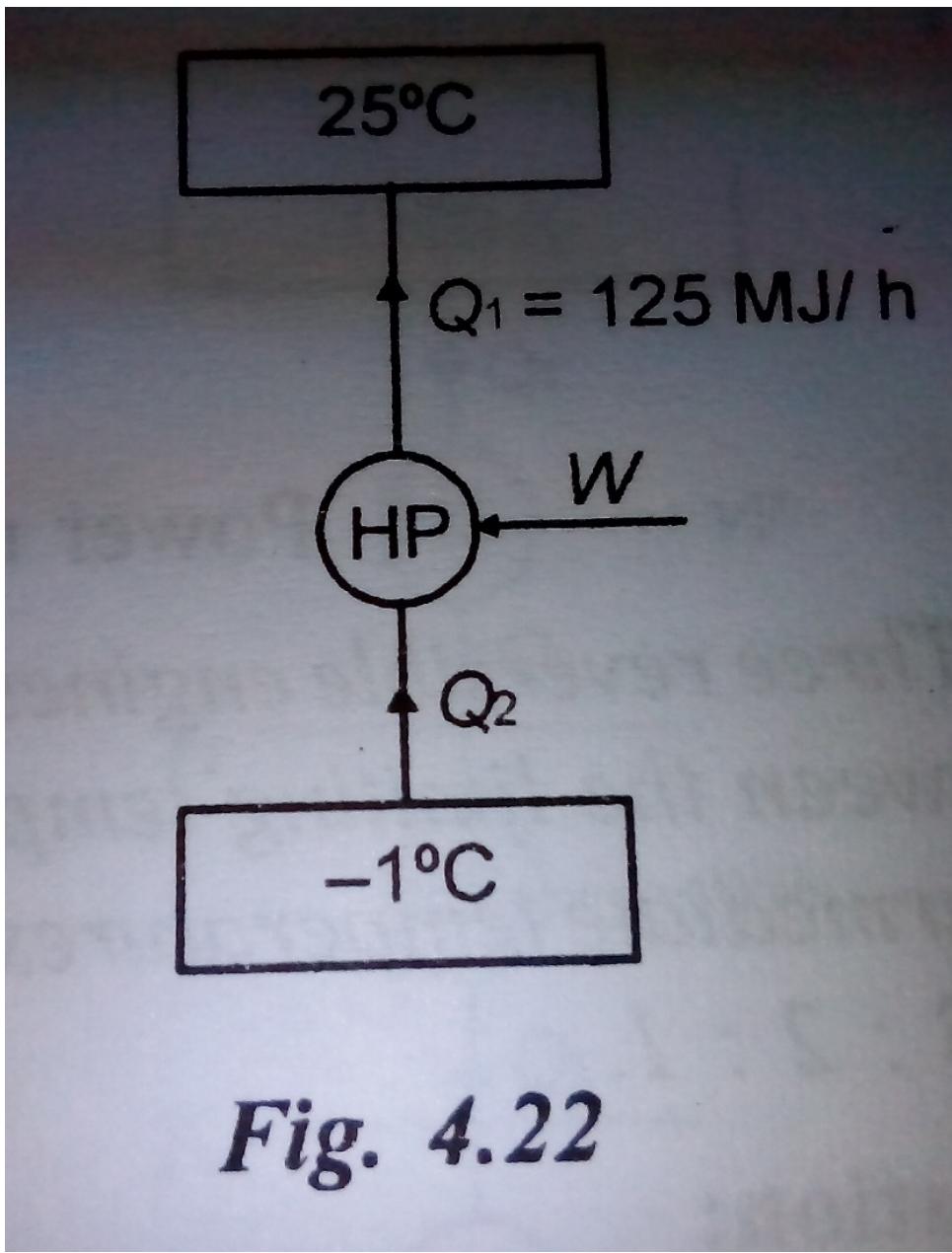
---

**Scilab code Exa 4.5** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);

```



*Fig. 4.22*

Figure 4.4: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 5

```

5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 5")
8 T1=(25+273.15); //temperature of inside of house in K
9 T2=(-1+273.15); //outside temperature in K
10 Q1=125; //heating load in MJ/Hr
11 disp("COP_HP=Q1/W=Q1/(Q1-Q2)=1/(1-(Q2/Q1))")
12 disp("also we know K=Q1/Q2=T1/T2")
13 disp("so K=T1/T2")
14 K=T1/T2
15 disp("so COP_HP=1/(1-(Q2/Q1))=1/(1-(1/K))")
16 COP_HP=1/(1-(1/K))
17 disp("also COP_HP=Q1/W")
18 disp("W=Q1/COP_HP in MJ/Hr")
19 W=Q1/COP_HP
20 disp("or W=1000*W/3600 in KW")
21 W=1000*W/3600
22 disp("so minimum power required (W) in KW ")
23 W

```

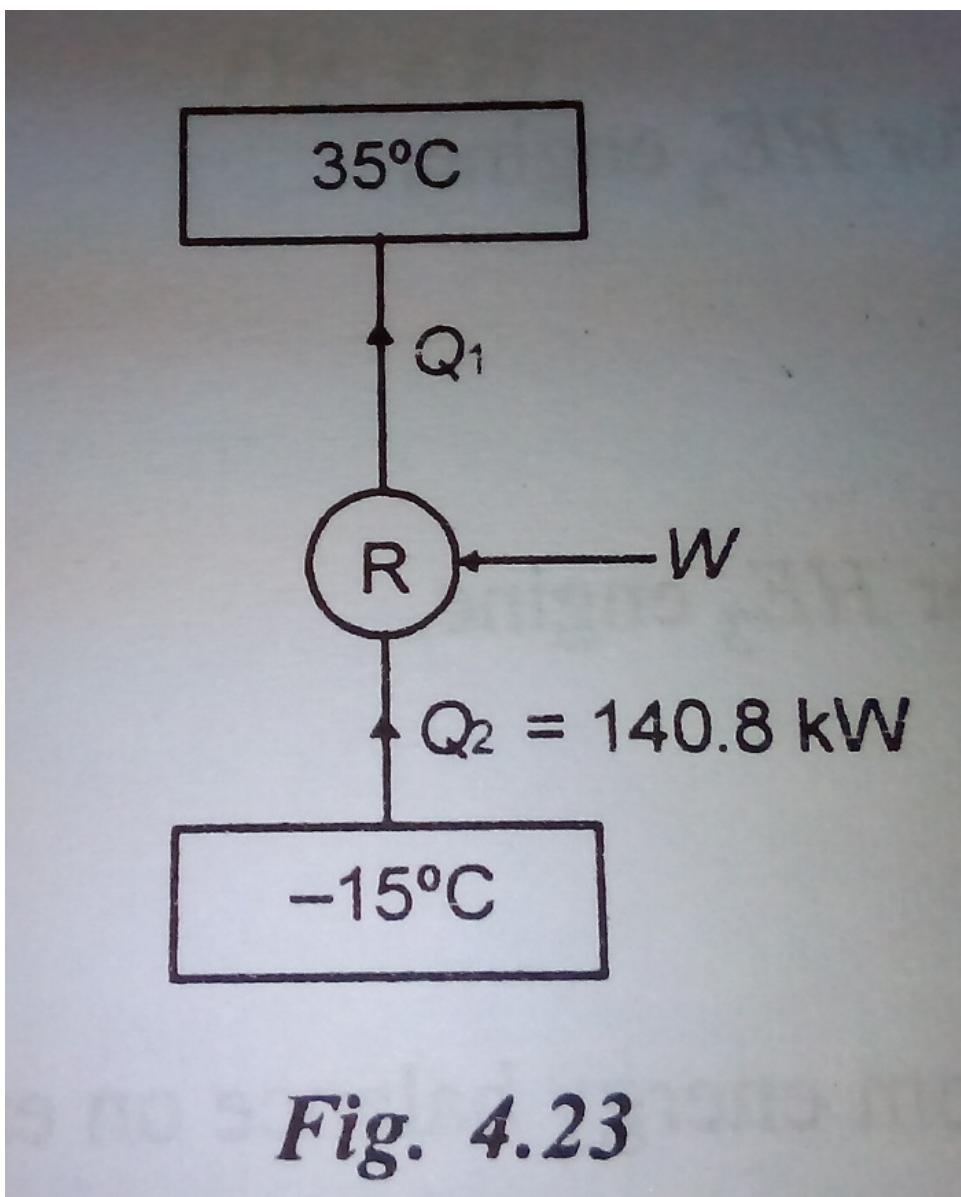
---

**Scilab code Exa 4.6** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 6

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 6")
8 T1=(-15+273.15); //inside temperature in K

```



*Fig. 4.23*

Figure 4.5: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 6

```

9 T2=(35+273); //atmospheric temperature in K
10 Q2=40; //refrigeration capacity of storage plant in
    tonnes
11 disp("cold storage plant can be considered as
        refrigerator operating between given temperatures
        limits")
12 disp("capacity of plant=heat to be extracted=Q2 in
        KW")
13 disp("we know that ,one ton of refrigeration as 3.52
        KW ")
14 disp("so Q2=Q2*3.52 in KW")
15 Q2=Q2*3.52
16 disp("carnot COP of plant (COP_carnot)=1/((T2/T1)-1)")
17 COP_carnot=1/((T2/T1)-1)
18 disp("performance is 1/4 of its carnot COP")
19 disp("COP=COP_carnot/4")
20 COP=COP_carnot/4
21 disp("also actual COP=Q2/W")
22 disp("W=Q2/COP in KW")
23 W=Q2/COP
24 disp("hence power required (W) in KW")
25 W

```

---

**Scilab code Exa 4.7** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
    Chapter 4 Example 7")

```

```

8 T1=(1150+273); //temperature of source in K
9 T2=(27+273); //temperature of sink in K
10 disp("highest efficiency is that of carnot engine , so
        let us find the carnot cycle efficiency for
        given temperature limits")
11 disp("n=1-(T2/T1)")
12 n=1-(T2/T1)
13 disp(" or n=n*100 %")
14 n=n*100

```

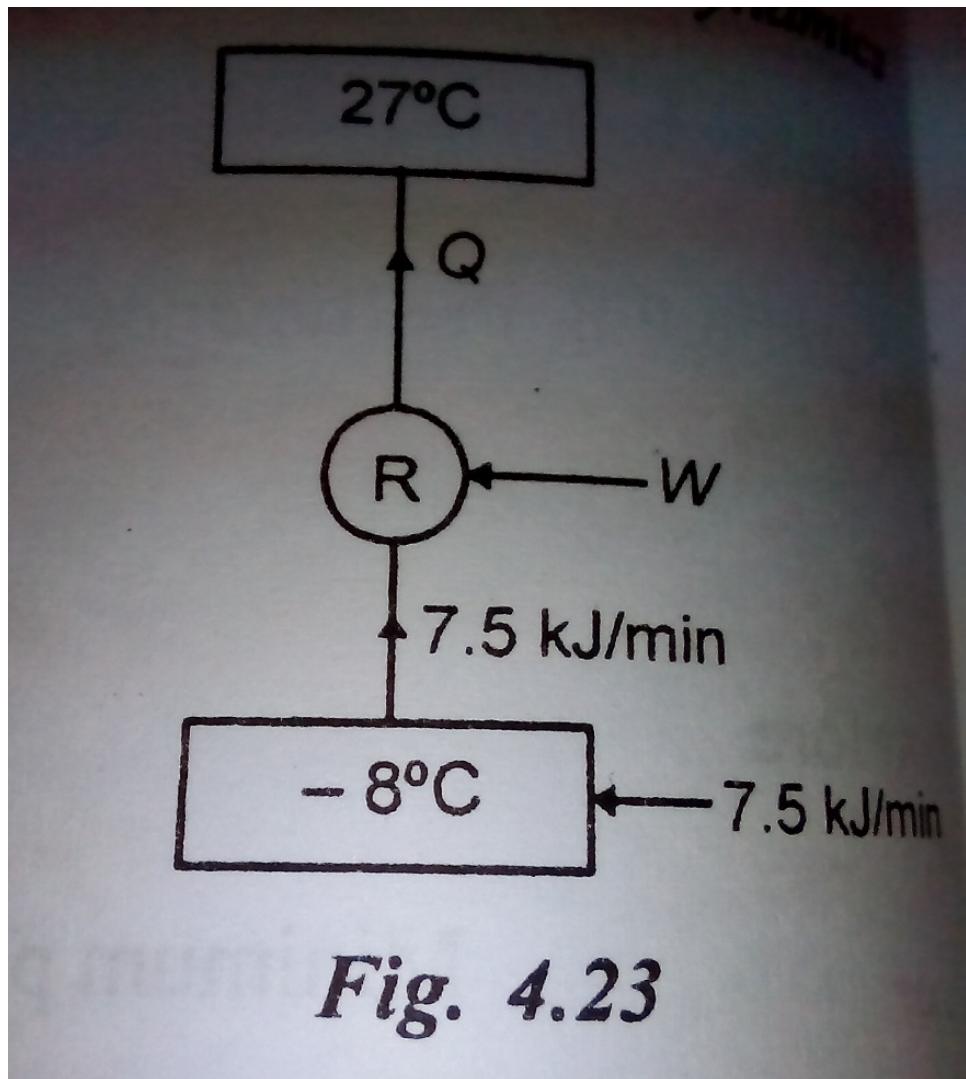
---

**Scilab code Exa 4.8** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 8

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 8")
8 T1=(27+273); //temperature of source in K
9 T2=(-8+273); //temperature of sink in K
10 Q=7.5; //heat leakage in KJ/min
11 disp("here heat to be removed continuously from
      refrigerated space(Q) in KJ/s")
12 Q=Q/60
13 disp("for refrigerated ,COP shall be Q/W=1/((T1/T2)
      -1)")
14 disp("W=Q*((T1/T2)-1) in KW")
15 W=Q*((T1/T2)-1)
16 disp("so power required (W) in KW")
17 W

```



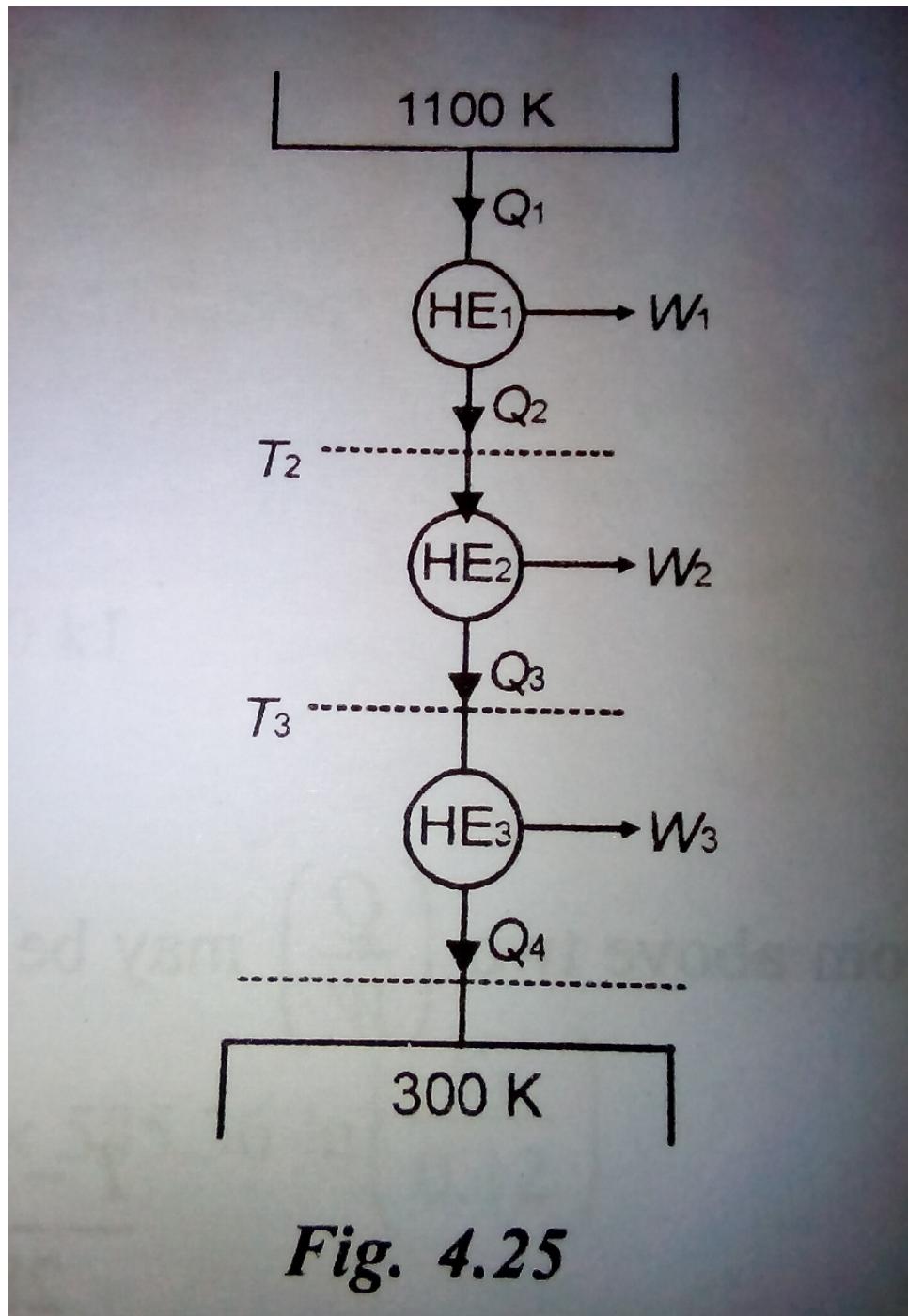
*Fig. 4.23*

Figure 4.6: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 8

---

**Scilab code Exa 4.9** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 9

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 9")
8 T1=1100;//temperature of high temperature reservoir
      in K
9 T4=300;//temperature of low temperature reservoir in
      K
10 disp("here W1:W2:W3=3:2:1")
11 disp("efficiency of engine ,HE1 ,")
12 disp("W1/Q1=(1-(T2/1100))")
13 disp("so Q1=(1100*W1)/(1100-T2)")
14 disp("for HE2 engine ,W2/Q2=(1-(T3/T2))")
15 disp("for HE3 engine ,W3/Q3=(1-(300/T3))")
16 disp("from energy balance on engine ,HE1")
17 disp("Q1=W1+Q2=>Q2=Q1-W1")
18 disp("above gives ,Q1=((1100*W1)/(1100-T2))-W1=(W1*(
      T2/(1100-T2)))")
19 disp("substituting Q2 in efficiency of HE2")
20 disp("W2/(W1*(T2/(1100-T2)))=1-(T3/T2)")
21 disp("W2/W1=(T2/(1100-T2))*(T2-T3)/T2=((T2-T3)-
      (1100-T2))")
22 disp("2/3=(T2-T3)/(1100-T2)")
23 disp("2200-2*T2=3*T2-3*T3")
24 disp("5*T2-3*T3=2200")
```



**Fig. 4.25**

Figure 4.7: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 9

```

25 disp("now energy balance on engine HE2 gives ,Q2=W2+
      Q3")
26 disp("substituting in efficiency of HE2,")
27 disp("W2/(W2+Q3)=(T2-T3)/T2")
28 disp("W2*T2=(W2+Q3)*(T2-T3)")
29 disp("Q3=(W2*T3)/(T2-T3)")
30 disp("substituting Q3 in efficiency of HE3,")
31 disp("W3/((W2*T3)/(T2-T3))=(T3-300)/T3")
32 disp("W3/W2=(T3/(T2-T3))*(T3-300)/T3")
33 disp("1/2=(T3-300)/(T2-T3)")
34 disp("3*T3-T2=600")
35 disp("solving equations of T2 and T3,")
36 disp("we get ,T3=(600+(2200/5))/(3-(3/5)) in K")
37 T3=(600+(2200/5))/(3-(3/5))
38 disp("and by eq 5,T2 in K")
39 T2=(2200+3*T3)/5
40 disp("so intermediate temperature are 700 K and
      433.33 K")

```

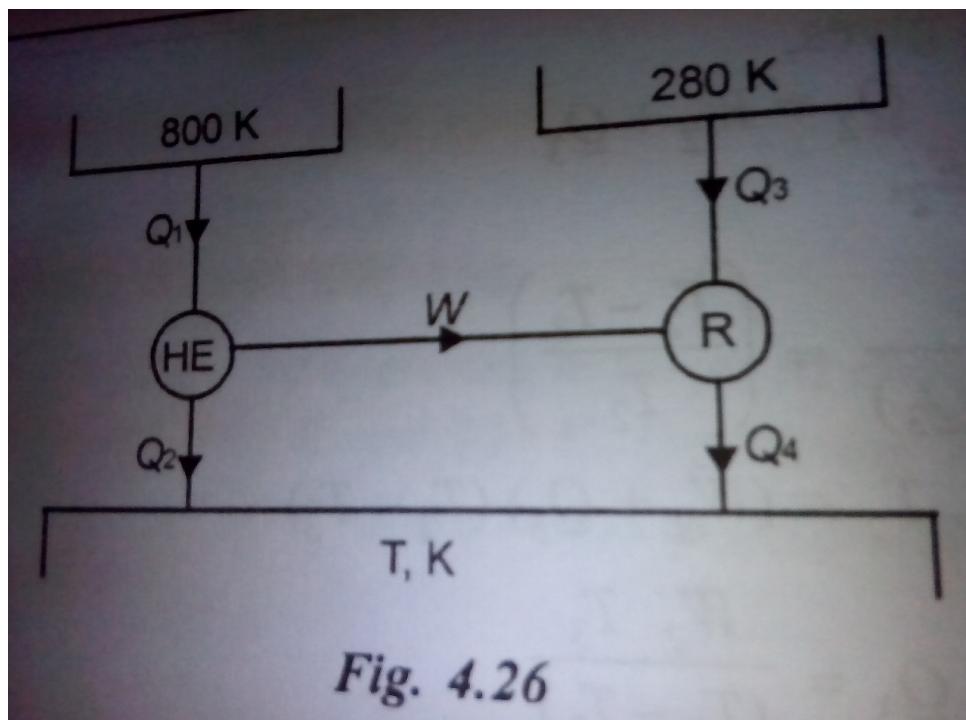
---

**Scilab code Exa 4.10** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 10

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 10")
8 T1=800; //temperature of source in K
9 T2=280; //temperature of sink in K
10 disp("efficiency of engine ,W/Q1=(800-T)/800")

```



*Fig. 4.26*

Figure 4.8: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 10

```

11 disp(" for refrigerator ,COP=Q3/W=280/(T-280)") )
12 disp(" it is given that Q1=Q3=Q")
13 disp(" so ,from engine ,W/Q=(800-T)/800")
14 disp(" from refrigerator ,Q/W=280/(T-280)") )
15 disp(" from above two(Q/W)may be equated ,")
16 disp(" (T-280)/280=(800-T)/800")
17 T=2*280*800/(800+280)
18 disp(" so temperature(T) in K")
19 T
20 disp(" efficiency of engine(n) is given as")
21 disp("n=(800-T)/800")
22 n=(800-T)/800
23 disp("COP of refrigerator is given as")
24 disp("COP=280/(T-280)") )
25 COP=280/(T-280)

```

---

**Scilab code Exa 4.11** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 11

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
        Chapter 4 Example 11")
8 n_carnot=0.5; //efficiency of carnot power cycle
9 m=0.5; //mass of air in kg
10 p2=7*10^5; //final pressure in pa
11 v2=0.12; //volume in m^3
12 R=287; //gas constant in J/kg K
13 Q_23=40*1000; //heat transfer to the air during

```

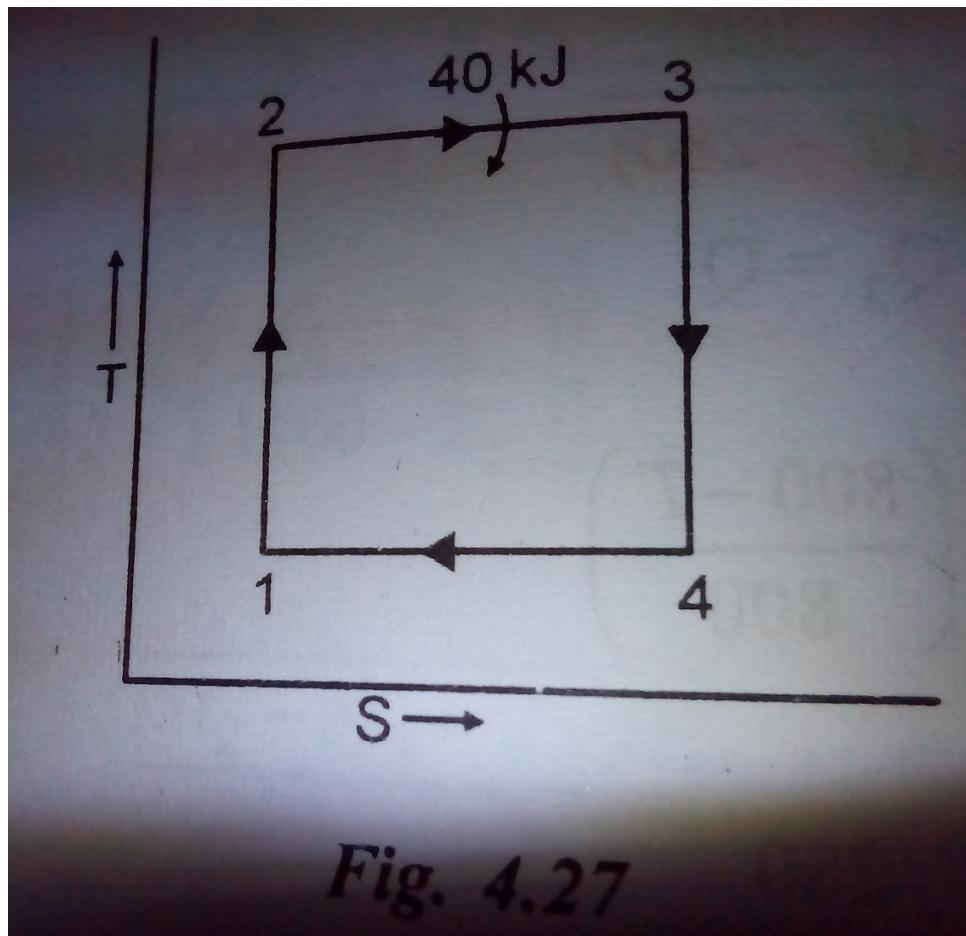


Figure 4.9: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 11

```

    isothermal expansion in J
14 Cp=1.008; // specific heat at constant pressure in KJ/
    kg K
15 Cv=0.721; // specific heat at constant volume in KJ/kg
    K
16 disp("let thermodynamic properties be denoted with
        respect to salient states ;")
17 disp("n_carnot=1-T1/T2")
18 disp("so T1/T2=1-0.5")
19 1-0.5
20 disp("so T1/T2=0.5")
21 disp("or T2=2*T1")
22 disp("corresponding to state 2 ,p2*v2=m*R*T2")
23 disp("so temperature(T2)=p2*v2/(m*R) in K")
24 T2=p2*v2/(m*R)
25 disp("heat transferred during process 2-3(isothermal
        expansion),Q_23=40 KJ")
26 disp("Q_23=W_23=p2*v2*log(v3/v2)")
27 disp("so volume(v3)=v2*exp(Q_23/(p2*v2)) in m^3")
28 v3=v2*exp(Q_23/(p2*v2))
29 disp("temperature at state 1 ,T1=T2/2 in K")
30 T1=T2/2
31 disp("during process 1-2,T2/T1=(p2/p1)^((y-1)/y)")
32 disp("here expansion constant(y)=Cp/Cv")
33 y=Cp/Cv
34 disp("so pressure(p1)=p2/(T2/T1)^(y/(y-1)) in pa")
35 p1=p2/(T2/T1)^(y/(y-1))
36 disp("p1 in bar")
37 p1=p1/10^5
38 disp("thus p1*v1=m*R*T1")
39 disp("so volume(v1)=m*R*T1/(p1*10^5) in m^3")
40 v1=m*R*T1/(p1*10^5)
41 disp("heat transferred during process 4-1(isothermal
        compression)shall be equal to the heat
        transferred during process2-3(isothermal
        expansion).")
42 disp("for isentropic process ,dQ=0,dW=dU")
43 disp("during process 1-2,isentropic process ,W_12=-m*

```

```

        Cv*(T2-T1) in KJ")
44 disp("Q_12=0,")
45 W_12=-m*Cv*(T2-T1)
46 disp("W_12=-105.51 KJ(-ve work)")
47 disp("during process 3-4,isentropic process ,W_34=-m*
        Cv*(T4-T3) in KJ")
48 disp("Q_31=0,")
49 T4=T1;
50 T3=T2;
51 W_34=-m*Cv*(T4-T3)
52 disp("ANS:")
53 disp("W_34=+105.51 KJ(+ve work)")
54 disp("so for process 1-2,heat transfer=0,work
        interaction=-105.51 KJ")
55 disp("for process 2-3,heat transfer=40 KJ,work
        interaction=40 KJ")
56 disp("for process 3-4,heat transfer=0,work
        interaction=+105.51 KJ")
57 disp("for process 4-1,heat transfer=-40 KJ,work
        interaction=-40 KJ")
58 disp("maximum temperature of cycle=585.36 KJ")
59 disp("minimum temperature of cycle=292.68 KJ")
60 disp("volume at the end of isothermal expansion
        =0.1932 m^3")

```

---

**Scilab code Exa 4.12** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 12

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh"

```

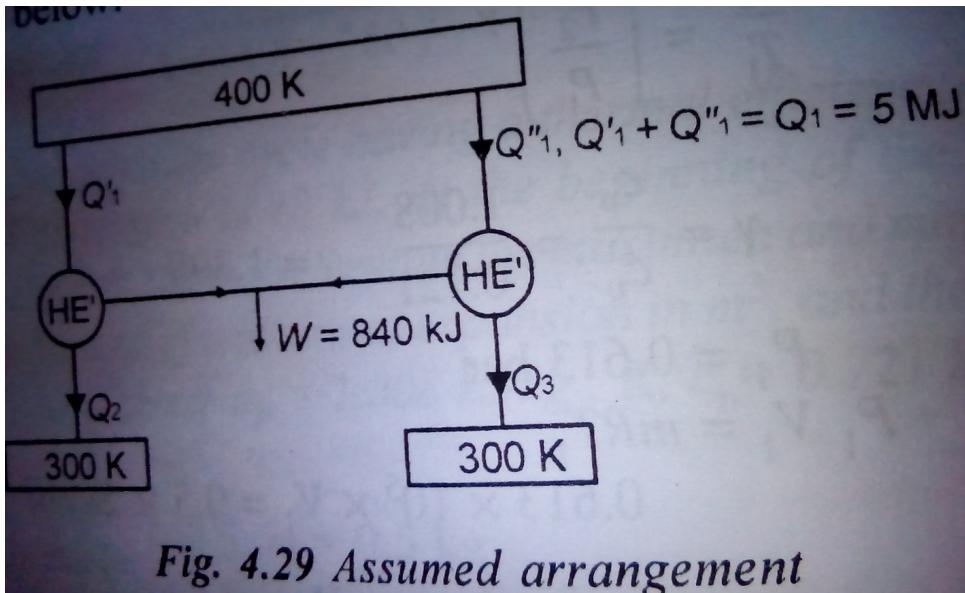
Chapter 4 Example 12”)

```

8 W=840; //work done by reservoir in KJ
9 disp("let us assume that heat engine rejects Q2 and
      Q3 heat to reservoir at 300 K and 200 K
      respectively.let us assume that there are two
      heat engines operating between 400 K and 300 K
      temperature reservoirs and between 400 K and 200
      K temperature reservoirs.let each heat engine
      receive Q1_a and Q1_b from reservoir at 400 K as
      shown below")
10 disp("thus ,Q1_a+Q1_b=Q1=5*10^3 KJ..... eq1"
      )
11 disp(" Also ,Q1_a/Q2=400/300,or Q1_a=4*Q2
      / 3 ..... eq2")
12 disp("Q1_b/Q3=400/200 or Q1_b=2*Q3 ..... eq3
      ")
13 disp(" substituting Q1_a and Q1_b in eq 1")
14 disp("4*Q2/3+2*Q3 = 5 0 0 0 ..... eq4")
15 disp(" also from total work output ,Q1_a+Q1_b-Q2-Q3=W"
      )
16 disp("5000-Q2-Q3=840")
17 disp("so Q2+Q3=5000-840=4160")
18 disp("Q3=4160-Q2")
19 disp("sunstituting Q3 in eq 4")
20 disp("4*Q2/3+2*(4160-Q2)=5000")
21 disp("so Q2=(5000-2*4160)/((4/3)-2) in KJ")
22 Q2=(5000-2*4160)/((4/3)-2)
23 disp("and Q3=4160-Q2 in KJ")
24 Q3=4160-Q2
25 disp("here negative sign with Q3 shows that the
      assumed direction of heat is not correct and
      actually Q3 heat will flow from reservoir to
      engine.actual sign of heat transfers and
      magnitudes are as under:")
26 disp("Q2=4980 KJ,from heat engine")
27 disp("Q3=820 KJ,to heat engine")

```

---



*Fig. 4.29 Assumed arrangement*

Figure 4.10: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 12

**Scilab code Exa 4.13** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 13

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);1
5 clear;
6 clc;
```

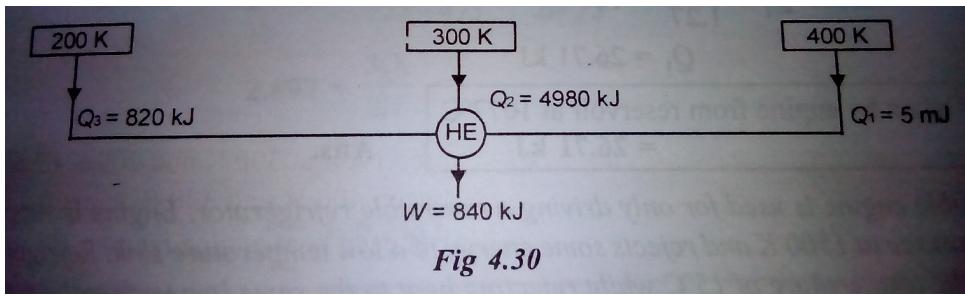
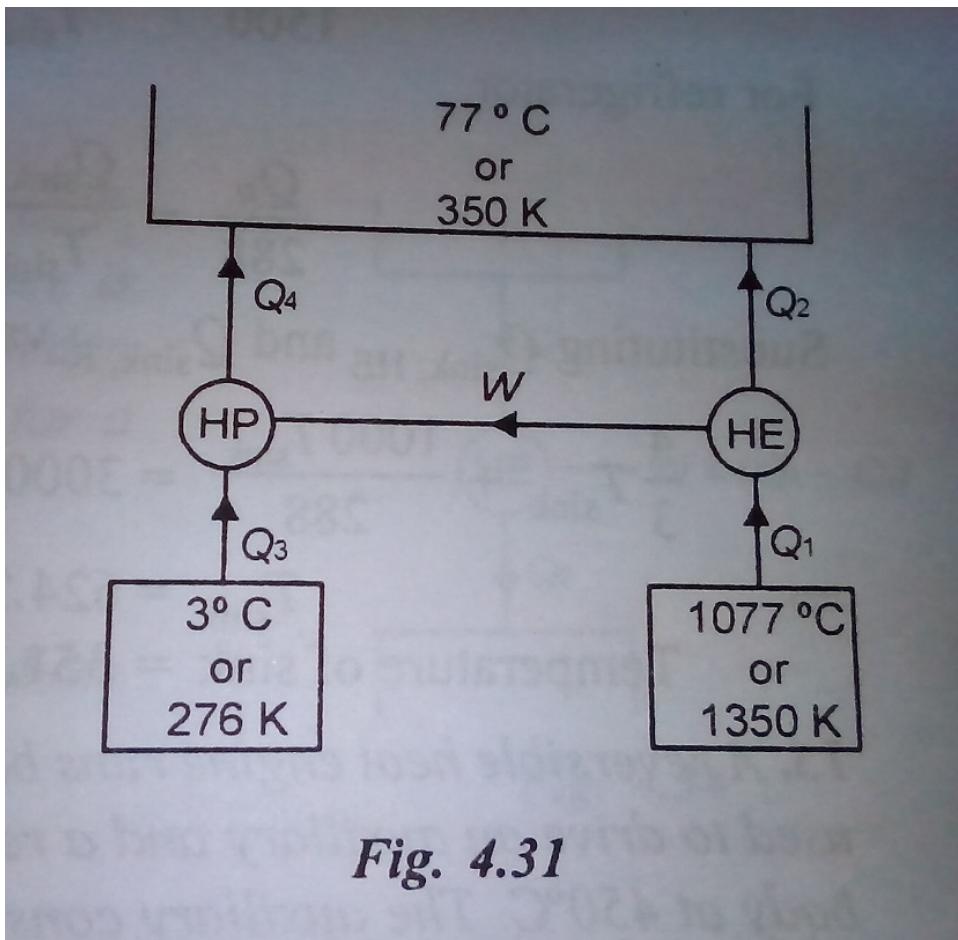


Figure 4.11: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 12

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 4 Example 13")
8 T2=(77+273); //temperature of reservoir 2
9 T1=(1077+273); //temperature of reservoir 1
10 T3=(3+273); //temperature of reservoir 3
11 disp("arrangement for heat pump and heat engine
operating together is shown here.engine and pump
both reject heat to reservoir at 77 degree
celcius (350 K)")
12 disp("for heat engine")
13 disp("ne=W/Q1=1-T2/T1")
14 disp("so (Q1-Q2)/Q1=")
15 1-T2/T1
16 disp("and Q2/Q1=")
17 1-0.7407
18 disp("Q2=0.2593*Q1")
19 disp("for heat pump,")
20 disp("COP_HP=Q4/(Q4-Q3)=T4/(T4-T3) ")
21 T4=T2;
22 T4/(T4-T3)
23 disp("Q4/Q3=")
24 4.73/3.73
25 disp("Q4=1.27*Q3")
26 disp("work output from engine =work input to pump")
27 disp("Q1-Q2=Q4-Q3=>Q1-0.2593*Q1=Q4-Q4/1.27")
28 disp("so Q4/Q1=")

```



*Fig. 4.31*

Figure 4.12: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 13

```

29 (1-0.2593)/(1-(1/1.27))
30 disp(" so Q4=3.484*Q1")
31 disp(" also it is given that Q2+Q4=100")
32 disp(" substituting Q2 and Q4 as function of Q1 in
      following expression ,")
33 disp("Q2+Q4=100")
34 disp(" so 0.2539*Q1+3.484*Q1=100")
35 disp(" so energy taken by engine from reservoir at
      1077 degree celcius(Q1) in KJ")
36 disp("Q1=100/(0.2539+3.484) in KJ")
37 Q1=100/(0.2539+3.484)
38 disp("NOTE=>In this question expression for
      calculating Q1 is written wrong in book which is
      corrected above.")

```

---

**Scilab code Exa 4.14** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 14

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 4 Example 14")
8 Q_source=2000;//heat supplied by heat engine in KJ/s
9 T_source=1500;//temperature of source in K
10 T_R=(15+273); //temperature of reservoir in K
11 Q_sink=3000;//heat received by sink in KJ/s
12 disp("let temperature of sink be T_sink K")
13 disp("Q_sink_HE+Q_sink_R=3000 ..... eq 1")
14 disp("since complete work output from engine is used")

```

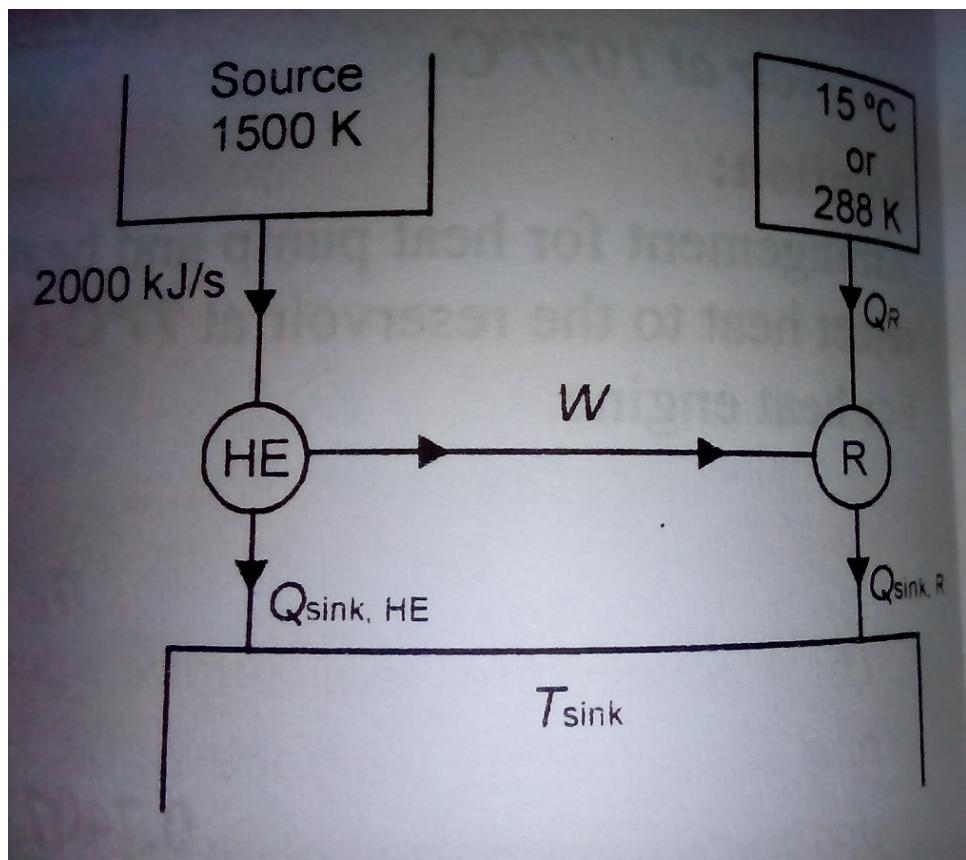


Figure 4.13: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 14

```

        to run refrigerator so,")
15 disp("2000-Q_sink_HE=Q_sink_R-Q_R ..... eq 2")
16 disp("by eq 1 and eq 2,we get Q_R in KJ/s")
17 Q_R=3000-2000
18 disp(" also for heat engine ,2000/1500=Q_sink_HE/
        T_sink")
19 disp("=>Q_sink_HE=4*T_sink/3")
20 disp(" for refrigerator ,Q_R/288=Q_sink_R/T_sink=>
        Q_sink_R=1000*T_sink/288")
21 disp(" substituting Q_sink_HE and Q_sink_R values")
22 disp(" 4*T_sink/3+1000*T_sink/288=3000")
23 disp(" so temperature of sink(T_sink)in K")
24 disp(" so T_sink=3000/((4/3)+(1000/288))")
25 T_sink=3000/((4/3)+(1000/288))
26 disp(" T_sink in degree celcius")
27 T_sink=T_sink-273

```

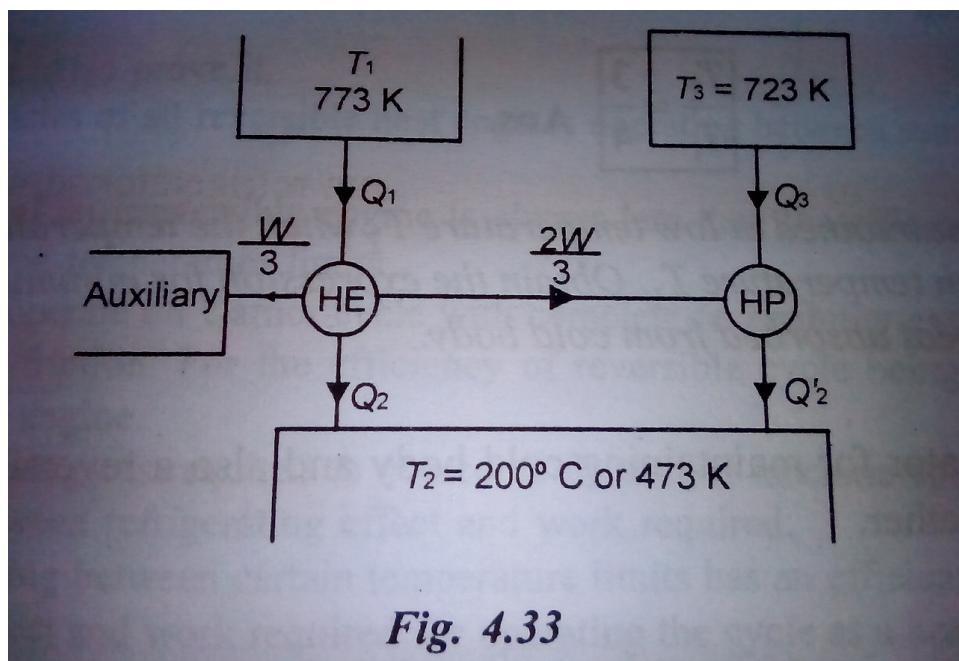
---

**Scilab code Exa 4.15** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 15

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
        Chapter 4 Example 15")
8 T1=(500+273); //temperature of source in K
9 T2=(200+273); //temperature of sink in K
10 T3=(450+273); //temperature of body in K
11 disp("let the output of heat engine be W.so W/3 is
        consumed for driving auxiliary and remaining 2*W

```



*Fig. 4.33*

Figure 4.14: Engineering Thermodynamics by Onkar Singh Chapter 4 Example 15

```

/3 is consumed for driving heat pump for heat
engine ,")
12 disp("n=W/Q1=1-(T2/T1)")
13 n=1-(T2/T1)
14 disp(" so n=W/Q1=0.3881")
15 disp("COP of heat pump=T3/(T3-T2)=Q3/(2*W/3) ")
16 COP=T3/(T3-T2)
17 disp(" so 2.892=3*Q3/2*W")
18 disp("Q3/Q1=")
19 2*COP*n/3
20 disp("so ratio of heat rejected to body at 450
degree celcius to the heat supplied by the
reservoir=0.7482")

```

---

**Scilab code Exa 4.16** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 16

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 4 Example 16")
8 disp("NOTE=>In question no. 16, condition for minimum
surface area for a given work output is
determine which cannot be solve using scilab
software .")

```

---

**Scilab code Exa 4.17** Engineering Thermodynamics by Onkar Singh Chapter 4 Example 17

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 4 Example 17")
8 disp("NOTE=>In question no. 17 expression for (
minimum theoretical ratio of heat supplied from
source to heat absorbed from cold body) is
derived which cannot be solve using scilab
software.")
```

---

# Chapter 5

## Entropy

**Scilab code Exa 5.1** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 5 Example 1")
8 p1=5; //initial pressure of air
9 T1=(27+273); //temperature of air in K
10 p2=2; //final pressure of air in K
11 R=0.287; //gas constant in KJ/kg K
12 Cp_air=1.004; //specific heat of air at constant
                  pressure in KJ/kg K
13 disp("entropy change may be given as ,")
14 disp("s2-s1=((Cp_air*log(T2/T1)-(R*log(p2/p1)))")
15 disp(" here for throttling process h1=h2=>Cp_air*T1=
      Cp_air*T2=>T1=T2")
16 disp("so change in entropy (deltaS) in KJ/kg K")
17 disp("deltaS=(Cp_air*log(1))-(R*log(p2/p1))")
```

```
18 deltaS=(Cp_air*log(1))-(R*log(p2/p1))
```

---

**Scilab code Exa 5.2** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 2

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 5 Example 2")
8 T1=(27+273); //temperature of water in K
9 T2=(100+273); //steam temperature of water in K
10 m=5; //mass of water in kg
11 q=2260; //heat of vaporisation at 100 degree celcius
            in KJ/kg
12 Cp=4.2; //specific heat of water at constant pressure
            in KJ/kg K
13 M=18; //molar mass for water/steam
14 R1=8.314; //gas constant in KJ/kg K
15 disp("total entropy change=entropy change during
      water temperature rise(deltaS1)+entropy change
      during water to steam change(deltaS2)+entropy
      change during steam temperature rise(deltaS3)")
16 disp("deltaS1=Q1/T1, where Q1=m*Cp*deltaT")
17 disp("heat added for increasing water temperature
      from 27 to 100 degree celcius (Q1) in KJ")
18 disp("Q1=m*Cp*(T2-T1)")
19 Q1=m*Cp*(T2-T1)
20 disp("deltaS1=Q1/T1 in KJ/K")
21 deltaS1=Q1/T1
22 disp("now heat of vaporisation (Q2)=m*q in KJ")
23 Q2=m*q
```

```

24 disp("entropy change during phase transformation(
    deltaS2) in KJ/K")
25 disp("deltaS2=Q2/T2")
26 deltaS2=Q2/T2
27 disp("entropy change during steam temperature rise(
    deltaS3) in KJ/K")
28 disp("deltaS3=m*Cp_steam*dT/T")
29 disp("here Cp_steam=R*(3.5+1.2*T+0.14*T^2)*10^-3 in
    KJ/kg K")
30 disp("R=R1/M in KJ/kg K")
31 R=R1/M
32 T2=(100+273.15); //steam temperature of water in K
33 T3=(400+273.15); //temperature of steam in K
34 disp("now deltaS3=(m*R*(3.5+1.2*T+0.14*T^2)*10^-3)*
    dT/T in KJ/K")
35 function y = f(T), y =(m*R*(3.5+1.2*T+0.14*T^2)
    *10^-3)/T , endfunction
36 deltaS3 = intg(T2, T3, f)
37 disp("total entropy change(deltaS)=deltaS1+deltaS2+
    deltaS3 in KJ/K")
38 deltaS3=51.84; //approximately
39 deltaS=deltaS1+deltaS2+deltaS3

```

---

**Scilab code Exa 5.3** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 3

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
    Chapter 5 Example 3")
8 R1=8.314; //gas constant in KJ/kg K

```

```

9 M=32; //molar mass for O2
10 T1=(27+273); //initial temperature of O2 in K
11 p1=125; //initial pressure of O2 in Kpa
12 p2=375; //final pressure of O2 in Kpa
13 Cp=1.004; // specific heat of air at constant pressure
    in KJ/kg K
14 disp("gas constant for oxygen(R) in KJ/kg K")
15 disp("R=R1/M")
16 R=R1/M
17 disp("for reversible process the change in entropy
    may be given as")
18 disp("deltaS=(Cp*log(T2/T1))-(R*log(p2/p1)) in KJ/kg
    K")
19 T2=T1; //isothermal process
20 deltaS=(Cp*log(T2/T1))-(R*log(p2/p1))
21 disp("so entropy change=deltaS in KJ/kg K")
22 deltaS

```

---

**Scilab code Exa 5.4** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
    Chapter 5 Example 4")
8 T1=(150+273.15); //temperature of copper block in K
9 T2=(25+273.15); //temperature of sea water in K
10 m=1; //mass of copper block in kg
11 C=0.393; //heat capacity of copper in KJ/kg K
12 disp("entropy change in universe(deltaS_universe)=
    deltaS_block+deltaS_water")

```

```

13 disp(" where deltaS_block=m*C*log(T2/T1) ")
14 disp(" here hot block is put into sea water , so block
      shall cool down upto sea water at 25 degree
      celcius as sea may be treated as sink")
15 disp(" therefore deltaS_block=m*C*log(T2/T1) in KJ/K")
16 deltaS_block=m*C*log(T2/T1)
17 disp(" heat loss by block =heat gained by water(Q) in
      KJ")
18 disp("Q=-m*C*(T1-T2)")
19 Q=-m*C*(T1-T2)
20 disp(" therefore deltaS_water=-Q/T2 in KJ/K")
21 deltaS_water=-Q/T2
22 disp(" thus deltaS_universe=(deltaS_block+
      deltaS_water)*1000 in J/K")
23 deltaS_universe=(deltaS_block+deltaS_water)*1000

```

---

**Scilab code Exa 5.5** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
      Chapter 5 Example 5")
8 m=1; //mass of copper block in kg
9 T=(27+273); //temperature of copper block in K
10 h=200; //height from which copper block dropped in
      sea water in m
11 C=0.393; //heat capacity for copper in KJ/kg K
12 g=9.81; //acceleration due to gravity in m/s^2
13 disp(" deltaS_universe=(deltaS_block+deltaS_seawater)
      ")

```

```

14 disp("since block and sea water both are at same
      temperature so ,")
15 disp("deltaS_universe=deltaS_seawater")
16 disp("conservation of energy equation yields ,")
17 disp("Q-W=deltaU+deltaP.E+deltaK.E")
18 disp("since in this case ,W=0,deltaK.E=0,deltaU=0")
19 disp("Q=deltaP.E")
20 disp("change in potential energy=deltaP.E=m*g*h in J
      ")
21 deltaPE=m*g*h
22 Q=deltaPE
23 disp("deltaS_universe=deltaS_seawater=Q/T in J/kg K"
      )
24 deltaS_universe=Q/T
25 disp("entropy change of universe(deltaS_universe)in
      J/kg K")
26 deltaS_universe

```

---

**Scilab code Exa 5.6** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 6

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 5 Example 6")
8 m1=1; //mass of first copper block in kg
9 m2=0.5; //mass of second copper block in kg
10 T1=(150+273.15); //temperature of first copper block
      in K
11 T2=(0+273.15); //temperature of second copper block
      in K

```

```

12 Cp_1=0.393; //heat capacity for copper block 1 in KJ/
    kg K
13 Cp_2=0.381; //heat capacity for copper block 2 in KJ/
    kg K
14 disp(" here deltaS_universe=deltaS_block1+
    deltaS_block2")
15 disp("two blocks at different temperatures shall
    first attain equilibrium temperature.let
    equilibrium temperature be Tf")
16 disp("then from energy conservation")
17 disp("m1*Cp_1*(T1-Tf)=m2*Cp_2*(Tf-T2)")
18 disp("Tf=((m1*Cp_1*T1)+(m2*Cp_2*T2))/(m1*Cp_1+m2*
    Cp_2)in K")
19 Tf=((m1*Cp_1*T1)+(m2*Cp_2*T2))/(m1*Cp_1+m2*Cp_2)
20 disp("hence ,entropy change in block 1(deltaS1),due
    to temperature changing from Tf to T1")
21 disp("deltaS1=m1*Cp_1*log(Tf/T1)in KJ/K")
22 deltaS1=m1*Cp_1*log(Tf/T1)
23 disp("entropy change in block 2(deltaS2)in KJ/K")
24 disp("deltaS2=m2*Cp_2*log(Tf/T2)")
25 deltaS2=m2*Cp_2*log(Tf/T2)
26 disp("entropy change of universe(deltaS)=deltaS1+
    deltaS2 in KJ/K")
27 deltaS=deltaS1+deltaS2

```

---

**Scilab code Exa 5.7** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh"

```

Chapter 5 Example 7")  
8 **disp**("NOTE=>in this question formula is derived  
which cannot be solve using scilab software")

---

**Scilab code Exa 5.8** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 8

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
    Chapter 5 Example 8")
8 T1=1800;//temperature of high temperature reservoir
    in K
9 T2=300;//temperature of low temperature reservoir in
    K
10 Q1=5;//heat addition in MW
11 W=2;//work done in MW
12 disp("for irreversible operation of engine ,")
13 disp("rate of entropy generation=Q1/T1+Q2/T2")
14 disp("W=Q1-Q2=>Q2=Q1-W in MW")
15 Q2=Q1-W
16 disp("entropy generated (deltaS_gen) in MW")
17 disp("deltaS_gen=Q1/T1+Q2/T2")
18 Q1=-5;//heat addition in MW
19 deltaS_gen=Q1/T1+Q2/T2
20 disp("work lost (W_lost) in MW")
21 disp("W_lost=T2*deltaS_gen")
22 W_lost=T2*deltaS_gen
```

---

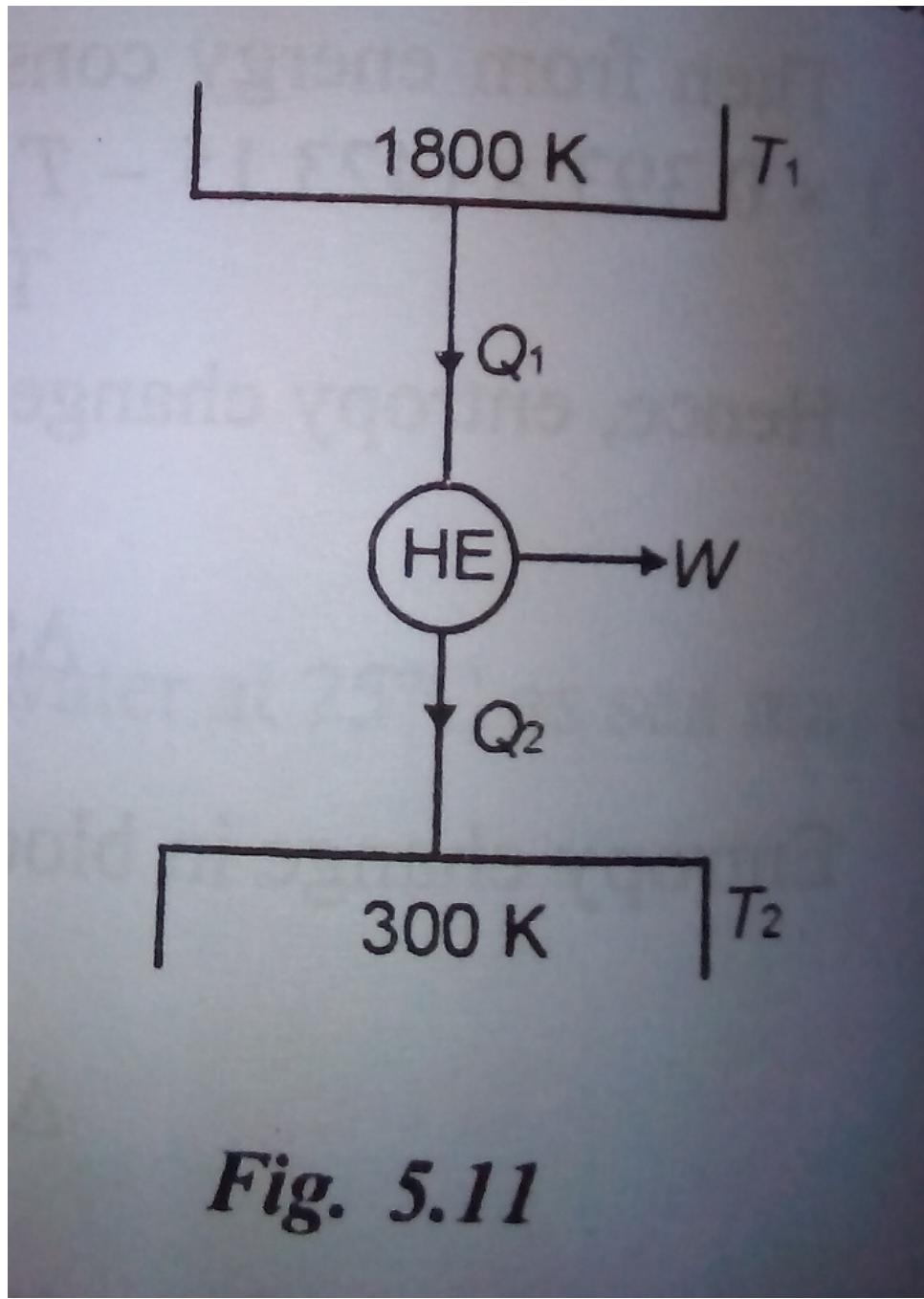
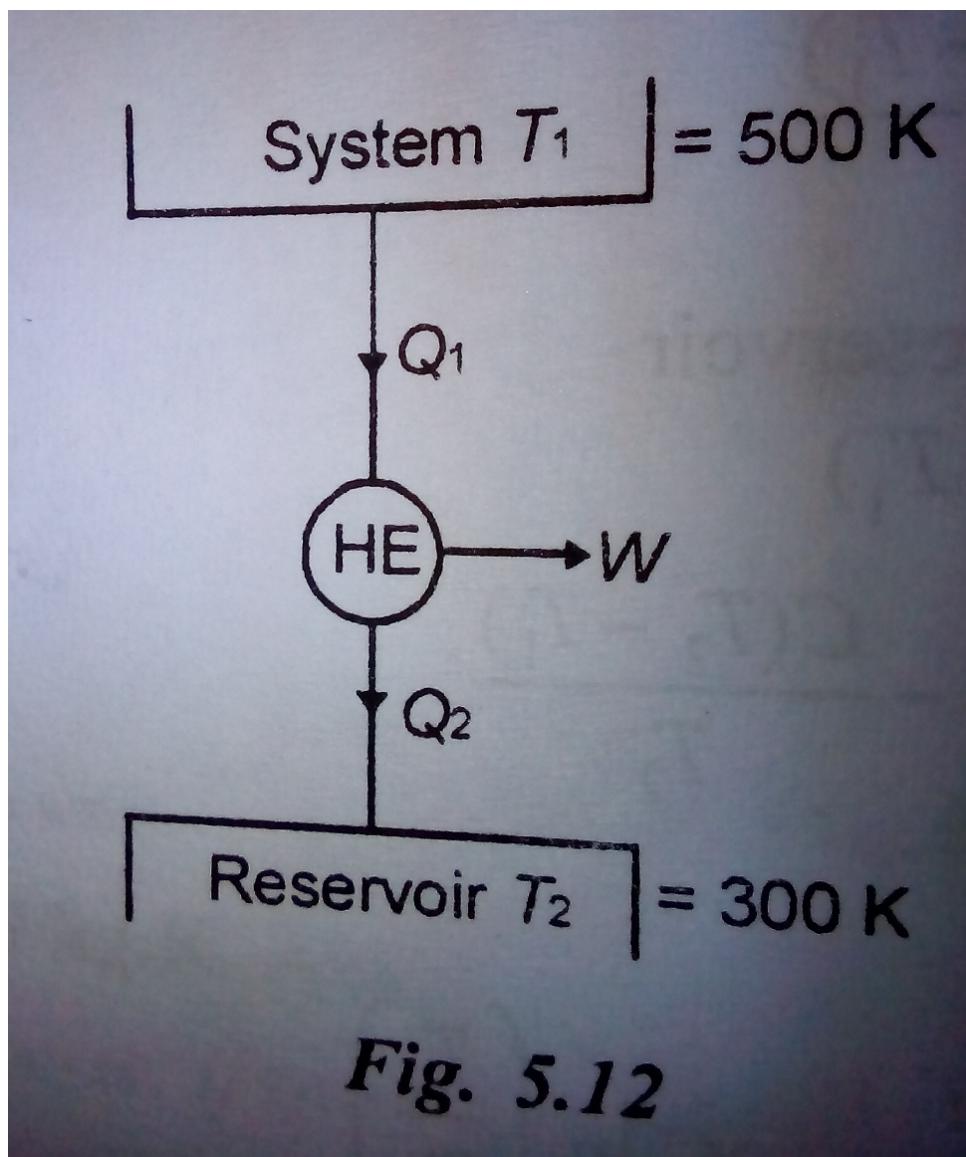


Figure 5.1: Engineering Thermodynamics by Onkar Singh Chapter 5 Example 8

**Scilab code Exa 5.9** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 9

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 5 Example 9")
8 T1=500; //temperature of system in K
9 T2=300; //temperature of reservoir in K
10 disp("system and reservoir can be treated as source
and sink.device thought of can be a carnot engine
operating between these two limits.maximum heat
available from system shall be the heat rejected
till its temperature drops from 500 K to 300 K")
11 disp("therefore ,maximum heat(Q1)=(C*dT) in J")
12 disp(" here C=0.05*T^2+0.10*T+0.085 in J/K")
13 disp(" so Q1=(0.05*T^2+0.10*T+0.085)*dT")
14 function y = f(T), y = (0.05*T^2+0.10*T+0.085),
    endfunction
15 Q1 = intg(T1, T2, f)
16 Q1=-Q1
17 disp("entropy change of system ,deltaS_system=C*dT/T
    in J/K")
18 disp(" so deltaS_system=(0.05*T^2+0.10*T+0.085)*dT/T")
19 function y = k(T), y = (0.05*T^2+0.10*T+0.085)/T,
    endfunction
20 deltaS_system = intg(T1, T2, k)
```



*Fig. 5.12*

Figure 5.2: Engineering Thermodynamics by Onkar Singh Chapter 5 Example 9

```

21 disp("deltaS_reservoir=Q2/T2=(Q1-W)/T2")
22 disp("also ,we know from entropy principle ,
      deltaS_universe is greater than equal to 0")
23 disp("deltaS_universe=deltaS_system+deltaS_reservoir
      ")
24 disp("thus ,upon substituting ,deltaS_system+
      deltaS_reservoir is greater than equal to 0")
25 disp("W is less than or equal to(Q1+deltaS_system*T2
      )/1000 in KJ")
26 W=(Q1+deltaS_system*T2)/1000
27 disp("hence maximum work=W in KJ")
28 W

```

---

**Scilab code Exa 5.10** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 10

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 5 Example 10")
8 p1=3; //initial pressure in Mpa
9 v1=0.05; //initial volume in m^3
10 v2=0.3; //final volume in m^3
11 disp("for reversible adiabatic process governing
      equation for expansion ,")
12 disp("P*V^1.4=constant")
13 disp("also ,for such process entropy change=0")
14 disp("using p2/p1=(v1/v2)^1.4 or v=(p1*(v1 ^ 1.4) / p)
      ^ (1/1.4)")
15 disp("final pressure (p2) in Mpa")
16 disp("p2=p1*(v1/v2) ^ 1.4")

```

```

17 p2=p1*(v1/v2)^1.4
18 disp("from first law ,second law and definition of
      enthalpy ;")
19 disp("dH=T*dS+v*dP")
20 disp(" for adiabatic process of reversible type ,dS=0"
      )
21 dS=0; //for adiabatic process of reversible type
22 disp(" so dH=v*dP")
23 disp(" integrating both side H2-H1=deltaH=v*dP in KJ"
      )
24 p1=3*1000; //initial pressure in Kpa
25 p2=244; //final pressure in Kpa
26 disp("so enthalpy change(deltaH) in KJ")
27 function y = f(p), y =(p1*(v1^1.4)/p)^(1/1.4),
      endfunction
28 deltaH = intg(p2, p1, f)
29 disp("and entropy change=0")

```

---

**Scilab code Exa 5.11** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 11

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 5 Example 11")
8 m=2; //mass of air in kg
9 v1=1; //initial volume of air in m^3
10 v2=10; //final volume of air in m^3
11 R=287; //gas constant in J/kg K
12 disp("during free expansion temperature remains same
      and it is an irreversible process .for getting

```

change in entropy let us approximate this expansion process as a reversible isothermal expansion”)

```

13 disp("a> change in entropy of air (deltaS_air) in J/K")
)
14 disp(" deltaS_air=m*R*log(v2/v1)")
15 deltaS_air=m*R*log(v2/v1)
16 disp("b> during free expansion no heat is gained or
lost to surrounding so ,")
17 disp(" deltaS_surrounding=0")
18 disp("entropy change of surroundings=0")
19 deltaS_surrounding=0; //entropy change of
surroundings
20 disp("c> entropy change of universe (deltaS_universe)
in J/K")
21 disp(" deltaS_universe=deltaS_air+deltaS_surrounding"
)
22 deltaS_universe=deltaS_air+deltaS_surrounding
```

---

**Scilab code Exa 5.12** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 12

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 5 Example 12")
8 m=0.5; //mass of air in kg
9 p1=1.013*10^5; //initial pressure of air in pa
10 p2=0.8*10^6; //final pressure of air in pa
11 T1=800; //initial temperature of air in K
12 n=1.2; //polytropic expansion constant
```

```

13 y=1.4; //expansion constant for air
14 Cv=0.71; //specific heat at constant volume in KJ/kg
    K
15 disp("let initial and final states be denoted by 1
        and 2")
16 disp("for poly tropic process pressure and
        temperature can be related as")
17 disp("(p2/p1)^((n-1)/n)=T2/T1")
18 disp("so temperature after compression (T2)=T1*(p2/p1
        )^((n-1)/n) in K")
19 T2=T1*(p2/p1)^((n-1)/n)
20 disp("substituting in entropy change expression for
        polytropic process ,")
21 disp("entropy change(deltaS) in KJ/kg K")
22 disp("deltaS=Cv*((n-y)/(n-1))*log(T2/T1)")
23 deltaS=Cv*((n-y)/(n-1))*log(T2/T1)
24 disp("NOTE=>answer given in book i.e -244.54 KJ/kg K
        is incorrect , correct answer is -.24454 KJ/kg K")
25 disp("total entropy change(deltaS)=m*deltaS*1000 in
        J/K")
26 deltaS=m*deltaS*1000

```

---

**Scilab code Exa 5.13** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 13

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
        Chapter 5 Example 13")
8 disp("NOTE=>In question no. 13, formula for maximum
        work is derived which cannot be solve using

```

scilab software”)

---

**Scilab code Exa 5.14** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 14

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 5 Example 14")
8 Q1=500; //heat supplied by source in kcal/s
9 T1=600; //temperature of source in K
10 T2=300; //temperature of sink in K
11 disp("clausius inequality can be used for cyclic
process as given below; consider 1 for source and
2 for sink")
12 disp("K=dQ/T=Q1/T1-Q2/T2")
13 disp("i> for Q2=200 kcal/s")
14 Q2=200; //heat rejected by sink in kcal/s
15 disp("K=Q1/T1-Q2/T2 in kcal/s K")
16 K=Q1/T1-Q2/T2
17 disp("as K is not greater than 0, therefore under
these conditions engine is not possible")
18 disp("ii> for Q2=400 kcal/s")
19 Q2=400; //heat rejected by sink in kcal/s
20 disp("K=Q1/T1-Q2/T2 in kcal/s K")
21 K=Q1/T1-Q2/T2
22 disp("as K is less than 0, so engine is feasible and
cycle is reversible")
23 disp("iii> for Q2=250 kcal/s")
24 Q2=250; //heat rejected by sink in kcal/s
25 disp("K=Q1/T1-Q2/T2 in kcal/s K")
```

```
26 K=Q1/T1-Q2/T2
27 disp("as K=0, so engine is feasible and cycle is
      reversible")
```

---

**Scilab code Exa 5.15** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 15

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 5 Example 15")
8 p1=0.5; //initial pressure of air in Mpa
9 T1=400; //initial temperature of air in K
10 p2=0.3; //final pressure of air in Mpa
11 T2=350; //initial temperature of air in K
12 R=0.287; //gas constant in KJ/kg K
13 Cp=1.004; //specific heat at constant pressure in KJ/
      kg K
14 disp("let the two points be given as states 1 and 2,
      ")
15 disp("let us assume flow to be from 1 to 2")
16 disp("so entropy change(deltaS1_2)=s1-s2=Cp*log(T1/
      T2)-R*log(p1/p2) in KJ/kg K")
17 deltaS1_2=Cp*log(T1/T2)-R*log(p1/p2)
18 disp("deltaS1_2=s1-s2=0.01254 KJ/kg K")
19 disp("it means s2 > s1 hence the assumption that
      flow is from 1 to 2 is correct as from second law
      of thermodynamics the entropy increases in a
      process i.e s2 is greater than or equal to s1")
20 disp("hence flow occurs from 1 to 2 i.e from 0.5 MPa
      ,400K to 0.3 Mpa & 350 K")
```

---

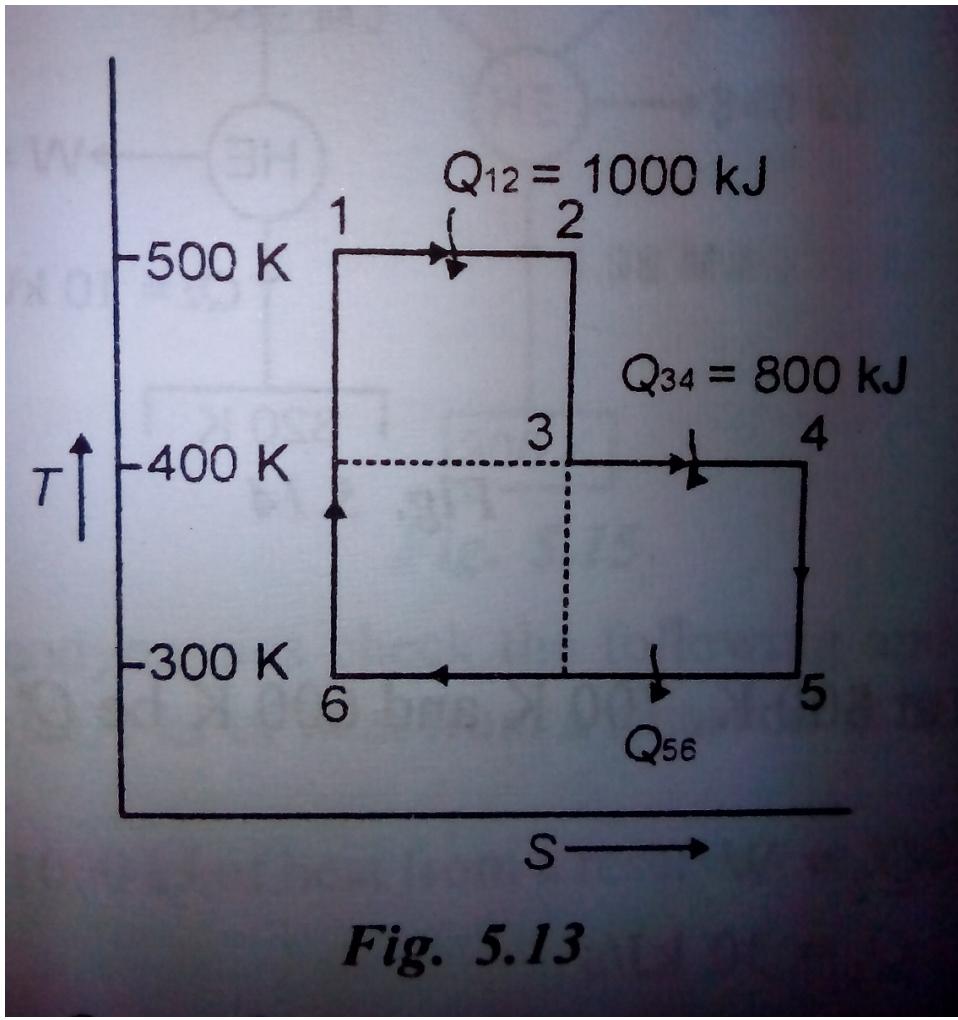
**Scilab code Exa 5.16** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 16

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 5 Example 16")
8 disp("NOTE=>In question no. 16,value of n is derived
which cannot be solve using scilab software.")
```

---

**Scilab code Exa 5.17** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 17

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 5 Example 17")
8 Q12=1000;//heat added during process 1–2 in KJ
9 Q34=800;//heat added during process 3–4 in KJ
10 T1=500;//operating temperature for process 1–2
11 T3=400;//operating temperature for process 3–4
```



**Fig. 5.13**

Figure 5.3: Engineering Thermodynamics by Onkar Singh Chapter 5 Example 17

```

12 T5=300; //operating temperature for process 5-6
13 T2=T1; //isothermal process
14 T4=T3; //isothermal process
15 T6=T5; //isothermal process
16 disp(" total heat added(Q) in KJ")
17 disp("Q=Q12+Q34")
18 Q=Q12+Q34
19 disp(" for heat addition process 1-2")
20 disp("Q12=T1*(s2-s1)")
21 disp(" deltaS=s2-s1=Q12/T1 in KJ/K")
22 deltaS=Q12/T1
23 disp(" or heat addition process 3-4")
24 disp("Q34=T3*(s4-s3)")
25 disp(" deltaS=s4-s3=Q34/T3 in KJ/K")
26 deltaS=Q34/T3
27 disp("or heat rejected in process 5-6(Q56) in KJ")
28 disp("Q56=T5*((s5-s6)=T5*((s2-s1)+(s4-s3))=T5*(deltaS
+deltaS)")
29 Q56=T5*(deltaS+deltaS)
30 disp(" net work done=net heat(W_net) in KJ")
31 disp(" W_net=(Q12+Q34)-Q56")
32 W_net=(Q12+Q34)-Q56
33 disp(" thermal efficiency of cycle(n)=W_net/Q")
34 n=W_net/Q
35 disp(" or n=n*100 %")
36 n=n*100
37 disp(" so work done=600 KJ and thermal efficiency
=33.33 %")

```

---

**Scilab code Exa 5.18** Engineering Thermodynamics by Onkar Singh Chapter 5 Example 18

```
1 // Display mode
```

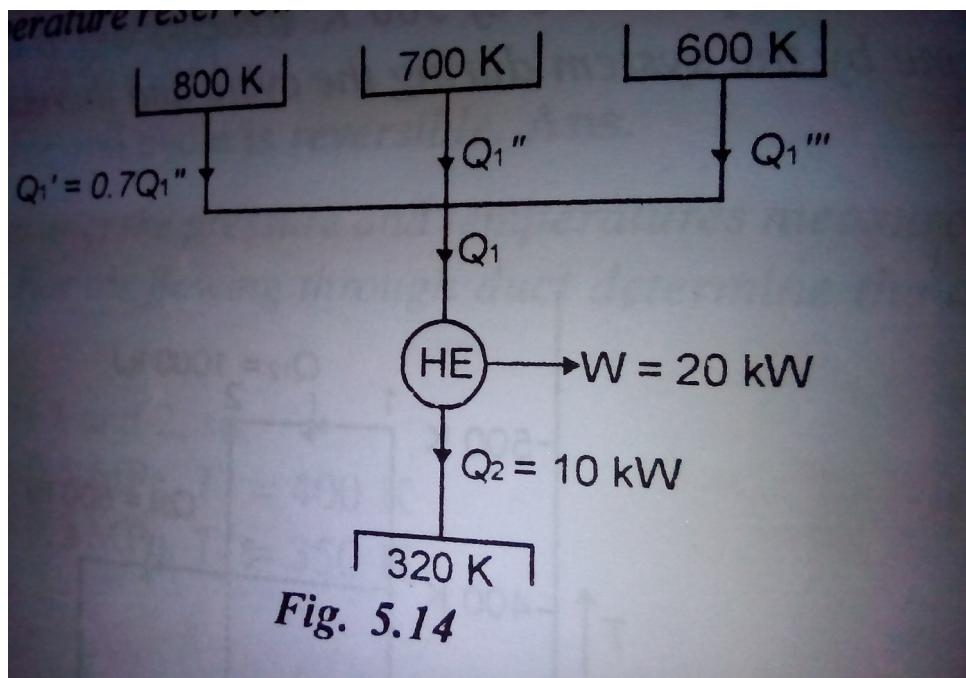


Figure 5.4: Engineering Thermodynamics by Onkar Singh Chapter 5 Example 18

```

2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 5 Example 18")
8 T1_a=800; //temperature of reservoir a in K
9 T1_b=700; //temperature of reservoir b in K
10 T1_c=600; //temperature of reservoir c in K
11 T2=320; //temperature of sink in K
12 W=20; //work done in KW
13 Q2=10; //heat rejected to sink in KW
14 disp("let heat supplied by reservoir at 800 K,700 K
,600 K be Q1_a , Q1_b , Q1_c")
15 disp("here Q1-Q2=W")
16 disp("so heat supplied by source(Q1)=W+Q2 in KW")
17 Q1=W+Q2
18 disp("also given that ,Q1_a=0.7*Q1_b ..... eq 1")
19 disp("Q1_c=Q1-(0.7*Q1_b+Q1_b)")
20 disp("Q1_c=Q1-1.7*Q1_b ..... eq 2")
21 disp("for reversible engine")
22 disp("Q1_a/T1_a+Q1_b/T1_b+Q1_c/T1_c-Q2/T2=0..... eq
3")
23 disp("substitute eq 1 and eq 2 in eq 3 we get , ")
24 disp("heat supplied by reservoir of 700 K(Q1_b) in KJ
/s")
25 disp("Q1_b=((Q2/T2)-(Q1/T1_c))/((0.7/T1_a)+(1/T1_b)
-(1.7/T1_c))")
26 Q1_b=((Q2/T2)-(Q1/T1_c))/((0.7/T1_a)+(1/T1_b)-(1.7/
T1_c))
27 disp("so heat supplied by reservoir of 800 K(Q1_a) in
KJ/s")
28 disp("Q1_a=0.7*Q1_b")
29 Q1_a=0.7*Q1_b
30 disp("and heat supplied by reservoir of 600 K(Q1_c)
in KJ/s")
31 disp("Q1_c=Q1-1.7*Q1_b")

```

```
32 Q1_c=Q1-1.7*Q1_b
33 disp("so heat supplied by reservoir at 800 K(Q1_a)") 
34 Q1_a
35 disp("so heat supplied by reservoir at 700 K(Q1_b)") 
36 Q1_b
37 disp("so heat supplied by reservoir at 600 K(Q1_c)") 
38 Q1_c=-Q1_c
39 disp("NOTE=>answer given in book for heat supplied
      by reservoir at 800 K,700 K,600 K i.e Q1_a=61.94
      KJ/s ,Q1_b=88.48 KJ/s ,Q1_c=120.42 KJ/s is wrong
      hence correct answer is calculated above.")
```

---

# Chapter 6

## Thermodynamic Properties Of Pure Substance

**Scilab code Exa 6.1** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 1")
8 disp("NOTE=>In question no. 1 expression for various
      quantities is derived which cannot be solve
      using scilab software.")
```

---

**Scilab code Exa 6.2** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7
8 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 2")
9 disp("during throttling ,h1=h2")
10 disp("at state 2,enthalpy can be seen for
        superheated steam using Table 4 at 0.05 Mpa and
        100 degree celcius")
11 disp("thus h2=2682.5 KJ/kg")
12 h2=2682.5;
13 disp("at state 1 ,before throttling")
14 disp("hf_10Mpa=1407.56 KJ/kg")
15 hf_10Mpa=1407.56;
16 disp("hfg_10Mpa=1317.1 KJ/kg")
17 hfg_10Mpa=1317.1;
18 disp("h1=hf_10Mpa+x1*hfg_10Mpa")
19 h1=h2; //during throttling
20 disp("dryness fraction (x1)may be given as")
21 disp("x1=(h1-hf_10Mpa)/hfg_10Mpa")
22 x1=(h1-hf_10Mpa)/hfg_10Mpa

```

---

**Scilab code Exa 6.3** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 3

```

1 // Display mode
2 mode(0);

```

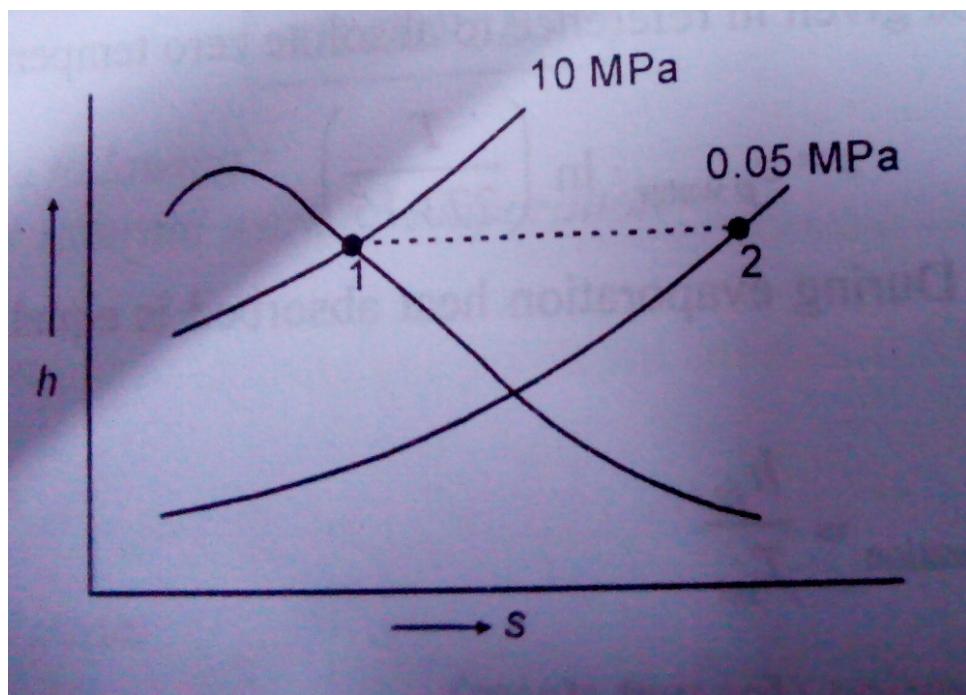


Figure 6.1: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 2

```

3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7
8 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 3")
9 h=2848; //enthalpy in KJ/kg
10 p=12*1000; //pressure in Kpa
11 v=0.017; //specific volume in m^3/kg
12 disp("internal energy(u)=h-p*v in KJ/kg")
13 u=h-p*v

```

---

**Scilab code Exa 6.4** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7
8 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 4")
9 m=5; //mass of steam in kg
10 p=2; //pressure of steam in Mpa
11 T_superheat=(300+273.15); //temperature of superheat
      steam in K
12 Cp_water=4.18; //specific heat of water at constant
      pressure in KJ/kg K
13 Cp_superheat=2.1; //specific heat of superheat steam
      at constant pressure in KJ/kg K

```

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

Contd.

Figure 6.2: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 4

```

14 disp("steam state 2 Mpa and 300 degree celcius lies
      in superheated region as saturation temperature
      at 2 Mpa is 212.42 degree celcius and hfg=1890.7
      KJ/kg")
15 T_sat=(212.42+273.15); //saturation temperature at 2
      Mpa in K
16 hfg_2Mpa=1890.7;
17 disp("entropy of unit mass of superheated steam with
      reference to absolute zero(S)in KJ/kg K")
18 disp("S=Cp_water*log (T_sat/273.15)+(hfg_2Mpa/T_sat)
      +(Cp_superheat*log (T_superheat/T_sat))")
19 S=Cp_water*log (T_sat/273.15)+(hfg_2Mpa/T_sat)+(
      Cp_superheat*log (T_superheat/T_sat))
20 disp("entropy of 5 kg of steam(S) in KJ/K")
21 disp("S=m*S")
22 S=m*S

```

---

**Scilab code Exa 6.5** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 5")
8 rho=1000; //density of water in kg/m^3
9 g=9.81; //acceleration due to gravity in m/s^2
10 h=0.50; //depth from above mentioned level in m
11 disp("boiling point =110 degree celcius ,pressure at
      which it boils=143.27 Kpa(from steam table ,sat.
      pressure for 110 degree celcius)")
12 p_boil=143.27; //pressure at which pond water boils

```

```

    in Kpa
13 disp("at further depth of 50 cm the pressure(p) in
      Kpa")
14 disp("p=p_boil -((rho*g*h)*10^-3)")
15 p=p_boil -((rho*g*h)*10^-3)
16 disp("boiling point at this depth=Tsat_138.365")
17 disp("from steam table this temperature
      =108.866=108.87 degree celcius")
18 disp("so boiling point = 108.87 degree celcius")

```

---

**Scilab code Exa 6.6** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 6

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 6")
8 V=0.5; //capacity of rigid vessel in m^3
9 disp("in a rigid vessel it can be treated as
      constant volume process.")
10 disp("so v1=v2")
11 disp("since final state is given to be critical
      state ,then specific volume at critical point ,")
12 disp("v2=0.003155 m^3/kg")
13 v2=0.003155; //specific volume at critical point in m

```

Table 2 Saturated Steam (temperature) table

Temp. °C T	Sat. press. kPa $P_{sat}$	Specific volume m³/kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg.K)		
		Sat. liquid $v_f$	Sat. vapour $v_g$	Sat. liquid $u_f$	Sat. Evap. $u_{fg}$	Sat. vapour $u_g$	Sat. liquid $h_f$	Sat. Evap. $h_{fg}$	Sat. vapour $h_g$	Sat. liquid $s_f$	Sat. Evap. $s_{fg}$	Sat. vapour $s_g$
100	0.10135	0.001044	1.6729	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.0480	7.3549
105	0.12082	0.001048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958
110	0.14327	0.001052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387
115	0.16906	0.001056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833
120	0.19853	0.001060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296
125	0.2321	0.001065	0.7706	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775
130	0.2701	0.001070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269
135	0.3130	0.001075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777
140	0.3613	0.001080	0.5089	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299
145	0.4154	0.001085	0.4463	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833
150	0.4758	0.001091	0.3928	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379
155	0.5431	0.001096	0.3468	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935
160	0.6178	0.001102	0.3071	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502
165	0.7005	0.001108	0.2727	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.9925	4.7153	6.7078
170	0.7917	0.001114	0.2428	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663
175	0.8920	0.001121	0.2168	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.0021	0.001127	0.19405	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1396	4.4461	6.5857
185	1.1227	0.001134	0.17409	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465
190	1.2544	0.001141	0.15654	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079
195	1.3978	0.001149	0.14105	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698
200	1.5538	0.001157	0.12736	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323
205	1.7230	0.001164	0.11521	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952
210	1.9062	0.001173	0.10441	895.53	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585
215	2.104	0.001181	0.09479	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221
220	2.318	0.001190	0.08619	940.87	1661.5	2602.4	943.62	1858.5	2802.1	2.5178	3.7683	6.2861
225	2.548	0.001199	0.07849	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503
230	2.795	0.001209	0.07158	986.74	1617.2	2603.9	990.12	1813.8	2804.0	2.6099	3.6047	6.2146
235	3.060	0.001219	0.06537	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1791
240	3.344	0.001229	0.05976	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437
245	3.648	0.001240	0.05471	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083
250	3.973	0.001251	0.05013	1080.39	1522.0	2602.4	1085.36	1716.2	2801.5	2.7927	3.2802	6.0730
255	4.319	0.001263	0.04598	1104.28	1506.7	2600.9	1109.73	1689.8	2799.5	2.8383	3.1992	6.0375
260	4.688	0.001276	0.04221	1128.39	1470.6	2599.0	1134.37	1662.5	2796.9	2.8838	3.1181	6.0019
265	5.081	0.001289	0.03877	1152.74	1443.9	2596.6	1159.28	1634.4	2793.6	2.9294	3.0368	5.9662
270	5.499	0.001302	0.03564	1177.36	1416.3	2593.7	1184.51	1605.2	2789.7	2.9751	2.9551	5.9301
275	5.942	0.001317	0.03279	1202.25	1387.9	2590.2	1210.07	1574.9	2785.0	3.0208	2.8730	5.8938
280	6.412	0.001332	0.03017	1227.46	1358.7	2586.1	1235.99	1543.6	2779.6	3.0668	2.7903	5.8571
285	6.909	0.001348	0.02777	1253.00	1328.4	2581.4	1262.31	1511.0	2773.3	3.1130	2.7070	5.8199
290	7.436	0.001366	0.02557	1278.92	1297.1	2576.0	1289.07	1477.1	2766.2	3.1594	2.6227	5.7821
295	7.993	0.001384	0.02354	1305.2	1264.7	2569.9	1316.3	1441.8	2758.1	3.2062	2.5375	5.7437
300	8.581	0.001404	0.02167	1332.0	1231.0	2563.0	1344.0	1404.9	2749.0	3.2534	2.4511	5.7045
305	9.202	0.001425	0.019948	1359.3	1195.9	2555.2	1372.4	1366.4	2738.7	3.3010	2.3633	5.6643
310	9.856	0.001447	0.018350	1387.1	1159.4	2546.4	1401.3	1326.0	2727.3	3.3493	2.2737	5.6230

Figure 6.3: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 5

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

Contd.

Figure 6.4: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 5

Table 2 Saturated Steam (temperature) table

Temp. °C T	Sat. press. kPa $P_{sat}$	Specific volume m³/kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg.K)		
		Sat. liquid $v_f$	Sat. vapour $v_g$	Sat. liquid $u_f$	Sat. Evap. $u_{fg}$	Sat. vapour $u_g$	Sat. liquid $h_f$	Sat. Evap. $h_{fg}$	Sat. vapour $h_g$	Sat. liquid $s_f$	Sat. Evap. $s_{fg}$	Sat. vapour $s_g$
100	0.10135	0.001044	1.6729	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.0480	7.3549
105	0.12082	0.001048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958
110	0.14327	0.001052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387
115	0.16906	0.001056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833
120	0.19853	0.001060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296
125	0.2321	0.001065	0.7706	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775
130	0.2701	0.001070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269
135	0.3130	0.001075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777
140	0.3613	0.001080	0.5089	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299
145	0.4154	0.001085	0.4463	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833
150	0.4758	0.001091	0.3928	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379
155	0.5431	0.001096	0.3468	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935
160	0.6178	0.001102	0.3071	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502
165	0.7005	0.001108	0.2727	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.9925	4.7153	6.7078
170	0.7917	0.001114	0.2428	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663
175	0.8920	0.001121	0.2168	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.0021	0.001127	0.19405	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1396	4.4461	6.5857
185	1.1227	0.001134	0.17409	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465
190	1.2544	0.001141	0.15654	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079
195	1.3978	0.001149	0.14105	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698
200	1.5538	0.001157	0.12736	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323
205	1.7230	0.001164	0.11521	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952
210	1.9062	0.001173	0.10441	895.53	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585
215	2.104	0.001181	0.09479	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221
220	2.318	0.001190	0.08619	940.87	1661.5	2602.4	943.62	1858.5	2802.1	2.5178	3.7683	6.2861
225	2.548	0.001199	0.07849	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503
230	2.795	0.001209	0.07158	986.74	1617.2	2603.9	990.12	1813.8	2804.0	2.6099	3.6047	6.2146
235	3.060	0.001219	0.06537	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1791
240	3.344	0.001229	0.05976	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437
245	3.648	0.001240	0.05471	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083
250	3.973	0.001251	0.05013	1080.39	1522.0	2602.4	1085.36	1716.2	2801.5	2.7927	3.2802	6.0730
255	4.319	0.001263	0.04598	1104.28	1506.7	2600.9	1109.73	1689.8	2799.5	2.8383	3.1992	6.0375
260	4.688	0.001276	0.04221	1128.39	1470.6	2599.0	1134.37	1662.5	2796.9	2.8838	3.1181	6.0019
265	5.081	0.001289	0.03877	1152.74	1443.9	2596.6	1159.28	1634.4	2793.6	2.9294	3.0368	5.9662
270	5.499	0.001302	0.03564	1177.36	1416.3	2593.7	1184.51	1605.2	2789.7	2.9751	2.9551	5.9301
275	5.942	0.001317	0.03279	1202.25	1387.9	2590.2	1210.07	1574.9	2785.0	3.0208	2.8730	5.8938
280	6.412	0.001332	0.03017	1227.46	1358.7	2586.1	1235.99	1543.6	2779.6	3.0668	2.7903	5.8571
285	6.909	0.001348	0.02777	1253.00	1328.4	2581.4	1262.31	1511.0	2773.3	3.1130	2.7070	5.8199
290	7.436	0.001366	0.02557	1278.92	1297.1	2576.0	1289.07	1477.1	2766.2	3.1594	2.6227	5.7821
295	7.993	0.001384	0.02354	1305.2	1264.7	2569.9	1316.3	1441.8	2758.1	3.2062	2.5375	5.7437
300	8.581	0.001404	0.02167	1332.0	1231.0	2563.0	1344.0	1404.9	2749.0	3.2534	2.4511	5.7045
305	9.202	0.001425	0.019948	1359.3	1195.9	2555.2	1372.4	1366.4	2738.7	3.3010	2.3633	5.6643
310	9.856	0.001447	0.018350	1387.1	1159.4	2546.4	1401.3	1326.0	2727.3	3.3493	2.2737	5.6230

Figure 6.5: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 6

```

^3/kg
14 disp("at 100 degree celcius saturation temperature ,
      from steam table")
15 disp(" vf_100=0.001044 m3/kg , vg_100=1.6729 m3/kg")
16 vf_100=0.001044;
17 vg_100=1.6729;
18 disp("and vfg_100=vg_100-vf_100 in m3/kg")
19 vfg_100=vg_100-vf_100
20 disp("thus for initial quality being x1")
21 disp("v1=vf_100+x1*vfg_100")
22 disp("so x1=(v1-vf_100)/vfg_100")
23 v1=v2; //rigid vessel
24 x1=(v1-vf_100)/vfg_100
25 disp("mass of water initially=total mass*(1-x1)")
26 disp("total mass of fluid/water(m)=V/v2 in kg")
27 m=V/v2
28 disp("volume of water(v)=m*vf_100 in m3")
29 v=m*vf_100

```

---

**Scilab code Exa 6.7** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 7")
8 disp("on mollier diadram(h-s diagram) the slope of
      isobaric line may be given as")
9 disp("(dh/ds)p=cons=slope of isobar")
10 disp("from 1st and 2nd law combined;")
11 disp("T*ds=dh-v*dp")

```

```
12 disp(”(dh/ds)_p=cons = T”)
13 disp(” here temperature ,T=773.15 K” )
14 disp(” here slope=(dh/ds))p=cons = 773.15” )
```

---

**Scilab code Exa 6.8** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 8

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(”Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 8”)
8 x=.10; //quality is 10%
9 disp(”at 0.15Mpa, from steam table;”)
10 disp(” hf=467.11 KJ/kg ,hg=2693.6 KJ/kg”)
11 hf=467.11;
12 hg=2693.6;
13 disp(”and hfg=hg-hf in KJ/kg”)
14 hfg=hg-hf
15 disp(” vf=0.001053 m^3/kg ,vg=1.1593 m^3/kg”)
16 vf=0.001053;
17 vg=1.1593;
18 disp(”and vfg=vg-vf in m^3/kg”)
19 vfg=vg-vf
20 disp(” sf=1.4336 KJ/kg ,sg=7.2233 KJ/kg”)
21 sf=1.4336;
22 sg=7.2233;
23 disp(”and sfg=sg-sf in KJ/kg K”)
24 sfg=sg-sf
25 disp(” enthalpy at x=.10(h) in KJ/kg”)
```

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

Contd.

Figure 6.6: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 8

```

26 disp("h=hf+x*hfg")
27 h=hf+x*hfg
28 disp("specific volume , (v) in m^3/kg")
29 disp("v=vf+x*vfg")
30 v=vf+x*vfg
31 disp("entropy (s) in KJ/kg K")
32 disp("s=sf+x*sfg")
33 s=sf+x*sfg

```

---

**Scilab code Exa 6.9** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 9

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 9")
8 p1=1*1000; //initial pressure of steam in Kpa
9 V1=0.05; //initial volume of steam in m^3
10 x1=.8; //dryness fraction is 80%
11 V2=0.2; //final volume of steam in m^3
12 p2=p1; //constant pressure process
13 disp("work done during constant pressure process(W)=
p1*(V2-V1) in KJ")
14 W=p1*(V2-V1)
15 disp("now from steam table at p1 , vf=0.001127 m^3/kg ,
vg=0.19444 m^3/kg , uf=761.68 KJ/kg , ufg=1822 KJ/kg"
)
16 vf=0.001127;
17 vg=0.19444;
18 uf=761.68;
19 ufg=1822;

```

```

20 disp(" so v1=vf+x1*vg in m^3/kg")
21 v1=vf+x1*vg
22 disp("now mass of steam(m)=V1/v1 in kg")
23 m=V1/v1
24 m=0.32097; //take m=0.32097 approx.
25 disp(" specific volume at final state(v2) in m^3/kg")
26 disp("v2=V2/m")
27 v2=V2/m
28 disp("corresponding to this specific volume the
      final state is to be located for getting the
      internal energy at final state at 1 Mpa")
29 disp("v2>vg_1Mpa")
30 disp("hence state lies in superheated region ,from
      the steam table by interpolation we get
      temperature as ;")
31 disp("state lies between temperature of 1000 degree
      celcius and 1100 degree celcius")
32 disp("so exact temperature at final state(T) in K")
33 T=1000+((100*(.62311-.5871))/(.6335-.5871))
34 disp("thus internal energy at final state ,1 Mpa
      ,1077.61 degree celcius ;")
35 disp("u2=4209.6 KJ/kg")
36 u2=4209.6;
37 disp("internal energy at initial state(u1) in KJ/kg")
38 disp("u1=uf+x1*ufg")
39 u1=uf+x1*ufg
40 disp("from first law of thermodynamics ,Q-W=deltaU")
41 disp("so heat added(Q)=(U2-U1)+W=m*(u2-u1)+W in KJ")
42 Q=m*(u2-u1)+W

```

---

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

Contd.

Figure 6.7: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 9

Table 4 Superheated steam table

<i>T</i> °C	<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>P</i> = 1.00 MPa (179.91 °C)				<i>P</i> = 1.20 MPa (187.99 °C)				<i>P</i> = 1.40 MPa (195.70 °C)			
					<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)
<i>P</i> = 1.00 MPa (179.91 °C)																
Sat.	0.19444	2583.6	2778.1	6.5865	0.16333	2588.8	2784.8	6.5233	0.14084	2592.8	2790.0	6.4693				
200	0.2060	2621.9	2827.9	6.6940	0.16930	2612.8	2815.9	6.5898	0.14302	2603.1	2803.3	6.4975				
250	0.2327	2709.9	2942.6	6.9247	0.19234	2704.2	2935.0	6.8294	0.16350	2698.3	2927.2	6.7467				
300	0.2579	2793.2	3051.2	7.1229	0.2138	2789.2	3045.8	7.0317	0.18228	2785.2	3040.4	6.9534				
350	0.2825	2875.2	3157.7	7.3011	0.2345	2872.2	3153.6	7.2121	0.2003	2869.2	3149.5	7.1360				
400	0.3066	2957.3	3263.9	7.4651	0.2548	2954.9	3260.7	7.3774	0.2178	2952.5	3257.5	7.3026				
500	0.3541	3124.4	3478.5	7.7622	0.2946	3122.8	3476.3	7.6759	0.2521	3121.1	3474.1	7.6027				
600	0.4011	3296.8	3697.9	8.0290	0.3339	3295.6	3696.3	7.9435	0.2860	3294.4	3694.8	7.8710				
700	0.4478	3475.3	3923.1	8.2731	0.3729	3474.4	3922.0	8.1881	0.3195	3473.6	3920.8	8.1160				
800	0.4943	3660.4	4154.7	8.4996	0.4118	3659.7	4153.8	8.4148	0.3528	3659.0	4153.0	8.3431				
900	0.5407	3852.2	4392.9	8.7118	0.4505	3851.6	4392.2	8.6272	0.3861	3851.1	4391.5	8.5556				
1000	0.5871	4050.5	4637.6	8.9119	0.4892	4050.0	4637.0	8.8274	0.4192	4049.5	4636.4	8.7559				
1100	0.6335	4255.1	4888.6	9.1017	0.5278	4254.6	4888.0	9.0172	0.4524	4254.1	4887.5	8.9457				
1200	0.6798	4465.6	5145.4	9.2822	0.5665	4465.1	5144.9	9.1977	0.4855	4464.7	5144.4	9.1262				
1300	0.7261	4681.3	5407.4	9.4543	0.6051	4680.9	5407.0	9.3698	0.5186	4680.4	5406.5	9.2984				

Table 4 Superheated steam table

<i>T</i> °C	<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>P</i> = 1.60 MPa (201.41 °C)				<i>P</i> = 1.80 MPa (207.15 °C)				<i>P</i> = 2.00 MPa (212.42 °C)			
					<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>v</i> <i>m</i> <sup>3</sup> / <i>kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)
<i>P</i> = 1.60 MPa (201.41 °C)																
Sat.	0.12380	2596.0	2794.0	6.4218	0.11042	2598.4	2797.1	6.3794	0.09963	2600.3	2799.5	6.3409				
225	0.13287	2644.7	2857.3	6.5518	0.11673	2636.6	2846.7	6.4808	0.10377	2628.3	2835.8	6.4147				
250	0.14184	2692.3	2919.2	6.6732	0.12497	2686.0	2911.0	6.6066	0.11144	2679.6	2902.5	6.5453				
300	0.15862	2781.1	3034.8	6.8844	0.14021	2776.9	3029.2	6.8226	0.12547	2772.6	3023.5	6.7664				
350	0.17456	2866.1	3145.4	7.0694	0.15457	2863.0	3141.2	7.0100	0.13857	2859.8	3137.0	6.9563				
400	0.19005	2950.1	3254.2	7.2374	0.16847	2947.7	3250.9	7.1794	0.15120	2945.2	3247.6	7.1271				
500	0.2203	3119.5	3472.0	7.5390	0.19550	3117.9	3469.8	7.4825	0.17568	3116.2	3467.6	7.4317				
600	0.2500	3293.3	3693.2	7.8080	0.2220	3292.1	3691.7	7.7523	0.19960	3290.9	3690.1	7.7024				
700	0.2794	3472.7	3919.7	8.0535	0.2482	3471.8	3971.8	7.9983	0.2232	3470.9	3917.4	7.9487				
800	0.3086	3658.3	4152.1	8.2808	0.2742	3657.6	4151.2	8.2258	0.2467	3657.0	4150.3	8.1765				
900	0.3377	3850.5	4390.8	8.4935	0.3001	3849.9	4390.1	8.4386	0.2700	3849.3	4389.4	8.3895				
1000	0.3668	4049.0	4635.8	8.6938	0.3260	4048.5	4635.2	8.6391	0.2933	4048.0	4634.6	8.5901				
1100	0.3958	4253.7	4887.0	8.8837	0.3518	4253.2	4886.4	8.8290	0.3166	4252.7	4885.9	8.7800				
1200	0.4248	4464.2	5143.9	9.0643	0.3776	4463.7	5143.4	9.0096	0.3398	4463.3	5142.9	8.9607				
1300	0.4538	4679.9	5406.0	9.2364	0.4034	4679.5	5405.6	9.1818	0.3631	4679.0	5405.1	9.1329				

Figure 6.8: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 9

**Scilab code Exa 6.10** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 10

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 10")
8 p1=800; //initial pressure of steam in Kpa
9 T1=200; //initial temperature of steam in degree
celcius
10 disp("here steam is kept in rigid vessel , therefore
its specific volume shall remain constant")
11 disp("it is superheated steam as Tsat=170.43 degree
celcius at 800 Kpa")
12 disp("from superheated steam table ;v1=0.2404 m^3/kg"
)
13 disp("at begining of condensation specific volume =
0.2404 m^3/kg")
14 disp("v2=0.2404 m^3/kg")
15 v2=0.2404;
16 disp("this v2 shall be specific volume corresponding
to saturated vapour state for condensation .")
17 disp("thus v2=vg=0.2404 m^3/kg")
18 vg=v2;
19 disp("looking into steam table vg=0.2404 m^3/kg
shall lie between temperature 175 degree celcius (
vg=0.2168 m^3/kg)and 170 degree celcius (vg=0.2428
m^3/kg)and pressure 892 Kpa(175 degree celcius )
and 791.7 Kpa(170 degree celcius ).")
20 disp("by interpolation ,temperature at begining of
condensation (T2) in K")
21 T2=175-((175-170)*(0.2404-0.2167))/(0.2428-.2168)
22 disp("similarly ,pressure (p2) in Kpa")
23 p=892-((892-791.7)*(0.2404-0.2168))/(0.2428-0.2168)
```

)

---

**Scilab code Exa 6.11** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 11

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 11")
8 p2=200; //feed water pump pressure in Kpa
9 disp("from 1st and 2nd law;")
10 disp("T*ds=dh-v*dp")
11 disp("for isentropic process ,ds=0")
12 disp("hence dh=v*dp")
13 disp("i.e (h2-h1)=v1*(p2-p1)")
14 disp("corresponding to initial state of saturated
liquid at 30 degree celcius;from steam table;")
15 disp("p1=4.25 Kpa , vf=v1=0.001004 m^3/kg")
16 p1=4.25;
17 v1=0.001004;
18 disp("therefore enthalpy change (deltah)=(h2-h1)=v1*(
p2-p1) in KJ/kg")
19 deltah=v1*(p2-p1)
```

---

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg			Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)				
		Sat. liquid		Sat. vapour	Sat. liquid		Sat. Evap.	Sat. vapour	Sat. liquid	Sat. h <sub>f</sub>	Sat. h <sub>fg</sub>	Sat. h <sub>g</sub>	Sat. s <sub>f</sub>	Sat. s <sub>fg</sub>	Sat. s <sub>g</sub>
		<i>v<sub>f</sub></i>	<i>v<sub>g</sub></i>	<i>u<sub>f</sub></i>	<i>u<sub>fg</sub></i>	<i>u<sub>g</sub></i>									
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594			
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844			
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233			
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717			
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271			
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878			
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527			
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209			
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919			
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652			
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405			
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175			
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959			
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565			
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213			
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893			
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600			
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331			
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080			
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847			
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628			
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421			
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226			
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041			
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865			
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536			
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233			
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953			
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693			
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448			
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896			
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409			
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972			
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575			
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869			
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253			
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701			
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734			
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892			
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133			
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432			
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722			
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141			

Contd.

Figure 6.9: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 10

Table 4 Superheated steam table

T °C	P = 0.20 MPa (120.23 °C)				P = 0.30 MPa (133.55 °C)				P = 0.40 MPa (143.63 °C)			
	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)
Sat.	0.8857	2529.5	2706.7	7.1272	0.6058	2543.6	2725.3	6.9919	0.4625	2553.6	2738.6	6.8959
150	0.9596	2576.9	2768.8	7.2795	0.6339	2570.8	2761.0	7.0778	0.4708	2564.5	2752.8	6.9299
200	1.0803	2654.4	2870.5	7.5066	0.7163	2650.7	2865.6	7.3115	0.5342	2646.8	2860.5	7.1706
250	1.1988	2731.2	2971.0	7.7086	0.7964	2728.7	2967.6	7.5166	0.5951	2726.1	2964.2	7.3789
300	1.3162	2808.6	3071.8	7.8926	0.8753	2806.7	3069.3	7.7022	0.6548	2804.8	3066.8	7.5662
400	1.5493	2966.7	3276.6	8.2218	1.0315	2965.6	3275.0	8.0330	0.7726	2964.4	3273.4	7.8983
500	1.7814	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	0.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0194	1.4957	3478.4	3927.1	8.8319	1.1215	3477.9	3926.5	8.6987
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2312	3662.4	4157.3	8.9244
900	2.705	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2692	1.3529	3853.9	4395.1	9.1362
1000	2.937	4052.5	4640.0	9.5663	1.9581	4052.3	4639.7	9.4690	1.4685	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.5840	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.5	10.0262	2.2661	4467.2	5147.1	9.8389	1.6996	4467.0	5146.8	9.7060
1300	3.630	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780

Table 4 Superheated steam table

T °C	P = 0.50 MPa (151.86 °C)				P = 0.60 MPa (158.85 °C)				P = 0.80 MPa (170.43 °C)			
	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)
Sat.	0.3749	2561.2	2748.7	6.8213	0.3157	2567.4	2756.8	6.7600	0.2404	2576.8	2769.1	6.6628
200	0.4249	2642.9	2855.4	7.0592	0.3520	2638.9	2850.1	6.9665	0.2608	2630.6	2839.3	6.8158
250	0.4744	2723.5	2960.7	7.2709	0.3938	2720.9	2957.2	7.1816	0.2931	2715.5	2950.0	7.0384
300	0.5226	2802.9	3064.2	7.4599	0.4344	2801.0	3061.6	7.3724	0.3241	2797.2	3056.5	7.2328
350	0.5701	2882.6	3167.7	7.6329	0.4742	2881.2	3165.7	7.5464	0.3544	2878.2	3161.7	7.4089
400	0.6173	2963.2	3271.9	7.7938	0.5137	2962.1	3270.3	7.7079	0.3843	2959.7	3267.1	7.5716
500	0.7109	3128.4	3483.9	8.0873	0.5920	3127.6	3482.8	8.0021	0.4433	3126.0	3480.6	7.8673
600	0.8041	3299.6	3701.7	7.3522	0.6697	3299.1	3700.9	8.2674	0.5018	3297.9	3699.4	8.1333
700	0.8969	3477.5	3925.9	8.5952	0.7472	3477.0	3925.3	8.5107	0.5601	3476.2	3924.2	8.3770
800	0.9896	3662.1	4156.9	8.8211	0.8215	3661.8	4156.5	8.7367	0.6181	3661.1	4155.6	8.6033
900	1.0822	3853.6	4394.7	9.0329	0.9017	3853.4	4394.4	8.9486	0.6761	3852.8	4393.7	8.8153
1000	1.1747	4051.8	4639.1	9.2328	0.9788	4051.5	4638.8	9.1485	0.7340	4051.0	4638.2	9.0153
1100	1.2672	4256.3	4889.9	9.4224	1.0559	4256.1	4889.6	9.3381	0.7919	4255.6	4889.1	9.2050
1200	1.3596	4466.8	5146.6	9.6029	1.1330	4466.5	5146.3	9.5185	0.8497	4466.1	5145.9	9.3855
1300	1.4521	4682.5	5408.6	9.7749	1.2101	4682.3	5408.3	9.6906	0.9076	4681.8	5407.9	9.5575

Figure 6.10: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 10

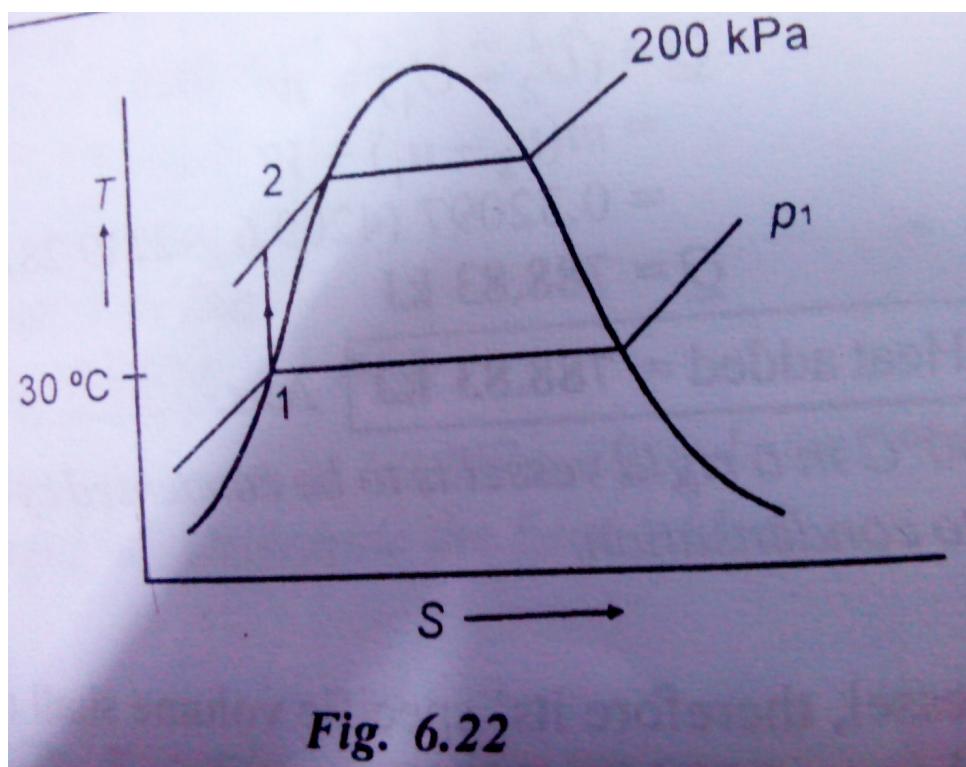


Figure 6.11: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 11

**Scilab code Exa 6.12** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 12

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 12")
8 V=2; //volume of vessel in m^3
9 disp("from steam table at 150 degree celcius")
10 disp("vf=0.001091 m^3/kg , vg=0.3928 m^3/kg")
11 Vf=0.001091;
12 Vg=0.3928;
13 disp("so volume occupied by water(Vw)=3*V/(3+2) in m
^3")
14 Vw=3*V/(3+2)
15 disp("and volume of steam(Vs)=2*V/(3+2) in m^3")
16 Vs=2*V/(3+2)
17 disp("mass of water(mf)=Vw/Vf in kg")
18 mf=Vw/Vf
19 disp("mass of steam(mg)=Vs/Vg in kg")
20 mg=Vs/Vg
21 disp("total mass in tank(m)=mf+mg in kg")
22 m=mf+mg
23 disp("quality or dryness fraction(x)")
24 disp("x=mg/m")
25 x=mg/m
```

## APPENDIX

**Table 1** Ideal-gas specific heats of various common gases at 300 K

<i>Gas</i>	<i>Formula</i>	<i>Gas constant R</i> <i>kJ/(kg.K)</i>	<i>c<sub>p</sub></i> <i>kJ/(kg.K)</i>	<i>c<sub>v</sub></i> <i>kJ/(kg.K)</i>	<i>γ</i>
Air	—	0.2870	1.005	0.718	1.400
Argon	Ar	0.2081	0.5203	0.3122	1.667
Butane	C <sub>4</sub> H <sub>10</sub>	0.1433	1.7164	1.5734	1.091
Carbon dioxide	CO <sub>2</sub>	0.1889	0.846	0.657	1.289
Carbon monoxide	CO	0.2968	1.040	0.744	1.400
Ethane	C <sub>2</sub> H <sub>6</sub>	0.2765	1.7662	1.4897	1.186
Ethylene	C <sub>2</sub> H <sub>4</sub>	0.2964	1.5482	1.2518	1.237
Helium	He	2.0769	5.1926	3.1156	1.667
Hydrogen	H <sub>2</sub>	4.1240	14.307	10.183	1.405
Methane	CH <sub>4</sub>	0.5182	2.2537	1.7354	1.299
Neon	Ne	0.4119	1.0299	0.6179	1.667
Nitrogen	N <sub>2</sub>	0.2968	1.039	0.743	1.400
Octane	C <sub>8</sub> H <sub>18</sub>	0.0729	1.7113	1.6385	1.044
Oxygen	O <sub>2</sub>	0.2598	0.918	0.658	1.395
Propane	C <sub>3</sub> H <sub>8</sub>	0.1885	1.6794	1.4909	1.126
Steam	H <sub>2</sub> O	0.4615	1.8723	1.4108	1.327

**Table 2** Saturated Steam (temperature) table

Temp °C T	Sat. press. kPa P <sub>sat</sub>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid	Sat. vapour	Sat. liquid	Evap.	Sat. vapour	Sat. liquid	Evap.	Sat. vapour	Sat. liquid	Evap.	Sat. vapour
		v <sub>f</sub>	v <sub>g</sub>	u <sub>f</sub>	u <sub>fg</sub>	u <sub>g</sub>	h <sub>f</sub>	h <sub>fg</sub>	h <sub>g</sub>	s <sub>f</sub>	s <sub>fg</sub>	s <sub>g</sub>
0.01	0.6113	0.001000	206.14	0.0	2375.3	2375.3	0.01	2501.4	2501.4	0.000	9.1562	9.1562
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	0.1510	8.7498	8.9008
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	0.2245	8.5569	8.7814
20	2.3339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	0.2966	8.3706	8.6672
25	3.169	0.001003	43.36	104.88	2409.8	2309.8	104.89	2442.3	2547.2	0.3674	8.1905	8.5580
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	0.4369	8.0164	8.4533
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	0.5053	7.8478	8.3531
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	0.5725	7.6845	8.2570
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	0.6387	7.5261	8.1648
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0763
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8310
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7553
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6824
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.6122
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.5445
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.4791
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.96	2270.2	2668.1	1.2500	6.1659	7.4159

Figure 6.12: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 11

Table 2 Saturated Steam (temperature) table

Temp. °C T	Sat. press. kPa $P_{sat}$	Specific volume m³/kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg.K)		
		Sat. liquid $v_f$	Sat. vapour $v_g$	Sat. liquid $u_f$	Sat. Evap. $u_{fg}$	Sat. vapour $u_g$	Sat. liquid $h_f$	Sat. Evap. $h_{fg}$	Sat. vapour $h_g$	Sat. liquid $s_f$	Sat. Evap. $s_{fg}$	Sat. vapour $s_g$
100	0.10135	0.001044	1.6729	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.0480	7.3549
105	0.12082	0.001048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958
110	0.14327	0.001052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387
115	0.16906	0.001056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833
120	0.19853	0.001060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296
125	0.2321	0.001065	0.7706	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775
130	0.2701	0.001070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269
135	0.3130	0.001075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777
140	0.3613	0.001080	0.5089	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299
145	0.4154	0.001085	0.4463	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833
150	0.4758	0.001091	0.3928	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379
155	0.5431	0.001096	0.3468	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935
160	0.6178	0.001102	0.3071	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502
165	0.7005	0.001108	0.2727	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.9925	4.7153	6.7078
170	0.7917	0.001114	0.2428	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663
175	0.8920	0.001121	0.2168	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256
180	1.0021	0.001127	0.19405	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1396	4.4461	6.5857
185	1.1227	0.001134	0.17409	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465
190	1.2544	0.001141	0.15654	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079
195	1.3978	0.001149	0.14105	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698
200	1.5538	0.001157	0.12736	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323
205	1.7230	0.001164	0.11521	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952
210	1.9062	0.001173	0.10441	895.53	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585
215	2.104	0.001181	0.09479	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221
220	2.318	0.001190	0.08619	940.87	1661.5	2602.4	943.62	1858.5	2802.1	2.5178	3.7683	6.2861
225	2.548	0.001199	0.07849	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503
230	2.795	0.001209	0.07158	986.74	1617.2	2603.9	990.12	1813.8	2804.0	2.6099	3.6047	6.2146
235	3.060	0.001219	0.06537	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1791
240	3.344	0.001229	0.05976	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437
245	3.648	0.001240	0.05471	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083
250	3.973	0.001251	0.05013	1080.39	1522.0	2602.4	1085.36	1716.2	2801.5	2.7927	3.2802	6.0730
255	4.319	0.001263	0.04598	1104.28	1506.7	2600.9	1109.73	1689.8	2799.5	2.8383	3.1992	6.0375
260	4.688	0.001276	0.04221	1128.39	1470.6	2599.0	1134.37	1662.5	2796.9	2.8838	3.1181	6.0019
265	5.081	0.001289	0.03877	1152.74	1443.9	2596.6	1159.28	1634.4	2793.6	2.9294	3.0368	5.9662
270	5.499	0.001302	0.03564	1177.36	1416.3	2593.7	1184.51	1605.2	2789.7	2.9751	2.9551	5.9301
275	5.942	0.001317	0.03279	1202.25	1387.9	2590.2	1210.07	1574.9	2785.0	3.0208	2.8730	5.8938
280	6.412	0.001332	0.03017	1227.46	1358.7	2586.1	1235.99	1543.6	2779.6	3.0668	2.7903	5.8571
285	6.909	0.001348	0.02777	1253.00	1328.4	2581.4	1262.31	1511.0	2773.3	3.1130	2.7070	5.8199
290	7.436	0.001366	0.02557	1278.92	1297.1	2576.0	1289.07	1477.1	2766.2	3.1594	2.6227	5.7821
295	7.993	0.001384	0.02354	1305.2	1264.7	2569.9	1316.3	1441.8	2758.1	3.2062	2.5375	5.7437
300	8.581	0.001404	0.02167	1332.0	1231.0	2563.0	1344.0	1404.9	2749.0	3.2534	2.4511	5.7045
305	9.202	0.001425	0.019948	1359.3	1195.9	2555.2	1372.4	1366.4	2738.7	3.3010	2.3633	5.6643
310	9.856	0.001447	0.018350	1387.1	1159.4	2546.4	1401.3	1326.0	2727.3	3.3493	2.2737	5.6230

Figure 6.13: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 12

```
26 disp("NOTE=>answer given in book for mass=1103.99 kg  
is incorrect and correct answer is 1101.945  
which is calculated above.")
```

---

**Scilab code Exa 6.13** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 13

```
1 // Display mode  
2 mode(0);  
3 // Display warning for floating point exception  
4 ieee(1);  
5 clear;  
6 clc;  
7 disp("Engineering Thermodynamics by Onkar Singh  
Chapter 6 Example 13")  
8 disp("from S.F.S.E on steam turbine;")  
9 disp("W=h1-h2")  
10 disp("initially at 4Mpa,300 degree celcius the steam  
is super heated so enthalpy from superheated  
steam or mollier diagram")  
11 disp("h1=2886.2 KJ/kg ,s1=6.2285 KJ/kg K")  
12 h1=2886.2;  
13 s1=6.2285;  
14 disp("reversible adiabatic expansion process has  
entropy remaining constant.on mollier diagram the  
state 2 can be simply located at intersection of  
constant temperature line for 50 degree celcius  
and isentropic expansion line.")  
15 disp("else from steam tables at 50 degree celcius  
saturation temperature;")  
16 disp("hf=209.33 KJ/kg ,sf=0.7038 KJ/kg K")  
17 hf=209.33;  
18 sf=0.7038;  
19 disp("hfg=2382.7 KJ/kg ,sfg =7.3725 KJ/kg K")  
20 hfg=2382.7;
```

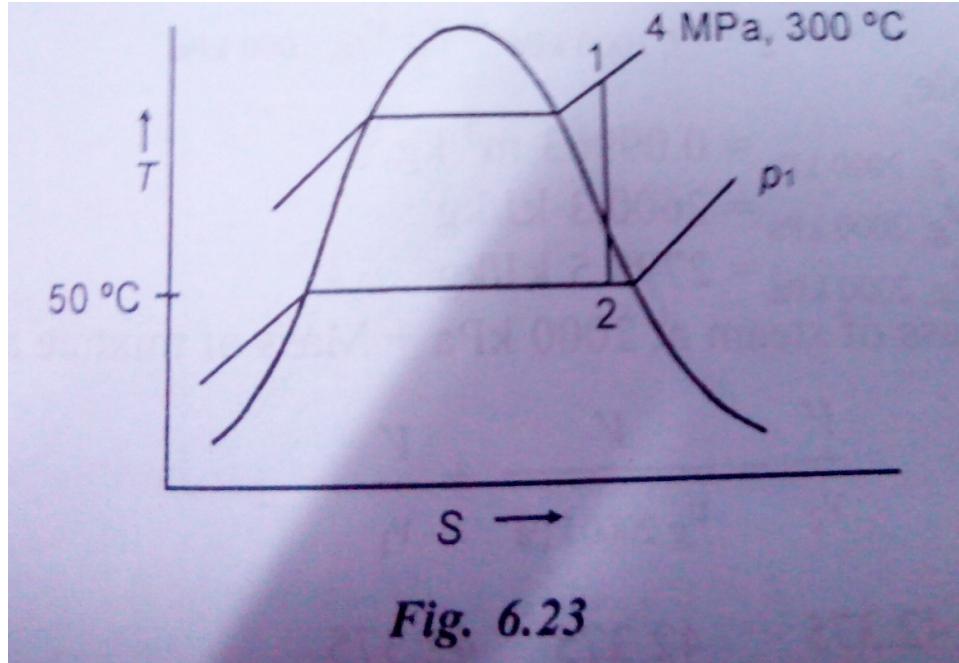


Figure 6.14: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 13

```

21 sfg=7.3725;
22 disp(" here s1=s2 , let dryness fraction at 2 be x2")
23 disp(" x2=(s1-sf)/sfg")
24 x2=(s1-sf)/sfg
25 disp(" hence enthalpy at state 2")
26 disp(" h2=hf+x2*hfg in KJ/kg")
27 h2=hf+x2*hfg
28 disp(" steam turbine work(W) in KJ/kg")
29 disp("W=h1-h2")
30 W=h1-h2
31 disp(" so turbine output=W")
32 W

```

---

**Scilab code Exa 6.14** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 14

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 14")
8 x1=0.5; //dryness fraction
9 m1=100; //mass of steam in kg
10 v1=0.8475; //
11 disp("it is constant volume process")
12 disp("volume of vessel(V)=mass of vapour * specific
volume of vapour")
13 disp("initial specific volume ,v1")
14 disp("v1=vf_100Kpa+x1*vg_100 in m^3/kg")
15 disp("at 100 Kpa from steam table ;")
16 disp("hf_100Kpa=417.46 KJ/kg , uf_100Kpa=417.36 KJ/kg ,
vf_100Kpa=0.001043 m^3/kg , hfg_100Kpa=2258 KJ/kg ,
ufg_100Kpa=2088.7 KJ/kg , vg_100Kpa=1.6940 m^3/kg")
17 hf_100Kpa=417.46;
18 uf_100Kpa=417.36;
19 vf_100Kpa=0.001043;
20 hfg_100Kpa=2258;
21 ufg_100Kpa=2088.7;
22 vg_100Kpa=1.6940;
23 disp(" here vfg_100Kpa=vg_100Kpa-vf_100Kpa in m^3/kg
")
24 vfg_100Kpa=vg_100Kpa-vf_100Kpa
```

```

25 disp(" so v1=vf_100Kpa+x1*vfg_100Kpa in m^3/kg")
26 v1=vf_100Kpa+x1*vfg_100Kpa
27 disp("and volume of vessel(V)=m1*x1*v1 in m^3")
28 V=m1*x1*v1
29 disp(" enthalpy at 1,h1=hf_100Kpa+x1*hfg_100Kpa in KJ
    /kg")
30 h1=hf_100Kpa+x1*hfg_100Kpa
31 disp(" internal energy in the beginning=U1=m1*u1 in
    KJ")
32 U1=m1*(uf_100Kpa+x1*ufg_100Kpa)
33 disp(" let the mass of dry steam added be m, final
    specific volume inside vessel ,v2")
34 disp(" v2=vf_1000Kpa+x2*vfg_1000Kpa")
35 disp(" at 2000 Kpa ,from steam table ,")
36 disp(" vg_2000Kpa=0.09963 m^3/kg , ug_2000Kpa=2600.3 KJ
    /kg , hg_2000Kpa=2799.5 KJ/kg")
37 vg_2000Kpa=0.09963;
38 ug_2000Kpa=2600.3;
39 hg_2000Kpa=2799.5;
40 disp(" total mass inside vessel=mass of steam at2000
    Kpa+mass of mixture at 100 Kpa")
41 disp("V/v2=V/vg_2000Kpa+V/v1")
42 disp(" so v2=1/((1/vg_2000Kpa)+(1/v1)) in m^3/kg")
43 v2=1/((1/vg_2000Kpa)+(1/v1))
44 disp(" here v2=vf_1000Kpa+x2*vfg_1000Kpa in m^3/kg")
45 disp(" at 1000 Kpa from steam table ,")
46 disp(" hf_1000Kpa=762.81 KJ/kg , hfg_1000Kpa=2015.3 KJ/
    kg , vf_1000Kpa=0.001127 m^3/kg , vg_1000Kpa=0.19444
    m^3/kg")
47 hf_1000Kpa=762.81;
48 hfg_1000Kpa=2015.3;
49 vf_1000Kpa=0.001127;
50 vg_1000Kpa=0.19444;
51 disp(" here vfg_1000Kpa=vg_1000Kpa-vf_1000Kpa in m^3/
    kg")
52 vfg_1000Kpa=vg_1000Kpa-vf_1000Kpa
53 disp(" so x2=(v2-vf_1000Kpa)/vfg_1000Kpa")
54 x2=(v2-vf_1000Kpa)/vfg_1000Kpa

```

```

55 disp(" for adiabatic mixing ,(100+m)*h2=100*h1+m*
      hg_2000Kpa")
56 disp(" so mass of dry steam at 2000 Kpa to be added(m
      ) in kg")
57 disp("m=(100*(h1-h2))/(h2-hg_2000Kpa)") )
58 m=(100*(h1-(hf_1000Kpa+x2*hfg_1000Kpa)))/(
      hf_1000Kpa+x2*hfg_1000Kpa)-hg_2000Kpa)
59 disp(" quality of final mixture=x2")
60 x2

```

---

**Scilab code Exa 6.15** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 15

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
          Chapter 6 Example 15")
8 p_vaccum=71.5; //recorded condenser vaccum in cm of
                  mercury
9 p_barometer=76.8; //barometer reading in cm of
                     mercury
10 T_cond=35; //temperature of condensation in degree
                 celcius
11 T_hotwell=27.6; //temperature of hot well in degree
                 celcius
12 m_cond=1930; //mass of condensate per hour
13 m_w=62000; //mass of cooling water per hour

```

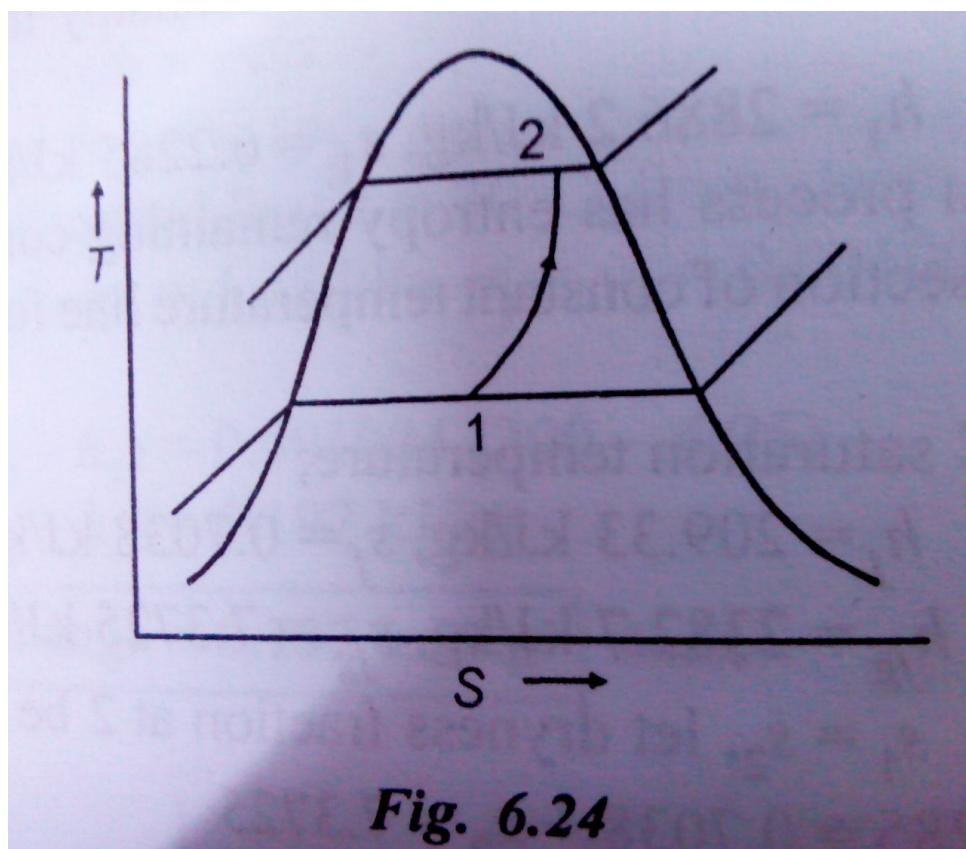


Figure 6.15: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 14

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

Contd.

Figure 6.16: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 14

```

14 Ti=8.51; // initial temperature in degree celcius
15 To=26.24; //outlet temperature in degree celcius
16 disp("from dalton law of partial pressure the total
      pressure inside condenser will be sum of partial
      pressures of vapour and liquid inside .")
17 disp("condenser pressure(p_condenser)=(p_barometer-
      p_vaccum)*101.325/73.55 in Kpa")
18 p_condenser=(p_barometer-p_vaccum)*101.325/73.55
19 disp(" partial pressure of steam corresponding to 35
      degree celcius from steam table ;")
20 disp(" p_steam=5.628 Kpa")
21 p_steam=5.628; //partial pressure of steam
22 disp(" enthalpy corresponding to 35 degree celcius
      from steam table ,")
23 disp(" hf=146.68 KJ/kg , hfg=2418.6 KJ/kg")
24 hf=146.68;
25 hfg=2418.6;
26 disp(" let quality of steam entering be x")
27 disp(" from energy balance ;")
28 disp("mw*(To-Ti)*4.18=m_cond*( hf+x*hfg -4.18*
      T_hotwell )")
29 disp(" so dryness fraction of steam entering (x) is
      given as ")
30 disp("x=(((m_w*(To-Ti)*4.18)/m_cond)-hf+4.18*
      T_hotwell)/hfg")
31 x=(((m_w*(To-Ti)*4.18)/m_cond)-hf+4.18*T_hotwell)/
      hfg

```

---

**Scilab code Exa 6.16** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 16

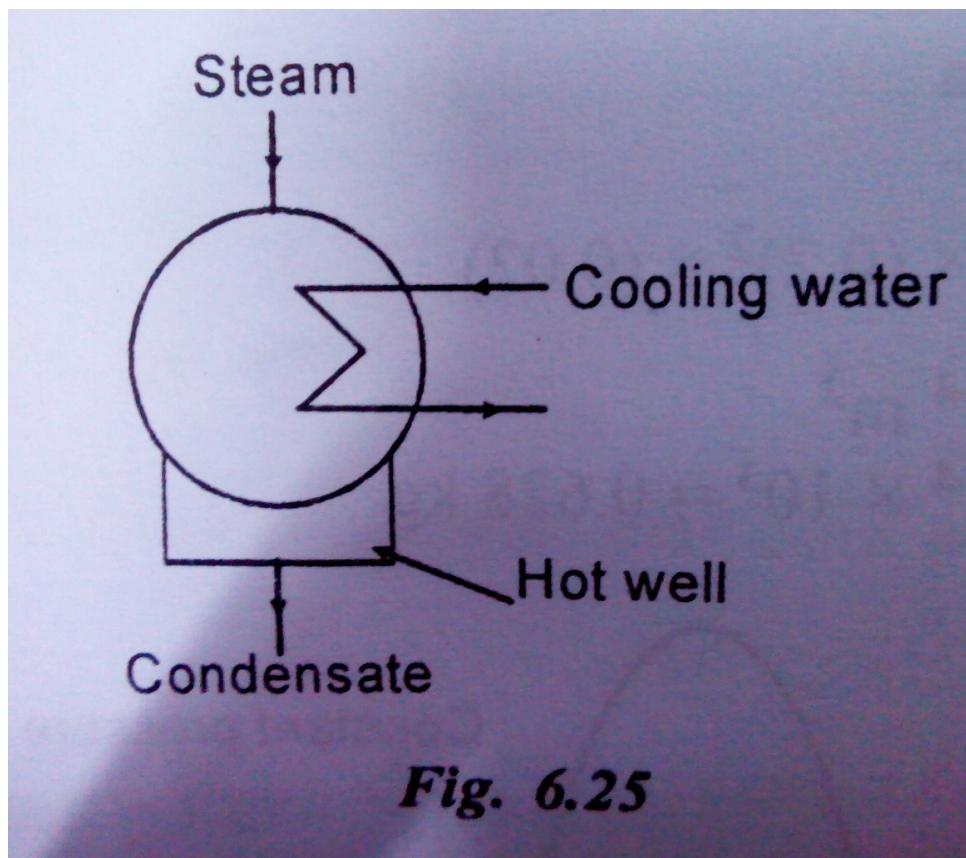


Figure 6.17: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 15

## APPENDIX

**Table 1** Ideal-gas specific heats of various common gases at 300 K

<i>Gas</i>	<i>Formula</i>	<i>Gas constant R</i> <i>kJ/(kg.K)</i>	<i>c<sub>p</sub></i> <i>kJ/(kg.K)</i>	<i>c<sub>v</sub></i> <i>kJ/(kg.K)</i>	<i>γ</i>
Air	—	0.2870	1.005	0.718	1.400
Argon	Ar	0.2081	0.5203	0.3122	1.667
Butane	C <sub>4</sub> H <sub>10</sub>	0.1433	1.7164	1.5734	1.091
Carbon dioxide	CO <sub>2</sub>	0.1889	0.846	0.657	1.289
Carbon monoxide	CO	0.2968	1.040	0.744	1.400
Ethane	C <sub>2</sub> H <sub>6</sub>	0.2765	1.7662	1.4897	1.186
Ethylene	C <sub>2</sub> H <sub>4</sub>	0.2964	1.5482	1.2518	1.237
Helium	He	2.0769	5.1926	3.1156	1.667
Hydrogen	H <sub>2</sub>	4.1240	14.307	10.183	1.405
Methane	CH <sub>4</sub>	0.5182	2.2537	1.7354	1.299
Neon	Ne	0.4119	1.0299	0.6179	1.667
Nitrogen	N <sub>2</sub>	0.2968	1.039	0.743	1.400
Octane	C <sub>8</sub> H <sub>18</sub>	0.0729	1.7113	1.6385	1.044
Oxygen	O <sub>2</sub>	0.2598	0.918	0.658	1.395
Propane	C <sub>3</sub> H <sub>8</sub>	0.1885	1.6794	1.4909	1.126
Steam	H <sub>2</sub> O	0.4615	1.8723	1.4108	1.327

**Table 2** Saturated Steam (temperature) table

Temp °C T	Sat. press. kPa P <sub>sat</sub>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid	Sat. vapour	Sat. liquid	Evap.	Sat. vapour	Sat. liquid	Evap.	Sat. vapour	Sat. liquid	Evap.	Sat. vapour
		v <sub>f</sub>	v <sub>g</sub>	u <sub>f</sub>	u <sub>fg</sub>	u <sub>g</sub>	h <sub>f</sub>	h <sub>fg</sub>	h <sub>g</sub>	s <sub>f</sub>	s <sub>fg</sub>	s <sub>g</sub>
0.01	0.6113	0.001000	206.14	0.0	2375.3	2375.3	0.01	2501.4	2501.4	0.000	9.1562	9.1562
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	0.1510	8.7498	8.9008
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	0.2245	8.5569	8.7814
20	2.3339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	0.2966	8.3706	8.6672
25	3.169	0.001003	43.36	104.88	2409.8	2309.8	104.89	2442.3	2547.2	0.3674	8.1905	8.5580
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	0.4369	8.0164	8.4533
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	0.5053	7.8478	8.3531
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	0.5725	7.6845	8.2570
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	0.6387	7.5261	8.1648
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0763
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8310
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7553
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6824
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.6122
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.5445
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.4791
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.96	2270.2	2668.1	1.2500	6.1659	7.4159

Figure 6.18: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 15

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 16")
8 F=10; //force applied externally upon piston in KN
9 d=.2; //diameter in m
10 h=0.02; //depth to which water filled in m
11 P_atm=101.3; //atmospheric pressure in Kpa
12 rho=1000; //density of water in kg/m^3
13 Q=600; //heat supplied to water in KJ
14 T=150; //temperature of water in degree celcius
15 disp("heating of water in vessel as described above
is a constant pressure heating. pressure at which
process occurs(p)=F/A+P_atm in Kpa")
16 disp("area(A)=%pi*d^2/4 in m^2")
17 A=%pi*d^2/4
18 disp("so p1=F/A+P_atm in Kpa")
19 p1=F/A+P_atm
20 disp("now at 419.61 Kpa, hf=612.1 KJ/kg , hfg=2128.7 KJ
/kg , vg=0.4435 m^3/kg")
21 hf=612.1;
22 hfg=2128.7;
23 vg=0.4435;
24 disp("volume of water contained(V1)=%pi*d^2*h/4 in m
^3")
25 V1=%pi*d^2*h/4
26 disp("mass of water(m)=V1*rho in kg")
27 m=V1*rho
28 disp("heat supplied shall cause sensible heating and
latent heating")
29 disp("hence , enthalpy change=heat supplied")
30 disp("Q=((hf+x*hfg)-(4.18*T)*m)")
31 disp("so dryness fraction of steam produced(x) can be
calculated as")

```

```

32 disp(" so x=((Q/m)+4.18*T-hf)/hfg")
33 x=((Q/m)+4.18*T-hf)/hfg
34 disp(" internal energy of water(U1) in KJ, initially")
35 h1=4.18*T; //enthalpy of water in KJ/kg
36 disp("U1=m*h1-p1*V1")
37 U1=m*h1-p1*V1
38 U1=393.5; //approx.
39 disp(" finally ,internal energy of wet steam(U2) in KJ"
)
40 disp("U2=m*h2-p2*V2")
41 disp(" here V2=m*x*vg in m^3")
42 V2=m*x*vg
43 disp(" hence U2=(m*h2)-p2*V2")
44 p2=p1; //constant pressure process
45 U2=(m*(hf+x*hfg))-p2*V2
46 U2=940.71; //approx.
47 disp(" hence change in internal energy(U)=U2-U1 in KJ"
)
48 U=U2-U1
49 disp(" work done(W)=p*(V2-V1) in KJ")
50 p=p1;
51 W=p*(V2-V1)

```

---

**Scilab code Exa 6.17** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 17

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;

```

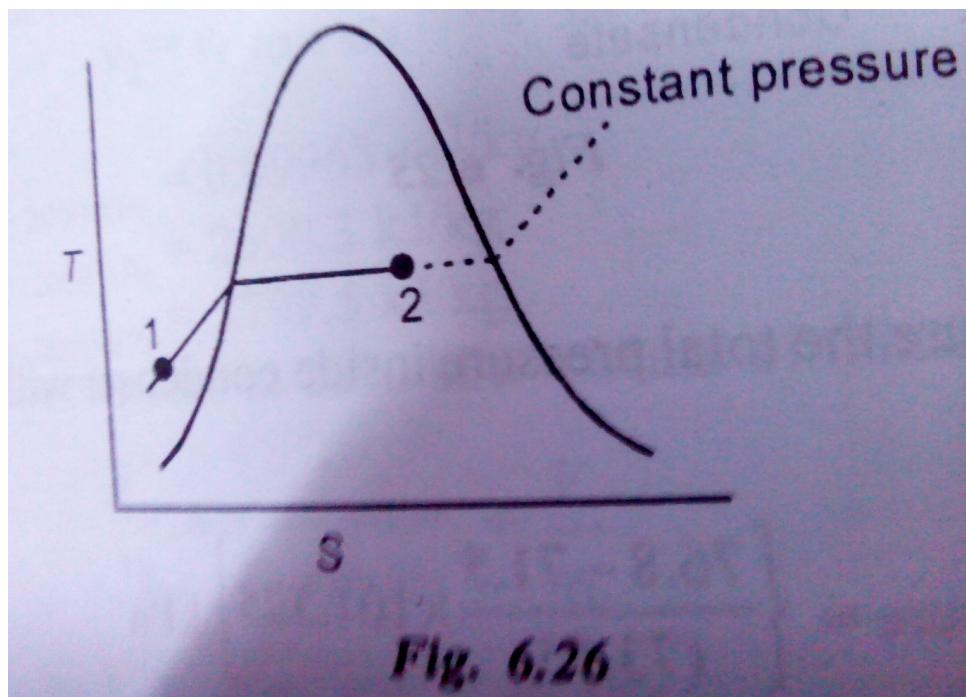


Figure 6.19: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 16

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

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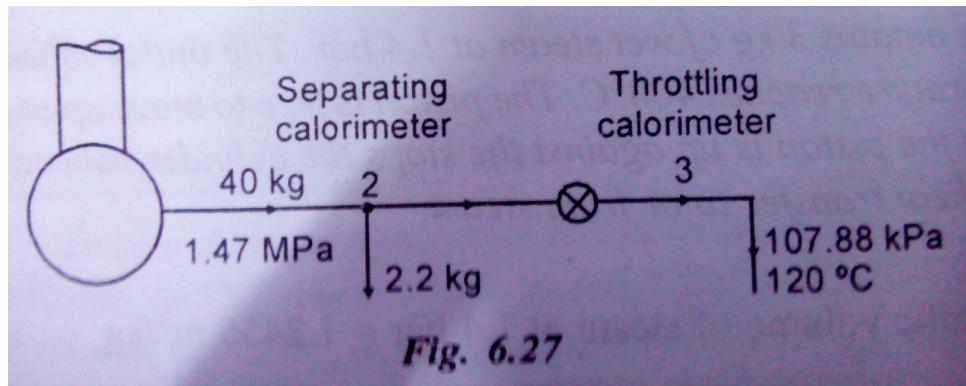
Figure 6.20: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 16

```

6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
      Chapter 6 Example 17")
8 ms=40; //mass of steam in kg
9 mw=2.2; //mass of water in kg
10 p1=1.47; //pressure before throttling in Mpa
11 T2=120; //temperature after throttling in degree
            celcius
12 p2=107.88; //pressure after throttling in Kpa
13 Cp_sup=2.09; //specific heat of superheated steam in
                 KJ/kg K
14 disp(" consider throttling calorimeter alone ,")
15 disp(" degree of superheat(T_sup)in degree celcius")
16 disp(" T_sup=T2-101.8")
17 T_sup=T2-101.8
18 disp(" enthalpy of superheated steam(h_sup)in KJ/kg")
19 disp(" h_sup=h+T_sup*Cp_sup")
20 disp(" at 120 degree celcius ,h=2673.95 KJ/kg from
      steam table")
21 h=2673.95;
22 h_sup=h+T_sup*Cp_sup
23 disp("now enthalpy before throttling = enthalpy
      after throttling")
24 disp(" hf+x2*hfg=h_sup")
25 disp(" here at 1.47 Mpa, hf=840.513 KJ/kg , hfg=1951.02
      KJ/kg from steam table")
26 hf=840.513;
27 hfg=1951.02;
28 disp(" so x2=(h_sup-hf)/hfg")
29 x2=(h_sup-hf)/hfg
30 disp(" for separating calorimeter alone , dryness
      fraction ,x1=(ms-mw)/ms")
31 x1=(ms-mw)/ms
32 disp(" overall dryness fraction (x)=(x1*x2)")
33 x=x1*x2

```

---



**Fig. 6.27**

Figure 6.21: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 17

**Scilab code Exa 6.18** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 18

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 6 Example 18")
8 v=0.4; //volume of air in part A and part B in m^3
9 p1=10*10^5; //initial pressure of steam in pa
10 p2=15*10^5; //final pressure of steam in pa

```

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

Contd.

Figure 6.22: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 18

```

11 disp("here heat addition to part B shall cause
      evaporation of water and subsequently the rise in
      pressure .")
12 disp("final , part B has dry steam at 15 bar .In order
      to have equilibrium the part A shall also have
      pressure of 15 bar .thus heat added")
13 disp("Q=v*(p2-p1)/1000 in KJ")
14 Q=v*(p2-p1)/1000
15 disp(" final enthalpy of dry steam at 15 bar ,h2=
      hg_15bar")
16 disp("h2=2792.2 KJ/kg from steam table")
17 h2=2792.2;
18 disp(" let initial dryness fraction be x1 ,initial
      enthalpy ,")
19 disp("h1=hf_10bar+x1*hfg_10bar ..... eq1")
20 disp(" here at 10 bar ,hf_10bar=762.83 KJ/kg ,hfg_10bar
      =2015.3 KJ/kg from steam table")
21 hf_10bar=762.83;
22 hfg_10bar=2015.3;
23 disp(" also heat balance yields ,")
24 disp("h1+Q=h2")
25 disp(" so h1=h2-Q in KJ/kg")
26 h1=h2-Q
27 disp(" so by eq 1=>x1=(h1-hf_10bar )/hfg_10bar")
28 x1=(h1-hf_10bar )/hfg_10bar
29 disp("heat added(Q) in KJ")
30 Q
31 disp("and initial quality (x1)")
32 x1

```

---

**Scilab code Exa 6.19** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 19

```

1 // Display mode
2 mode(0);

```

```

3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
    Chapter 6 Example 19")
8 m=3; //mass of wet steam in kg
9 p=1.4; //pressure of wet steam in bar
10 V1=2.25; //initial volume in m^3
11 V2=4.65; //final volume in m^3
12 T=400; //temperature of steam in degree celcius
13 disp("from steam table ,vg=1.2455 m^3/kg ,hf=457.99 KJ
    /kg ,hfg=2232.3 KJ/kg")
14 vg=1.2455;
15 hf=457.99;
16 hfg=2232.3;
17 disp(" specific volume of wet steam in cylinder ,v1=V1
    /m in m^3/kg")
18 v1=V1/m
19 disp(" dryness fraction of initial steam(x1)=v1/vg")
20 x1=v1/vg
21 x1=0.602; //approx .
22 disp(" initial enthalpy of wet steam ,h1=hf+x1*hfg in
    KJ/kg")
23 h1=hf+x1*hfg
24 disp("at 400 degree celcius specific volume of steam
    ,v2=V2/m in m^3/kg")
25 v2=V2/m
26 disp(" for specific volume of 1.55 m^3/kg at 400
    degree celcius the pressure can be seen from the
    steam table.From superheated steam tables the
    specific volume of 1.55 m^3/kg lies between the
    pressure of 0.10 Mpa (specific volume 3.103 m^3/
    kg at 400 degree celcius) and 0.20 Mpa( specific
    volume 1.5493 m^3/kg at 400 degree celcius)")
27 disp(" actual pressure can be obtained by
    interpolation")
28 p2=.1+((0.20-0.10)/(1.5493-3.103))*(1.55-3.103)

```

```

29 disp(" p2=0.20 MPa(approx.)")
30 p2=0.20;
31 disp("saturation temperature at 0.20 Mpa(t)=120.23
      degree celcius from steam table")
32 t=120.23;
33 disp("finally the degree of superheat(Tsup)in K")
34 disp("Tsup=T-t")
35 Tsup=T-t
36 disp("final enthalpy of steam at 0.20 Mpa and 400
      degree celcius ,h2=3276.6 KJ/kg from steam table")
37 h2=3276.6;
38 disp("heat added during process(deltaQ)in KJ")
39 disp("deltaQ=m*(h2-h1)")
40 deltaQ=m*(h2-h1)
41 disp("internal energy of initial wet steam ,u1=uf+x1*
      ufg in KJ/kg")
42 disp("here at 1.4 bar ,from steam table ,uf=457.84 KJ/
      kg ,ufg=2059.34 KJ/kg")
43 uf=457.84;
44 ufg=2059.34;
45 u1=uf+x1*ufg
46 disp("internal energy of final state ,u2=u at 0.2 Mpa
      ,400 degree celcius")
47 disp("u2=2966.7 KJ/kg")
48 u2=2966.7;
49 disp("change in internal energy(deltaU)in KJ")
50 disp("deltaU=m*(u2-u1)")
51 deltaU=m*(u2-u1)
52 disp("form first law of thermodynamics ,work done(
      deltaW)in KJ")
53 disp("deltaW=deltaQ-deltaU")
54 deltaW=deltaQ-deltaU
55 disp("so heat transfer(deltaQ)in KJ")
56 deltaQ
57 disp("and work transfer(deltaW)in KJ")
58 deltaW
59 disp("NOTE=>In book value of u1=1707.86 KJ/kg is
      calculated wrong taking x1=0.607, hence correct")

```

```
    value of u1 using x1=0.602 is 1697.5627 KJ/kg")
60 disp("and corresponding values of heat transfer=
        4424.2962 KJ and work transfer=616.88424 KJ.")
```

---

**Scilab code Exa 6.20** Engineering Thermodynamics by Onkar Singh Chapter 6 Example 20

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
          Chapter 6 Example 20")
8 disp("here throttling process is occurring therefore
          enthalpy before and after expansion remains same.
          Let initial and final states be given by 1 and 2.
          Initial enthalpy ,from steam table.")
9 disp("at 500 degree celcius ,h1_10bar_500oc=3478.5 KJ
          /kg ,s1_10bar_500oc=7.7622 KJ/kg K, v1_10bar_500oc
          =0.3541 m^3/kg")
10 h1_10bar_500oc=3478.5;
11 s1_10bar_500oc=7.7622;
12 v1_10bar_500oc=0.3541;
13 disp("finally pressure becomes 1 bar so finally
          enthalpy(h2) at this pressure(of 1 bar) is also
          3478.5 KJ/kg which lies between superheat
          temperature of 400 degree celcius and 500 degree
          celcius at 1 bar.Let temperature be T2,")
14 h2=h1_10bar_500oc;
```

Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. vapour <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
0.100	99.63	0.001043	1.6940	417.36	2088.7	2506.1	417.46	2258.0	2675.5	1.3026	6.0568	7.3594
0.125	105.99	0.001048	1.3749	444.19	2069.3	2513.5	444.32	2241.0	2685.4	1.3740	5.9104	7.2844
0.150	111.37	0.001053	1.1593	466.94	2052.7	2519.7	467.11	2226.5	2693.6	1.4336	5.7897	7.2233
0.175	116.06	0.001057	1.0036	486.80	2038.1	2524.9	486.99	2213.6	2700.6	1.4849	5.6868	7.1717
0.200	120.23	0.001061	0.8857	504.49	2025.0	2529.5	504.70	2201.9	2706.7	1.5301	5.5970	7.1271
0.225	124.00	0.001064	0.7933	520.47	2013.1	2533.6	520.72	2191.3	2712.1	1.5706	5.5173	7.0878
0.250	127.44	0.001067	0.7187	535.10	2002.1	2537.2	535.37	2181.5	2716.9	1.6072	5.4455	7.0527
0.275	130.60	0.001070	0.6573	548.59	1991.9	2540.5	548.89	2172.3	2721.3	1.6408	5.3801	7.0209
0.300	133.55	0.001073	0.6058	561.15	1982.4	2543.6	561.47	2163.8	2725.3	1.6718	5.3201	6.9919
0.325	136.30	0.001076	0.5620	572.90	1973.5	2546.4	573.25	2155.8	2729.0	1.7006	5.2646	6.9652
0.350	138.88	0.001079	0.5243	583.95	1965.0	2548.9	584.33	2148.1	2732.4	1.7275	5.2130	6.9405
0.375	141.32	0.001081	0.4914	594.40	1956.9	2551.3	594.81	2140.8	2735.6	1.7528	5.1647	6.9175
0.40	143.63	0.001084	0.4625	604.31	1949.3	2553.6	604.74	2133.8	2738.6	1.7766	5.1193	6.8959
0.45	147.93	0.001088	0.4140	622.77	1934.9	2557.6	623.25	2120.7	2743.9	1.8207	5.0359	6.8565
0.50	151.86	0.001093	0.3749	639.68	1921.6	2561.2	640.23	2108.5	2748.7	1.8607	4.9606	6.8213
0.55	155.48	0.001097	0.3427	655.32	1909.2	2564.5	665.93	2097.0	2753.0	1.8973	4.8920	6.7893
0.60	158.85	0.001101	0.3157	669.90	1897.5	2567.4	670.56	2086.3	2756.8	1.9312	4.8288	6.7600
0.65	162.01	0.001104	0.2927	683.56	1886.5	2570.1	684.28	2076.0	2760.3	1.9627	4.7703	6.7331
0.70	164.97	0.001008	0.2729	696.44	1876.1	2572.5	697.22	2066.3	2763.5	1.9922	4.7158	6.7080
0.75	167.78	0.001112	0.2556	708.64	1866.1	2574.7	709.47	2057.0	2766.4	2.0200	4.6647	6.6847
0.80	170.43	0.001115	0.2404	720.22	1856.6	2576.8	721.11	2048.0	2769.1	2.0462	4.6166	6.6628
0.85	172.96	0.001118	0.2270	731.27	1847.4	2578.7	732.22	2039.4	2771.6	2.0710	4.5711	6.6421
0.90	175.38	0.001121	0.2150	741.83	1838.6	2580.5	742.83	2031.0	2773.9	2.0946	4.5280	6.6226
0.95	177.69	0.001124	0.2042	751.95	1830.2	2582.1	753.02	2023.1	2776.1	2.1172	4.4869	6.6041
1.00	179.91	0.001127	0.19444	761.68	1822.0	2583.6	762.81	2015.3	2778.1	2.1387	4.4478	6.5865
1.10	184.09	0.001133	0.17753	780.09	1806.3	2586.4	781.34	2000.4	2781.7	2.1792	4.3744	6.5536
1.20	187.99	0.001139	0.16333	797.29	1791.5	2588.8	798.65	1986.2	2784.8	2.2166	4.3067	6.5233
1.30	191.64	0.001144	0.15125	813.44	1777.5	2591.0	814.93	1972.7	2787.6	2.2515	4.2438	6.4953
1.40	195.07	0.001149	0.14084	828.70	1764.1	2592.8	830.30	1959.7	2790.0	2.2842	4.1850	6.4693
1.50	198.32	0.001154	0.13177	843.16	1751.3	2594.5	844.89	1947.3	2792.2	2.3150	4.1298	6.4448
1.75	205.76	0.001166	0.11349	876.46	1721.4	2597.8	878.50	1917.9	2796.4	2.3851	4.0044	6.3896
2.00	212.42	0.001177	0.09963	906.44	1693.8	2600.3	908.79	1890.7	2799.5	2.4474	3.8935	6.3409
2.25	218.45	0.001187	0.08875	933.83	1668.2	2602.0	936.49	1865.2	2801.7	2.5035	3.7937	6.2972
2.5	223.99	0.001197	0.07998	959.11	1644.0	2603.1	962.11	1841.0	2803.1	2.5547	3.7028	6.2575
3.0	233.90	0.001217	0.06668	1004.78	1599.3	2604.1	1008.42	1795.7	2804.2	2.6457	3.5412	6.1869
3.5	242.60	0.001235	0.05707	1045.43	1558.3	2603.7	1049.75	1753.7	2803.4	2.7253	3.4000	6.1253
4	250.40	0.001252	0.04978	1082.31	1520.0	2602.3	1087.31	1741.1	2801.4	2.7964	3.2737	6.0701
5	263.99	0.001286	0.03944	1147.81	1449.3	2597.1	1154.23	1640.1	2794.3	2.9202	3.0532	5.9734
6	275.64	0.001319	0.03244	1205.44	1384.3	2589.7	1213.35	1571.0	2784.3	3.0267	2.8625	5.8892
7	285.88	0.001351	0.02737	1257.55	1323.0	2580.5	1267.00	1505.1	2772.1	3.1211	2.6922	5.8133
8	295.06	0.001384	0.02352	1305.57	1264.2	2569.8	1316.64	1441.3	2758.0	3.2068	2.5364	5.7432
9	303.40	0.001418	0.02048	1350.51	1207.3	2557.8	1363.26	1378.9	2742.1	3.2858	2.3915	5.6722
10	311.06	0.001452	0.018026	1393.04	1151.4	2544.4	1407.56	1317.1	2724.7	3.3596	2.2544	5.6141

Contd.

Figure 6.23: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 19

Table 4 Superheated steam table

T °C	P = 0.20 MPa (120.23 °C)				P = 0.30 MPa (133.55 °C)				P = 0.40 MPa (143.63 °C)			
	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)
Sat.	0.8857	2529.5	2706.7	7.1272	0.6058	2543.6	2725.3	6.9919	0.4625	2553.6	2738.6	6.8959
150	0.9596	2576.9	2768.8	7.2795	0.6339	2570.8	2761.0	7.0778	0.4708	2564.5	2752.8	6.9299
200	1.0803	2654.4	2870.5	7.5066	0.7163	2650.7	2865.6	7.3115	0.5342	2646.8	2860.5	7.1706
250	1.1988	2731.2	2971.0	7.7086	0.7964	2728.7	2967.6	7.5166	0.5951	2726.1	2964.2	7.3789
300	1.3162	2808.6	3071.8	7.8926	0.8753	2806.7	3069.3	7.7022	0.6548	2804.8	3066.8	7.5662
400	1.5493	2966.7	3276.6	8.2218	1.0315	2965.6	3275.0	8.0330	0.7726	2964.4	3273.4	7.8983
500	1.7814	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	0.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0194	1.4957	3478.4	3927.1	8.8319	1.1215	3477.9	3926.5	8.6987
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2312	3662.4	4157.3	8.9244
900	2.705	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2692	1.3529	3853.9	4395.1	9.1362
1000	2.937	4052.5	4640.0	9.5663	1.9581	4052.3	4639.7	9.4690	1.4685	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.5840	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.5	10.0262	2.2661	4467.2	5147.1	9.8389	1.6996	4467.0	5146.8	9.7060
1300	3.630	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780

Table 4 Superheated steam table

T °C	P = 0.50 MPa (151.86 °C)				P = 0.60 MPa (158.85 °C)				P = 0.80 MPa (170.43 °C)			
	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)
Sat.	0.3749	2561.2	2748.7	6.8213	0.3157	2567.4	2756.8	6.7600	0.2404	2576.8	2769.1	6.6628
200	0.4249	2642.9	2855.4	7.0592	0.3520	2638.9	2850.1	6.9665	0.2608	2630.6	2839.3	6.8158
250	0.4744	2723.5	2960.7	7.2709	0.3938	2720.9	2957.2	7.1816	0.2931	2715.5	2950.0	7.0384
300	0.5226	2802.9	3064.2	7.4599	0.4344	2801.0	3061.6	7.3724	0.3241	2797.2	3056.5	7.2328
350	0.5701	2882.6	3167.7	7.6329	0.4742	2881.2	3165.7	7.5464	0.3544	2878.2	3161.7	7.4089
400	0.6173	2963.2	3271.9	7.7938	0.5137	2962.1	3270.3	7.7079	0.3843	2959.7	3267.1	7.5716
500	0.7109	3128.4	3483.9	8.0873	0.5920	3127.6	3482.8	8.0021	0.4433	3126.0	3480.6	7.8673
600	0.8041	3299.6	3701.7	7.3522	0.6697	3299.1	3700.9	8.2674	0.5018	3297.9	3699.4	8.1333
700	0.8969	3477.5	3925.9	8.5952	0.7472	3477.0	3925.3	8.5107	0.5601	3476.2	3924.2	8.3770
800	0.9896	3662.1	4156.9	8.8211	0.8215	3661.8	4156.5	8.7367	0.6181	3661.1	4155.6	8.6033
900	1.0822	3853.6	4394.7	9.0329	0.9017	3853.4	4394.4	8.9486	0.6761	3852.8	4393.7	8.8153
1000	1.1747	4051.8	4639.1	9.2328	0.9788	4051.5	4638.8	9.1485	0.7340	4051.0	4638.2	9.0153
1100	1.2672	4256.3	4889.9	9.4224	1.0559	4256.1	4889.6	9.3381	0.7919	4255.6	4889.1	9.2050
1200	1.3596	4466.8	5146.6	9.6029	1.1330	4466.5	5146.3	9.5185	0.8497	4466.1	5145.9	9.3855
1300	1.4521	4682.5	5408.6	9.7749	1.2101	4682.3	5408.3	9.6906	0.9076	4681.8	5407.9	9.5575

Figure 6.24: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 19

```

15 disp(" h_1bar_400oc=3278.2 KJ/kg , h_1bar_500oc=3488.1
      KJ/kg from steam table")
16 h_1bar_400oc=3278.2;
17 h_1bar_500oc=3488.1;
18 disp("h2=h_1bar_400oc+(h_1bar_500oc-h_1bar_400oc)*(%
      T2-400)/(500-400)")
19 disp("so final temperature(T2) in K")
20 disp("T2=400+((h2-h_1bar_400oc)*(500-400)/(%
      h_1bar_500oc-h_1bar_400oc))")
21 T2=400+((h2-h_1bar_400oc)*(500-400)/(h_1bar_500oc-
      h_1bar_400oc))
22 disp("entropy for final state(s2) in KJ/kg K")
23 disp("s2=(s_1bar_400oc+((s_1bar_500oc-s_1bar_400oc)*(%
      495.43-400)/(500-400)))")
24 disp("here from steam table ,s_1bar_400oc=8.5435 KJ/
      kg K,s_1bar_500oc=8.8342 KJ/kg K")
25 s_1bar_400oc=8.5435;
26 s_1bar_500oc=8.8342;
27 s2=s_1bar_400oc+((s_1bar_500oc-s_1bar_400oc)*(%
      495.43-400)/(500-400))
28 disp("so change in entropy(deltaS) in KJ/kg K")
29 disp("deltaS=s2-s1_10bar_500oc")
30 deltaS=s2-s1_10bar_500oc
31 disp("final specific volume ,v2=v_1bar_400oc+((%
      v_1bar_500oc-v_1bar_400oc)*(95.43)/(500-400)) in
      m^3/kg")
32 disp("here from steam table ,v_1bar_500oc=3.565 m^3/
      kg ,v_1bar_400oc=3.103 m^3/kg")
33 v_1bar_500oc=3.565;
34 v_1bar_400oc=3.103;
35 v2=v_1bar_400oc+((v_1bar_500oc-v_1bar_400oc)*(95.43)
      /(500-400))
36 disp("percentage of vessel volume initially occupied
      by steam=v1_1bar_500oc*100/v2")
37 v1_10bar_500oc*100/v2

```

---



Table 3 Saturated steam (pressure) table

Press. MPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg, K)		
		Sat. liquid <i>v<sub>f</sub></i>		Sat. vapour <i>v<sub>g</sub></i>		Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>
11	318.15	0.001489	0.015987	1433.7	1096.0	2529.8	1450.1	1255.5	2705.6	3.4295	2.1233	5.5527
12	324.75	0.001527	0.014263	1473.0	1040.7	2513.7	1491.3	1193.3	2684.9	3.4962	1.9962	5.4924
13	330.93	0.001567	0.012780	1511.1	985.0	2496.1	1531.5	1130.7	2662.2	3.5606	1.8718	5.4323
14	336.75	0.001611	0.011485	1548.6	928.2	2476.8	1571.1	1066.5	2637.6	3.6232	1.7485	5.3717
15	342.24	0.001658	0.010337	1585.6	869.8	2455.5	1610.5	1000.0	2610.5	3.6848	1.6249	5.3098
16	347.44	0.001711	0.009306	1622.7	809.0	2431.7	1650.1	930.6	2580.6	3.7461	1.4994	5.2455
17	352.37	0.001770	0.008364	1660.2	744.8	2405.0	1690.3	856.9	2547.2	3.8079	1.3698	5.1777
18	357.06	0.001840	0.007489	1698.9	675.4	2374.3	1732.0	777.1	2509.1	3.8715	1.2329	5.1044
19	361.54	0.001924	0.006657	1739.9	598.1	2338.1	1776.5	688.0	2464.5	3.9388	1.0839	5.0228
20	365.81	0.002036	0.005834	1785.6	507.5	2293.0	1826.3	583.4	2409.7	4.0139	0.9130	4.9269
21	369.89	0.002207	0.004952	1842.1	388.5	2230.6	1888.4	446.2	2334.6	4.1075	0.6938	4.8013
22	373.80	0.002742	0.003568	1961.9	125.2	2087.1	2022.2	143.4	2165.6	4.3110	0.2216	4.5327
22.09	374.12	0.003155	0.003155	2029.6	0	2029.6	2099.3	0	2099.3	4.4298	0	4.4298

Table 4 Superheated steam table

T °C	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m <sup>3</sup> /kg	u kJ/kg	h kJ/kg	s kJ/(kg K)
	P = 0.01 MPa (45.81 °C)				P = 0.05 MPa (81.33 °C)				P = 0.10 MPa (99.63 °C)			
	Sat.	14.674	2437.9	2584.7	8.1502	3.240	2483.9	2645.9	7.5939	1.6940	2506.1	2675.5
50	14.869	2483.9	2592.6	8.1749	3.418	2511.6	2682.5	7.6947	1.6958	2506.7	2676.2	7.3614
100	17.196	2515.5	2687.5	8.4479	3.889	2585.6	2780.1	7.9401	1.9364	2582.8	2776.4	7.6134
150	19.512	2587.9	2783.0	8.6882	4.356	2659.9	2877.7	8.1580	2.172	2658.1	2875.3	7.8343
200	21.825	2661.3	2879.5	8.9038	4.820	2735.0	2976.0	8.3556	2.406	2733.7	2974.3	8.0333
250	24.136	2736.0	2977.3	9.1002	5.284	2811.3	3075.5	8.5373	2.639	2810.4	3074.3	8.2158
300	26.445	2812.1	3075.5	9.2813	6.209	2968.5	3278.9	8.8642	3.103	2967.9	3278.2	8.5435
400	31.063	2968.9	3279.6	9.6077	7.134	3132.0	3488.7	9.1546	3.565	3131.6	3488.1	8.8342
500	35.679	3132.3	3489.1	9.8978	8.057	3302.2	3705.1	9.4178	4.028	3301.9	3704.4	9.0976
600	40.295	3302.5	3705.4	10.1608	8.981	3479.4	3928.5	9.6599	4.490	3479.2	3928.2	9.3398
700	44.911	3479.6	3928.7	10.4028	9.904	3663.6	4158.0	9.8852	4.952	3663.5	4158.6	9.5652
800	49.526	3663.8	4159.0	10.6281	10.828	3854.9	4396.3	10.0967	5.414	3854.8	4396.1	9.7767
900	54.141	3855.0	4396.4	10.8396	11.751	4052.9	4640.5	10.2964	5.875	4052.8	4640.3	9.9764
1000	58.757	4053.0	4640.6	11.0393	12.674	4257.4	4891.1	10.4859	6.337	4257.3	4891.0	10.1659
1100	63.372	4257.5	4891.2	11.2287	13.597	4467.8	5147.7	10.6662	6.799	4467.7	5147.6	10.3463
1200	67.987	4467.9	5147.8	11.4091	14.521	4683.6	5409.6	10.8382	7.260	4683.5	5409.5	10.5183
1300	72.602	4683.7	5409.7	11.5811								

Figure 6.25: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 20

Table 4 Superheated steam table

<i>T</i> °C	<i>v</i> m³/kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>P = 1.00 MPa (179.91 °C)</i>				<i>P = 1.20 MPa (187.99 °C)</i>				<i>P = 1.40 MPa (195.70 °C)</i>			
					<i>m³/kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>m³/kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>m³/kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)
<i>P = 1.00 MPa (179.91 °C)</i>																
Sat.	0.19444	2583.6	2778.1	6.5865	0.16333	2588.8	2784.8	6.5233	0.14084	2592.8	2790.0	6.4693				
200	0.2060	2621.9	2827.9	6.6940	0.16930	2612.8	2815.9	6.5898	0.14302	2603.1	2803.3	6.4975				
250	0.2327	2709.9	2942.6	6.9247	0.19234	2704.2	2935.0	6.8294	0.16350	2698.3	2927.2	6.7467				
300	0.2579	2793.2	3051.2	7.1229	0.2138	2789.2	3045.8	7.0317	0.18228	2785.2	3040.4	6.9534				
350	0.2825	2875.2	3157.7	7.3011	0.2345	2872.2	3153.6	7.2121	0.2003	2869.2	3149.5	7.1360				
400	0.3066	2957.3	3263.9	7.4651	0.2548	2954.9	3260.7	7.3774	0.2178	2952.5	3257.5	7.3026				
500	0.3541	3124.4	3478.5	7.7622	0.2946	3122.8	3476.3	7.6759	0.2521	3121.1	3474.1	7.6027				
600	0.4011	3296.8	3697.9	8.0290	0.3339	3295.6	3696.3	7.9435	0.2860	3294.4	3694.8	7.8710				
700	0.4478	3475.3	3923.1	8.2731	0.3729	3474.4	3922.0	8.1881	0.3195	3473.6	3920.8	8.1160				
800	0.4943	3660.4	4154.7	8.4996	0.4118	3659.7	4153.8	8.4148	0.3528	3659.0	4153.0	8.3431				
900	0.5407	3852.2	4392.9	8.7118	0.4505	3851.6	4392.2	8.6272	0.3861	3851.1	4391.5	8.5556				
1000	0.5871	4050.5	4637.6	8.9119	0.4892	4050.0	4637.0	8.8274	0.4192	4049.5	4636.4	8.7559				
1100	0.6335	4255.1	4888.6	9.1017	0.5278	4254.6	4888.0	9.0172	0.4524	4254.1	4887.5	8.9457				
1200	0.6798	4465.6	5145.4	9.2822	0.5665	4465.1	5144.9	9.1977	0.4855	4464.7	5144.4	9.1262				
1300	0.7261	4681.3	5407.4	9.4543	0.6051	4680.9	5407.0	9.3698	0.5186	4680.4	5406.5	9.2984				

Table 4 Superheated steam table

<i>T</i> °C	<i>v</i> m³/kg	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>P = 1.60 MPa (201.41 °C)</i>				<i>P = 1.80 MPa (207.15 °C)</i>				<i>P = 2.00 MPa (212.42 °C)</i>			
					<i>m³/kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>m³/kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)	<i>m³/kg</i>	<i>u</i> kJ/kg	<i>h</i> kJ/kg	<i>s</i> kJ/(kg K)
<i>P = 1.60 MPa (201.41 °C)</i>																
Sat.	0.12380	2596.0	2794.0	6.4218	0.11042	2598.4	2797.1	6.3794	0.09963	2600.3	2799.5	6.3409				
225	0.13287	2644.7	2857.3	6.5518	0.11673	2636.6	2846.7	6.4808	0.10377	2628.3	2835.8	6.4147				
250	0.14184	2692.3	2919.2	6.6732	0.12497	2686.0	2911.0	6.6066	0.11144	2679.6	2902.5	6.5453				
300	0.15862	2781.1	3034.8	6.8844	0.14021	2776.9	3029.2	6.8226	0.12547	2772.6	3023.5	6.7664				
350	0.17456	2866.1	3145.4	7.0694	0.15457	2863.0	3141.2	7.0100	0.13857	2859.8	3137.0	6.9563				
400	0.19005	2950.1	3254.2	7.2374	0.16847	2947.7	3250.9	7.1794	0.15120	2945.2	3247.6	7.1271				
500	0.2203	3119.5	3472.0	7.5390	0.19550	3117.9	3469.8	7.4825	0.17568	3116.2	3467.6	7.4317				
600	0.2500	3293.3	3693.2	7.8080	0.2220	3292.1	3691.7	7.7523	0.19960	3290.9	3690.1	7.7024				
700	0.2794	3472.7	3919.7	8.0535	0.2482	3471.8	3971.8	7.9983	0.2232	3470.9	3917.4	7.9487				
800	0.3086	3658.3	4152.1	8.2808	0.2742	3657.6	4151.2	8.2258	0.2467	3657.0	4150.3	8.1765				
900	0.3377	3850.5	4390.8	8.4935	0.3001	3849.9	4390.1	8.4386	0.2700	3849.3	4389.4	8.3895				
1000	0.3668	4049.0	4635.8	8.6938	0.3260	4048.5	4635.2	8.6391	0.2933	4048.0	4634.6	8.5901				
1100	0.3958	4253.7	4887.0	8.8837	0.3518	4253.2	4886.4	8.8290	0.3166	4252.7	4885.9	8.7800				
1200	0.4248	4464.2	5143.9	9.0643	0.3776	4463.7	5143.4	9.0096	0.3398	4463.3	5142.9	8.9607				
1300	0.4538	4679.9	5406.0	9.2364	0.4034	4679.5	5405.6	9.1818	0.3631	4679.0	5405.1	9.1129				

Figure 6.26: Engineering Thermodynamics by Onkar Singh Chapter 6 Example 20

# Chapter 7

## Availability And General Thermodynamic Relations

**Scilab code Exa 7.1** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 1")
8 C2=150; //leave velocity of steam in m/s
9 m=2.5; //steam mass flow rate in kg/s
10 disp("let us neglect the potential energy change
during the flow.")
11 disp("applying S.F.E.E, neglecting inlet velocity and
change in potential energy ,")
12 disp("W_max=(h1-To*s1)-(h2+C2^2/2-To*s2)")
13 disp("W_max=(h1-h2)-To*(s1-s2)-C2^2/2")
14 disp("from steam tables ,")
15 disp("h1=h_1 .6 Mpa_300=3034.8 KJ/kg , s1=s_1 .6 Mpa_300")
```

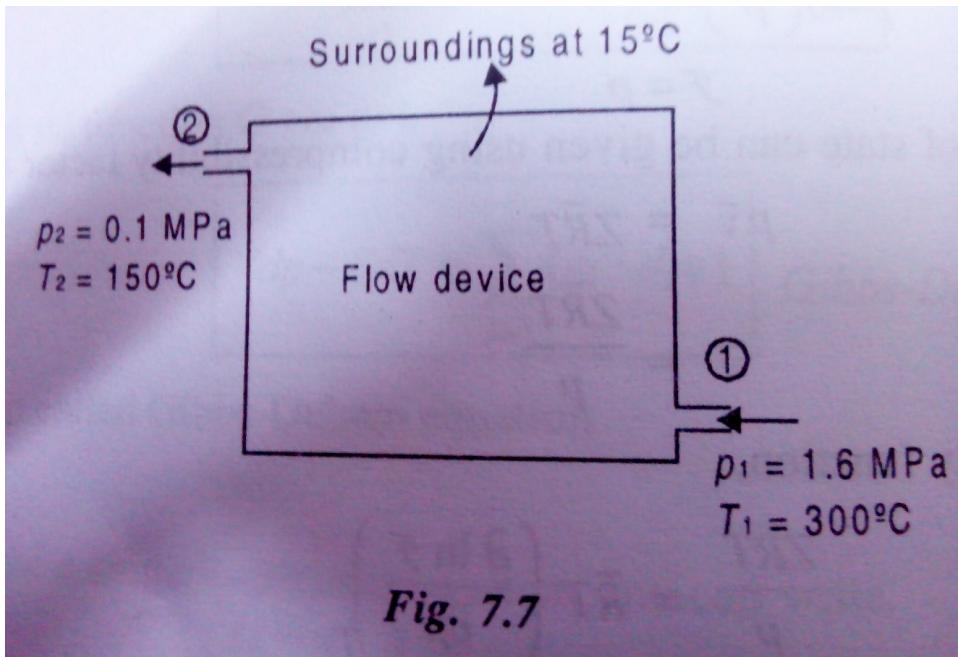


Figure 7.1: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 1

```

=6.8844 KJ/kg , h2=h_0 .1 Mpa_150=2776.4 KJ/kg , s2=
s_150Mpa_150=7.6134 KJ/kg" )

16 h1=3034.8;
17 s1=6.8844;
18 h2=2776.4;
19 s2=7.6134;
20 disp(" given To=288 K")
21 To=288;
22 disp(" so W_max in KJ/kg")
23 W_max=(h1-h2)-To*(s1-s2)-(C2^2/2*10^-3)
24 disp(" maximum possible work(W_max)=m*W_max in KW")
25 W_max=m*W_max

```

---

**Table 4** Superheated steam table

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg K)
	P = 1.60 MPa (201.41 °C)				P = 1.80 MPa (207.15 °C)				P = 2.00 MPa (212.42 °C)			
Sat	0.12380	2596.0	2794.0	6.4218	0.11042	2598.4	2797.1	6.3794	0.09963	2600.3	2799.5	6.3409
225	0.13287	2644.7	2857.3	6.5518	0.11673	2636.6	2846.7	6.4808	0.10377	2628.3	2835.8	6.4147
250	0.14184	2692.3	2919.2	6.6732	0.12497	2686.0	2911.0	6.6066	0.11144	2679.6	2902.5	6.5453
300	0.15862	2781.1	3034.8	6.8844	0.14021	2776.9	3029.2	6.8226	0.12547	2772.6	3023.5	6.7664
350	0.17456	2866.1	3145.4	7.0694	0.15457	2863.0	3141.2	7.0100	0.13857	2859.8	3137.0	6.9563
400	0.19005	2950.1	3254.2	7.2374	0.16847	2947.7	3250.9	7.1794	0.15120	2945.2	3247.6	7.1271
500	0.2203	3119.5	3472.0	7.5390	0.19550	3117.9	3469.8	7.4825	0.17568	3116.2	3467.6	7.4317
600	0.2500	3293.3	3693.2	7.8080	0.2220	3292.1	3691.7	7.7523	0.19960	3290.9	3690.1	7.7024
700	0.2794	3472.7	3919.7	8.0535	0.2482	3471.8	3971.8	7.9983	0.2232	3470.9	3917.4	7.9487
800	0.3086	3658.3	4152.1	8.2808	0.2742	3657.6	4151.2	8.2258	0.2467	3657.0	4150.3	8.1765
900	0.3377	3850.5	4390.8	8.4935	0.3001	3849.9	4390.1	8.4386	0.2700	3849.3	4389.4	8.3895
1000	0.3668	4049.0	4635.8	8.6938	0.3260	4048.5	4635.2	8.6391	0.2933	4048.0	4634.6	8.5901
1100	0.3958	4253.7	4887.0	8.8837	0.3518	4253.2	4886.4	8.8290	0.3166	4252.7	4885.9	8.7800
1200	0.4248	4464.2	5143.9	9.0643	0.3776	4463.7	5143.4	9.0096	0.3398	4463.3	5142.9	8.9607
1300	0.4538	4679.9	5406.0	9.2364	0.4034	4679.5	5405.6	9.1818	0.3631	4679.0	5405.1	9.1329

Figure 7.2: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 1

### Scilab code Exa 7.2 Engineering Thermodynamics by Onkar Singh Chapter 7 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 2")
8 m=1; //mass of air in kg
9 Po=1*10^5; //atmospheric pressure in pa
10 To=(15+273); //temperature of atmosphere in K

```

```

11 Cv=0.717; // specific heat at constant volume in KJ/kg
   K
12 R=0.287; //gas constant in KJ/kg K
13 Cp=1.004; // specific heat at constant pressure in KJ/
   kg K
14 T=(50+273); //temperature of tanks A and B in K
15 disp("In these tanks the air stored is at same
      temperature of 50 degree celcius. Therefore ,for
      air behaving as perfect gas the internal energy
      of air in tanks shall be same as it depends upon
      temperature alone.But the availability shall be
      different .")
16 disp("BOTH THE TANKS HAVE SAME INTERNAL ENERGY")
17 disp(" availability of air in tank ,A")
18 disp("A=(E-Uo)+Po*(V-Vo)-To*(S-So)")
19 disp("=m*{(e-uo)+Po(v-vo)-To(s-so)}")
20 disp("m*{Cv*(T-To)+Po*(R*T/P-R*To/Po)-To(Cp*log(T/To
      )-R*log(P/Po))}")
21 disp(" so A=m*{Cv*(T-To)+R*(Po*T/P-To)-To*Cp*log(T/To
      )+To*R*log(P/Po)}")
22 disp(" for tank A,P=1*10^5 pa ,so availability_A in KJ
      ")
23 P=1*10^5; //pressure in tank A in pa
24 availability_A=m*{Cv*(T-To)+R*(Po*T/P-To)-To*Cp*log(
      T/To)+To*R*log(P/Po)}
25 disp(" for tank B,P=3*10^5 pa ,so availability_B in KJ
      ")
26 P=3*10^5; //pressure in tank B in pa
27 availability_B=m*{Cv*(T-To)+R*(Po*T/P-To)-To*Cp*log(
      T/To)+To*R*log(P/Po)}
28 disp("so availability of air in tank B is more than
      that of tank A")
29 disp(" availability of air in tank A=1.98 KJ")
30 disp(" availability of air in tank B=30.98 KJ")

```

---

**Scilab code Exa 7.3** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 3

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 3")
8 m=15; //steam flow rate in kg/s
9 V2=160; //exit velocity of steam in m/s
10 To=(15+273); //pond water temperature in K
11 disp("inlet conditions ,")
12 disp("from steam tables , ,h1=3051.2 KJ/kg ,s1=7.1229
KJ/kg K")
13 h1=3051.2;
14 s1=7.1229;
15 disp("outlet conditions ,at 0.05 bar and 0.95 dryness
fraction")
16 disp("from steam tables ,sf=0.4764 KJ/kg K,s_fg
=7.9187 KJ/kg K,x=0.95,hf=137.82 KJ/kg ,h_fg
=2423.7 KJ/kg")
17 sf=0.4764;
18 s_fg=7.9187;
19 x=0.95;
20 hf=137.82;
21 h_fg=2423.7;
22 disp("so s2=sf+x*s_fg in KJ/kg K")
23 s2=sf+x*s_fg
24 disp("and h2=hf+x*h_fg in KJ/kg")
25 h2=hf+x*h_fg
26 disp("neglecting the change in potential energy and
velocity at inlet to turbine ,the steady flow
energy equation may be written as to give work
output .")
27 disp("w=(h1-h2)-V2^2*10^-3/2 in KJ/kg")
```

```

28 w=(h1-h2)-V2^2*10^-3/2
29 disp(" power output=m*w in KW")
30 m*w
31 disp("maximum work for given end states ,")
32 disp("w_max=(h1-To*s1)-(h2+V2^2*10^-3/2-To*s2) in KJ
    /kg")
33 w_max=(h1-To*s1)-(h2+V2^2*10^-3/2-To*s2)
34 w_max=850.38; //approx.
35 disp("w_max in KW")
36 w_max=m*w_max
37 disp("so maximum power output=12755.7 KW")
38 disp("maximum power that could be obtained from
    exhaust steam shall depend upon availability with
    exhaust steam and the dead state.stream
    availability of exhaust steam ,")
39 disp("A_exhaust=(h2+V^2/2-To*s2)-(ho-To*so)")
40 disp("=(h2-ho)+V2^2/2-To(s2-so)")
41 disp("approximately the enthalpy of water at dead
    state of 1 bar,15 degree celcius can be
    approximated to saturated liquid at 15 degree
    celcius")
42 disp("from steam tables ,at 15 degree celcius ,ho
    =62.99 KJ/kg ,so=0.2245 KJ/kg K")
43 ho=62.99;
44 so=0.2245;
45 disp("maximum work available from exhaust steam ,
    A_exhaust in KJ/kg")
46 disp("A_exhaust=(h2-ho)+V2^2*10^-3/2-To*(s2-so)")
47 A_exhaust=(h2-ho)+V2^2*10^-3/2-To*(s2-so)
48 A_exhaust=151.1; //approx.
49 disp("maximum power that could be obtained from
    exhaust steam=m*A_exhaust in KW")
50 m*A_exhaust
51 disp("so maximum power from exhaust steam=2266.5 KW"
    )

```

---

Table 4 Superheated steam table

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$T$ °C	$v$ $m^3/kg$	$u$ $kJ/kg$	$h$ $kJ/kg$	$s$ $kJ/(kg K)$	$v$ $m^3/kg$	$u$ $kJ/kg$	$h$ $kJ/kg$	$s$ $kJ/(kg K)$	$v$ $m^3/kg$	$u$ $kJ/kg$	$h$ $kJ/kg$	$s$ $kJ/(kg K)$				
	Sat.	P = 1.00 MPa (179.91 °C)	P = 1.20 MPa (187.99 °C)	P = 1.40 MPa (195.70 °C)	0.19444	2583.6	2778.1	6.5865	0.16930	2612.8	2815.9	6.5898	0.14302	2603.1	2803.3	6.4975
200	0.2060	2621.9	2827.9	6.6940	0.19234	2704.2	2935.0	6.8294	0.16350	2698.3	2927.2	6.7467	0.14084	2592.8	2790.0	6.4693
250	0.2327	2709.9	2942.6	6.9247	0.2138	2789.2	3045.8	7.0317	0.18228	2785.2	3040.4	6.9534	0.16050	2685.2	2883.0	6.7854
300	0.2579	2793.2	3051.2	7.1229	0.2345	2872.2	3153.6	7.2121	0.2003	2869.2	3149.5	7.1360	0.18285	2785.2	3040.4	6.9534
350	0.2825	2875.2	3157.7	7.3011	0.2548	2954.9	3260.7	7.3774	0.2178	2952.5	3257.5	7.3026	0.20350	2869.2	3149.5	7.1360
400	0.3066	2957.3	3263.9	7.4651	0.2946	3122.8	3476.3	7.6759	0.2521	3121.1	3474.1	7.6027	0.22425	2952.5	3257.5	7.3026
500	0.3541	3124.4	3478.5	7.7622	0.4011	3296.8	3697.9	8.0290	0.3339	3295.6	3696.3	7.9435	0.2860	3294.4	3694.8	7.8710
600	0.4011	3475.3	3923.1	8.2731	0.4478	3660.4	4154.7	8.4996	0.3729	3474.4	3922.0	8.1881	0.3195	3473.6	3920.8	8.1160
700	0.4478	3852.2	4392.9	8.7118	0.4943	4050.5	4637.6	8.9119	0.4118	3659.7	4153.8	8.4148	0.3528	3659.0	4153.0	8.3431
800	0.4943	4255.1	4888.6	9.1017	0.5407	4254.6	4888.0	9.0172	0.4505	3851.6	4392.2	8.6272	0.3861	3851.1	4391.5	8.5556
900	0.5407	4465.6	5145.4	9.2822	0.5871	4465.1	5144.9	9.1977	0.5665	4465.1	5144.9	9.1977	0.4855	4464.7	5144.4	9.1262
1000	0.6335	4635.1	5145.4	9.2822	0.6798	4680.9	5407.0	9.3698	0.6051	4680.9	5407.0	9.3698	0.5186	4680.4	5406.5	9.2984
1100	0.7261	481.3	5407.4	9.4543												

Figure 7.3: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 3

### Scilab code Exa 7.4 Engineering Thermodynamics by Onkar Singh Chapter 7 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 4")
8 m=5; //mass of steam in kg

```

**Table 2** Saturated Steam (temperature) table

Temp. °C <i>T</i>	Sat. press. kPa <i>P<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg			Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg.K)				
		Sat. liquid		Sat. vapour	Sat. liquid		Sat. Evap.	Sat. vapour	Sat. liquid		Sat. Evap.	Sat. vapour	Sat. liquid		
		<i>v<sub>f</sub></i>	<i>v<sub>g</sub></i>	<i>u<sub>f</sub></i>	<i>u<sub>fg</sub></i>	<i>u<sub>g</sub></i>			<i>h<sub>f</sub></i>	<i>h<sub>fg</sub></i>	<i>h<sub>g</sub></i>		<i>s<sub>f</sub></i>	<i>s<sub>fg</sub></i>	<i>s<sub>g</sub></i>
0.01	0.6113	0.001000	206.14	0.0	2375.3	2375.3	0.01	2501.4	2501.4	0.000	9.1562	9.1562			
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	0.0761	8.9496	9.0257			
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	0.1510	8.7498	8.9008			
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	0.2245	8.5569	8.7814			
20	2.339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	0.2966	8.3706	8.6672			
25	3.169	0.001003	43.36	104.88	2409.8	2309.8	104.89	2442.3	2547.2	0.3674	8.1905	8.5580			
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	0.4369	8.0164	8.4533			
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	0.5053	7.8478	8.3531			
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	0.5725	7.6845	8.2570			
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	0.6387	7.5261	8.1648			
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0763			
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913			
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096			
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8310			
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7553			
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6824			
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.6122			
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.5445			
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.4791			
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.96	2270.2	2668.1	1.2500	6.1659	7.4159			

Figure 7.4: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 3

```

9 z1=10; //initial elevation in m
10 V1=25; //initial velocity of steam in m/s
11 z2=2; //final elevation in m
12 V2=10; //final velocity of steam in m/s
13 Po=100; //environmental pressure in Kpa
14 To=(25+273); //environmental temperature in K
15 g=9.81; //acceleration due to gravity in m/s^2
16 disp("for dead state of water ,")
17 disp("from steam tables ,uo=104.86 KJ/kg ,vo
      =1.0029*10^-3 m^3/kg ,so=0.3673 KJ/kg K")
18 uo=104.86;
19 vo=1.0029*10^-3;
20 so=0.3673;
21 disp("for initial state of water ,")
22 disp("from steam tables ,u1=2550 KJ/kg ,v1=0.5089 m^3/
      kg ,s1=6.93 KJ/kg K")
23 u1=2550;
24 v1=0.5089;
25 s1=6.93;
26 disp("for final state of water ,")
27 disp("from steam tables ,u2=83.94 KJ/kg ,v2
      =1.0018*10^-3 m^3/kg ,s2=0.2966 KJ/kg K")
28 u2=83.94;
29 v2=1.0018*10^-3;
30 s2=0.2966;
31 disp("availability at any state can be given by")
32 disp("A=m*((u-uo)+Po*(v-vo)-To*(s-so)+V^2/2+g*z")")
33 disp("so availability at initial state ,A1 in KJ")
34 disp("A1=m*((u1-uo)+Po*(v1-vo)-To*(s1-so)+V1
      ^2*10^-3/2+g*z1*10^-3")")
35 A1=m*((u1-uo)+Po*(v1-vo)-To*(s1-so)+V1^2*10^-3/2+g*
      z1*10^-3)
36 disp("and availability at final state ,A2 in KJ")
37 disp("A2=m*((u2-uo)+Po*(v2-vo)-To*(s2-so)+V2
      ^2*10^-3/2+g*z2*10^-3")")
38 A2=m*((u2-uo)+Po*(v2-vo)-To*(s2-so)+V2^2*10^-3/2+g*
      z2*10^-3)
39 disp("change in availability ,A2-A1 in KJ")

```

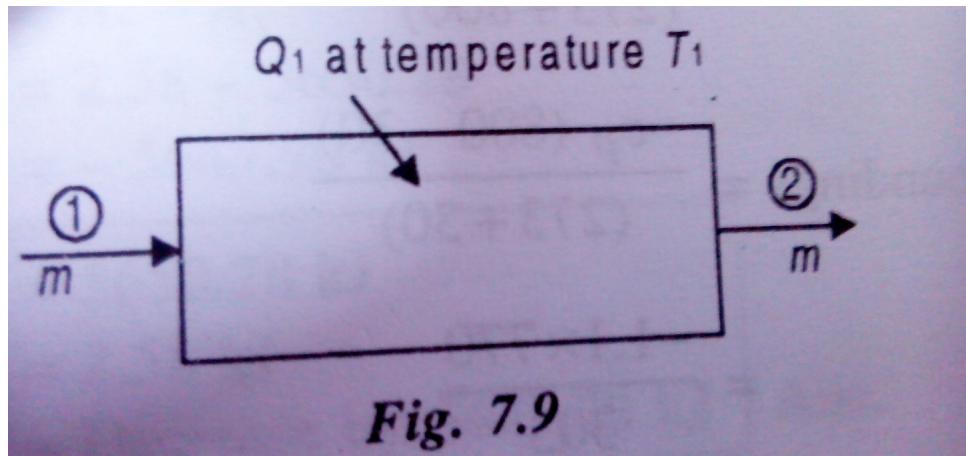


Figure 7.5: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 5

---

```

40 A2-A1
41 disp(" hence availability decreases by 2702.188 KJ")
42 disp("NOTE=>In this question ,due to large
       calculations ,answers are approximately correct .")

```

---

**Scilab code Exa 7.5** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 5")
8 disp("In question no. 5 expression I=To*S_gen is

```

derived which cannot be solve using scilab software.”)

---

### Scilab code Exa 7.6 Engineering Thermodynamics by Onkar Singh Chapter 7 Example 6

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 6")
8 To=(30+273); //temperature of surrounding in K
9 W=1050; //work done in engine in KJ/kg
10 Cp=1.1; //specific heat at constant pressure in KJ/kg
K
11 T=(800+273); //temperature of exhaust gas in K
12 disp("loss of available energy=irreversibility=To*
deltaSc")
13 disp("deltaSc=deltaSs+deltaSe")
14 disp("change in entropy of system (deltaSs)=W/T in KJ/
kg K")
15 deltaSs=W/T
16 disp("change in entropy of surrounding (deltaSe)=-Cp
*(T-To)/To in KJ/kg K")
17 deltaSe=-Cp*(T-To)/To
18 disp("loss of available energy (E)=To*(deltaSs+
deltaSe) in KJ/kg")
19 E=To*(deltaSs+deltaSe)
20 disp("loss of available energy (E)=")
21 E=-E
22 disp("ratio of lost available exhaust gas energy to
engine work=E/W")
```

**Scilab code Exa 7.7** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 7

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 7")
8 m=10; //mass of water in kg
9 C1=25; //initial velocity in m/s
10 C2=10; //final velocity in m/s
11 Po=0.1*1000; //environmental pressure in Kpa
12 To=(25+273.15); //environmental temperature in K
13 g=9.8; //acceleration due to gravity in m/s^2
14 z1=10; //initial elevation in m
15 z2=3; //final elevation in m
16 disp("let us consider velocities and elevations to
be given in reference to environment. Availability
is given by")
17 disp("A=m*((u-uo)+Po*(v-vo)-To(s-so)+C^2/2+g*z)")
18 disp("dead state of water ,from steam tables ,uo
=104.88 KJ/kg ,vo=1.003*10^-3 m^3/kg ,so=0.3674 KJ/
kg K")
19 uo=104.88;
20 vo=1.003*10^-3;
21 so=0.3674;
22 disp("for initial state of saturated vapour at 150
degree celcius")
23 disp("from steam tables ,u1=2559.5 KJ/kg ,v1=0.3928 m
^3/kg ,s1=6.8379 KJ/kg K")
```

```

24 u1=2559.5;
25 v1=0.3928;
26 s1=6.8379;
27 disp("for final state of saturated liquid at 20
degree celcius")
28 disp("from steam tables ,u2=83.95 KJ/kg ,v2=0.001002 m
^3/kg ,s2=0.2966 KJ/kg K")
29 u2=83.95;
30 v2=0.001002;
31 s2=0.2966;
32 disp("substituting in the expression for
availability")
33 disp("initial state availability ,A1 in KJ")
34 disp("A1=m*((u1-uo)+Po*(v1-vo)-To*(s1-so)+C1
^2*10^-3/2+g*z1*10^-3")
35 A1=m*((u1-uo)+Po*(v1-vo)-To*(s1-so)+C1^2*10^-3/2+g*
z1*10^-3)
36 disp("final state availability ,A2 in KJ")
37 disp("A2=m*((u2-uo)+Po*(v2-vo)-To*(s2-so)+C2
^2*10^-3/2+g*z2*10^-3")
38 A2=m*((u2-uo)+Po*(v2-vo)-To*(s2-so)+C2^2*10^-3/2+g*
z2*10^-3)
39 disp("change in availability ,deltaA=A2-A1 in KJ")
40 deltaA=A2-A1
41 disp("so initial availability =5650.28 KJ")
42 disp("final availability=2.58 KJ ")
43 disp("change in availability=decrease by 5647.70 KJ
")

```

---

**Scilab code Exa 7.8** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 8

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 8")
8 m=5; //steam flow rate in kg/s
9 p1=5*1000; //initial pressure of steam in Kpa
10 T1=(500+273.15); //initial temperature of steam in K
11 p2=0.2*1000; //final pressure of steam in Kpa
12 T2=(140+273.15); //final temperature of steam in K
13 po=101.3; //pressure of steam at dead state in Kpa
14 To=(25+273.15); //temperature of steam at dead state
in K
15 Q=600; //heat loss through turbine in KJ/s
16 disp("let inlet and exit states of turbine be
denoted as 1 and 2")
17 disp("at inlet to turbine ,")
18 disp("from steam tables ,h1=3433.8 KJ/kg ,s1=6.9759 KJ
/kg K")
19 h1=3433.8;
20 s1=6.9759;
21 disp("at exit from turbine ,")
22 disp("from steam tables ,h2=2748 KJ/kg ,s2=7.228 KJ/kg
K")
23 h2=2748;
24 s2=7.228;
25 disp("at dead state ,")
26 disp("from steam tables ,ho=104.96 KJ/kg ,so=0.3673 KJ
/kg K")
27 ho=104.96;
28 so=0.3673;
29 disp(" availability of steam at inlet ,A1=m*((h1-ho)-
To*(s1-so)) in KJ")
30 A1=m*((h1-ho)-To*(s1-so))
31 disp("so availability of steam at inlet =6793.43 KJ")
32 disp(" applying first law of thermodynamics ,")
33 disp("Q+m*h1=m*h2+W")
34 disp(" so W=m*(h1-h2)-Q in KJ/s")

```

```

35 W=m*(h1-h2)-Q
36 disp("so turbine output=2829 KW")
37 disp("maximum possible turbine output will be
       available when irreversibility is zero.")
38 disp("W_rev=W_max=A1-A2")
39 disp("W_max=m*((h1-h2)-To*(s1-s2)) in KJ/s")
40 W_max=m*((h1-h2)-To*(s1-s2))
41 disp("so maximum output=3804.81 KW")
42 disp("irreversibility can be estimated by the
       difference between the maximum output and turbine
       output.")
43 disp("I=W_max-W in KW")
44 I=W_max-W
45 disp("so irreversibility=975.81807 KW")
46 disp("NOTE=>In book ,W_max is calculated wrong ,so
       irreversibility also comes wrong ,which are
       corrected above.")

```

---

**Scilab code Exa 7.9** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 9

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 9")

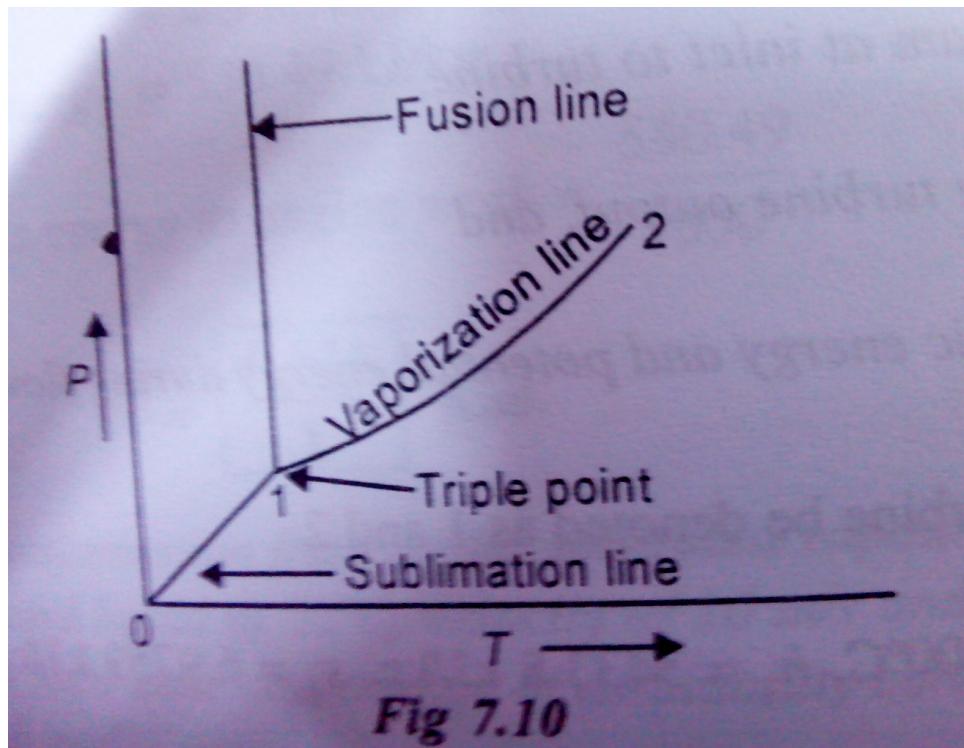
```

T °C	v	u	h	s	v	u	h	s	v	u	h	s
	m³/kg	kJ/kg	kJ/kg	kJ/(kg K)		m³/kg	kJ/kg	kJ/kg		m³/kg	kJ/kg	kJ/kg
<i>P = 4.0 MPa (250.40 °C)</i>				<i>P = 4.5 MPa (257.49 °C)</i>				<i>P = 5.0 MPa (263.99 °C)</i>				
Sat.	0.04978	2602.3	2801.4	6.0701	0.04406	2600.1	2798.3	6.0198	0.03944	2597.1	2794.3	5.9734
275	0.05457	2667.9	2886.2	6.2285	0.04730	2650.3	2863.2	6.1401	0.04141	2631.3	2838.3	6.0544
300	0.05884	2725.3	2960.7	6.3615	0.05135	2712.0	2943.1	6.2828	0.04532	2698.0	2924.5	6.2084
350	0.06645	2826.7	3092.5	6.5821	0.05840	2817.8	3080.6	6.5131	0.05194	2808.7	3068.4	6.4493
400	0.07341	2919.9	3213.6	6.7690	0.06475	2913.3	3204.7	6.7047	0.05781	2906.6	3195.7	6.6459
450	0.08002	3010.2	3330.3	6.9363	0.07074	3005.0	3323.3	6.8746	0.06330	2999.7	3316.2	6.8186
500	0.08643	3099.5	3445.3	7.0901	0.07651	3095.3	3439.6	7.0301	0.06857	3091.0	3433.8	6.9759
600	0.09885	3279.1	3674.4	7.3688	0.08765	3276.0	3670.5	7.3110	0.07869	3273.0	3666.5	7.2589
700	0.11095	3462.1	3905.9	7.6198	0.09847	3459.9	3903.0	7.5631	0.08849	3457.6	3900.1	7.5122
800	0.12287	3650.0	4141.5	7.8502	0.10911	3648.3	4139.3	7.7942	0.09811	3646.6	4137.1	7.7440
900	0.13469	3843.6	4382.3	8.0647	0.11965	3842.2	4380.6	8.0091	0.10762	3840.7	4378.8	7.9593
1000	0.14645	4042.9	4628.7	8.2662	0.13013	4041.6	4627.2	8.2108	0.11707	4040.4	4625.7	8.1612
1100	0.15817	4248.0	4880.6	8.4567	0.14056	4246.8	4879.3	8.4015	0.12648	4245.6	4878.0	8.3520
1200	0.16987	4458.6	5138.1	8.6376	0.15098	4457.5	5136.9	8.5825	0.13587	4456.3	5135.7	8.5331
1300	0.18156	4674.3	5400.5	8.8100	0.16139	4673.1	5399.4	8.7549	0.14526	4672.0	5398.2	8.7055

Figure 7.6: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 8

T °C	v	u	h	s	v	u	h	s	v	u	h	s
	m³/kg	kJ/kg	kJ/kg	kJ/(kg K)		m³/kg	kJ/kg	kJ/kg		m³/kg	kJ/kg	kJ/kg
<i>P = 0.20 MPa (120.23 °C)</i>				<i>P = 0.30 MPa (133.55 °C)</i>				<i>P = 0.40 MPa (143.63 °C)</i>				
Sat.	0.8857	2529.5	2706.7	7.1272	0.6058	2543.6	2725.3	6.9919	0.4625	2553.6	2738.6	6.8959
150	0.9596	2576.9	2768.8	7.2795	0.6339	2570.8	2761.0	7.0778	0.4708	2564.5	2752.8	6.9299
200	1.0803	2654.4	2870.5	7.5066	0.7163	2650.7	2865.6	7.3115	0.5342	2646.8	2860.5	7.1706
250	1.1988	2731.2	2971.0	7.7086	0.7964	2728.7	2967.6	7.5166	0.5951	2726.1	2964.2	7.3789
300	1.3162	2808.6	3071.8	7.8926	0.8753	2806.7	3069.3	7.7022	0.6548	2804.8	3066.8	7.5662
400	1.5493	2966.7	3276.6	8.2218	1.0315	2965.6	3275.0	8.0330	0.7726	2964.4	3273.4	7.8985
500	1.7814	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	0.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0194	1.4957	3478.4	3927.1	8.8319	1.1215	3477.9	3926.5	8.6987
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2312	3662.4	4157.3	8.9244
900	2.705	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2692	1.3529	3853.9	4395.1	9.1362
1000	2.937	4052.5	4640.0	9.5663	1.9581	4052.3	4639.7	9.4690	1.4685	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.5840	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.5	10.0262	2.2661	4467.2	5147.1	9.8389	1.6996	4467.0	5146.8	9.7060
1300	3.630	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780

Figure 7.7: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 8



**Fig 7.10**

Figure 7.8: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 9

8 **disp**("In question no.9 comparision between  
sublimation and vaporisation line is made which  
cannot be solve using scilab software.")

---

**Scilab code Exa 7.10** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 10

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 10")
8 disp("In question no. 10 expression for change in
      internal energy of gas is derive which cannot be
      solve using scilab software.")
```

---

**Scilab code Exa 7.11** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 11

```
1 // Display modeK
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 11")
8 To=280; //surrounding temperature in K
9 Q=500; //heat removed in KJ
10 T1=835; //temperature of reservoir in K
```

```

11 T2=720; //temperature of system in K
12 disp(" availability for heat reservoir (A_HR)=To*
      deltaS_reservoir in KJ/kg K")
13 A_HR=To*Q/T1
14 disp("now availability for system (A_system)=To*
      deltaS_system in KJ/kg K")
15 A_system=To*Q/T2
16 disp("net loss of available energy(A)=A_HR-A_system
      in KJ/kg K")
17 A=A_HR-A_system
18 disp("so loss of available energy=26.77 KJ/kg K")

```

---

**Scilab code Exa 7.12** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 12

```

1 // Display modeK
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 12")
8 h1=4142; //enthalpy at entrance in KJ/kg
9 h2=2585; //enthalpy at exit in KJ/kg
10 W1=1787; //availability of steam at entrance in KJ/kg
11 W2=140; //availability of steam at exit in KJ/kg
12 disp("here dead state is given as 300 K and maximum
      possible work for given change of state of steam
      can be estimated by the difference of flow
      availability as given under:")
13 disp("W_max=W1-W2 in KJ/kg")
14 W_max=W1-W2
15 disp("actual work from turbine ,W_actual=h1-h2 in KJ/
      kg")

```

```
16 W_actual=h1-h2
17 disp("so actual work=1557 KJ/kg")
18 disp("maximum possible work=1647 KJ/kg")
```

---

**Scilab code Exa 7.13** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 13

```
1 // Display modeK
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 13")
8 T_min=(20+273); //minimum temperature reservoir
      temperature in K
9 T_max=(500+273); //maximum temperature reservoir
      temperature in K
10 n=0.25; //efficiency of heat engine
11 disp("reversible engine efficiency , n_rev=1-(T_min/
      T_max)")
12 n_rev=1-(T_min/T_max)
13 disp("second law efficiency=n/n_rev")
14 n/n_rev
15 disp(" in %")
16 n*100/n_rev
```

---

**Scilab code Exa 7.14** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 14

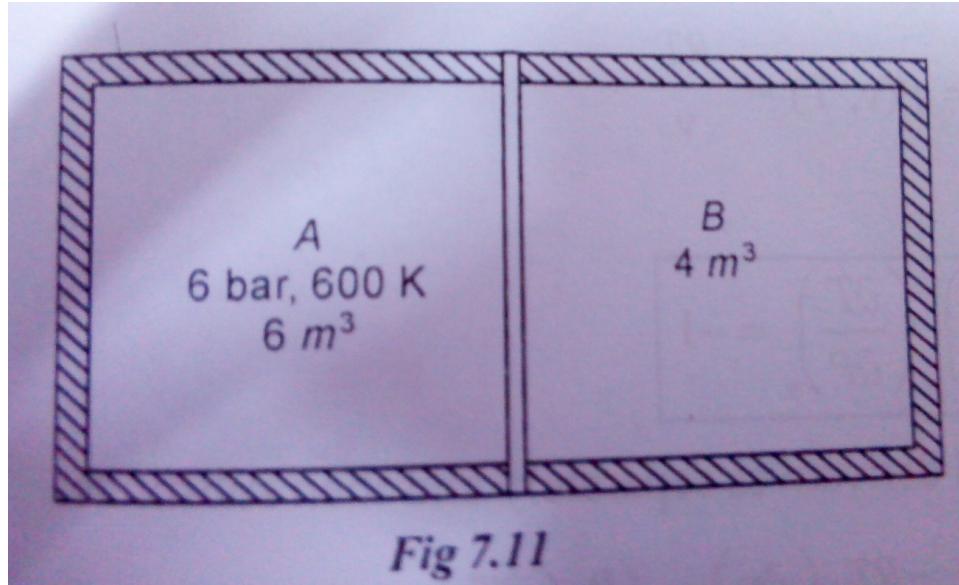


Figure 7.9: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 14

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 14")
8 V_A=6; //volume of compartment A in m^3
9 V_B=4; //volume of compartment B in m^3
10 T0=300; //temperature of atmosphere in K
11 P0=1*10^5; //atmospheric pressure in pa
12 P1=6*10^5; //initial pressure in pa
13 T1=600; //initial temperature in K
14 V1=V_A; //initial volume in m^3
15 V2=(V_A+V_B); //final volume in m^3
16 y=1.4; //expansion constant
17 R=287; //gas constant in J/kg K

```

```

18 Cv=0.718; // specific heat at constant volume in KJ/kg
    K
19 disp("expansion occurs in adiabatic conditions.")
20 disp("temperature after expansion can be obtained by
        considering adiabatic expansion")
21 disp("T2/T1=(V1/V2)^(y-1)")
22 disp("so T2=T1*(V1/V2)^(y-1) in K")
23 T2=T1*(V1/V2)^(y-1)
24 T2=489.12; //approx.
25 disp("mass of air ,m=(P1*V1)/(R*T1) in kg")
26 m=(P1*V1)/(R*T1)
27 m=20.91; //approx.
28 disp("change in entropy of control system ,deltaSs=(

        S2-S1)=m*Cv*log(T2/T1)+m*R*10^-3*log(V2/V1) in KJ/
        K")
29 deltaSs=m*Cv*log(T2/T1)+m*R*10^-3*log(V2/V1)
30 disp("here ,there is no change in entropy of
        environment ,deltaSe=0")
31 deltaSe=0;
32 disp("total entropy change of combined system=
        deltaSc=deltaSs+deltaSe in KJ/K")
33 deltaSc=deltaSs+deltaSe
34 disp("loss of available energy (E)=irreversibility=To
        *deltaSc in KJ")
35 E=To*deltaSc
36 disp("so loss of available energy ,E=0.603 KJ")

```

---

**Scilab code Exa 7.15** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 15

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;

```

```
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 15")
8 disp("In question no. 15 prove for ideal gas
      satisfies the cyclic relation is done which
      cannot be solve using scilab software.")
```

---

**Scilab code Exa 7.16** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 16

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 16")
8 To=(17+273); //temperature of surrounding in K
9 T1=(700+273); //temperature of high temperature
      reservoir in K
10 T2=(30+273); //temperature of low temperature
      reservoir in K
11 Q1=2*10^4; //rate of heat receive in KJ/min
12 W_useful=0.13*10^3; //output of engine in KW
13 disp(" availability or reversible work ,W_rev=n_rev*Q1
      in KJ/min")
14 n_rev=(1-T2/T1);
15 W_rev=n_rev*Q1
16 W_rev=W_rev/60; //W_rev in KJ/s
17 disp(" rate of irreversibility ,I=W_rev-W_useful in KJ
      /sec")
18 I=W_rev-W_useful
19 disp("second law efficiency=W_useful/W_rev")
20 W_useful/W_rev
```

```

21 disp("in percentage")
22 W_useful*100/W_rev
23 disp("so availability =1.38*10^4 KJ/min")
24 disp("and rate of irreversibility =100 KW, second law
      efficiency =56.63 %")
25 disp("NOTE=>In this question ,wrong values are put in
      expression for W_rev in book ,however answer is
      calculated correctly .")

```

---

**Scilab code Exa 7.17** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 17

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 7 Example 17")
8 To=(27+273); //temperature of surrounding in K
9 T1=(60+273); //initial temperature of air in K
10 P1=1.5*10^5; //initial pressure of air in pa
11 P2=2.5*10^5; //final pressure of air in pa
12 T_reservoir=(400+273); //temperature of reservoir in
      K
13 Cp=1.005; //specific heat at constant pressure in KJ/
      kg K
14 disp("loss of available energy=irreversibility=To*
      deltaSc")
15 disp("deltaSc=deltaSs+deltaSe")
16 disp("change in entropy of system=deltaSs")
17 disp("change in entropy of environment/surroundings=
      deltaSe")
18 disp("here heat addition process causing rise in
      "

```

```

pressure from 1.5 bar to 2.5 bar occurs
isochorically.let initial and final states be
given by subscript 1 and 2")
19 disp("P1/T1=P2/T2")
20 disp("so T2=P2*T1/P1 in K")
21 T2=P2*T1/P1
22 disp("heat addition to air in tank")
23 disp("Q=m*Cp*deltaT in KJ/kg")
24 deltaT=T2-T1;
25 Q=Cp*deltaT
26 disp("deltaSs=Q/T1 in KJ/kg K")
27 deltaSs=Q/T1
28 disp("deltaSe=-Q/T_reservoir in KJ/kg K")
29 deltaSe=-Q/T_reservoir
30 disp("and deltaSc=deltaSs+deltaSe in KJ/kg K")
31 deltaSc=deltaSs+deltaSe
32 disp("so loss of available energy (E) in KJ/kg")
33 E=T0*deltaSc

```

---

**Scilab code Exa 7.18** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 18

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 18")
8 disp("In question no. 18,relation for T*ds using
maxwell relation is derived which cannot be solve
using scilab software .")

```

---

**Scilab code Exa 7.19** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 19

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 19")
8 T=(200+273); //temperature of water in K
9 disp("clapeyron equation says , h_fg=T*v_fg*(dp/dT)
_sat")
10 disp("from steam tables , vg=0.12736 m^3/kg , vf
=0.001157 m^3/kg")
11 vg=0.12736;
12 vf=0.001157;
13 disp(" v_fg=(vg-vf) _200oc in m^3/kg")
14 v_fg=(vg-vf)
15 disp(" let us approximate ,")
16 disp(" (dp/dT) _sat_200oc=(deltaP/deltaT) _200oc=(

P_205oc-P_195oc)/(205-195) in Mpa/oc")
17 disp(" here from steam tables , P_205oc=1.7230 Mpa,
P_195oc=1.3978 Mpa")
18 P_205oc=1.7230; //pressure at 205 degree celcius in
Mpa
19 P_195oc=1.3978; //pressure at 195 degree celcius in
Mpa
20 (P_205oc-P_195oc)/(205-195)
21 disp("substituting in clapeyron equation ,")
22 disp("h_fg in KJ/kg")
```

530 ————— Thermodynamics

Temp. °C <i>T</i>	Sat. press kPa <i>P<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg			Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid <i>v<sub>f</sub></i>		Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. <i>s<sub>fg</sub></i>	Sat. vapour <i>s<sub>g</sub></i>	
		Sat. liquid <i>v<sub>f</sub></i>	Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. <i>s<sub>fg</sub></i>	Sat. vapour <i>s<sub>g</sub></i>		
100	0.10135	0.001044	1.6729	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.0480	7.3549	
105	0.12082	0.001048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958	
110	0.14327	0.001052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387	
115	0.16906	0.001056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833	
120	0.19853	0.001060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296	
125	0.2321	0.001065	0.7706	524.74	2009.9	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775	
130	0.2701	0.001070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269	
135	0.3130	0.001075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777	
140	0.3613	0.001080	0.5089	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299	
145	0.4154	0.001085	0.4463	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833	
150	0.4758	0.001091	0.3928	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379	
155	0.5431	0.001096	0.3468	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935	
160	0.6178	0.001102	0.3071	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502	
165	0.7005	0.001108	0.2727	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.9925	4.7153	6.7078	
170	0.7917	0.001114	0.2428	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663	
175	0.8920	0.001121	0.2168	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256	
180	1.0021	0.001127	0.19405	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1396	4.4461	6.5857	
185	1.1227	0.001134	0.17409	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465	
190	1.2544	0.001141	0.15654	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079	
195	1.3978	0.001149	0.14105	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698	
200	1.5538	0.001157	0.12736	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323	
205	1.7230	0.001164	0.11521	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952	
210	1.9062	0.001173	0.10441	895.53	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585	
215	2.104	0.001181	0.09479	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221	
220	2.318	0.001190	0.08619	940.87	1661.5	2602.4	943.62	1858.5	2802.1	2.5178	3.7683	6.2861	
225	2.548	0.001199	0.07849	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503	
230	2.795	0.001209	0.07158	986.74	1617.2	2603.9	990.12	1813.8	2804.0	2.6099	3.6047	6.2146	
235	3.060	0.001219	0.06537	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1791	
240	3.344	0.001229	0.05976	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437	
245	3.648	0.001240	0.05471	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083	
250	3.973	0.001251	0.05013	1080.39	1522.0	2602.4	1085.36	1716.2	2801.5	2.7927	3.2802	6.0730	
255	4.319	0.001263	0.04598	1104.28	1596.7	2600.9	109.73	1689.8	2799.5	2.8383	3.1992	6.0375	
260	4.688	0.001276	0.04221	1128.39	1470.6	2599.0	1134.37	1662.5	2796.9	2.8838	3.1181	6.0019	
265	5.081	0.001289	0.03877	1152.74	1443.9	2596.6	1159.28	1634.4	2793.6	2.9294	3.0368	5.9662	
270	5.499	0.001302	0.03564	1177.36	1416.3	2593.7	1184.51	1605.2	2789.7	2.9751	2.9551	5.9301	
275	5.942	0.001317	0.03279	1202.25	1387.9	2590.2	1210.07	1574.9	2785.0	3.0208	2.8730	5.8938	
280	6.412	0.001332	0.03017	1227.46	1358.7	2586.1	1235.99	1543.6	2779.6	3.0668	2.7903	5.8571	
285	6.909	0.001348	0.02777	1253.00	1328.4	2581.4	1262.31	1511.0	2773.3	3.1130	2.7070	5.8199	
290	7.436	0.001366	0.02557	1278.92	1297.1	2576.0	1289.07	1477.1	2766.2	3.1594	2.6227	5.7821	
295	7.993	0.001384	0.02354	1305.2	1264.7	2569.9	1316.3	1441.8	2758.1	3.2062	2.5375	5.7437	
300	8.581	0.001404	0.02167	1332.0	1231.0	2563.0	1344.0	1404.9	2749.0	3.2534	2.4511	5.7045	
305	9.202	0.001425	0.019948	1359.3	1195.9	2555.2	1372.4	1366.4	2738.7	3.3010	2.3633	5.6643	
310	9.856	0.001447	0.018350	1387.1	1159.4	2546.4	1401.3	1326.0	2727.3	3.3493	2.2737	5.6230	

Figure 7.10: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 19

```

23 h_fg=T*v_fg*(P_205oc-P_195oc)*1000/(205-195)
24 disp("so calculated enthalpy of vaporisation=1941.25
        KJ/kg")
25 disp("and enthalpy of vaporisation from steam table
        =1940.7 KJ/kg")

```

---

**Scilab code Exa 7.20** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 20

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
        Chapter 7 Example 20")
8 P2=260.96; //saturation pressure at -5 degree celcius
9 P1=182.60; //saturation pressure at -15 degree
        celcius
10 vg=0.07665; //specific volume of gas at -10 degree
        celcius in m^3/kg
11 vf=0.00070 //specific volume at -10 degree celcius in
        m^3/kg
12 R=0.06876; //gas constant in KJ/kg K
13 h_fg=156.3; //enthalpy in KJ/kg K
14 T2=(-5+273); //temperature in K
15 T1=(-15+273); //temperature in K
16 disp("by clapeyron equation")
17 disp("h_fg=T2*v_fg*(do/dT)_sat ")
18 disp("h_fg=T2*(vg-vf)*(deltaP/deltaT) in KJ/kg")
19 h_fg=T2*(vg-vf)*(P1-P2)/(T1-T2)
20 disp("by clapeyron-clausius equation ,")
21 disp("log(P2/P1)_sat=(h_fg/R)*((1/T1)-(1/T2))_sat")
22 disp("log(P2/P1)=(h_fg/R)*((1/T1)-(1/T2))")

```

**Table 4** Superheated steam table

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)	v m³/kg	u kJ/kg	h kJ/kg	s kJ/(kg·K)
	P = 0.20 MPa (120.23 °C)				P = 0.30 MPa (133.55 °C)				P = 0.40 MPa (143.63 °C)			
Sat.	0.8857	2529.5	2706.7	7.1272	0.6058	2543.6	2725.3	6.9919	0.4625	2553.6	2738.6	6.8959
150	0.9596	2576.9	2768.8	7.2795	0.6339	2570.8	2761.0	7.0778	0.4708	2564.5	2752.8	6.9299
200	1.0803	2654.4	2870.5	7.5066	0.7163	2650.7	2865.6	7.3115	0.5342	2646.8	2860.5	7.1706
250	1.1988	2731.2	2971.0	7.7086	0.7964	2728.7	2967.6	7.5166	0.5951	2726.1	2964.2	7.3789
300	1.3162	2808.6	3071.8	7.8926	0.8753	2806.7	3069.3	7.7022	0.6548	2804.8	3066.8	7.5662
400	1.5493	2966.7	3276.6	8.2218	1.0315	2965.6	3275.0	8.0330	0.7726	2964.4	3273.4	7.8985
500	1.7814	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	0.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0194	1.4957	3478.4	3927.1	8.8319	1.1215	3477.9	3926.5	8.6987
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2312	3662.4	4157.3	8.9244
900	2.705	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2692	1.3529	3853.9	4395.1	9.1362
1000	2.937	4052.5	4640.0	9.5663	1.9581	4052.3	4639.7	9.4690	1.4685	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.5840	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.5	10.0262	2.2661	4467.2	5147.1	9.8389	1.6996	4467.0	5146.8	9.7060
1300	3.630	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780

Figure 7.11: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 21

```

23 disp(" so h_fg=log(P2/P1)*R/((1/T1)-(1/T2)) in KJ/kg")
24 h_fg=log(P2/P1)*R/((1/T1)-(1/T2))
25 disp("% deviation from clapeyron equation in %")
26 (169.76-159.49)*100/159.49
27 disp(" h_fg by clapeyron equation=159.49 KJ/kg")
28 disp(" h_fg by clapeyron-clausius equation=169.76 KJ/
    kg")
29 disp("% deviation in h_fg value by clapeyron-
    clausius equation from the value from clapeyron
    equation=6.44%")

```

---

**Scilab code Exa 7.21** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 21

1 // Display mode

```

2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 21")
8 disp("volume expansion=(1/v)*(dv/dT)_P")
9 disp("isothermal compressibility=-(1/v)*(dv/dp)_T")
10 disp("let us write dv/dT=deltav/deltaT and dv/dP=
deltav/deltaP.The difference may be taken for
small pressure and temperature changes.")
11 disp("volume expansivity in K^-1")
12 disp("=(1/v)*(dv/dT)_300Kpa")
13 disp("=(1/v_300Kpa_300oc)*((v_350oc-v_250oc)
/(350-250))_300Kpa")
14 disp("from steam tables ,v_300Kpa_300oc=0.8753 in m
^3/kg ,v_350oc=0.9534 in m^3/kg ,v_250oc=0.7964 in
m^3/kg")
15 v_300Kpa_300oc=0.8753; //specific volume at 300Kpa
and 300 degree celcius
16 v_350oc=0.9534; //specific volume 350 degree celcius
17 v_250oc=0.7964; //specific volume 250 degree celcius
18 (1/v_300Kpa_300oc)*(v_350oc-v_250oc)/(350-250)
19 disp("volume expansivity=1.7937*10^-3 K^-1")
20 disp("isothermal compressibility in Kpa^-1")
21 disp("=(-1/v_300Kpa_300oc)*((v_350Kpa-v_250Kpa)
/(350-250))_300oc")
22 disp("from steam tables ,v_300Kpa_300oc=0.8753 in m
^3/kg ,v_350Kpa=0.76505 in m^3/kg ,v_250Kpa=1.09575
in m^3/kg")
23 v_350Kpa=0.76505; //specific volume 350 Kpa
24 v_250Kpa=1.09575; //specific volume 250 Kpa
25 (-1/v_300Kpa_300oc)*(v_350Kpa-v_250Kpa)/(350-250)
26 disp("so isothermal compressibility=3.778*10^-3 Kpa
^-1")

```

---

**Scilab code Exa 7.22** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 22

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 22")
8 Cp=1.005; // specific heat at constant pressure in KJ/
kg K
9 Cv=0.718; // specific heat at constant volume in KJ/kg
K
10 Ti=(25+273.15); //atmospheric temperature in K
11 disp(" filling of the tank is a transient flow(
unsteady) process. for the transient filling
process , considering subscripts i and f for
initial and final states ,")
12 disp(" hi=uf")
13 disp("Cp* Ti=Cv* Tf")
14 disp(" so Tf=Cp*Ti/Cv in K")
15 Tf=Cp*Ti/Cv
16 disp(" inside final temperature ,Tf=417.33 K")
17 disp(" change in entropy ,deltaS_gen=(Sf-Si)+
deltaS_surr in KJ/kg K")
18 disp("Cp*log (Tf/Ti)+0")
19 deltaS_gen=Cp*log(Tf/Ti)
20 disp(" change in entropy ,deltaS_gen=0.3379 KJ/kg K")
21 disp(" irreversibility ,I=To*deltaS_gen in KJ/kg")
22 To=Ti;
23 I=To*deltaS_gen
24 disp(" irreversibility ,I=100.74 KJ/kg")
```

---

**Scilab code Exa 7.23** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 23

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 23")
8 m=75; //mass of hot water in kg
9 T1=(400+273); //temperature of hot water in K
10 T2=(27+273); //temperature of environment in K
11 Cp=4.18; //specific heat of water in KJ/kg K
12 disp("here the combined closed system consists of
hot water and heat engine.here there is no
thermal reservoir in the system under
consideration.for the maximum work output ,
irreversibility=0")
13 disp("therefore ,d(E-To-S)/dt=W_max")
14 disp("or W_max=(E-To-S)1-(E-To-S)2")
15 disp("here E1=U1=m*Cp*T1 ,E2=U2=m*Cp*T2")
16 disp("therefore ,W_max=m*Cp*(T1-T2)-To*m*Cp*log (T1/T2
) in KJ")
17 To=T2;
18 W_max=m*Cp*(T1-T2)-To*m*Cp*log(T1/T2)
19 disp("so maximum work in KJ=")
20 W_max
```

---

**Scilab code Exa 7.24** Engineering Thermodynamics by Onkar Singh Chapter 7 Example 24

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 7 Example 24")
8 C1=150; //steam entering velocity in m/s
9 C2=50; //steam leaving velocity in m/s
10 To=(15+273); //dead state temperature in K
11 W=1000; //expansion work in KJ/kg
12 disp("from steam tables ,h1=h_50bar_600oc=3666.5 KJ/
kg ,s1=s_50bar_600oc=7.2589 KJ/kg K,h2=hg=2584.7
KJ/kg ,s2=sg=8.1502 KJ/kg K")
13 h1=3666.5;
14 s1=7.2589;
15 h2=2584.7;
16 s2=8.1502;
17 disp("inlet stream availability=(h1+C1^2*10^-3/2)-To
*s1 in KJ/kg")
18 (h1+C1^2*10^-3/2)-To*s1
19 disp("input stream availability is equal to the
input absolute availability .")
20 disp("exit stream availability=(h2+C2^2*10^-3/2)-To
*s2 in KJ/kg")
21 (h2+C2^2*10^-3/2)-To*s2
22 disp("exit stream availability is equal to the exit
absolute availability .")
23 disp("W_rev in KJ/kg")
24 W_rev=1587.18-238.69
25 disp("irreversibility=W_rev-W in KJ/kg")
26 W_rev-W
27 disp("this irreversibility is in fact the
availability loss .")
28 disp("inlet stream availability=1587.18 KJ/kg")
29 disp("exit stream availability=238.69 KJ/kg")
30 disp("irreversibility=348.49 KJ/kg")

```

**Table 4** Superheated steam table

T °C	v	u	h	s	v	u	h	s	v	u	h	s
	m³/kg	kJ/kg	kJ/kg	kJ/(kg·K)	m³/kg	kJ/kg	kJ/kg	kJ/(kg·K)	m³/kg	kJ/kg	kJ/kg	kJ/(kg·K)
<i>P = 4.0 MPa (250.40 °C)</i>				<i>P = 4.5 MPa (257.49 °C)</i>				<i>P = 5.0 MPa (263.99 °C)</i>				
Sat.	0.04978	2602.3	2801.4	6.0701	0.04406	2600.1	2798.3	6.0198	0.03944	2597.1	2794.3	5.9734
275	0.05457	2667.9	2886.2	6.2285	0.04730	2650.3	2863.2	6.1401	0.04141	2631.3	2838.3	6.0544
300	0.05884	2725.3	2960.7	6.3615	0.05135	2712.0	2943.1	6.2828	0.04532	2698.0	2924.5	6.2084
350	0.06645	2826.7	3092.5	6.5821	0.05840	2817.8	3080.6	6.5131	0.05194	2808.7	3068.4	6.4493
400	0.07341	2919.9	3213.6	6.7690	0.06475	2913.3	3204.7	6.7047	0.05781	2906.6	3195.7	6.6459
450	0.08002	3010.2	3330.3	6.9363	0.07074	3005.0	3323.3	6.8746	0.06330	2999.7	3316.2	6.8186
500	0.08643	3099.5	3445.3	7.0901	0.07651	3095.3	3439.6	7.0301	0.06857	3091.0	3433.8	6.9759
600	0.09885	3279.1	3674.4	7.3688	0.08765	3276.0	3670.5	7.3110	0.07869	3273.0	3666.5	7.2589
700	0.11095	3462.1	3905.9	7.6198	0.09847	3459.9	3903.0	7.5631	0.08849	3457.6	3900.1	7.5122
800	0.12287	3650.0	4141.5	7.8502	0.10911	3648.3	4139.3	7.7942	0.09811	3646.6	4137.1	7.7440
900	0.13469	3843.6	4382.3	8.0647	0.11965	3842.2	4380.6	8.0091	0.10762	3840.7	4378.8	7.9593
1000	0.14645	4042.9	4628.7	8.2662	0.13013	4041.6	4627.2	8.2108	0.11707	4040.4	4625.7	8.1612
1100	0.15817	4248.0	4880.6	8.4567	0.14056	4246.8	4879.3	8.4015	0.12648	4245.6	4878.0	8.3520
1200	0.16987	4458.6	5138.1	8.6376	0.15098	4457.5	5136.9	8.5825	0.13587	4456.3	5135.7	8.5331
1300	0.18156	4674.3	5400.5	8.8100	0.16139	4673.1	5399.4	8.7549	0.14526	4672.0	5398.2	8.7055

Figure 7.12: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 24

- 31 **disp**("NOTE=>In book this question is solve using dead state temperature 25 degree celcius which is wrong as we have to take dead state temperature 15 degree celcius ,now this question is correctly solve above taking dead state temperature 15 degree celcius as mentioned in question . ")
-

Table 3 Saturated steam (pressure) table

Press. kPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg			Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat.		Sat.		Sat.		Sat.		Sat.		Sat.	
		liquid	vapour	liquid	vapour	liquid	vapour	liquid	vapour	liquid	vapour	liquid	vapour
113	0.01	0.001000	206.14	0.00	2375.3	2375.3	0.01	2501.3	2501.4	0.0000	9.1562	9.1562	
10	6.98	0.001000	129.21	29.30	2355.7	2385.0	29.30	2484.9	2514.2	0.1059	8.8697	8.9756	
15	13.03	0.001001	87.98	54.71	2338.6	2393.3	54.71	2470.6	2525.3	0.1957	8.6322	8.8279	
20	17.50	0.001001	67.00	73.48	2326.0	2399.5	73.48	2460.0	2533.5	0.2607	8.4629	8.7237	
25	21.08	0.001002	54.25	88.48	2315.9	2404.4	88.49	2451.6	2540.0	0.3120	8.3311	8.6432	
30	24.08	0.001003	45.67	101.04	2307.5	2408.5	101.05	2444.5	2545.5	0.3545	8.2231	8.5776	
40	28.96	0.001004	34.80	121.45	2293.7	2415.2	121.46	2432.9	2554.4	0.4226	8.0520	8.4746	
50	32.88	0.001005	28.19	137.81	2282.7	2420.5	137.82	2423.7	2561.5	0.4764	7.9187	8.3951	
75	40.29	0.001008	19.24	168.78	2261.7	2430.5	168.79	2406.0	2576.8	0.5764	7.6750	8.2515	
10	45.81	0.001010	14.67	191.82	2246.1	2437.9	191.83	2392.8	2584.7	0.6493	7.5009	8.1502	
15	53.97	0.001014	10.02	225.92	2222.8	2448.7	225.94	2373.1	2599.1	0.7549	7.2536	8.0085	
20	60.06	0.001017	7.649	251.38	2205.4	2456.7	251.40	2358.3	2609.7	0.8320	7.0766	7.9085	
25	64.97	0.001020	6.204	271.90	2191.2	2463.1	271.93	2346.3	2618.2	0.8931	6.9383	7.8314	
30	69.10	0.001022	5.229	289.20	2179.2	2468.4	289.23	2336.1	2625.3	0.9439	6.8247	7.7686	
40	75.87	0.001027	3.993	317.53	2159.5	2477.0	317.58	2319.2	2636.8	1.0259	6.6441	7.6700	
50	81.33	0.001030	3.240	340.44	2143.4	2483.9	340.49	2305.4	2645.9	1.0910	6.5029	7.5329	
75	91.78	0.001037	2.217	384.31	2112.4	2496.7	384.39	2278.6	2663.0	1.2130	6.2434	7.4364	

Figure 7.13: Engineering Thermodynamics by Onkar Singh Chapter 7 Example 24

# Chapter 8

## Vapour Power Cycles

**Scilab code Exa 8.1** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 8 Example 1")
8 disp("T-S representation for carnot cycle operating
      between pressure of 7 MPa and 7KPa is shown in
      fig .")
9 disp("enthalpy at state 2,h2= hg at 7 MPa")
10 disp("from steam table ,h=2772.1 KJ/kg")
11 h2=2772.1;
12 disp("entropy at state 2,s2=sg at 7MPa")
13 disp("from steam table ,s2=5.8133 KJ/kg K")
14 s2=5.8133;
15 disp("enthalpy and entropy at state 3,")
16 disp("from steam table ,h3=hf at 7 MPa =1267 KJ/kg
      and s3=sf at 7 MPa=3.1211 KJ/kg K")
```

```

17 h3=1267;
18 s3=3.1211;
19 disp(" for process 2-1,s1=s2 . Let dryness fraction at
      state 1 be x1 ")
20 s1=s2;
21 disp(" from steam table , sf at 7 KPa=0.5564 KJ/kg K,
      sfg at 7 KPa=7.7237 KJ/kg K")
22 sf=0.5564;
23 sfg=7.7237;
24 disp(" s1=s2=sf+x1*sfg")
25 disp(" so x1=(s2-sf)/sfg ")
26 x1=(s2-sf)/sfg
27 x1=0.6806; //approx .
28 disp(" from steam table , hf at 7 KPa=162.60 KJ/kg , hfg
      at 7 KPa=2409.54 KJ/kg")
29 hf=162.60;
30 hfg=2409.54;
31 disp(" enthalpy at state 1,h1=hf+x1*hfg in KJ/kg")
32 h1=hf+x1*hfg
33 disp(" let dryness fraction at state 4 be x4")
34 disp(" for process 4-3,s4=s3=sf+x4*sfg")
35 s4=s3;
36 disp(" so x4=(s4-sf)/sfg")
37 x4=(s4-sf)/sfg
38 x4=0.3321; //approx .
39 disp(" enthalpy at state 4,h4=hf+x4*hfg in KJ/kg")
40 h4=hf+x4*hfg
41 disp(" thermal efficiency=net work/heat added")
42 disp(" expansion work per kg=(h2-h1) in KJ/kg")
43 (h2-h1)
44 disp(" compression work per kg=(h3-h4) in KJ/kg(+ve)")
        )
45 (h3-h4)
46 disp(" heat added per kg=(h2-h3) in KJ/kg(-ve)")
47 (h2-h3)
48 disp(" net work per kg=(h2-h1)-(h3-h4) in KJ/kg")
49 (h2-h1)-(h3-h4)
50 disp(" thermal efficiency")

```

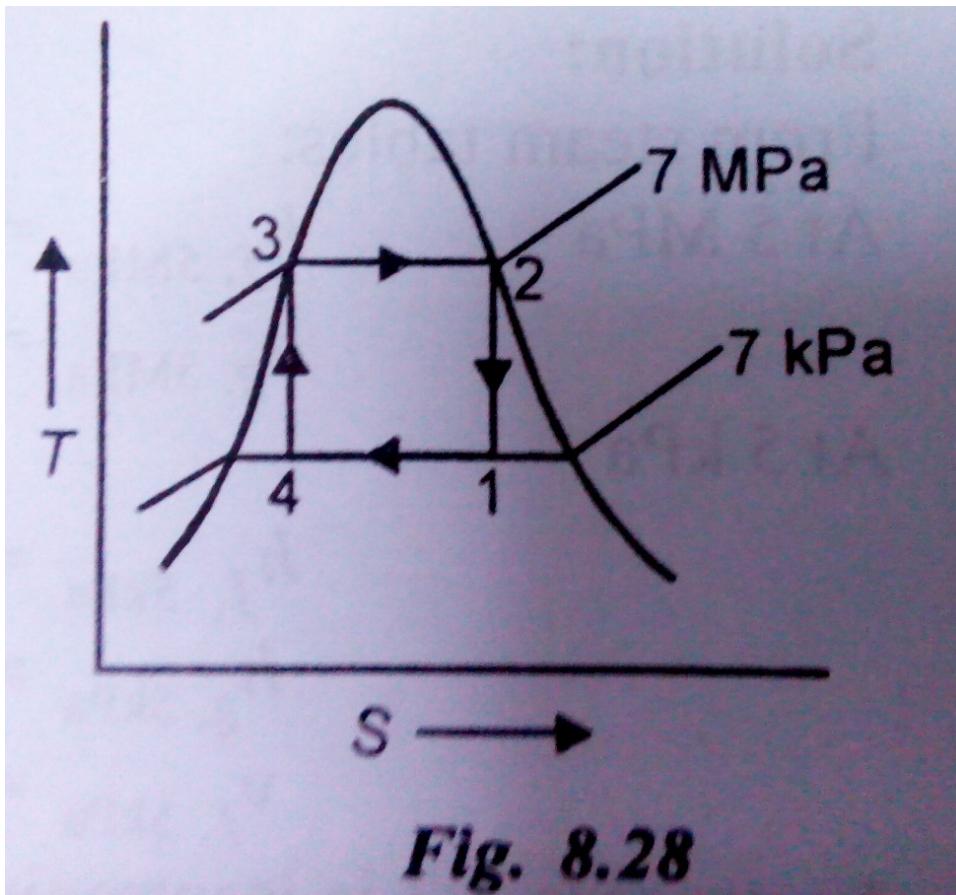


Figure 8.1: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 1

```

51 ((h2-h1)-(h3-h4))/(h2-h3)
52 disp("in percentage")
53 ((h2-h1)-(h3-h4))/(h2-h3)*100
54 disp("so thermal efficiency=44.21%")
55 disp("turbine work=969.57 KJ/kg(+ve)")
56 disp("compression work=304.19 KJ/kg(-ve)")
```

---

**Scilab code Exa 8.2** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 2

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 2")
8 disp("from steam tables , at 5 MPa, hf_5MPa=1154.23 KJ/
kg , sf_5MPa=2.92 KJ/kg K")
9 disp("hg_5MPa=2794.3 KJ/kg , sg_5MPa=5.97 KJ/kg K")
10 hf_5MPa=1154.23;
11 sf_5MPa=2.92;
12 hg_5MPa=2794.3;
13 sg_5MPa=5.97;
14 disp("from steam tables , at 5 Kpa , hf_5KPa=137.82 KJ/
kg , sf_5KPa=0.4764 KJ/kg K")
15 disp("hg_5KPa=2561.5 KJ/kg , sg_5KPa=8.3951 KJ/kg K,
vf_5KPa=0.001005 m^3/kg")
16 hf_5KPa=137.82;
17 sf_5KPa=0.4764;
18 hg_5KPa=2561.5;
19 sg_5KPa=8.3951;
20 vf_5KPa=0.001005;
21 disp("as process 2-3 is isentropic , so s2=s3")
22 disp("and s3=sf_5KPa+x3*sfg_5KPa=s2=sg_5MPa")
23 s2=sg_5MPa;
24 s3=s2;
25 disp("so x3=(s3-sf_5KPa)/sfg_5KPa")
```

```

26 x3=(s3-sf_5KPa)/(sg_5KPa-sf_5KPa)
27 x3=0.694; //approx .
28 disp(" hence enthalpy at 3 ,")
29 disp(" h3=hf_5KPa+x3*hfg_5KPa in KJ/kg")
30 h3=hf_5KPa+x3*(hg_5KPa-hf_5KPa)
31 disp(" enthalpy at 2 , h2=hg_5KPa=2794.3 KJ/kg")
32 disp(" process 1-4 is isentropic , so s1=s4")
33 s1=sf_5MPa;
34 disp(" s1=sf_5KPa+x4*(sg_5KPa-sf_5KPa)")
35 disp(" so x4=(s1-sf_5KPa)/(sg_5KPa-sf_5KPa)")
36 x4=(s1-sf_5KPa)/(sg_5KPa-sf_5KPa)
37 x4=0.308; //approx .
38 disp(" enthalpy at 4 , h4=hf_5KPa+x4*(hg_5KPa-hf_5KPa)
      in KJ/kg")
39 h4=hf_5KPa+x4*(hg_5KPa-hf_5KPa)
40 disp(" enthalpy at 1 , h1=hf_5MPa in KJ/kg")
41 h1=hf_5MPa
42 disp(" carnot cycle(1-2-3-4-1) efficiency :")
43 disp(" n_carnot=net work/heat added")
44 disp(" n_carnot=((h2-h3)-(h1-h4))/(h2-h1)")
45 h2=hg_5MPa;
46 n_carnot=((h2-h3)-(h1-h4))/(h2-h1)
47 disp(" in percentage")
48 n_carnot=n_carnot*100
49 disp(" so n_carnot=42.95%")
50 disp(" In rankine cycle ,1-2-3-5-6-1 ,")
51 disp(" pump work , h6-h5=vf_5KPa*(p6-p5) in KJ/kg")
52 p6=5000; //boiler pressure in KPa
53 p5=5; //condenser pressure in KPa
54 vf_5KPa*(p6-p5)
55 disp(" h5=hf_5KPa=137.82 KJ/kg")
56 h5=hf_5KPa;
57 disp(" hence h6 in KJ/kg")
58 h6=h5+(vf_5KPa*(p6-p5))
59 disp(" net work in rankine cycle=(h2-h3)-(h6-h5) in KJ
      /kg")
60 (h2-h3)-(h6-h5)
61 disp(" heat added=(h2-h6) in KJ/kg")

```

```

62 (h2-h6)
63 disp("rankine cycle efficiency (n_rankine)="" )
64 n_rankine=((h2-h3)-(h6-h5))/(h2-h6)
65 disp("in percentage")
66 n_rankine=n_rankine*100
67 disp("so n_rankine=36.56%")

```

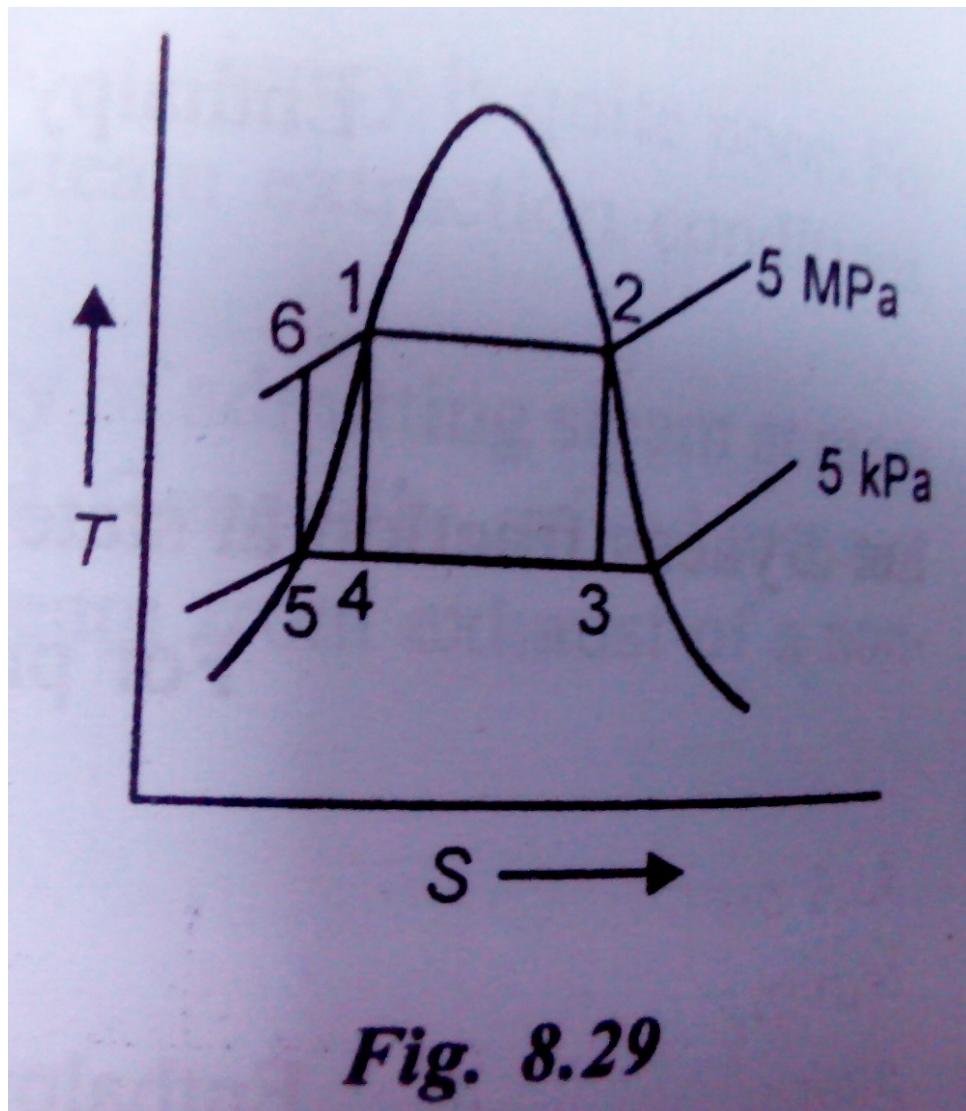
---

**Scilab code Exa 8.3** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 3

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 3")
8 disp("from steam tables ,h2=hg_40bar=3092.5 KJ/kg")
9 h2=3092.5;
10 disp("s2=sg_40bar=6.5821 KJ/kg K")
11 s2=6.5821;
12 disp("h4=hf_0 .05 bar=137.82 KJ/kg , hfg=2423.7 KJ/kg ")
13 h4=137.82;
14 hfg=2423.7;
15 disp("s4=sf_0 .05 bar=0.4764 KJ/kg K, sfg =7.9187 KJ/kg
K")
16 s4=0.4764;
17 sfg=7.9187;
18 disp("v4=vf_0 .05 bar=0.001005 m^3/kg")
19 v4=0.001005;

```



**Fig. 8.29**

Figure 8.2: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 2

```

20 disp("let the dryness fraction at state 3 be x3 ,")
21 disp(" for ideal process ,2-3,s2=s3")
22 s3=s2;
23 disp(" s2=s3=6.5821=sf_0 .05 bar+x3*sfg_0 .05 bar")
24 disp(" so x3=(s2-s4)/(sfg )")
25 x3=(s2-s4)/(sfg)
26 x3=0.7711; //approx .
27 disp("h3=hf_0 .05 bar+x3*hfg_0 .05 bar in KJ/kg")
28 h3=h4+x3*hfg
29 disp(" for pumping process ,")
30 disp("h1-h4=v4*deltap=v4*(p1-p4)")
31 disp(" so h1=h4+v4*(p1-p4) in KJ/kg")
32 p1=40*100; //pressure of steam enter in turbine in
               mPa
33 p4=0.05*100; //pressure of steam leave turbine in mPa
34 h1=h4+v4*(p1-p4)
35 disp("pump work per kg of steam=(h1-h4) in KJ/kg")
36 (h1-h4)
37 disp(" net work per kg of steam =(expansion work-pump
           work)per kg of steam")
38 disp("=(h2-h3)-(h1-h4) in KJ/kg")
39 (h2-h3)-(h1-h4)
40 disp(" cycle efficiency=net work/heat added")
41 ((h2-h3)-(h1-h4))/(h2-h1)
42 disp(" in percentage")
43 ((h2-h3)-(h1-h4))*100/(h2-h1)
44 disp("so net work per kg of steam=1081.74 KJ/kg")
45 disp(" cycle efficiency=36.67%")
46 disp("pump work per kg of steam=4.02 KJ/kg")

```

---

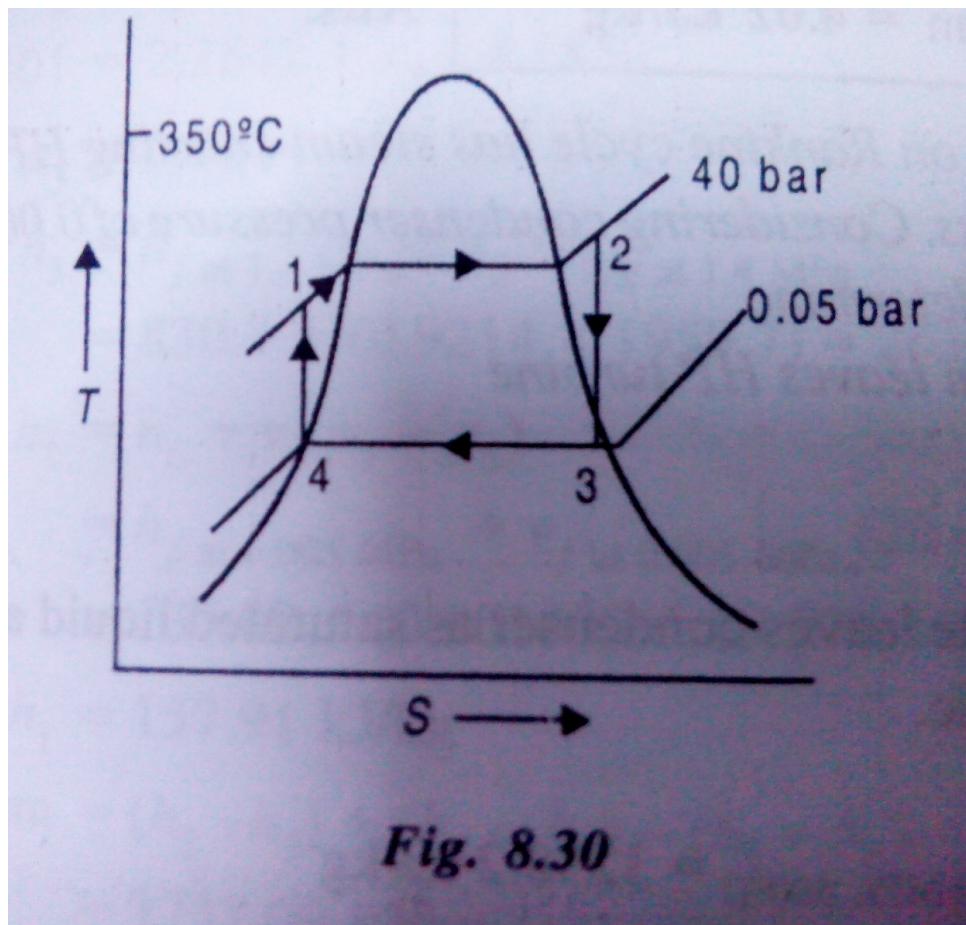


Figure 8.3: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 3

**Scilab code Exa 8.4** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 4

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 4")
8 disp("Let us assume that the condensate leaves
condenser as saturated liquid and the expansion
in turbine and pumping processes are isentropic.")
9 disp("from steam tables ,h2=h_20MPa=3238.2 KJ/kg")
10 h2=3238.2;
11 disp("s2=6.1401 KJ/kg K")
12 s2=6.1401;
13 disp("h5=h_0.005MPa in KJ/kg")
14 disp("from steam tables ,at 0.005 MPa, hf=137.82 KJ/kg
, hfg=2423.7 KJ/kg , sf=0.4764 KJ/kg K, sfg=7.9187 KJ
/kg K")
15 hf=137.82;
16 hfg=2423.7;
17 sf=0.4764;
18 sfg=7.9187;
19 disp("h5=hf+0.9* hfg in KJ/kg")
20 h5=hf+0.9*hfg
21 disp("s5=sf+0.9* sfg in KJ/kg K")
22 s5=sf+0.9*sfg
23 disp("h6=hf=137.82 KJ/kg")
24 h6=137.82;
25 disp("it is given that temperature at state 4 is 500
degree celcius and due to isentropic processes
s4=s5=7.6032 KJ/kg K.The state 4 can be
conveniently located on mollier chart by the
intersection of 500 degree celcius constant")
```

temperature line and entropy value of 7.6032 KJ/kg K and the pressure and enthalpy obtained .but these shall be approximate .")

```
26 disp("The state 4 can also be located by  
interpolation using steam table .The entropy value  
of 7.6032 KJ/kg K lies between the superheated  
steam states given under ,p=1.20 MPa,s at 1.20 MPa  
=7.6027 KJ/kg K")  
27 disp("p=1.40 MPa,s at 1.40 MPa=7.6027 KJ/kg K")  
28 disp("by interpolation state 4 lies at pressure=")  
29 1.20+((1.40-1.20)/(7.6027-7.6759))*(7.6032-7.6759)  
30 disp("=1.399,approx.=1.40 MPa")  
31 disp("thus ,steam leaves HP turbine at 1.40 MPa")  
32 disp("enthalpy at state 4,h4=3474.1 KJ/kg")  
33 h4=3474.1;  
34 disp(" for process 2-33,s2=s3=6.1401 KJ/kg K. The  
state 3 thus lies in wet region as s3<sg at 1.40  
MPa. Let dryness fraction at state 3 be x3.")  
35 s3=s2;  
36 disp(" s3=sf+x3*sfg")  
37 disp("from staem tables ,at 1.4 MPa, sf=2.2842 KJ/kg K  
, sfg=4.1850 KJ/kg K")  
38 sf=2.2842;  
39 sfg=4.1850;  
40 disp(" so x3=(s3-sf)/sfg")  
41 x3=(s3-sf)/sfg  
42 disp("h3=hf+x3*hfg in KJ/kg")  
43 disp(" from steam tables ,at 1.4 MPa, hf=830.3 KJ/kg ,  
hfg=1959.7 KJ/kg")  
44 hf=830.3;  
45 hfg=1959.7;  
46 h3=hf+x3*hfg  
47 disp(" enthalpy at 1,h1=h6+v6*(p1-p6) in KJ/kg")  
48 disp("h1=hf at 0.005MPa+vf at 0.005MPa*(p1-p6)")  
49 disp(" from steam tables , at 0.005 MPa,h6=137.82 KJ/  
kg ,v6=0.001005 m^3/kg")  
50 h6=137.82;  
51 v6=0.001005;
```

```

52 p1=20*1000; //steam entering HP turbine in KPa
53 p6=0.005*1000; //condensor pressure in KPa
54 h1=h6+v6*(p1-p6)
55 disp(" net work per kg steam=(h2-h3)+(h4-h5)-(h1-h6)
      in KJ/kg")
56 (h2-h3)+(h4-h5)-(h1-h6)
57 disp(" heat added per kg of steam=(h2-h1) in KJ/kg")
58 (h2-h1)
59 disp(" thermal efficiency=net work/heat added")
60 ((h2-h3)+(h4-h5)-(h1-h6))/(h2-h1)
61 disp(" in percentage")
62 (((h2-h3)+(h4-h5)-(h1-h6))/(h2-h1))*100
63 disp(" pressure of steam leaving HP turbine=1.40 MPa")
64 disp(" thermal efficiency =56.39%")

```

---

**Scilab code Exa 8.5** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
      Chapter 8 Example 5")
8 P=50*10^3; //output of plant in KW
9 CpW=4.18; //specific heat of water in KJ/kg K
10 Tw_in=15; //cooling water entering condenser
              temperature in degree celcius

```

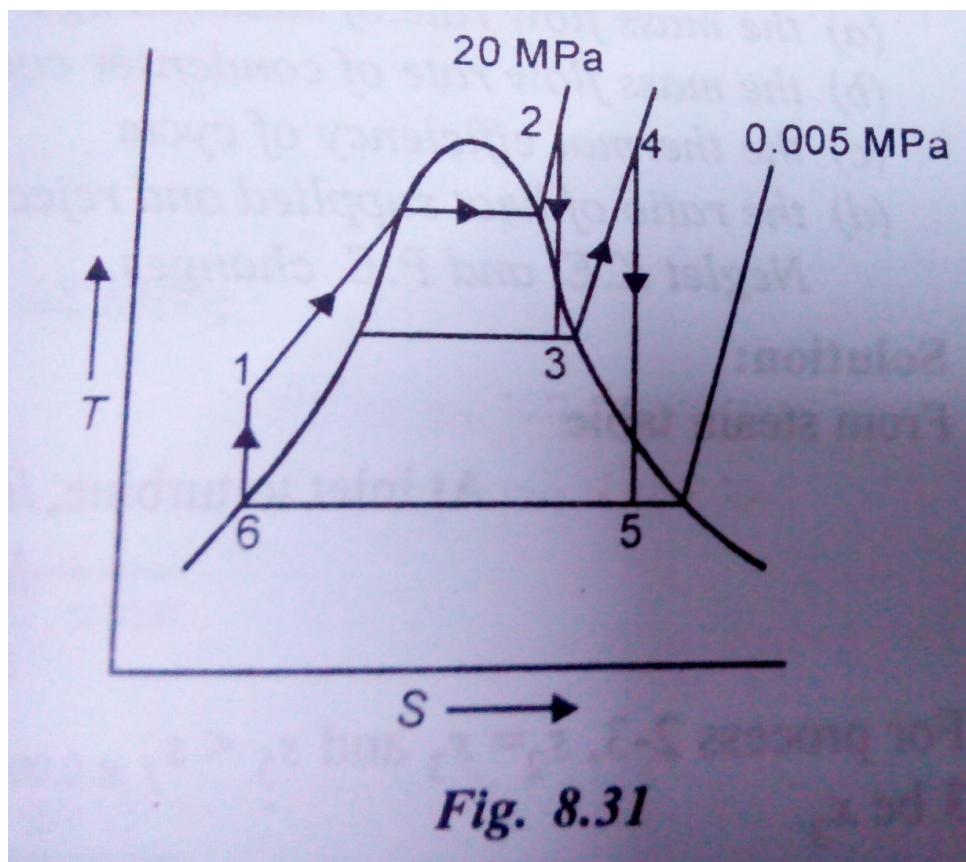


Figure 8.4: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 4

```

11 Tw_out=30; //cooling water leaving condenser
    temperature in degree celcius
12 disp("from steam table ,at inlet to turbine ,")
13 disp("h2=h_10MPa,700 oc")
14 disp("h2=3870.5 KJ/kg ,s2=7.1687 KJ/kg K")
15 h2=3870.5;
16 s2=7.1687;
17 s3=s2;
18 disp(" for process 2-3,s2=s3 and s3<sf at 0.005 MPa
        so state 3 lies in wet region .Let dryness
        fraction at state 3 be x3 .")
19 disp("s3=7.1687=sf at 0.005 MPa+x3*sfg at 0.005 MPa"
)
20 disp("from steam tables ,at 0.005 MPa, sf=0.4764 KJ/kg
        K, sfg =7.9187 KJ/kg")
21 sf=0.4764;
22 sfg=7.9187;
23 disp(" so x3=(s3-sf )/sfg ")
24 x3=(s3-sf)/sfg
25 x3=0.845; //approx .
26 disp("h3=hf at 0.005 MPa+x3*hfg at 0.005 MPa")
27 disp("from steam tables ,at 0.005 MPa, hf=137.82 KJ/kg
        , hfg =2423.7 KJ/kg")
28 hf=137.82;
29 hfg=2423.7;
30 disp("so h3=hf+x3*hfg in KJ/kg")
31 h3=hf+x3*hfg
32 disp("h4=hf at 0.005 MPa")
33 h4=hf;
34 disp("for pumping process ,(h1-h4)=v4*(p1-p4)")
35 disp("from steam tables ,v4=vf at 0.005 MPa=0.001005
        m^3/kg")
36 v4=0.001005;
37 disp("h1=h4+v4*(p1-p4) in KJ/kg")
38 p1=10; //pressure of steam leave boiler in MPa
39 p4=0.005; //pressure of steam leave turbine in MPa
40 h1=h4+v4*(p1-p4)*100
41 disp(" net output per kg of steam ,w_net=(h2-h3)-(h1-

```

```

        h4) in KJ/kg")
42 w_net=(h2-h3)-(h1-h4)
43 disp("mass flow rate of steam ,ms=P/w_net in kg/s")
44 ms=P/w_net
45 ms=29.69; //approx .
46 disp("by heat balance on condenser ,for mass flow
      rate of water being mw kg/s")
47 disp("(h3-h4)*ms=mw*Cpw*(Tw_out-Tw_in)")
48 disp("so mw=(h3-h4)*ms/(Cpw*(Tw_out-Tw_in)) in kg/s"
      )
49 mw=(h3-h4)*ms/(Cpw*(Tw_out-Tw_in))
50 disp("the heat added per kg of steam (q_add)=(h2-h1)
      in KJ/kg")
51 q_add=(h2-h1)
52 disp("thermal efficiency=w_net/q_add")
53 w_net/q_add
54 disp("in percentage")
55 w_net*100/q_add
56 disp("ratio of heat supplied and rejected=(h2-h1)/(
      h3-h4)")
57 (h2-h1)/(h3-h4)
58 disp("mass of flow rate of steam=29.69 kg/s")
59 disp("mass flow rate of condenser cooling water
      =969.79 kg/s")
60 disp("thermal efficiency=45.12%")
61 disp("ratio of heat supplied and rejected=1.822")

```

---

**Scilab code Exa 8.6** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 6

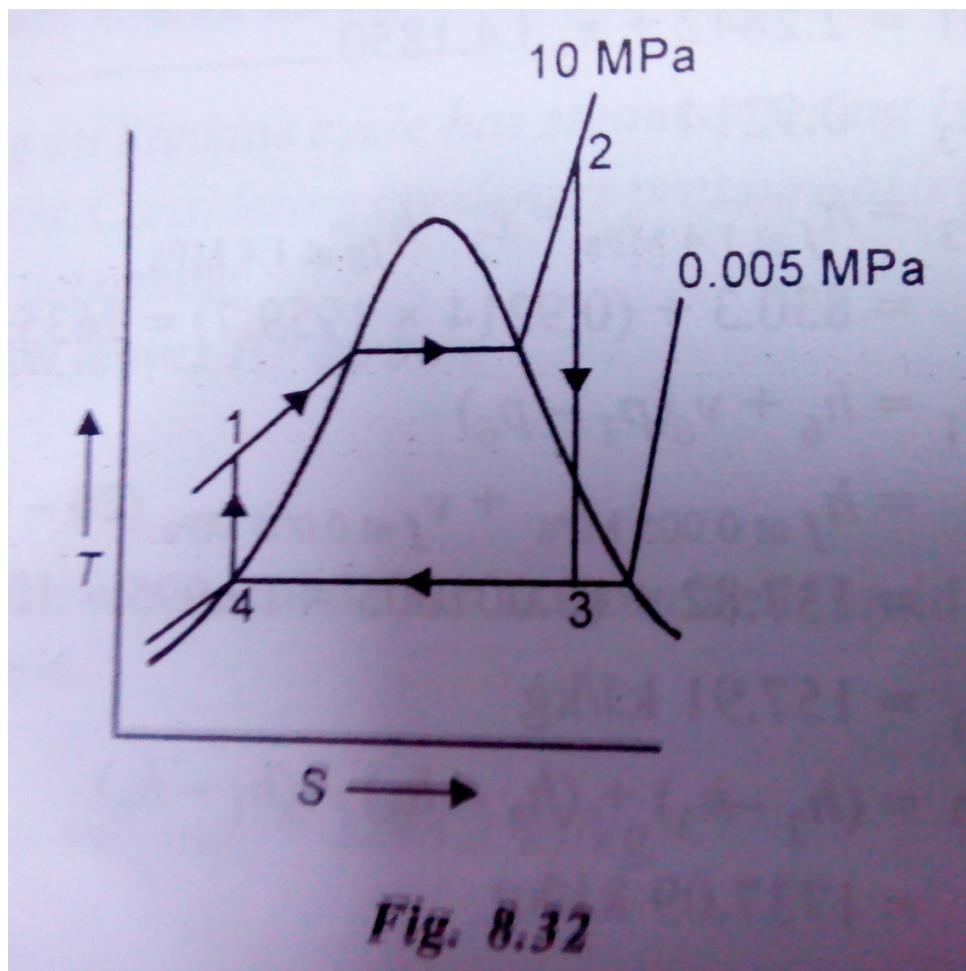


Figure 8.5: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 6")
8 disp("case (a) When there is no feed water heater")
9 disp("Thermal efficiency of cycle=((h2-h3)-(h1-h4))
/(h2-h1)")
10 disp("from steam tables ,h2=h at 200 bar ,650 oc=3675.3
KJ/kg ,s2=s at 200 bar ,650 oc=6.6582 KJ/kg K,h4=hf
at 0.05 bar=137.82 KJ/kg ,v4=vf at 0.05 bar
=0.001005 m^3/kg")
11 h2=3675.3;
12 s2=6.6582;
13 h4=137.82;
14 v4=0.001005;
15 disp(" hf at 0.05 bar=137.82 KJ/kg ,hfg at 0.05 bar
=2423.7 KJ/kg ,sf at 0.05 bar=0.4764 KJ/kg K, sfg
at 0.05 bar=7.9187 KJ/kg K")
16 hf=137.82;
17 hfg=2423.7;
18 sf=0.4764;
19 sfg=7.9187;
20 disp("For process 2-3,s2=s3 . Let dryness fraction at
3 be x3 .")
21 s3=s2;
22 disp("s3=6.6582=sf at 0.05 bar+x3*sfg at 0.05 bar")
23 disp("so x3=(s3-sf)/sfg")
24 x3=(s3-sf)/sfg
25 x3=0.781; //approx .
26 disp("h3=hf at 0.05 bar+x3*hfg at 0.05 bar in KJ/kg"
)
27 h3=hf+x3*hfg
28 disp("For pumping process 4-1,")
29 disp("h1-h4=v4*deltap")

```

```

30 disp("h1=h4+v4*(200-0.5)*10^2 in KJ/kg")
31 h1=h4+v4*(200-0.5)*10^2
32 disp("Thermal efficiency of cycle=")
33 ((h2-h3)-(h1-h4))/(h2-h1)
34 disp("in percentage")
35 ((h2-h3)-(h1-h4))*100/(h2-h1)
36 disp("case (b) When there is only one feed water
      heater working at 8 bar")
37 disp("here ,let mass of steam bled for feed heating
      be m kg")
38 disp("For process 2-6,s2=s6=6.6582 KJ/kg K")
39 s6=s2;
40 disp("Let dryness fraction at state 6 be x6")
41 disp("s6=sf at 8 bar+x6*sfg at 8 bar")
42 disp("from steam tables ,hf at 8 bar=721.11 KJ/kg ,vf
      at 8 bar=0.001115 m^3/kg ,hfg at 8 bar=2048 KJ/kg ,
      sf at 8 bar=2.0462 KJ/kg K, sfg at 8 bar=4.6166 KJ
      /kg K")
43 hf=721.11;
44 vf=0.001115;
45 hfg=2048;
46 sf=2.0462;
47 sfg=4.6166;
48 disp("substituting entropy values ,x6=(s6-sf)/sfg")
49 x6=(s6-sf)/sfg
50 x6=0.999; //approx.
51 disp("h6=hf at at 8 bar+x6*hfg at 8 bar in KJ/kg")
52 h6=hf+x6*hfg
53 disp("Assuming the state of fluid leaving open feed
      water heater to be saturated liquid at 8 bar.h7=
      hf at 8 bar=721.11 KJ/kg")
54 h7=721.11;
55 disp("For process 4-5,h5=h4+v4*(8-.05)*10^2 in KJ/kg
      ")
56 h5=h4+v4*(8-.05)*10^2
57 disp("Applying energy balance at open feed water
      heater ,")
58 disp("m*h6+(1-m)*h5=1*h7")

```

```

59 disp(" so m=(h7-h5)/(h6-h5) in kg")
60 m=(h7-h5)/(h6-h5)
61 disp("For process 7-1,h1=h7+v7*(200-8)*10^2 in KJ/kg
      ")
62 disp(" here h7=hf at 8 bar ,v7=vf at 8 bar")
63 h7=hf;
64 v7=vf;
65 h1=h7+v7*(200-8)*10^2
66 disp(" Thermal efficiency of cycle=((h2-h6)+(1-m)*(h6
      -h3)-{(1-m)*(h5-h4)+(h1-h7)})/(h2-h1)")
67 ((h2-h6)+(1-m)*(h6-h3)-{(1-m)*(h5-h4)+(h1-h7)})/(h2-
      h1)
68 disp(" in percentage")
69 ((h2-h6)+(1-m)*(h6-h3)-{(1-m)*(h5-h4)+(h1-h7)})*
      100/(h2-h1)
70 disp(" case (c) When there are two feed water heaters
      working at 40 bar and 4 bar")
71 disp("here , let us assume the mass of steam at 40
      bar ,4 bar to be m1 kg and m2 kg respectively .")
72 disp("2-10-9-3,s2=s10=s9=s3=6.6582 KJ/kg K")
73 s3=s2;
74 s9=s3;
75 s10=s9;
76 disp("At state 10.s10>sg at 40 bar(6.0701 KJ/kg K) so
      state 10 lies in superheated region at 40 bar
      pressure .")
77 disp("From steam table by interpolation ,T10=370.6oc ,
      so h10=3141.81 KJ/kg")
78 T10=370.6;
79 h10=3141.81;
80 disp("Let dryness fraction at state 9 be x9 so ,")
81 disp("s9=6.6582=sf at 4 bar+x9*sfg at 4 bar")
82 disp("from steam tables ,at 4 bar ,sf=1.7766 KJ/kg K,
      sfg=5.1193 KJ/kg K")
83 sf=1.7766;
84 sfg=5.1193;
85 disp("x9=(s9-sf)/sfg")
86 x9=(s9-sf)/sfg

```

```

87 x9=0.9536; //approx.
88 disp("h9=hf at 4 bar+x9*hfg at 4 bar in KJ/kg")
89 disp("from steam tables ,at 4 bar ,hf=604.74 KJ/kg ,hfg
      =2133.8 KJ/kg")
90 hf=604.74;
91 hfg=2133.8;
92 h9=hf+x9*hfg
93 disp("Assuming the state of fluid leaving open feed
      water heater to be saturated liquid at respective
      pressures i.e.")
94 disp("h11=hf at 4 bar=604.74 KJ/kg ,v11=0.001084 m^3/
      kg=vf at 4 bar")
95 h11=604.74;
96 v11=0.001084;
97 disp("h13=hf at 40 bar=1087.31 KJ/kg ,v13=0.001252 m
      ^3/kg=vf at 40 bar")
98 h13=1087.31;
99 v13=0.001252;
100 disp("For process 4-8,i.e in CEP.")
101 disp("h8=h4+v4*(4-0.05)*10^2 in KJ/kg")
102 h8=h4+v4*(4-0.05)*10^2
103 disp("For process 11-12,i.e in FP2,")
104 disp("h12=h11+v11*(40-4)*10^2 in KJ/kg")
105 h12=h11+v11*(40-4)*10^2
106 disp("For process 13-1_a i.e. in FP1,h1_a=h13+v13
      *(200-40)*10^2 in KJ/kg")
107 h1_a=h13+v13*(200-40)*10^2
108 disp("m1*3141.81+(1-m1)*608.64=1087.31")
109 disp("so m1=(1087.31-608.64)/(3141.81-608.64) in kg")
110 m1=(1087.31-608.64)/(3141.81-608.64)
111 disp("Applying energy balance on open feed water
      heater 1 (OFWH1)")
112 disp("m1*h10+(1-m1)*h12)=1*h13")
113 disp("so m1=(h13-h12)/(h10-h12) in kg")
114 m1=(h13-h12)/(h10-h12)
115 disp("Applying energy balance on open feed water
      heater 2 (OFWH2)")
116 disp("m2*h9+(1-m1-m2)*h8=(1-m1)*h11")

```

```

117 disp(" so m2=(1-m1)*(h11-h8)/(h9-h8) in kg")
118 m2=(1-m1)*(h11-h8)/(h9-h8)
119 disp(" Thermal efficiency of cycle ,n=[{(h2-h10)+(1-m1
    )*(h10-h9)+(1-m1-m2)*(h9-h3)}-{W_CEP+W_FP1+W_FP2
    }] / (h2-h1_a)")
120 disp("W_CEP=(1-m1-m2)*(h8-h4) in KJ/kg steam from
    boiler")
121 W_CEP=(1-m1-m2)*(h8-h4)
122 disp("W_FP1=(h1_a-h13) in KJ/kg of steam from boiler"
    )
123 W_FP1=(h1_a-h13)
124 disp("W_FP2=(1-m1)*(h12-h11) in KJ/kg of steam from
    boiler")
125 W_FP2=(1-m1)*(h12-h11)
126 disp("W_CEP+W_FP1+W_FP2 in KJ/kg of steam from
    boiler")
127 W_CEP+W_FP1+W_FP2
128 disp("n=[{(h2-h10)+(1-m1)*(h10-h9)+(1-m1-m2)*(h9-h3)
    }-{W_CEP+W_FP1+W_FP2}] / (h2-h1_a)")
129 n=[{(h2-h10)+(1-m1)*(h10-h9)+(1-m1-m2)*(h9-h3)}-{W_CEP+W_FP1+W_FP2}]/(h2-h1_a)
130 disp(" in percentage")
131 n=n*100
132 disp(" so cycle thermal efficiency ,na=46.18%")
133 disp(" nb=49.76%")
134 disp(" nc=51.37%")
135 disp(" hence it is obvious that efficiency increases
    with increase in number of feed heaters .")

```

---

**Scilab code Exa 8.7** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
    Chapter 8 Example 7")
8 disp("from steam tables ,")
9 disp("h2=h at 50 bar ,500 oc=3433.8 KJ/kg ,s2=s at 50
    bar ,500 oc=6.9759 KJ/kg K")
10 h2=3433.8;
11 s2=6.9759;
12 disp("s3=s2=6.9759 KJ/kg K")
13 s3=s2;
14 disp("by interpolation from steam tables ,")
15 disp("T3=183.14 oc at 5 bar ,h3=2818.03 KJ/kg ,h4= h at
    5 bar ,400 oc=3271.9 KJ/kg ,s4= s at 5 bar ,400 oc
    =7.7938 KJ/kg K")
16 T3=183.14;
17 h3=2818.03;
18 h4=3271.9;
19 s4=7.7938;
20 disp("for expansion process 4-5,s4=s5=7.7938 KJ/kg K
    ")
21 s5=s4;
22 disp("let dryness fraction at state 5 be x5")
23 disp("s5=sf at 0.05 bar+x5*sfg at 0.05 bar")
24 disp("from steam tables ,at 0.05 bar ,sf=0.4764 KJ/kg
    K, sfg=7.9187 KJ/kg K")
25 sf=0.4764;
26 sfg=7.9187;
27 disp("so x5=(s5-sf)/sfg")
28 x5=(s5-sf)/sfg
29 x5=0.924; //approx .
30 disp("h5=hf at 0.05 bar+x5*hfg at 0.05 bar in KJ/kg"
    )
31 disp("from steam tables ,hf at 0.05 bar=137.82 KJ/kg ,
    hfg at 0.05 bar=2423.7 KJ/kg")
32 hf=137.82;
33 hfg=2423.7;

```

```

34 h5=hf+x5*hfg
35 disp("h6=hf at 0.05 bar=137.82 KJ/kg")
36 h6=137.82;
37 disp("v6=vf at 0.05 bar=0.001005 m^3/kg")
38 v6=0.001005;
39 disp("for process 6-1 in feed pump, h1=h6+v6*(p1-p6)
      in KJ/kg")
40 p1=50; //steam generation pressure in bar
41 p6=0.05; //steam entering temperature in turbine in
             bar
42 h1=h6+v6*(p1-p6)*100
43 disp("cycle efficiency=W_net/Q_add")
44 disp("Wt=(h2-h3)+(h4-h5) in KJ/kg")
45 Wt=(h2-h3)+(h4-h5)
46 disp("W_pump=(h1-h6) in KJ/kg")
47 W_pump=(h1-h6)
48 disp("W_net=Wt-W_pump in KJ/kg")
49 W_net=Wt-W_pump
50 disp("Q_add=(h2-h1) in KJ/kg")
51 Q_add=(h2-h1)
52 disp("cycle efficiency=")
53 W_net/Q_add
54 disp("in percentage")
55 W_net*100/Q_add
56 disp("we know ,1 hp=0.7457 KW")
57 disp("specific steam consumption=0.7457*3600/W_net
      in kg/hp hr")
58 0.7457*3600/W_net
59 disp("work ratio=net work/positive work=W_net/Wt")
60 W_net/Wt
61 disp("so cycle efficiency=45.74%, specific steam
      consumption =1.78 kg/hp hr ,work ratio=0.9967")

```

---

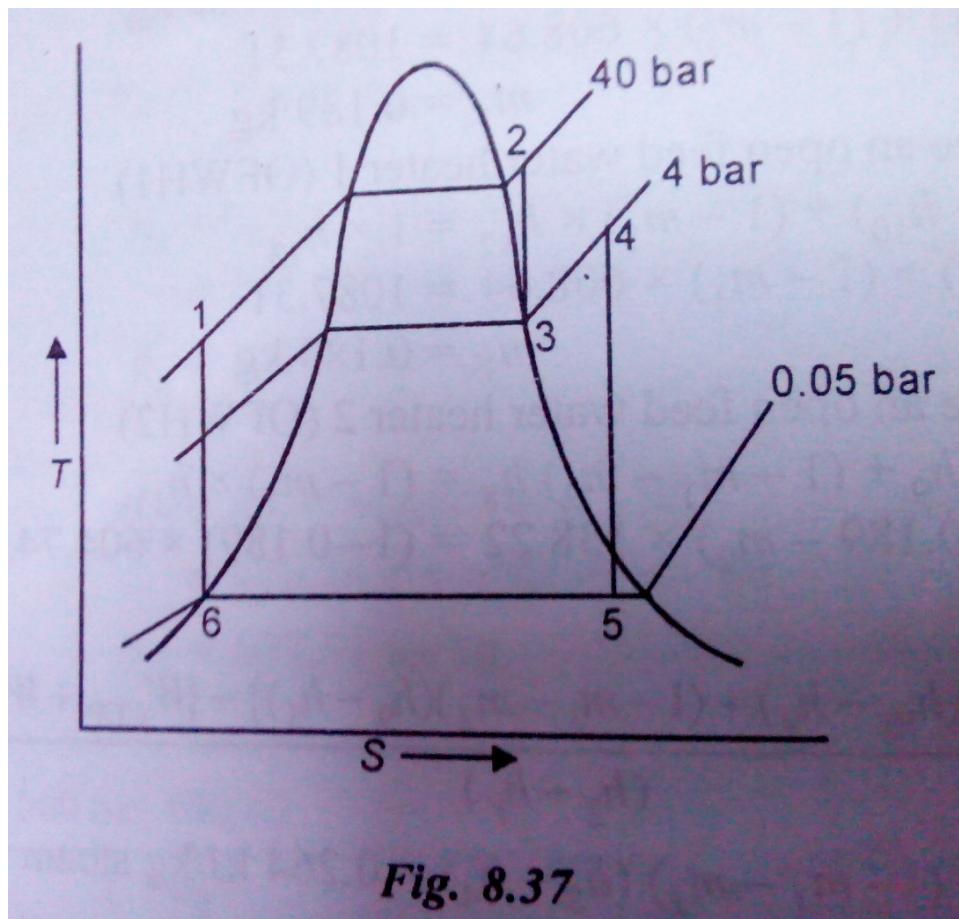


Figure 8.6: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 7

**Scilab code Exa 8.8** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 8

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 8 Example 8")
8 T_cond=115; //condensate temperature in degree
                celcius
9 Cp=4.18; // specific heat at constant pressure in KJ/
            kg K
10 P=30*10^3; //actual alternator output in KW
11 n_boiler=0.9; //boiler efficiency
12 n_alternator=0.98; //alternator efficiency
13 disp("from steam tables ,at state 2,h2=3301.8 KJ/kg ,
      s2=6.7193 KJ/kg K")
14 h2=3301.8;
15 s2=6.7193;
16 disp("h5=hf at 0.05 bar=137.82 KJ/kg,v5= vf at 0.05
      bar=0.001005 m^3/kg")
17 h5=137.82;
18 v5=0.001005;
19 disp("Let mass of steam bled for feed heating be m
      kg/kg of steam generated in boiler.Let us also
      assume that condensate leaves closed feed water
      heater as saturated liquid i.e")
20 disp("h8=hf at 3 bar=561.47 KJ/kg")
21 h8=561.47;
```

```

22 disp(" for process 2-3-4,s2=s3=s4=6.7193 KJ/kg K")
23 s3=s2;
24 s4=s3;
25 disp("Let dryness fraction at state 3 and state 4 be
           x3 and x4 respectively.")
26 disp("s3=6.7193=sf at 3 bar+x3* sfg at 3 bar")
27 disp("from steam tables ,sf=1.6718 KJ/kg K,sfg=5.3201
           KJ/kg K")
28 sf_3bar=1.6718;
29 sfg_3bar=5.3201;
30 disp("so x3=(s3-sf_3bar)/sfg_3bar")
31 x3=(s3-sf_3bar)/sfg_3bar
32 x3=0.949; //approx.
33 disp("s4=6.7193=sf at 0.05 bar+x4* sfg at 0.05 bar")
34 disp("from steam tables ,at 0.05 bar ,sf=0.4764 KJ/kg
           K,sfg=7.9187 KJ/kg K")
35 sf=0.4764;
36 sfg=7.9187;
37 disp("so x4=(s4-sf)/sfg")
38 x4=(s4-sf)/sfg
39 x4=0.788; //approx.
40 disp("thus ,h3=hf at 3 bar+x3* hfg at 3 bar in KJ/kg"
      )
41 disp("here from steam tables ,at 3 bar ,hf_3bar
           =561.47 KJ/kg ,hfg_3bar=2163.8 KJ/kg K")
42 hf_3bar=561.47;
43 hfg_3bar=2163.8;
44 h3=hf_3bar+x3*hfg_3bar
45 disp("h4=hf at 0.05 bar+x4*hfg at 0.05 bar in KJ/kg"
      )
46 disp("from steam tables ,at 0.05 bar ,hf=137.82 KJ/kg ,
           hfg=2423.7 KJ/kg")
47 hf=137.82;
48 hfg=2423.7;
49 h4=hf+x4*hfg
50 disp("assuming process across trap to be of
           throttling type so ,h8=h9=561.47 KJ/kg .Assuming v5
           =v6 ,")

```

```

51 h9=h8;
52 v6=v5;
53 disp(" pumping work=(h7-h6)=v5*(p1-p5) in KJ/kg")
54 p1=60; // pressure of steam in high pressure turbine
      in bar
55 p5=0.05; // pressure of steam in low pressure turbine
      in bar
56 v5*(p1-p5)*100
57 disp(" for mixing process between condenser and feed
      pump,")
58 disp("(1-m)*h5+m*h9=1*h6")
59 disp(" h6=m(h9-h5)+h5")
60 disp(" we get , h6=137.82+m*423.65")
61 disp(" therefore h7=h6+6.02=143.84+m*423.65")
62 disp(" Applying energy balance at closed feed water
      heater ;")
63 disp("m*h3+(1-m)*h7=m*h8+(Cp*T_cond)")
64 disp(" so (m*2614.92)+(1-m)*(143.84+m*423.65)=m
      *561.47+480.7")
65 disp(" so m=0.144 kg")
66 m=0.144;
67 h6=137.82+m*423.65;
68 h7=143.84+m*423.65;
69 disp("steam bled for feed heating=0.144 kg/kg steam
      generated")
70 disp("The net power output , W_net=(h2-h3)+(1-m)*(h3-
      h4)-(1-m)*(h7-h6) in KJ/kg steam generated")
71 W_net=(h2-h3)+(1-m)*(h3-h4)-(1-m)*(h7-h6)
72 disp("mass of steam required to be generated=in kg/s
      ")
73 P/(n_alternator*W_net)
74 disp(" or in kg/hr")
75 26.23*3600
76 disp("so capacity of boiler required=94428 kg/hr")
77 disp(" overall thermal efficiency=W_net/Q_add")
78 disp(" here Q_add=(h2-h1)/n_boiler in KJ/kg")
79 Q_add=(h2-Cp*T_cond)/n_boiler
80 disp(" overall thermal efficiency=")

```

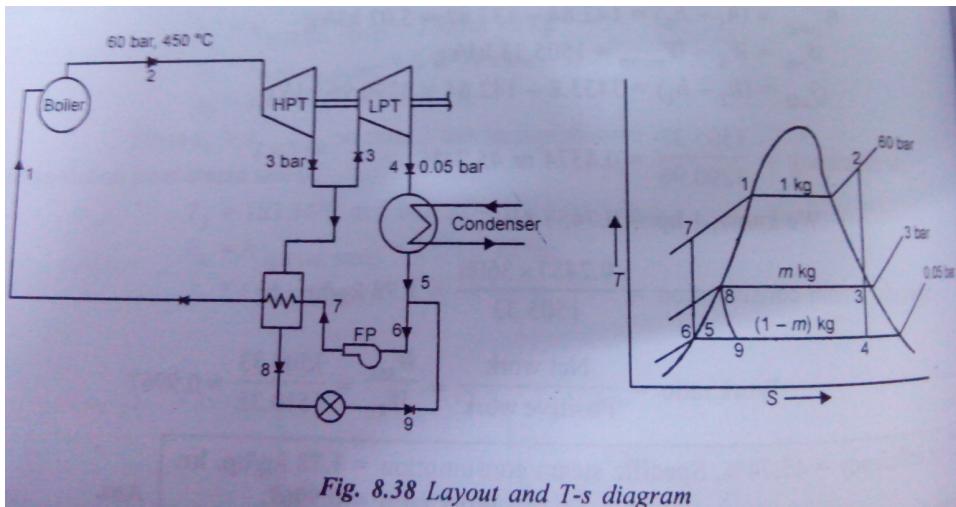


Fig. 8.38 Layout and T-s diagram

Figure 8.7: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 8

```

81 W_net/Q_add
82 disp("in percentage")
83 W_net*100/Q_add
84 disp("so overall thermal efficiency =37.24%")

```

---

**Scilab code Exa 8.9** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 9

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;

```

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 9")
8 P=15*10^3; //turbine output in KW
9 disp("At inlet to first turbine stage ,h2=3230.9 KJ/
kg ,s2=6.9212 KJ/kg K")
10 h2=3230.9;
11 s2=6.9212;
12 disp("For ideal expansion process ,s2=s3")
13 s3=s2;
14 disp("By interpolation ,T3=190.97 degree celcius from
superheated steam tables at 6 bar ,h3=2829.63 KJ/
kg")
15 T3=190.97;
16 h3=2829.63;
17 disp("actual state at exit of first stage ,h3_a=h2
-0.8*(h2-h3) in KJ/kg")
18 h3_a=h2-0.8*(h2-h3)
19 disp("actual state 3_a shall be at 232.78 degree
celcius ,6 bar ,so s3_a=7.1075 KJ/kg K")
20 s3_a=7.1075;
21 disp("for second stage ,s3_a=s4;By interpolation ,s4
=7.1075=sf at 1 bar+x4*sfg at 1 bar")
22 s4=7.1075;
23 disp("from steam tables ,at 1 bar ,sf=1.3026 KJ/kg K,
sfg=6.0568 KJ/kg K")
24 sf=1.3026;
25 sfg=6.0568;
26 disp("so x4=(s4-sf)/sfg")
27 x4=(s4-sf)/sfg
28 x4=0.958; //approx.
29 disp("h4=hf at 1 bar+x4*hfg at 1 bar in KJ/kg")
30 disp("from steam tables ,at 1 bar ,hf=417.46 KJ/kg ,hfg
=2258.0 KJ/kg")
31 hf=417.46;
32 hfg=2258.0;
33 h4=hf+x4*hfg
34 disp("actual enthalpy at exit from second stage ,h4_a
=h3_a - .8*(h3_a-h4) in KJ/kg")

```

```

35 h4_a=h3_a-.8*(h3_a-h4)
36 disp(" actual dryness fraction ,x4_a=>h4_a=hf at 1 bar
      +x4_a*hfg at 1 bar")
37 disp(" so x4_a=(h4_a-hf)/hfg")
38 x4_a=(h4_a-hf)/hfg
39 disp(" x4_a=0.987, actual entropy ,s4_a=7.2806 KJ/kg K"
      )
40 s4_a=7.2806;
41 disp(" for third stage ,s4_a=7.2806=sf at 0.075 bar+x5
      *sfg at 0.075 bar")
42 disp(" from steam tables ,at 0.075 bar ,sf=0.5764 KJ/kg
      K, sfg =7.6750 KJ/kg K")
43 sf=0.5764;
44 sfg=7.6750;
45 disp(" so x5=(s4_a-sf)/sfg")
46 x5=(s4_a-sf)/sfg
47 x5=0.8735; //approx.
48 disp(" h5=2270.43 KJ/kg")
49 h5=2270.43;
50 disp(" actual enthalpy at exit from third stage ,h5_a=
      h4_a -0.8*(h4_a-h5) in KJ/kg")
51 h5_a=h4_a-0.8*(h4_a-h5)
52 disp(" Let mass of steam bled out be m1 and m2 kg at
      6 bar ,1 bar respectively .")
53 disp("By heat balance on first closed feed water
      heater ,( see schematic arrangement )")
54 disp("h11=hf at 6 bar=670.56 KJ")
55 h11=670.56;
56 disp("m1*h3_a+h10=m1*h11+4.18*150")
57 disp("(m1*2829.63)+h10=(m1*670.56)+627")
58 disp("h10+2159.07*m1=627")
59 disp("By heat balance on second closed feed water
      heater ,( see schematic arrangement )")
60 disp("h7=hf at 1 bar=417.46 KJ/kg")
61 h7=417.46;
62 disp("m2*h4+(1-m1-m2)*4.18*38=(m1+m2)*h7+4.18*95*(1-
      m1-m2)")
63 disp("m2*2646.4+(1-m1-m2)*158.84=((m1+m2)*417.46)

```

```

        +(397.1*(1-m1-m2))")
64 disp("m2*2467.27-m1*179.2-238.26=0")
65 disp("heat balance at point of mixing ,")
66 disp("h10=(m1+m2)*h8+(1-m1-m2)*4.18*95")
67 disp("neglecting pump work , h7=h8")
68 disp("h10=m2*417.46+(1-m1-m2)*397.1")
69 disp("substituting h10 and solving we get ,m1=0.1293
      kg and m2=0.1059 kg/kg of steam generated")
70 m1=0.1293;
71 m2=0.1059;
72 disp("Turbine output per kg of steam generated ,Wt=(h2-h3_a)+(1-m1)*(h3_a-h4_a)+(1-m1-m2)*(h4_a-h5_a)
      in KJ/kg of steam generated")
73 Wt=(h2-h3_a)+(1-m1)*(h3_a-h4_a)+(1-m1-m2)*(h4_a-h5_a
      )
74 disp("Rate of steam generation required=P/Wt in kg/s
      ")
75 P/Wt
76 disp("in kg/hr")
77 P*3600/Wt
78 disp("capacity of drain pump i.e. FP shown in layout
      =(m1+m2)*69192 in kg/hr")
79 (m1+m2)*69192
80 disp("so capacity of drain pump=16273.96 kg/hr")

```

---

**Scilab code Exa 8.10** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 10

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

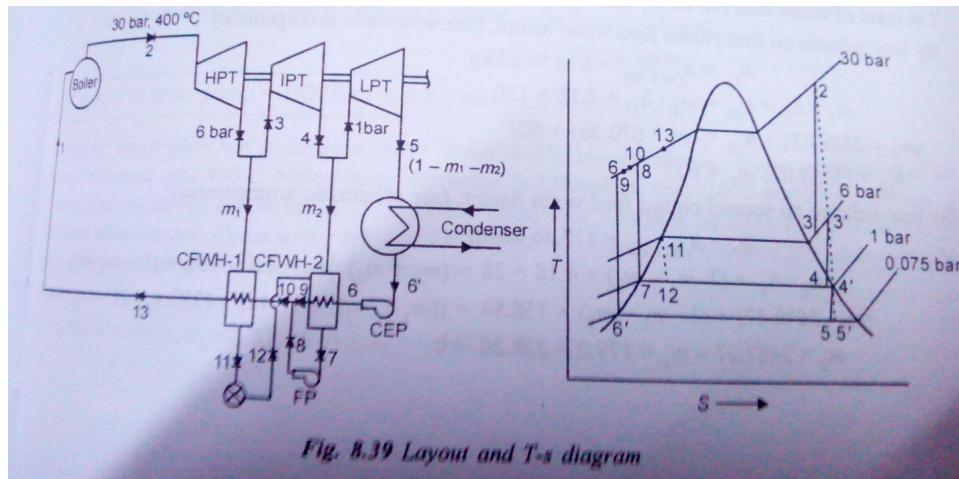


Fig. 8.39 Layout and  $T-s$  diagram

Figure 8.8: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 9

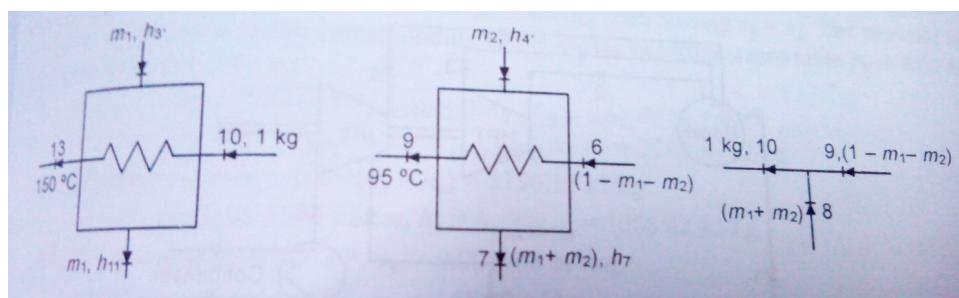


Figure 8.9: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 9

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 10")
8 disp("at inlet to HP turbine ,h2=3287.1 KJ/kg ,s2
=6.6327 KJ/kg K")
9 h2=3287.1;
10 s2=6.6327;
11 disp("By interpolation state 3 i.e. for isentropic
expansion between 2-3 lies at 328.98oc at 30 bar
.h3=3049.48 KJ/kg")
12 h3=3049.48;
13 disp("actual enthalpy at 3_a ,h3_a=h2 - 0.80*(h2-h3) in
KJ/kg")
14 h3_a=h2 - 0.80*(h2-h3)
15 disp("enthalpy at inlet to LP turbine ,h4=3230.9 KJ/
kg ,s4=6.9212 KJ K")
16 h4=3230.9;
17 s4=6.9212;
18 disp("for ideal expansion from 4-6,s4=s6 .Let dryness
fraction at state 6 be x6 .")
19 s6=s4;
20 disp("s6=6.9212=sf at 0.075 bar+x6* sfg at 0.075 bar
in KJ/kg K")
21 disp("from steam tables ,at 0.075 bar ,sf=0.5764 KJ/kg
K, sfg=7.6750 KJ/kg K")
22 sf=0.5764;
23 sfg=7.6750;
24 disp("so x6=(s6-sf) / sfg ")
25 x6=(s6-sf) / sfg
26 x6=0.827; //approx .
27 disp("h6=hf at 0.075 bar+x6*hfg at 0.075 bar in KJ/
kg K")
28 disp("from steam tables ,at 0.075 bar ,hf=168.79 KJ/kg
, hfg=2406.0 KJ/kg")
29 hf =168.79;
30 hfg=2406.0;

```

```

31 h6=hf+x6*hfg
32 disp(" for actual expansion process in LP turbine .")
33 disp(" h6_a=h4-0.85*(h4-h6) in KJ/kg")
34 h6_a=h4-0.85*(h4-h6)
35 disp(" Ideally , enthalpy at bleed point can be
        obtained by locating state 5 using s5=s4 . The
        pressure at bleed point shall be saturation
        pressure corresponding to the 140oc i.e from
        steam tables . Let dryness fraction at state 5 be
        x5 . ")
36 p5=3.61;
37 s5=s4;
38 disp(" s5_a=6.9212=sf at 140oc+x5*sfg at 140oc")
39 disp(" from steam tables , at 140oc , sf=1.7391 KJ/kg K,
        sfg=5.1908 KJ/kg K")
40 sf=1.7391;
41 sfg=5.1908;
42 disp(" so x5=(s5-sf)/sfg")
43 x5=(s5-sf)/sfg
44 x5=0.99; //approx .
45 disp(" h5=hf at 140oc+x5*hfg at 140oc in KJ/kg")
46 disp(" from steam tables , at 140oc , hf=589.13 KJ/kg , hfg
        =2144.7 KJ/kg")
47 hf=589.13;
48 hfg=2144.7;
49 h5=hf+x5*hfg
50 disp(" actual enthalpy , h5_a=h4-0.85*(h4-h5) in KJ/kg")
51 h5_a=h4-0.85*(h4-h5)
52 disp(" enthalpy at exit of open feed water heater , h9=
        hf at 30 bar=1008.42 KJ/kg")
53 h9=1008.42;
54 disp(" specific volume at inlet of CEP , v7=0.001008 m
        ^3/kg")
55 v7=0.001008;
56 disp(" enthalpy at inlet of CEP , h7=168.79 KJ/kg")
57 h7=168.79;
58 disp(" for pumping process 7-8 , h8=h7+v7*(3.61 - 0.075)
        *10^2 in KJ/kg")

```

```

59 h8=h7+v7*(3.61-0.075)*10^2
60 disp(" Applying energy balance at open feed water
      heater.Let mass of bled steam be m kg per kg of
      steam generated .")
61 disp("m*h5+(1-m)*h8=h9")
62 disp(" so m=(h9-h8)/(h5-h8) in kg /kg of steam
      generated")
63 m=(h9-h8)/(h5-h8)
64 disp("For process on feed pump,9-1,v9=vf at 140oc
      =0.00108 m^3/kg")
65 v9=0.00108;
66 disp("h1=h9+v9*(70 -3.61)*10^2 in KJ/kg")
67 h1=h9+v9*(70-3.61)*10^2
68 disp("Net work per kg of steam generated ,W_net=(h2-
      h3_a)+(h4-h5_a)+(1-m)*(h5_a-h6_a)-{(1-m)*(h8-h7)
      +(h1-h9)}in KJ/kg steam generated")
69 W_net=(h2-h3_a)+(h4-h5_a)+(1-m)*(h5_a-h6_a)-{(1-m)*(
      h8-h7)+(h1-h9)}
70 disp(" heat added per kg of steam generated ,q_add=(h2
      -h1)+(h4-h3_a) in KJ/kg of steam generated")
71 q_add=(h2-h1)+(h4-h3_a)
72 disp("Thermal efficiency ,n=W_net/q_add")
73 n=W_net/q_add
74 disp(" in percentage")
75 n=n*100
76 disp("so thermal efficiency =39.03%")
77 disp("NOTE=>In this question there is some
      calculation mistake while calculating W_net and
      q_add in book , which is corrected above and the
      answers may vary .")

```

---

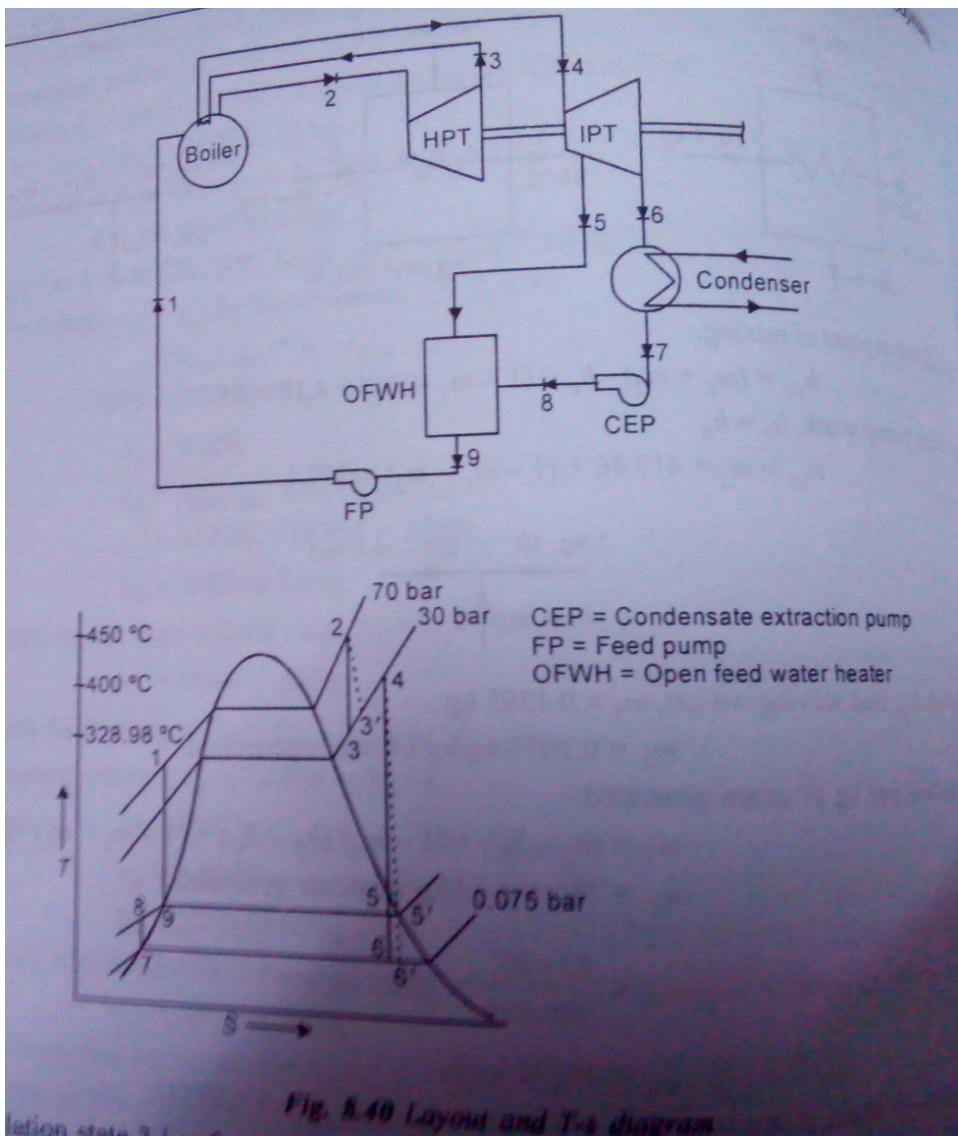


Fig. 8.40 Layout and T-s diagram

Figure 8.10: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 10

**Scilab code Exa 8.11** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 11

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 11")
8 disp("Enthalpy of steam entering ST1, h2=3308.6 KJ/kg
, s2=6.3443 KJ/kg K")
9 h2=3308.6;
10 s2=6.3443;
11 disp("for isentropic expansion 2-3-4-5, s2=s3=s4=s5")
12 s3=s2;
13 s4=s3;
14 s5=s4;
15 disp("Let dryness fraction of states 3,4 and 5 be x3
, x4 and x5")
16 disp("s3=6.3443=sf at 10 bar+x3*sfg at 10 bar")
17 disp("so x3=(s3-sf)/sfg")
18 disp("from steam tables ,at 10 bar ,sf=2.1387 KJ/kg K,
sfg=4.4478 KJ/kg K")
19 sf=2.1387;
20 sfg=4.4478;
21 x3=(s3-sf)/sfg
22 x3=0.945; //approx.
23 disp("h3=hf+x3*hfg in KJ/kg")
24 disp("from steam tables ,hf=762.81 KJ/kg ,hfg=2015.3
KJ/kg")
25 hf=762.81;
26 hfg=2015.3;
27 h3=hf+x3*hfg
28 disp("s4=6.3443=sf at 1.5 bar+x4*sfg at 1.5 bar")
29 disp("so x4=(s4-sf)/sfg")
30 disp("from steam tables ,at 1.5 bar ,sf=1.4336 KJ/kg K")
```

```

        , sfg = 5.7897 KJ/kg K" )
31 sf = 1.4336;
32 sfg = 5.7897;
33 x4 = (s4 - sf) / sfg
34 x4 = 0.848; // approx .
35 disp (" so h4=hf+x4*hfg in KJ/kg" )
36 disp (" from steam tables , at 1.5 bar , hf=467.11 KJ/kg ,
          hfg=2226.5 KJ/kg" )
37 hf = 467.11;
38 hfg = 2226.5;
39 h4 = hf + x4 * hfg
40 disp (" s5=6.3443=sf at 0.05 bar+x5*sfg at 0.05 bar" )
41 disp (" so x5=(s5-sf)/sfg" )
42 disp (" from steam tables , at 0.05 bar , sf=0.4764 KJ/kg
          K, sfg = 7.9187 KJ/kg K" )
43 sf = 0.4764;
44 sfg = 7.9187;
45 x5 = (s5 - sf) / sfg
46 x5 = 0.739; // approx .
47 disp (" h5=hf+x5*hfg in KJ/kg" )
48 disp (" from steam tables , at 0.05 bar , hf=137.82 KJ/kg ,
          hfg=2423.7 KJ/kg" )
49 hf = 137.82;
50 hfg = 2423.7;
51 h5 = hf + x5 * hfg
52 disp (" h6=hf at 0.05 bar=137.82 KJ/kg" )
53 h6 = 137.82;
54 disp (" v6=vf at 0.05 bar=0.001005 m^3/kg" )
55 v6 = 0.001005;
56 disp (" h7=h6+v6*(1.5-0.05)*10^2 in KJ/kg" )
57 h7 = h6 + v6 * (1.5 - 0.05) * 10 ^ 2
58 disp (" h8=hf at 1.5 bar=467.11 KJ/kg" )
59 h8 = 467.11;
60 disp (" v8=0.001053 m^3/kg=vf at 1.5 bar" )
61 v8 = 0.001053;
62 disp (" h9=h8+v8*(150-1.5)*10^2 in KJ/kg" )
63 h9 = h8 + v8 * (150 - 1.5) * 10 ^ 2
64 disp (" h10=hf at 150 bar=1610.5 KJ/kg" )

```

```

65 h10=1610.5;
66 disp("v10=0.001658 m^3/kg=vf at 150 bar")
67 v10=0.001658;
68 disp("h12=h10+v10*(150-10)*10^2 in KJ/kg")
69 h12=h10+v10*(150-10)*10^2
70 disp("Let mass of steam bled out at 10 bar ,1.5 bar
      be m1 and m2 per kg of steam generated .")
71 disp("Heat balance on closed feed water heater
      yields ,")
72 disp("m1*h3+(1-m)*h9=m1*h10+(1-m1)*4.18*150")
73 disp("so m1=(4.18*150-h9)/(h3-h9-h10+4.18*150) in kg/
      kg of steam generated .")
74 m1=(4.18*150-h9)/(h3-h9-h10+4.18*150)
75 disp("heat balance on open feed water can be given
      as under ,")
76 disp("m2*h4+(1-m1-m2)*h7=(1-m1)*h8")
77 disp("so m2=((1-m1)*(h8-h7))/(h4-h7) in kg/kg of
      steam")
78 m2=((1-m1)*(h8-h7))/(h4-h7)
79 disp("for mass flow rate of 300 kg/s=>m1=36 kg/s ,m2
      =39 kg/s")
80 disp("For mixing after closed feed water heater ,")
81 disp("h1=(4.18*150)*(1-m1)+m1*h12 in KJ/kg")
82 h1=(4.18*150)*(1-m1)+m1*h12
83 disp("Net work output per kg of steam generated=
      W_ST1+W_ST2+W_ST3-{W_CEP+W_FP+W_FP2}")
84 disp("W_net=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)
      -{(1-m1-m2)*(h7-h6)+(1-m1)*(h9-h8)+(m1*(h12-h10)) }
      } in KJ/kg of steam generated .")
85 W_net=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)-{(1-
      m1-m2)*(h7-h6)+(1-m1)*(h9-h8)+(m1*(h12-h10)) }
86 disp("heat added per kg of steam generated ,q_add=(h2
      -h1) in KJ/kg")
87 q_add=(h2-h1)
88 disp("cycle thermal efficiency ,n=W_net/q_add")
89 n=W_net/q_add
90 disp("in percentage")
91 n=n*100

```

```
92 disp("Net power developed in KW=1219*300 in KW")
93 1219*300
94 disp("cycle thermal efficiency =47.6%")
95 disp("Net power developed=365700 KW")
```

---

**Scilab code Exa 8.12** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 12

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 12")
8 P=100*10^3; //net power output in KW
9 disp("At inlet to HPT, h2=3373.7 KJ/kg , s2=6.5966 KJ/
kg K")
10 h2=3373.7;
11 s2=6.5966;
12 disp("For isentropic expansion between 2-3-4-5,s2=s3
=s4=s5")
13 s3=s2;
14 s4=s3;
15 s5=s4;
16 disp("state 3 lies in superheated region as s3>s4 at
20 bar.By interpolation from superheated steam
table ,T3=261.6oc .Enthalpy at 3 ,h3=2930.57 KJ/kg")
```

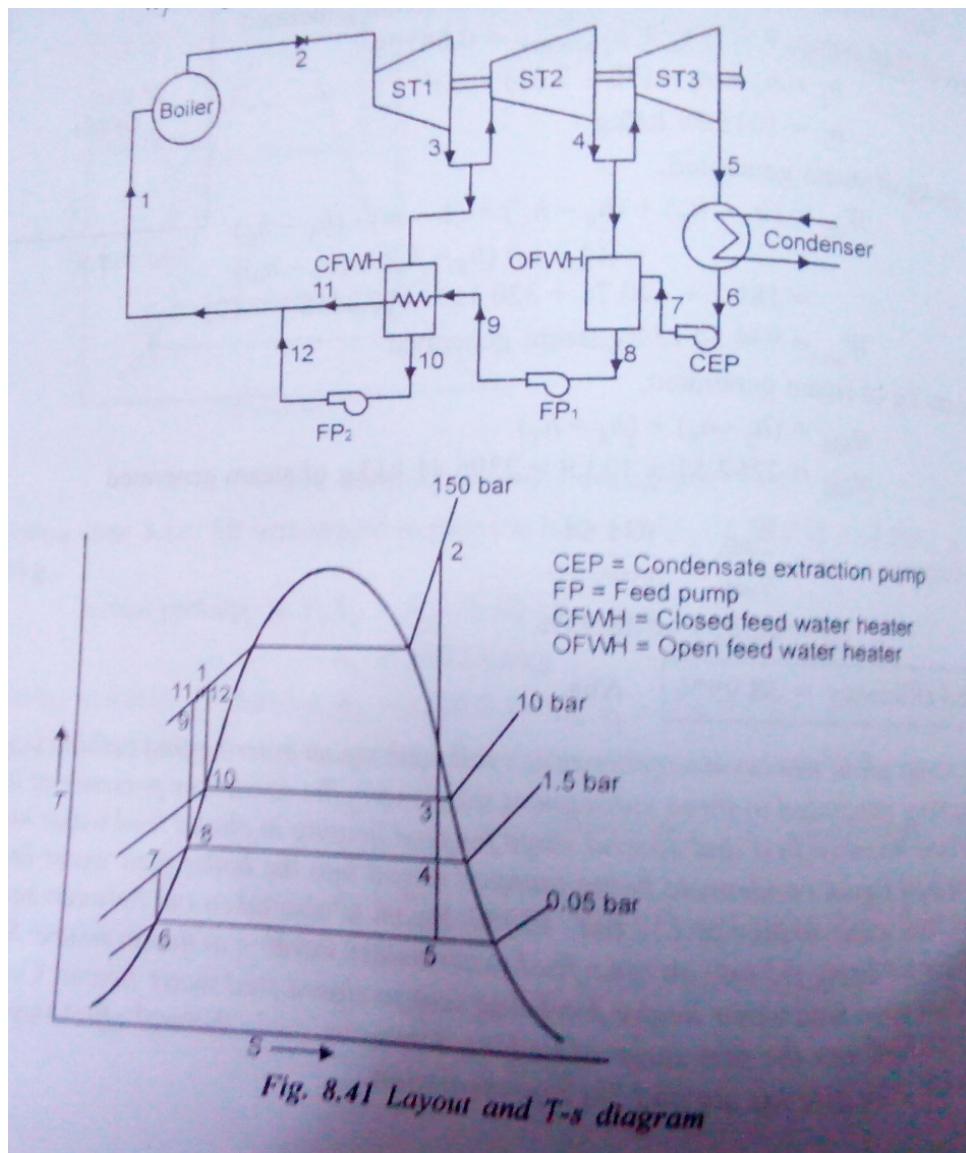


Figure 8.11: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 11

```

17 T3=261.6;
18 h3=2930.57;
19 disp("since s4<sg at 4 bar so state 4 and 5 lies in
      wet region .")
20 disp("Let dryness fraction at state 4 ans 5 be x4
      and x5 .")
21 disp("s4=6.5966=sf at 4 bar+x4*sfg at 4 bar")
22 disp("from steam tables ,at 4 bar ,sf=1.7766 KJ/kg K,
      sfg=5.1193 KJ/kg K")
23 sf=1.7766;
24 sfg=5.1193;
25 disp("x4=(s4-sf)/sfg")
26 x4=(s4-sf)/sfg
27 x4=0.941; //approx .
28 disp("h4=hf at 4 bar+x4*hfg at 4 bar in KJ/kg")
29 disp("from steam tables ,at 4 bar ,hf=604.74 KJ/kg ,hfg
      =2133.8 KJ/kg")
30 hf=604.74;
31 hfg=2133.8;
32 h4=hf+x4*hfg
33 disp("for state 5 ,")
34 disp("s5=6.5966=sf at 0.075 bar+x5*sfg at 0.075 bar"
      )
35 disp("from steam tables ,at 0.075 bar ,sf=0.5764 KJ/kg
      K, sfg=7.6750 KJ/kg K")
36 sf=0.5764;
37 sfg=7.6750;
38 disp("x5=(s5-sf)/sfg")
39 x5=(s5-sf)/sfg
40 x5=0.784; //approx .
41 disp("h5=hf at 0.075 bar+x5*hfg at 0.075 bar in KJ/
      kg")
42 disp("from steam tables ,at 0.075 bar ,hf=168.76 KJ/kg
      ,hfg=2406.0 KJ/kg")
43 hf=168.76;
44 hfg=2406.0;
45 h5=hf+x5*hfg
46 disp("Let mass of steam bled at 20 bar be m1 and m2")

```

```

        per kg of steam generated .")
47 disp("h10=hf at 20 bar=908.76 KJ/kg ,h8=hf at 4 bar
      =604.74 KJ/kg")
48 h10=908.76;
49 h8=604.74;
50 disp("At trap h10=h11=908.79 KJ/kg")
51 h11=h10;
52 disp("At condensate extraction pump ,(CEP) ,h7-h6=v6
      *(4-0.075)*10^2 in KJ/kg")
53 disp(" here v6=vf at 0.075 bar=0.001008 m^3/kg ,h6=hf
      at 0.075 bar=168.79 KJ/kg")
54 v6=0.001008;
55 h6=168.79;
56 disp(" so h7=h6+v6*(4-0.075)*10^2 in KJ/kg")
57 h7=h6+v6*(4-0.075)*10^2
58 disp("At feed pump ,(FP) ,h9-h8=v8*(20-4)*10^2 in KJ/
      kg")
59 disp(" here v8=vf at 4 bar=0.001084 m^3/kg ,h8=hf at 4
      bar=604.74 KJ/kg")
60 v8=0.001084;
61 h8=604.74;
62 disp(" so h9=h8+v8*(20-4)*10^2 in KJ/kg")
63 h9=h8+v8*(20-4)*10^2
64 disp("Let us apply heat balance at closed feed water
      heater ,")
65 disp("m1*h3+h9=m1*h10+4.18*200")
66 disp("so m1=(4.18*200-h9)/(h3-h10) in kg")
67 m1=(4.18*200-h9)/(h3-h10)
68 m1=0.114; //approx .
69 disp("Applying heat balance at open feed water ,")
70 disp("m1*h11+m2*h4+(1-m1-m2)*h7=h8")
71 disp("so m2=(h8-m1*h11-h7+m1*h7)/(h4-h7) in kg")
72 m2=(h8-m1*h11-h7+m1*h7)/(h4-h7)
73 m2=0.144; //approx .
74 disp("Net work per kg steam generated ,")
75 disp("w_net=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)
      -{(1-m1-m2)*(h7-h6)+(h9-h8)} in KJ/kg")
76 w_net=(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)*(h4-h5)-{(1-

```

```

        m1-m2)*(h7-h6)+(h9-h8)}
77 disp("Heat added per kg steam generated , q_add=(h2-h1
      ) in KJ/kg")
78 h1=4.18*200;
79 q_add=(h2-h1)
80 disp("Thermal efficiency=w_net/q_add")
81 w_net/q_add
82 disp("in percentage")
83 w_net*100/q_add
84 disp("steam generation rate=P/w_net in kg/s")
85 P/w_net
86 disp("so thermal efficiency=44.78%")
87 disp("steam generation rate=87.99 kg/s")
88 disp("a> For the reheating introduced at 20 bar up
      to 400oc.The modified cycle representation is
      shown on T-S diagram by 1-2-3-3_a-4_a-5_a
      -6-7-8-9-10-11")
89 disp("At state 2,h2=3373.7 KJ/kg ,s2=6.5966 KJ/kg K")
90 h2=3373.7;
91 s2=6.5966;
92 disp("At state 3,h3=2930.57 KJ/kg")
93 h3=2930.57;
94 disp("At state 3_a ,h3_a=3247.6 KJ/kg ,s3_a=7.1271 KJ/
      kg K")
95 h3_a=3247.6;
96 s3_a=7.1271;
97 disp("At state 4_a and 5_a ,s3_a=s4_a=s5_a=7.1271 KJ/
      kg K")
98 s4_a=s3_a;
99 s5_a=s4_a;
100 disp("From steam tables by interpolation state 4_a
      is seen to be at 190.96oc at 4 bar ,h4_a=2841.02
      KJ/kg")
101 h4_a=2841.02;
102 disp("Let dryness fraction at state 5_a be x5 ,")
103 disp("s5_a=7.1271=sf at 0.075 bar+x5_a*sfg at 0.075
      bar")
104 disp("from steam tables ,at 0.075 bar ,sf=0.5764 KJ/kg

```

```

        K, sfg =7.6750 KJ/kg K")
105 disp(" so x5_a=(s5_a-sf)/sfg")
106 x5_a=(s5_a-sf)/sfg
107 x5_a=0.853; //approx.
108 disp(" h5_a=hf at 0.075 bar+x5_a*hfg at 0.075 bar in
        KJ/kg")
109 disp(" from steam tables ,at 0.075 bar ,hf=168.76 KJ/kg
        ,hfg=2406.0 KJ/kg")
110 h5_a=hf+x5_a*hfg
111 disp(" Let mass of bled steam at 20 bar and 4 bar be
        m1_a,m2_a per kg of steam generated . Applying heat
        balance at closed feed water heater .")
112 disp(" m1_a*h3+h9=m1*h10+4.18*200")
113 disp(" so m1_a=(4.18*200-h9)/(h3-h10) in kg")
114 m1_a=(4.18*200-h9)/(h3-h10)
115 m1_a=0.114; //approx.
116 disp(" Applying heat balance at open feed water
        heater ,")
117 disp(" m1_a*h11+m2_a*h4_a+(1-m1_a-m2_a)*h7=h8")
118 disp(" so m2_a=(h8-m1_a*h11-h7+m1_a*h7)/(h4_a-h7) in
        kg")
119 m2_a=(h8-m1_a*h11-h7+m1_a*h7)/(h4_a-h7)
120 m2_a=0.131; //approx.
121 disp(" Net work per kg steam generated")
122 disp(" w_net=(h2-h3)+(1-m1_a)*(h3_a-h4_a)+(1-m1_a-
        m2_a)*(h4_a-h5_a)-{(1-m1_a-m2_a)*(h7-h6)+(h9-h8)}
        in KJ/kg")
123 w_net=(h2-h3)+(1-m1_a)*(h3_a-h4_a)+(1-m1_a-m2_a)*(
        h4_a-h5_a)-{(1-m1_a-m2_a)*(h7-h6)+(h9-h8)}
124 disp(" Heat added per kg steam generated ,q_add=(h2-h1
        )+(1-m1_a)*(h3_a-h3) in KJ/kg")
125 q_add=(h2-h1)+(1-m1_a)*(h3_a-h3)
126 disp(" Thermal efficiency ,n=w_net/q_add")
127 n=w_net/q_add
128 disp(" in percentage")
129 n=n*100
130 disp("% increase in thermal efficiency due to
        reheating=(0.4503-0.4478)*100/0.4478")

```

```
131 (0.4503-0.4478)*100/0.4478
132 disp("so thermal efficiency of reheat cycle=45.03%")
133 disp("% increase in efficiency due to reheating=0.56
%")
```

---

**Scilab code Exa 8.13** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 13

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 13")
8 disp("For mercury cycle ,")
9 disp("insentropic heat drop=349-234.5 in KJ/kg Hg")
10 349-234.5
11 disp("actual heat drop=0.85*114.5 in KJ/kg Hg")
12 0.85*114.5
13 disp("Heat rejected in condenser=(349-97.325-35) in
KJ/kg")
14 (349-97.325-35)
15 disp("heat added in boiler=349-35 in KJ/kg")
16 349-35
17 disp("For steam cycle ,")
18 disp("Enthalpy of steam generated=h at 40 bar ,0.98
dry=2767.13 KJ/kg")
19 h=2767.13;
20 disp("Enthalpy of inlet to steam turbine ,h2=h at 40
bar ,450 oc=3330.3 KJ/kg")
21 h2=3330.3;
```

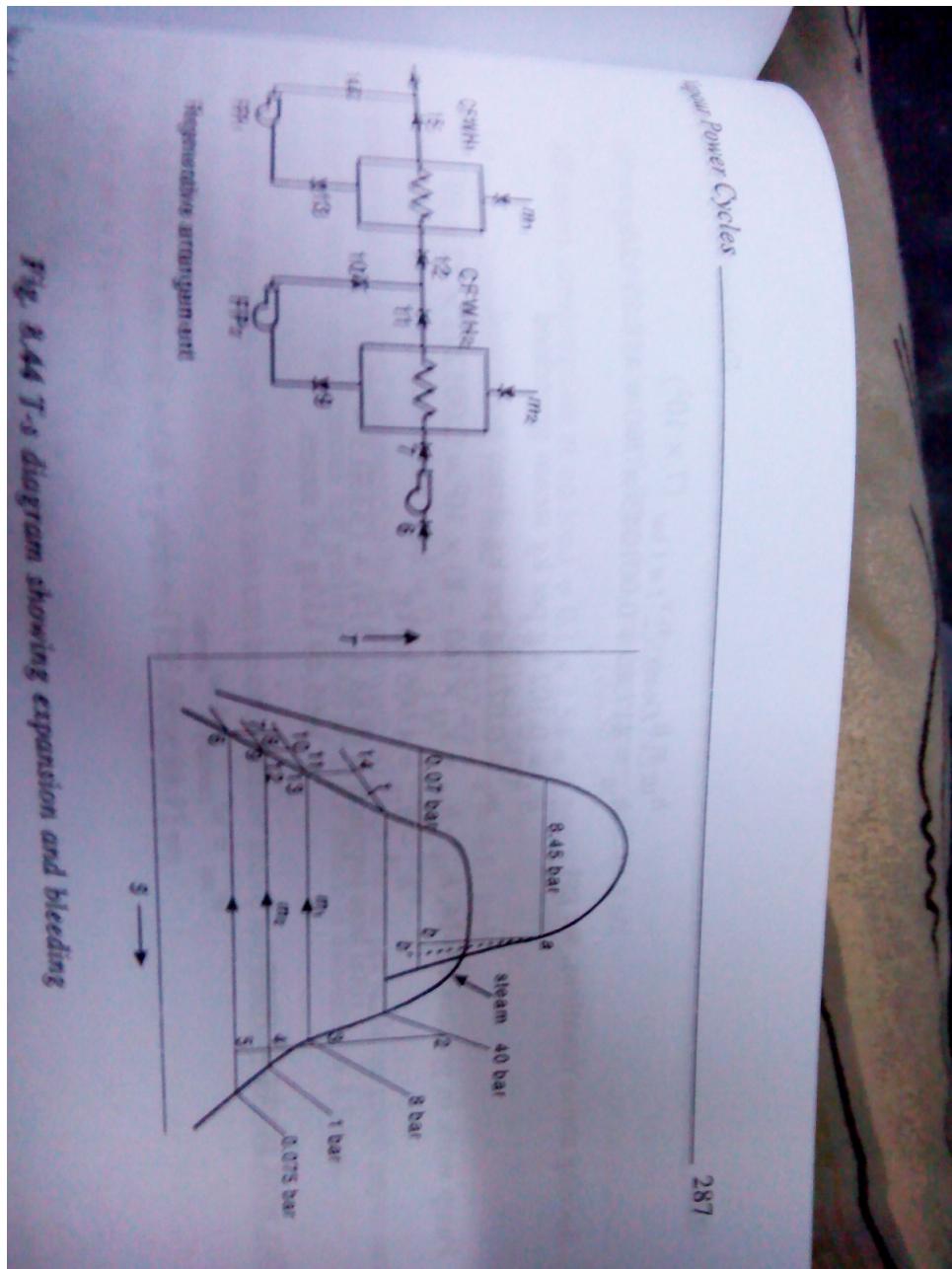


Fig. 8.44 *T-s* diagram showing expansion and bleeding

Figure 8.12: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 13

```

22 disp("Entropy of steam at inlet to steam turbine ,s2
       =6.9363 KJ/kg K")
23 s2=6.9363;
24 disp("Therefore ,heat added in condenser of mercury
       cycle=h at 40 bar ,0.98 dry-h_feed at 40 bar in KJ
       /kg")
25 h=4.18*150
26 disp("Therefore ,mercury required per kg of steam
       =2140.13/heat rejected in condenser in kg per kg
       of steam")
27 2140.13/216.675
28 disp("for isentropic expansion ,s2=s3=s4=s5 =6.9363 KJ
       /kg K")
29 s3=s2;
30 s4=s3;
31 s5=s4;
32 disp("state 3 lies in superheated region ,by
       interpolation the state can be given by ,
       temperature 227.07 oc at 8 bar ,h3=2899.23 KJ/kg")
33 h3=2899.23;
34 disp("state 4 lies in wet region ,say with dryness
       fraction x4")
35 disp("s4=6.9363=sf at 1 bar+x4*sfg at 1 bar")
36 disp("so x4=(s4-sf)/sfg")
37 disp("from steam tables ,at 1 bar ,sf=1.3026 KJ/kg K,
       sfg=6.0568 KJ/kg K")
38 sf=1.3026;
39 sfg=6.0568;
40 x4=(s4-sf)/sfg
41 x4=0.93; //approx.
42 disp("h4=hf at 1 bar+x4*hfg at 1 bar in KJ/kg")
43 disp("from steam tables ,at 1 bar ,hf=417.46 KJ/kg ,hfg
       =2258.0 KJ/kg")
44 hf=417.46;
45 hfg=2258.0;
46 h4=hf+x4*hfg
47 disp("Let state 5 lie in wet region with dryness
       fraction x5,")

```

```

48 disp(" s5=6.9363=sf at 0.075 bar+x5*sfg at 0.075 bar"
      )
49 disp(" so x5=(s5-sf)/sfg")
50 disp(" from steam tables ,at 0.075 bar ,sf=0.5764 KJ/kg
      K, sfg=7.6750 KJ/kg K")
51 sf=0.5764;
52 sfg=7.6750;
53 x5=(s5-sf)/sfg
54 x5=0.828; //approx .
55 disp(" h5=hf+x5*hfg in KJ/kg")
56 disp(" from steam tables ,at 0.075 bar ,hf=168.79 KJ/kg
      ,hfg=2406.0 KJ/kg")
57 hf=168.79;
58 hfg=2406.0;
59 h5=hf+x5*hfg
60 disp("Let mass of steam bled at 8 bar and 1 bar be
      m1 and m2 per kg of steam generated .")
61 disp("h7=h6+v6*(1-0.075)*10^2 in KJ/kg")
62 disp("from steam tables ,at 0.075 bar ,h6=hf=168.79 KJ
      /kg ,v6=vf=0.001008 m^3/kg")
63 h6=168.79;
64 v6=0.001008;
65 h7=h6+v6*(1-0.075)*10^2
66 disp("h9=hf at 1 bar=417.46 KJ/kg ,h13=hf at 8 bar
      =721.11 KJ/kg")
67 h9=417.46;
68 h13=721.11;
69 disp(" Applying heat balance on CFWH1,T1=150oc and
      also T15=150oc")
70 T1=150;
71 T15=150;
72 disp("m1*h3+(1-m1)*h12=m1*h13 +(4.18*150)*(1-m1)")
73 disp("(m1-2899.23)+(1-m1)*h12=(m1*721.11)+627*(1-m1)
      ")
74 disp(" Applying heat balance on CFEH2,T11=90oc")
75 T11=90;
76 disp("m2*h4+(1-m1-m2)*h7=m2*h9+(1-m1-m2)*4.18*90")
77 disp("(m2*2517.4)+(1-m1-m2)*168.88=(m2*417.46)

```

```

+376.2*(1-m1-m2)")

78 disp("Heat balance at mixing between CFWH1 and CFWH2
      ,")
79 disp("(1-m1-m2)*4.18*90+m2*h10=(1-m1)*h12")
80 disp("376.2*(1-m1-m2)+m2*h10=(1-m1)*h12")
81 disp("For pumping process ,9-10 ,h10=h9+v9*(8-1)*10^2
      in KJ/kg")
82 disp("from steam tables ,h9=hf at 1 bar=417.46 KJ/kg ,
      v9=vf at 1 bar=0.001043 m^3/kg")
83 h9=417.46;
84 v9=0.001043;
85 h10=h9+v9*(8-1)*10^2
86 disp("solving above equations ,we get")
87 disp("m1=0.102 kg per kg steam generated")
88 disp("m2=0.073 kg per kg steam generated")
89 m1=0.102;
90 m2=0.073;
91 disp("pump work in process 13-14,h14-h13=v13*(40-8)
      *10^2")
92 disp("so h14-h13 in KJ/kg")
93 v13=0.001252;
94 v13*(40-8)*10^2
95 disp("Total heat supplied (q_add)=(9.88*314)
      +(3330.3-2767.13) in KJ/kg of steam")
96 q_add=(9.88*314)+(3330.3-2767.13)
97 disp("net work per kg of steam ,w_net=w_mercury+
      w_steam")
98 disp("w_net=(9.88*97.325)+{(h2-h3)+(1-m1)*(h3-h4)
      +(1-m1-m2)*(h4-h5)-(1-m1-m2)*(h4-h6)-m2*(h10-h9)-
      m1*(h14-h13)} in KJ/kg")
99 w_net=(9.88*97.325)+{(h2-h3)+(1-m1)*(h3-h4)+(1-m1-m2)
      *(h4-h5)-(1-m1-m2)*(h7-h6)-m2*(h10-h9)-m1*4.006}
100 disp("thermal efficiency of binary vapour cycle=
      w_net/q_add")
101 w_net/q_add
102 disp("in percentage")
103 w_net*100/q_add
104 disp("so thermal efficiency =55.36%")

```

105 **disp**("NOTE=>In this question there is some mistake  
in formula used for w\_net which is corrected  
above .")

---

**Scilab code Exa 8.14** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 14

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 14")
8 n=0.8; //efficiency of both HP and LP turbine
9 P=2500; //output in hp
10 disp("This is a mixed pressure turbine so the output
of turbine shall be sum of the contributions by
HP and LP steam streams .")
11 disp("For HP:at inlet of HP steam=>h1=3023.5 KJ/kg ,
s1=6.7664 KJ/kg K")
12 h1=3023.5;
13 s1=6.7664;
14 disp(" ideally , s2=s1=6.7664 KJ/kg K")
15 s2=s1;
16 disp("s2=sf at 0.075 bar +x3* sfg at 0.075 bar")
17 disp("from steam tables ,at 0.075 bar ,sf=0.5764 KJ/kg
K, sfg=7.6750 KJ/kg K")
18 sf=0.5764;
19 sfg=7.6750;
20 disp(" so x3=(s2-sf)/sfg")
21 x3=(s2-sf)/sfg
```

```

22 x3=0.806; //approx .
23 disp("h_3HP=hf at 0.075 bar+x3*hfg at 0.075 bar in
      KJ/kg")
24 disp("from steam tables ,at 0.075 bar ,hf=168.79 KJ/kg
      ,hfg=2406.0 KJ/kg")
25 hf=168.79;
26 hfg=2406.0;
27 h_3HP=hf+x3*hfg
28 disp("actual enthalpy drop in HP(h_HP)=(h1-h_3HP)*n
      in KJ/kg")
29 h_HP=(h1-h_3HP)*n
30 disp("for LP:at inlet of LP steam")
31 disp("h2=2706.7 KJ/kg ,s2=7.1271 KJ/kg K")
32 h2=2706.7;
33 s2=7.1271;
34 disp("Enthalpy at exit ,h_3LP=2222.34 KJ/kg")
35 h_3LP=2222.34;
36 disp("actual enthalpy drop in LP(h_LP)=(h2-h_3LP)*n
      in KJ/kg")
37 h_LP=(h2-h_3LP)*n
38 disp("HP steam consumption at full load=P*0.7457/
      h_HP in kg/s")
39 P*0.7457/h_HP
40 disp("HP steam consumption at no load=0.10*(P
      *0.7457/h_HP) in kg/s")
41 0.10*(P*0.7457/h_HP)
42 disp("LP steam consumption at full load=P*0.7457/
      h_LP in kg/s")
43 P*0.7457/h_LP
44 disp("LP steam consumption at no load=0.10*(P
      *0.7457/h_LP) in kg/s")
45 0.10*(P*0.7457/h_LP)
46 disp("The problem can be solved geometrically by
      drawing willans line as per scale on graph paper
      and finding out the HP stream requirement for
      getting 1000 hp if LP stream is available at 1.5
      kg/s .")
47 disp("or ,Analytically the equation for willans line

```

can be obtained for above full load and no load conditions for HP and LP seperately .")

```

48 disp(" Willans line for HP:y=m*x+C, here y=steam
       consumption , kg/s")
49 disp("x=load , hp")
50 disp("y_HP=m_HP*x+C_HP")
51 disp("0.254=m_HP*0+C_HP")
52 disp(" so C_HP=0.254")
53 C_HP=0.254;
54 disp("2.54=m_HP*2500+C_HP")
55 disp(" so m_HP=(2.54-C_HP)/2500")
56 m_HP=(2.54-C_HP)/2500
57 disp(" so y_HP=9.144*10^-4*x_HP+0.254")
58 disp(" Willans line for LP:y_LP=m_LP*x_LP+C_LP")
59 disp("0.481=m_LP*0+C_LP")
60 disp(" so C_LP=0.481")
61 C_LP=0.481;
62 disp("4.81=m_LP*2500+C_LP")
63 disp(" so m_LP=(4.81-C_LP)/2500")
64 m_LP=(4.81-C_LP)/2500
65 disp(" so y_LP=1.732*10^-3*x_LP+0.481")
66 disp("Total output(load) from mixed turbine ,x=x_HP+
       x_LP")
67 disp("For load of 1000 hp to be met by mixed turbine
       , let us find out the load shared by LP for steam
       flow rate of 1.5 kg/s")
68 y_LP=1.5;
69 disp("from y_LP=1.732*10^-3*x_LP+0.481 ,")
70 disp("x_LP=(y_LP-0.481)/1.732*10^-3")
71 x_LP=(y_LP-0.481)/(1.732*10^-3)
72 disp("since by 1.5 kg/s of LP steam only 588.34 hp
       output contribution is made so remaining
       (1000-588.34)=411.66 hp ,411.66 hp should be
       contributed by HP steam .By willans line for HP
       turbine ,")
73 x_HP=411.66;
74 disp("from y_HP=9.144*10^-4*x_HP+C_HP in kg/s")
75 y_HP=9.144*10^-4*x_HP+C_HP

```

```
76 disp("so HP steam requirement=0.63 kg/s")
```

---

**Scilab code Exa 8.15** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 15

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 15")
8 disp("Let us carry out analysis for 1 kg of steam
generated in boiler.")
9 disp("Enthalpy at inlet to HPT, h2=2960.7 KJ/kg , s2
=6.3615 KJ/kg K")
10 h2=2960.7;
11 s2=6.3615;
12 disp("state at 3 i.e. exit from HPT can be
identified by s2=s3=6.3615 KJ/kg K")
13 s3=s2;
14 disp("Let dryness fraction be x3 , s3=6.3615=sf at 2
bar+x3*sfg at 2 bar")
15 disp("so x3=(s3-sf)/sfg")
16 disp("from stem tables , at 2 bar , sf=1.5301 KJ/kg K,
sfg=5.5970 KJ/kg K")
17 sf=1.5301;
18 sfg=5.5970;
19 x3=(s3-sf)/sfg
20 x3=0.863; //approx .
21 disp("h3=2404.94 KJ/kg")
22 h3=2404.94;
23 disp("If one kg of steam is generated in bolier then
at exit of HPT,0.5 kg goes into process heater")
```

```

        and 0.5 kg goes into separator")
24 disp("mass of moisture retained in separator(m)=(1-
        x3)*0.5 kg")
25 m=(1-x3)*0.5
26 disp("Therefore , mass of steam entering LPT(m_LP)
        =0.5-m kg")
27 m_LP=0.5-m
28 disp("Total mass of water entering hot well at 8(i.e
        . from process heater and drain from separator)
        =(0.5+0.685)=0.5685 kg")
29 disp("Let us assume the temperature of water leaving
        hotwell be T oc. Applying heat balance for mixing
        ;")
30 disp("(0.5685*4.18*90)+(0.4315*4.18*40)=(1*4.18*T)")
31 disp("so T=((0.5685*4.18*90)+(0.4315*4.18*40))/4.18
        in degree celcius")
32 T=((0.5685*4.18*90)+(0.4315*4.18*40))/4.18
33 disp("so temperature of water leaving hotwell=68.425
        degree celcius")
34 disp("Applying heat balanced on trap")
35 disp("0.5*h7+0.0685*hf at 2 bar=(0.5685*4.18*90)")
36 disp("so h7=((0.5685*4.18*90)-(0.0685*hf))/0.5 in KJ
        /kg")
37 disp("from steam tables ,at 2 bar ,hf=504.70 KJ/kg")
38 hf=504.70;
39 h7=((0.5685*4.18*90)-(0.0685*hf))/0.5
40 disp("Therefore ,heat transferred in process heater
        =0.5*(h3-h7) in KJ/kg steam generated")
41 0.5*(h3-h7)
42 disp("so heat transferred per kg steam generated
        =1023.175 KJ/kg steam generated")
43 disp("For state 10 at exit of LPT,s10=s3=s2=6.3615
        KJ/kg K")
44 s10=s3;
45 disp("Let dryness fraction be x10")
46 disp("s10=6.3615=sf at 0.075 bar+x10*sfg at 0.075
        bar")
47 disp("from steam tables ,at 0.075 bar ,sf=0.5764 KJ/kg

```

```

        K, sfg =7.6750  KJ/kg  K")
48 sf=0.5764;
49 sfg=7.6750;
50 disp(" so x10=(s10-sf)/sfg")
51 x10=(s10-sf)/sfg
52 x10=0.754; //approx.
53 disp("h10=hf at 0.075 bar+x10*hfg at 0.075 bar")
54 disp("from steam tables ,at 0.075 bar ,hf=168.79 KJ/kg
      ,hfg=2406.0 KJ/kg")
55 hf=168.79;
56 hfg=2406.0;
57 disp(" so h10=hf+x10*hfg in KJ/kg ")
58 h10=hf+x10*hfg
59 disp("net work output ,neglecting pump work per kg of
      steam generated ,")
60 disp("w_net=(h2-h3)*1+0.4315*(h3-h10) in KJ/kg steam
      generated")
61 w_net=(h2-h3)*1+0.4315*(h3-h10)
62 disp("Heat added in boiler per kg steam generated ,
      q_add=(h2-h1) in KJ/kg")
63 q_add=(h2-4.18*68.425)
64 disp("thermal efficiency=w_net/q_add")
65 w_net/q_add
66 disp("in percentage")
67 w_net*100/q_add
68 disp("so Thermal efficiency=27.58%")

```

---

**Scilab code Exa 8.16** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 16

1 // Display mode

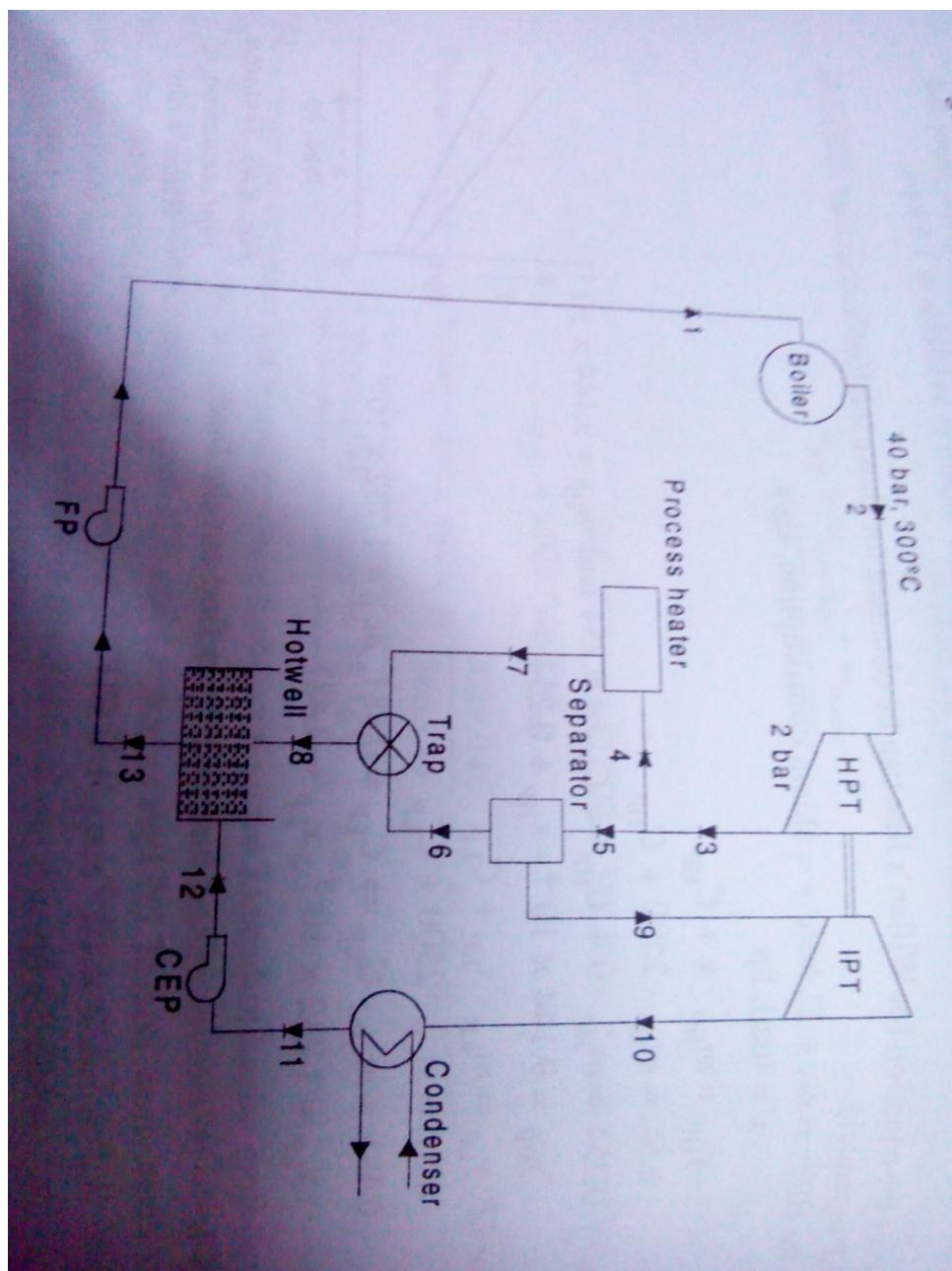


Figure 8.13: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 15

```

2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 16")
8 m=35; //mass flow rate in kg/s
9 disp("from steam tables ,h1=3530.9 KJ/kg ,s1=6.9486 KJ
/kg K")
10 h1=3530.9;
11 s1=6.9486;
12 disp("Assuming isentropic expansion in nozzle ,s1=s2
=6.9486")
13 s2=s1;
14 disp("Let dryness fraction at state 2,x2=0.864")
15 disp("s2=sf at 0.2 bar+x2*sfg at 0.2 bar")
16 disp("from steam tables ,sf=0.8320 KJ/kg K,sfg=7.0766
KJ/kg K")
17 sf=0.8320;
18 sfg=7.0766;
19 disp("so x2=(s2-sf)/sfg")
20 x2=(s2-sf)/sfg
21 x2=0.864; //approx .
22 disp("hence ,h2=hf at 0.2 bar+x2*hfg at 0.2 bar in KJ
/kg")
23 disp("from steam tables ,hf at 0.2 bar=251.4 KJ/kg ,
hfg at 0.2 bar=2358.3 KJ/kg")
24 hf=251.4;
25 hfg=2358.3;
26 h2=hf+x2*hfg
27 disp("considering pump work to be of isentropic type
,deltah_34=v3*deltap_34")
28 disp("from steam table ,v3=vf at 0.2 bar=0.001017 m
^3/kg")
29 v3=0.001017;
30 disp("or deltah_34=v3*(p3-p4) in KJ/kg")
31 p3=70; //;pressure of steam entering turbine in bar

```

```

32 p4=0.20; //condenser pressure in bar
33 deltah_34=v3*(p3-p4)*100
34 disp("pump work ,Wp=deltah_34 in KJ/kg")
35 Wp=deltah_34
36 disp(" turbine work ,Wt=deltah_12=(h1-h2) in KJ/kg")
37 Wt=(h1-h2)
38 disp(" net work (W_net)=Wt-Wp in KJ/kg")
39 W_net=Wt-Wp
40 disp(" power produced (P)=mass flow rate*W_net in KJ/s
      ")
41 P=m*W_net
42 disp(" so net power=43.22 MW")
43 disp(" heat supplied in boiler (Q)=(h1-h4) in KJ/kg")
44 disp(" enthalpy at state 4 ,h4=h3+deltah_34 in KJ/kg")
45 h3=hf;
46 h4=h3+deltah_34
47 disp(" total heat supplied to boiler (Q)=m*(h1-h4) in
      KJ/s")
48 Q=m*(h1-h4)
49 disp(" thermal efficiency=net work/heat supplied=
      W_net/Q")
50 P/Q
51 disp(" in percentage")
52 P*100/Q
53 disp(" so thermal efficiency=37.73%")

```

---

**Scilab code Exa 8.17** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 17

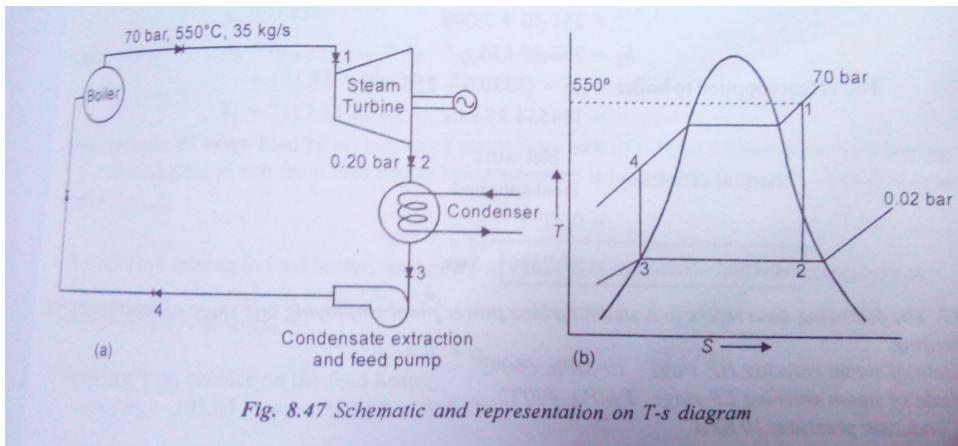


Figure 8.14: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 16

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 17")
8 P=10*10^3; //output in KW
9 disp("from steam tables ,h1=3625.3 KJ/s ,s1=6.9029 KJ/
kg K")
10 h1=3625.3;
11 s1=6.9029;
12 disp("due to isentropic expansion ,s1=s2=s3=6.9029 KJ
/kg K")
13 s2=s1;
14 s3=s2;
15 disp("at state 2,i.e at pressure of 2 MPa and
entropy 6.9029 KJ/kg K")
16 disp("by interpolating state for s2 between 2 MPa
,300 degree celcius and 2 MPa,350 degree celcius
from steam tables ,")

```

Table 2 Saturated Steam (temperature) table

Temp. °C <i>T</i>	Sat. press. MPa <i>P<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg			Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg.K)				
		Sat. liquid <i>v<sub>f</sub></i>		Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>		Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>		Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>		
315	10.547	0.001472	0.016867		1415.5	1121.1	2536.6		1431.0	1283.5	2714.5		3.3982	2.1821	5.5804
320	11.274	0.001499	0.015488		1444.6	1080.9	2525.5		1461.5	1238.6	2700.1		3.4480	2.0882	5.5362
330	12.845	0.001561	0.012996		1505.3	993.7	2498.9		1525.3	1140.6	2665.9		3.5507	1.8909	5.4417
340	14.586	0.001638	0.010797		1570.3	894.3	2464.6		1594.2	1027.9	2622.0		3.6594	1.6763	5.3357
350	16.513	0.001740	0.008813		1641.9	776.6	2418.4		1670.6	893.4	2563.9		3.7777	1.4335	5.2112
360	18.651	0.001893	0.006945		1725.2	626.3	2351.5		1760.5	720.3	2481.0		3.9147	1.1379	5.0526
370	21.03	0.002213	0.004925		1844.0	384.5	2228.5		1890.5	441.6	2332.1		4.1106	0.6865	4.7971
374.14	22.09	0.003155	0.003155		2029.6	0	2029.6		2099.3	0	2099.3		4.4298	0	4.4298

Table 3 Saturated steam (pressure) table

Press. kPa <i>P</i>	Sat. Temp. °C <i>T<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg			Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg.K)			
		Sat. liquid <i>v<sub>f</sub></i>		Sat. vapour <i>v<sub>g</sub></i>	Sat. liquid <i>u<sub>f</sub></i>	Sat. Evap. <i>u<sub>fg</sub></i>	Sat. vapour <i>u<sub>g</sub></i>	Sat. liquid <i>h<sub>f</sub></i>	Sat. Evap. <i>h<sub>fg</sub></i>	Sat. vapour <i>h<sub>g</sub></i>	Sat. liquid <i>s<sub>f</sub></i>	Sat. Evap. <i>s<sub>fg</sub></i>	Sat. vapour <i>s<sub>g</sub></i>	
0.6113	0.01	0.001000	206.14		0.00	2375.3	2375.3		0.01	2501.3	2501.4	0.0000	9.1562	9.1562
1.0	6.98	0.001000	129.21		29.30	2355.7	2385.0		29.30	2484.9	2514.2	0.1059	8.8697	8.9756
1.5	13.03	0.001001	87.98		54.71	2338.6	2393.3		54.71	2470.6	2525.3	0.1957	8.6322	8.8279
2.0	17.50	0.001001	67.00		73.48	2326.0	2399.5		73.48	2460.0	2533.5	0.2607	8.4629	8.7237
2.5	21.08	0.001002	54.25		88.48	2315.9	2404.4		88.49	2451.6	2540.0	0.3120	8.3311	8.6432
3.0	24.08	0.001003	45.67		101.04	2307.5	2408.5		101.05	2444.5	2545.5	0.3545	8.2231	8.5776
4.0	28.96	0.001004	34.80		121.45	2293.7	2415.2		121.46	2432.9	2554.4	0.4226	8.0520	8.4746
5.0	32.88	0.001005	28.19		137.81	2282.7	2420.5		137.82	2423.7	2561.5	0.4764	7.9187	8.3951
7.5	40.29	0.001008	19.24		168.78	2261.7	2430.5		168.79	2406.0	2576.8	0.5764	7.6750	8.2515
10	45.81	0.001010	14.67		191.82	2246.1	2437.9		191.83	2392.8	2584.7	0.6493	7.5009	8.1502
15	53.97	0.001014	10.02		225.92	2222.8	2448.7		225.94	2373.1	2599.1	0.7549	7.2536	8.0085
20	60.06	0.001017	7.649		251.38	2205.4	2456.7		251.40	2358.3	2609.7	0.8320	7.0766	7.9085
25	64.97	0.001020	6.204		271.90	2191.2	2463.1		271.93	2346.3	2618.2	0.8931	6.9383	7.8314
30	69.10	0.001022	5.229		289.20	2179.2	2468.4		289.23	2336.1	2625.3	0.9439	6.8247	7.7686
40	75.87	0.001027	3.993		317.53	2159.5	2477.0		317.58	2319.2	2636.8	1.0259	6.6441	7.6700
50	81.33	0.001030	3.240		340.44	2143.4	2483.9		340.49	2305.4	2645.9	1.0910	6.5029	7.5939
75	91.78	0.001037	2.217		384.31	2112.4	2496.7		384.39	2278.6	2663.0	1.2130	6.2434	7.4564

Figure 8.15: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 16

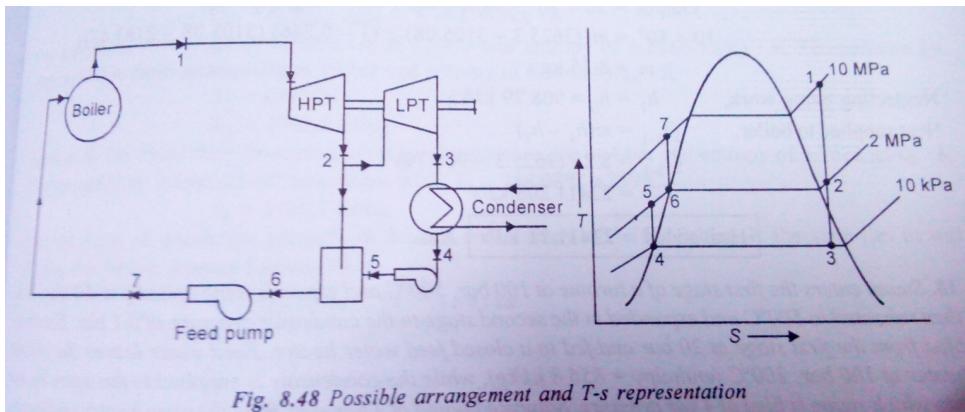


Fig. 8.48 Possible arrangement and T-s representation

Figure 8.16: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 17

```

17 disp("h2=3105.08 KJ/kg ")
18 h2=3105.08;
19 disp(" for state 3,i.e at pressure of 0.01 MPa
        entropy ,s3 lies in wet region as s3<sg at 0.01
        MPa. Let dryness fraction be x3 at this state")
20 disp("s3=sf at 0.01 MPa+x3*sfg at 0.01 MPa")
21 disp("from steam tables ,sf at 0.01 MPa=0.6493 KJ/kg
        K, sfg at 0.01 MPa=7.5009 KJ/kg K")
22 sf=0.6493;
23 sfg=7.5009;
24 disp(" so x3=(s3-sf )/sfg ")
25 x3=(s3-sf)/sfg
26 x3=0.834; //approx .
27 disp(" enthalpy at state 3,h3= hf at 0.01 MPa+x3*hfg
        at 0.01 MPa in KJ/kg")
28 disp("from steam tables ,at 0.01 MPa, hf=191.83 KJ/kg ,
        hfg=2392.8 KJ/kg")
29 hf=191.83;
30 hfg=2392.8;
31 h3=hf+x3*hfg
32 disp("let the mass of steam bled be mb per kg of
        steam from exit of HP for regenerative feed
        heating .")

```

```

33 disp("Considering state at exit from feed heater
      being saturated liquid the enthalpy at exit of
      feed heater will be , hf at 2 MPa")
34 disp("h6=hf at 2 MPa=908.79 KJ/kg")
35 h6=908.79;
36 disp("for adiabatic mixing in feed heater ,for one kg
      of steam leaving boiler ,the heat balance yields ,
      ")
37 disp("(1-mb)*h5+mb*h2=h6")
38 disp(" while neglecting pump work ,")
39 disp("h5=h4=hf at 0.01MPa=191.83 KJ/kg")
40 h4=191.83;
41 h5=h4;
42 disp("substituting in heat balance on the feed
      heater ,")
43 disp("(1-mb)*h5+mb*h2=h6")
44 disp("so mb=(h6-h5)/(h2-h5) in kg per kg of steam
      entering HP turbine")
45 mb=(h6-h5)/(h2-h5)
46 mb=0.246; //approx .
47 disp("steam bled per kg of steam passing through HP
      stage=0.246 kg")
48 disp("let mass of steam leaving boiler be m kg/s")
49 disp("output(P)=m*(h1-h2)+m*(1-mb)*(h2-h3)")
50 disp("so m=P/((h1-h2)+(1-mb)*(h2-h3)) in kg/s")
51 m=P/((h1-h2)+(1-mb)*(h2-h3))
52 m=8.25; //approx .
53 disp("neglecting pump work ,h7=h6=908.79 KJ/kg")
54 h7=h6;
55 disp("heat supplied to boiler ,Q_71=m*(h1-h7) in KJ/s
      ")
56 Q_71=m*(h1-h7)
57 disp("so heat added=22411.21 KJ/s")

```

---

**Scilab code Exa 8.18** Engineering Thermodynamics by Onkar Singh Chapter 8 Example 18

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 8 Example 18")
8 W_net=50*10^3; //net output of turbine in KW
9 disp("from steam tables ,at inlet to first stage of
turbine ,h1=h at 100 bar ,500oc=3373.7 KJ/kg ,s1=s
at 100 bar ,500oc=6.5966 KJ/kg")
10 h1=3373.7;
11 s1=6.5966;
12 disp("Due to isentropic expansion ,s1=s6=s2 and s3=s8
=s4")
13 s2=s1;
14 s6=s2;
15 disp("State at 6 i.e bleed state from HP turbine ,
temperature by interpolation from steam table
=261.6oc .")
16 disp("At inlet to second stage of turbine ,h6
=2930.572 KJ/kg")
17 h6=2930.572;
18 disp("h3=h at 10 bar ,500oc=3478.5 KJ/kg ,s3=s at 10
bar ,500oc=7.7622 KJ/kg K")
19 h3=3478.5;
20 s3=7.7622;
21 s4=s3;
22 s8=s4;
23 disp("At exit from first stage of turbine i.e. at 10
bar and entropy of 6.5966 KJ/kg K, Temperature by
interpolation from steam table at 10 bar and
entropy of 6.5966 KJ/kg K")
24 disp("T2=181.8oc ,h2=2782.8 KJ/kg")
```

```

25 T2=181.8;
26 h2=2782.8;
27 disp("state at 8,i.e bleed state from second stage
         of expansion ,i.e at 4 bar and entropy of 7.7622
         KJ/kg K, Temperature by interpolation from steam
         table ,T8=358.98oc=359oc")
28 T8=359;
29 disp("h8=3188.7 KJ/kg")
30 h8=3188.7;
31 disp("state at 4 i.e. at condenser pressure of 0.1
         bar and entropy of 7.7622 KJ/kg K,the state lies
         in wet region .So let the dryness fraction be x4.")
32 )
32 disp("s4=sf at 0.1 bar+x4*sfg at 0.1 bar")
33 disp("from steam tables ,at 0.1 bar ,sf=0.6493 KJ/kg K
         ,sfg=7.5009 KJ/kg K")
34 sf=0.6493;
35 sfg=7.5009;
36 disp(" so x4=(s4-sf)/sfg")
37 x4=(s4-sf)/sfg
38 x4=0.95; //approx.
39 disp("h4=hf at 0.1 bar+x4*hfg at 0.1 bar in KJ/kg ")
40 disp("from steam tables ,at 0.1 bar ,hf=191.83 KJ/kg ,
         hfg=2392.8 KJ/kg")
41 hf=191.83;
42 hfg=2392.8;
43 h4=hf+x4*hfg
44 disp(" given ,h4=2464.99 KJ/kg ,h11=856.8 KJ/kg ,h9=hf
         at 4 bar=604.74 KJ/kg")
45 h4=2464.99;
46 h11=856.8;
47 h9=604.74;
48 disp("considering pump work ,the net output can be
         given as ,")
49 disp("W_net=W_HPT+W_LPT-(W_CEP+W_FP)")
50 disp("where ,W_HPT={(h1-h6)+(1-m6)*(h6-h2)} per kg of
         steam from boiler .")
51 disp("WLPT={(1-m6)+(h3-h8)*(1-m6-m8)*(h8-h4)} per kg

```

```

        of steam from boiler .")
52 disp(" for closed feed water heater , energy balance
       yields ;")
53 disp("m6*h6+h10=m6*h7+h11")
54 disp(" assuming condensate leaving closed feed water
       heater to be saturated liquid ,")
55 disp("h7=hf at 20 bar=908.79 KJ/kg")
56 h7=908.79;
57 disp("due to throttling ,h7=h7_a=908.79 KJ/kg")
58 h7_a=h7;
59 disp("for open feed water heater , energy balance
       yields ,")
60 disp("m6*h7_a+m8*h8+(1-m6-m8)*h5=h9")
61 disp("for condensate extraction pump,h5-h4_a=v4_a*
       deltap")
62 disp("h5-hf at 0.1 bar=vf at 0.1 bar*(4-0.1)*10^2 ")
63 disp("from steam tables ,at 0.1 bar ,hf=191.83 KJ/kg ,
       vf=0.001010 m^3/kg")
64 hf=191.83;
65 vf=0.001010;
66 disp("so h5=hf+vf*(4-0.1)*10^2 in KJ/kg")
67 h5=hf+vf*(4-0.1)*10^2
68 disp("for feed pump,h10-h9=v9*deltap")
69 disp("h10=h9+vf at 4 bar*(100-4)*10^2 in KJ/kg")
70 disp("from steam tables ,at 4 bar ,hf=604.74 KJ/kg ,vf
       =0.001084 m^3/kg ")
71 hf=604.74;
72 vf=0.001084;
73 h10=h9+vf*(100-4)*10^2
74 disp("substituting in energy balance upon closed
       feed water heater ,")
75 disp("m6=(h11-h10)/(h6-h7) in kg per kg of steam from
       boiler")
76 m6=(h11-h10)/(h6-h7)
77 disp("substituting in energy balance upon feed water
       heater ,")
78 disp("m8=(h9-m6*h7_a+m6*h5-h5)/(h8-h5) in kg per kg
       of steam from boiler")

```

```

79 m8=(h9-m6*h7_a+m6*h5-h5)/(h8-h5)
80 disp("Let the mass of steam entering first stage of
      turbine be m kg ,then")
81 disp("W_HPT=m*{(h1-h6)+(1-m6)*(h6-h2)}")
82 disp("W_HPT/m=")
83 {(h1-h6)+(1-m6)*(h6-h2)}
84 disp(" so W_HPT=m*573.24 KJ")
85 disp(" also ,W_LPT={(1-m6)*(h3-h8)+(1-m6-m8)*(h8-h4)}"
      per kg of steam from boiler")
86 disp("W_LPT/m=")
87 {(1-m6)*(h3-h8)+(1-m6-m8)*(h8-h4)}
88 disp(" so W_LPT=m*813.42 KJ")
89 disp("pump works( negative work )")
90 disp("W_CEP=m*(1-m6-m8)*(h5-h4_a)")
91 h4_a=191.83; //h4_a=hf at 0.1 bar
92 disp("W_CEP/m=")
93 (1-m6-m8)*(h5-h4_a)
94 disp(" so W_CEP=m* 0.304")
95 disp("W_FP=m*(h10-h9)")
96 disp("W_FP/m=")
97 (h10-h9)
98 disp(" so W_FP=m*10.41")
99 disp(" net output ,")
100 disp(" W_net=W_HPT+W_LPT-W_CEP-W_FP ")
101 disp(" so 50*10^3=(573.24*m+813.42*m-0.304*m-10.41*m"
      ")
102 disp(" so m=W_net/(573.24+813.42-0.304-10.41) in kg/s"
      )
103 m=W_net/(573.24+813.42-0.304-10.41)
104 disp("heat supplied in boiler ,Q_add=m*(h1-h11) in KJ
      /s")
105 Q_add=m*(h1-h11)
106 disp("Thermal efficiency=W_net/Q_add")
107 W_net/Q_add
108 disp("in percentage")
109 W_net*100/Q_add
110 disp("so mass of steam bled at 20 bar=0.119 kg per
      kg of steam entering first stage")

```

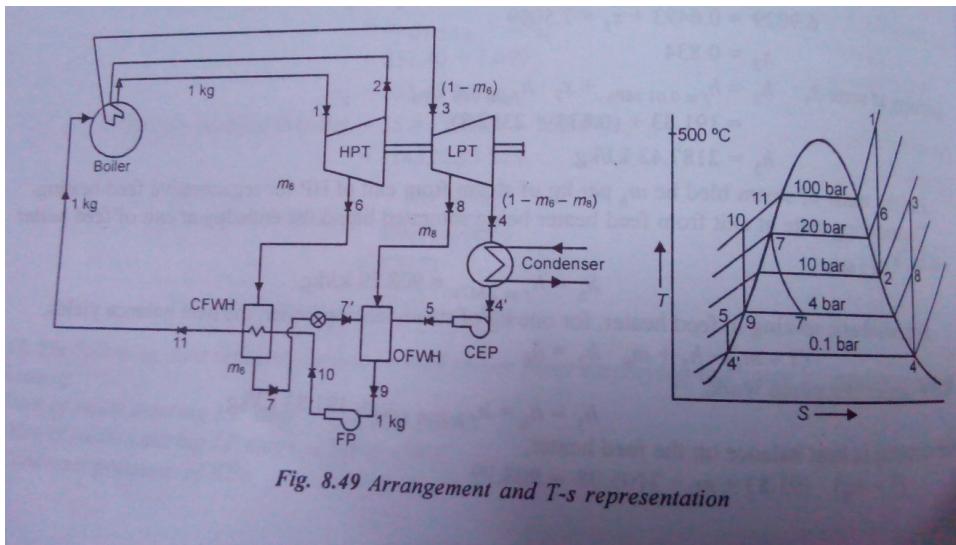


Fig. 8.49 Arrangement and T-s representation

Figure 8.17: Engineering Thermodynamics by Onkar Singh Chapter 8 Example 18

```

111 disp("mass of steam bled at 4 bar=0.109 kg per kg of
      steam entering first stage")
112 disp("mass of steam entering first stage=36.33 kg/s"
      )
113 disp(" thermal efficiency =54.66%")
114 disp("NOTE=>In this question there is some
      calculation mistake while calculating m6 in book,
      which is corrected above so some answers may vary
      .")

```

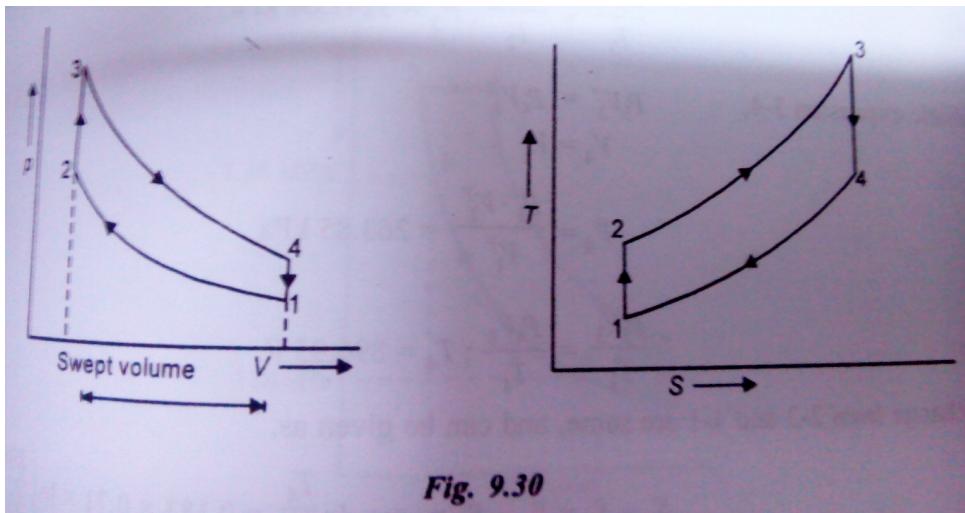
---

# Chapter 9

## Gas Power Cycles

**Scilab code Exa 9.1** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 9 Example 1")
8 Cp=1; // specific heat at constant pressure in KJ/kg K
9 Cv=0.71; // specific heat at constant volume in KJ/kg
            K
10 P1=98; // pressure at begining of compression in KPa
11 T1=(60+273.15); // temperature at begining of
                     compression in K
12 Q23=150; // heat supplied in KJ/kg
13 r=6; // compression ratio
14 R=0.287; // gas constant in KJ/kg K
15 disp("SI engine operate on otto cycle . consider")
```



**Fig. 9.30**

Figure 9.1: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 1

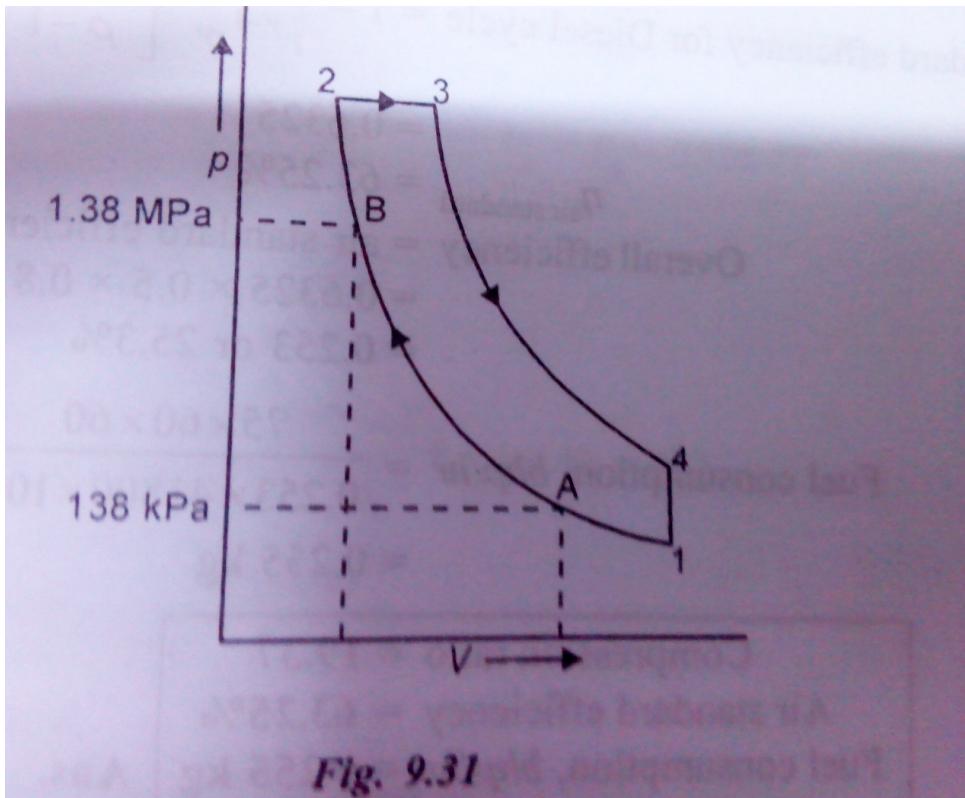
working fluid to be perfect gas.”)

- 16 **disp**(“here ,  $y=C_p/C_v$ ”)
- 17  $y=C_p/C_v$
- 18  $y=1.4; //approx.$
- 19 **disp**(“ $C_p-C_v=R$  in KJ/kg K”)
- 20  $R=C_p-C_v$
- 21 **disp**(“compression ratio ,  $r=V_1/V_2=(0.15+V_2)/V_2$ ”)
- 22 **disp**(“so  $V_2=0.15/(r-1)$  in  $m^3$ ”)
- 23  $V_2=0.15/(r-1)$
- 24 **disp**(“so  $V_2=0.03 m^3$ ”)
- 25 **disp**(“total cylinder volume= $V_1=r*V_2 m^3$ ”)
- 26  $V_1=r*V_2$
- 27 **disp**(“from perfect gas law ,  $P*V=m*R*T$ ”)
- 28 **disp**(“so  $m=P_1*V_1/(R*T_1)$  in kg”)
- 29  $m=P_1*V_1/(R*T_1)$
- 30  $m=0.183; //approx.$
- 31 **disp**(“from state 1 to 2 by  $P*V^y=P_2*V_2^y$ ”)
- 32 **disp**(“so  $P_2=P_1*(V_1/V_2)^y$  in KPa”)
- 33  $P_2=P_1*(V_1/V_2)^y$
- 34 **disp**(“also ,  $P_1*V_1/T_1=P_2*V_2/T_2$ ”)

```

35 disp(" so T2=P2*V2*T1/(P1*V1) in K")
36 T2=P2*V2*T1/(P1*V1)
37 disp("from heat addition process 2-3")
38 disp("Q23=m*CV*(T3-T2)")
39 disp("T3=T2+(Q23/(m*CV)) in K")
40 T3=T2+(Q23/(m*CV))
41 disp(" also from ,P3*V3/T3=P2*V2/T2")
42 disp("P3=P2*V2*T3/(V3*T2) in KPa")
43 V3=V2; //constant volume process
44 P3=P2*V2*T3/(V3*T2)
45 disp("for adiabatic expansion 3-4,")
46 disp("P3*V3^y=P4*V4^y")
47 disp("and V4=V1")
48 V4=V1;
49 disp(" hence ,P4=P3*V3^y/V1^y in KPa")
50 P4=P3*V3^y/V1^y
51 disp("and from P3*V3/T3=P4*V4/T4")
52 disp("T4=P4*V4*T3/(P3*V3) in K")
53 T4=P4*V4*T3/(P3*V3)
54 disp("entropy change from 2-3 and 4-1 are same, and
      can be given as ,")
55 disp("S3-S2=S4-S1=m*CV*log(T4/T1)")
56 disp("so entropy change ,deltaS_32=deltaS_41 in KJ/K")
57 deltaS_32=m*CV*log(T4/T1)
58 deltaS_41=deltaS_32;
59 disp("heat rejected ,Q41=m*CV*(T4-T1) in KJ")
60 Q41=m*CV*(T4-T1)
61 disp(" net work(W)=Q23-Q41 in KJ")
62 W=Q23-Q41
63 disp(" efficiency (n)=W/Q23")
64 n=W/Q23
65 disp(" in percentage")
66 n=n*100
67 disp("mean effective pressure(mep)=work/volume
      change=W/0.15 in KPa")
68 mep=W/0.15
69 disp(" so mep=511.67 KPa")

```



**Fig. 9.31**

Figure 9.2: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 2

**Scilab code Exa 9.2** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);

```

```

5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 2")
8 Pa=138; //pressure during compression at 1/8 of
stroke in KPa
9 Pb=1.38*10^3; //pressure during compression at 7/8 of
stroke in KPa
10 n_ite=0.5; //indicated thermal efficiency
11 n_mech=0.8; //mechanical efficiency
12 C=41800; //calorific value in KJ/kg
13 y=1.4; //expansion constant
14 disp("as given")
15 disp("Va=V2+(7/8)*(V1-V2)")
16 disp("Vb=V2+(1/8)*(V1-V2)")
17 disp("and also")
18 disp("Pa*Va^y=Pb*Vb^y")
19 disp("so (Va/Vb)=(Pb/Pa)^(1/y)")
20 (Pb/Pa)^(1/y)
21 disp("also substituting for Va and Vb")
22 disp("(V2+(7/8)*(V1-V2))/(V2+(1/8)*(V1-V2))=5.18")
23 disp("so V1/V2=r=1+(4.18*8/1.82)")
24 r=1+(4.18*8/1.82)
25 disp("it gives r=19.37 or V1/V2=19.37, compression
ratio=19.37")
26 disp("as given; cut off occurs at (V1-V2)/15 volume")
27 disp("V3=V2+(V1-V2)/15")
28 disp("cut off ratio , rho=V3/V2")
29 rho=1+(r-1)/15
30 disp("air standard efficiency for diesel cycle(
n_airstandard)=1-(1/(r^(y-1)*y))*((rho^y-1)/(rho
-1))")
31 n_airstandard=1-(1/(r^(y-1)*y))*((rho^y-1)/(rho-1))
32 disp("in percentage")
33 n_airstandard=n_airstandard*100
34 disp("overall efficiency (n_overall)=n_airstandard *
n_ite*n_mech")
35 n_airstandard=0.6325;

```

```

36 n_overall=n_airstandard*n_ite*n_mech
37 disp("in percentage")
38 n_overall=n_overall*100
39 disp(" fuel consumption ,bhp/hr in kg=")
40 n_overall=0.253;
41 75*60*60/(n_overall*C*100)
42 disp(" so compression ratio=19.37")
43 disp(" air standard efficiency=63.25%")
44 disp(" fuel consumption ,bhp/hr=0.255 kg")

```

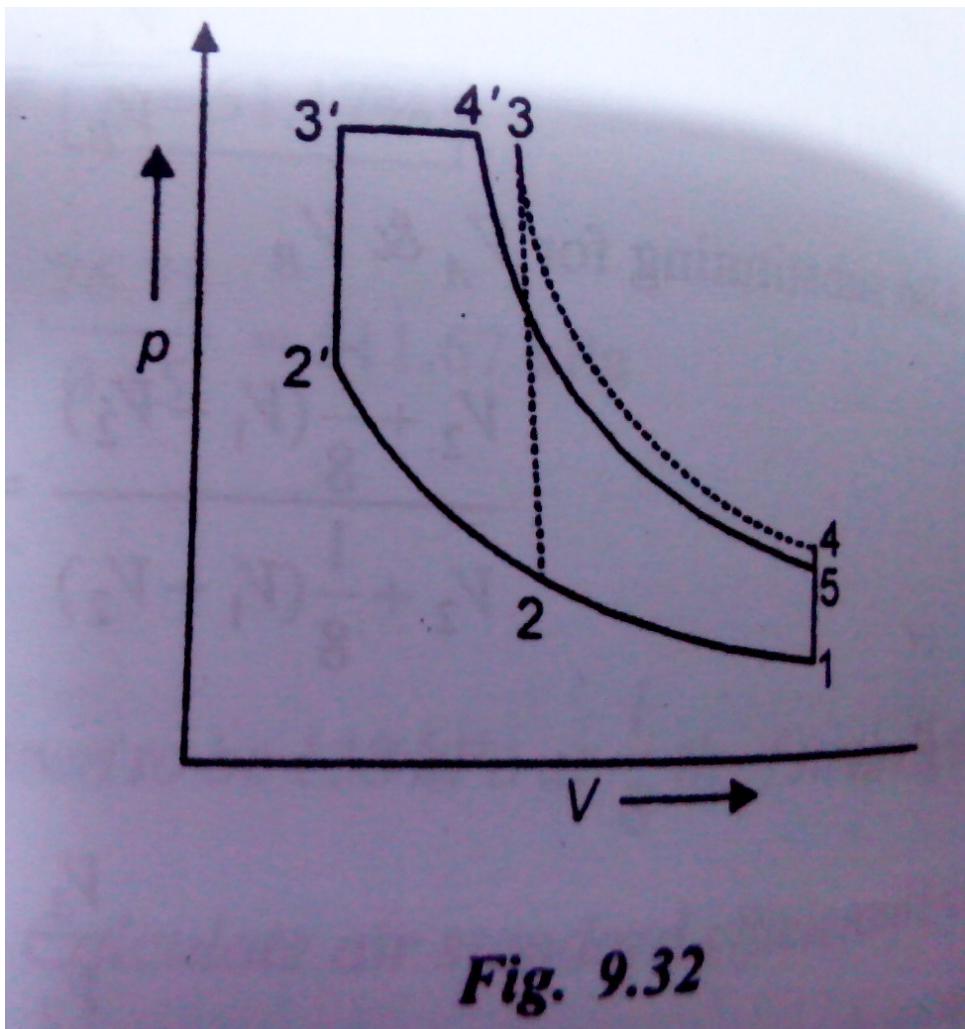
---

**Scilab code Exa 9.3** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 3

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 3")
8 T1=(100+273.15); //temperature at beginning of
compresssion in K
9 P1=103; //pressure at beginning of compresssion in
KPa
10 Cp=1.003; // specific heat at constant pressure in KJ/
kg K
11 Cv=0.71; // specific heat at constant volume in KJ/kg
K
12 Q23=1700; //heat added during combustion in KJ/kg
13 P3=5000; //maximum pressure in cylinder in KPa
14 disp("1-2-3-4=cycle a")
15 disp("1-2_a-3_a-4_a-5=cycle b")

```



**Fig. 9.32**

Figure 9.3: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 3

```

16 disp(" here Cp/Cv=y")
17 y=Cp/Cv
18 y=1.4; //approx .
19 disp("and R=0.293 KJ/kg K")
20 R=0.293;
21 disp("let us consider 1 kg of air for perfect gas ,")
22 m=1; //mass of air in kg
23 disp("P*V=m*R*T")
24 disp(" so V1=m*R*T1/P1 in m^3")
25 V1=m*R*T1/P1
26 disp("at state 3 ,")
27 disp(" P3*V3=m*R*T3")
28 disp(" so T3/V2=P3/(m*R) ")
29 P3/(m*R)
30 disp(" so T3=17064.8*V2 ..... eq1")
31 disp(" for cycle a and also for cycle b")
32 disp(" T3_a=17064.8*V2_a ..... eq2")
33 disp("a> for otto cycle ,")
34 disp("Q23=Cv*(T3-T2)")
35 disp(" so T3-T2=Q23/Cv")
36 Q23/Cv
37 disp(" and T2=T3 - 2394.36..... eq3")
38 disp(" from gas law ,P2*V2/T2=P3*V3/T3")
39 disp(" here V2=V3 and using eq 3,we get")
40 disp(" so P2/(T3-2394.36)=5000/T3")
41 disp(" substituting T3 as function of V2")
42 disp("P2/(17064.8*V2-2394.36)=5000/(17064.8*V2)")
43 disp("P2=5000*(17064.8*V2-2394.36)/(17064.8*V2)")
44 disp(" also P1*V1^y=P2*V2^y")
45 disp(" or 103*(1.06)^1.4=(5000*(17064.8*V2-2394.36)
46 /(17064.8*V2))*V2^1.4")
47 disp("upon solving it yields")
48 disp(" 381.4*V2=17064.8*V2^2.4-2394.36*V2^1.4")
49 disp(" or V2^1.4-0.140*V2^0.4-.022=0")
50 V2=0.18;
51 disp("thus compression ratio ,r=V1/V2")
52 r=V1/V2

```



```

87 disp(" so V4_a=P3_a*V3_a*T4_a/(T3_a*P4_a) in m^3 ")
88 disp(" here P3_a=P4_a and V2_a=V3_a")
89 V4_a=V2_a*T4_a/(T3_a)
90 disp(" using adiabatic formulations V4_a=0.172 m^3")
91 disp(" (V5/V4_a)^(y-1)=(T4_a/T5), here V5=V1")
92 V5=V1;
93 disp(" so T5=T4_a/(V5/V4_a)^(y-1) in K")
94 T5=T4_a/(V5/V4_a)^(y-1)
95 disp(" heat rejected in process 5-1,Q51=Cv*(T5-T1) in
KJ")
96 Q51=Cv*(T5-T1)
97 disp(" efficiency of mixed cycle (n_mixed)=(Q23-Q51)/
Q23")
98 n_mixed=(Q23-Q51)/Q23
99 disp(" in percentage")
100 n_mixed=n_mixed*100
101 ("NOTE=>In this question temperature difference (T3-
T2) for part a> in book is calculated wrong i.e
2328.77, which is corrected above and comes to be
2394.36, however it doesn't effect the efficiency
of any part of this question.")

```

---

**Scilab code Exa 9.4** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 4")

```

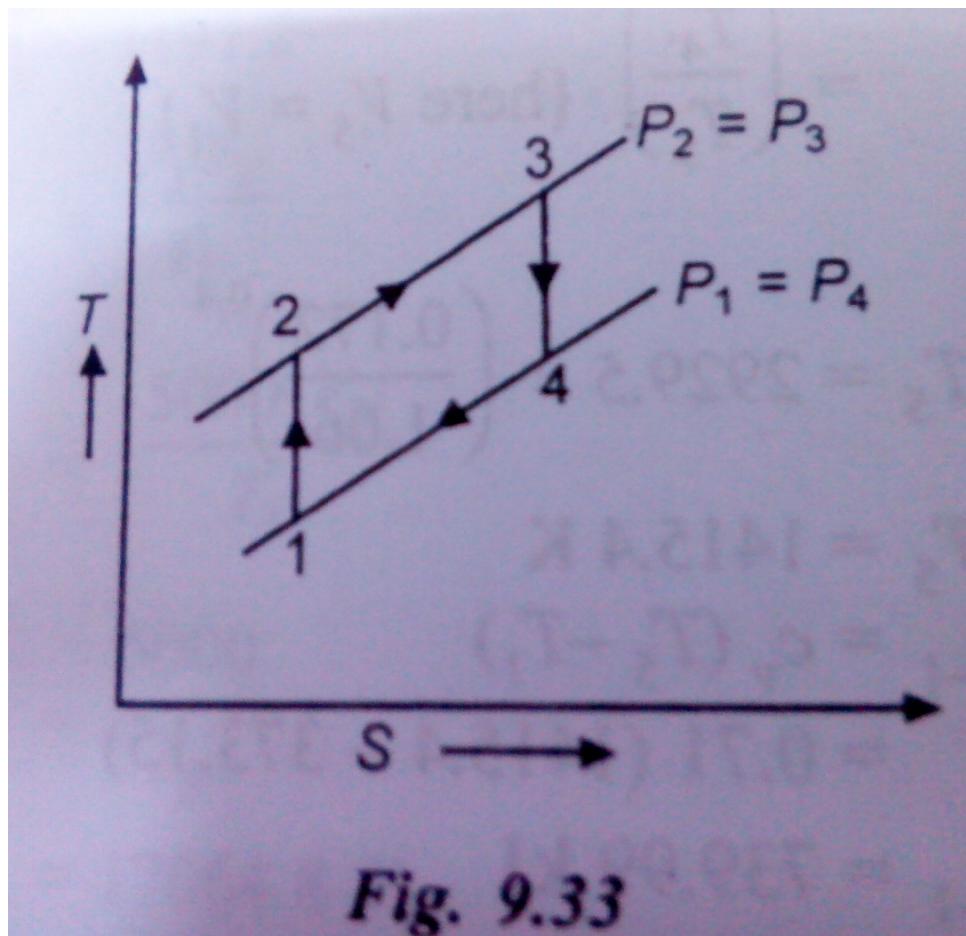


Figure 9.4: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 4

```

8 T3=1200; //maximum temperature in K
9 T1=300; //minimum temperature in K
10 y=1.4; //expansion constant
11 Cp=1.005; // specific heat at constant pressure in KJ/
    kg K
12 disp("optimum pressure ratio for maximum work output
    ,")
13 disp(" rp=(T_max/T_min) ^((y)/(2*(y-1))) ")
14 T_max=T3;
15 T_min=T1;
16 rp=(T_max/T_min)^((y)/(2*(y-1)))
17 disp(" so p2/p1=11.3,For process 1-2, T2/T1=(p2/p1) ^
    y/(y-1)) ")
18 disp(" so T2=T1*(p2/p1) ^((y-1)/y) in K")
19 T2=T1*(rp)^((y-1)/y)
20 disp(" For process 3-4,")
21 disp(" T3/T4=(p3/p4) ^((y-1)/y)=(p2/p1) ^((y-1)/y) ")
22 disp(" so T4=T3/( rp ) ^((y-1)/y) in K")
23 T4=T3/(rp)^((y-1)/y)
24 disp(" heat supplied ,Q23=Cp*(T3-T2) in KJ/kg")
25 Q23=Cp*(T3-T2)
26 disp(" compressor work ,Wc=Cp*(T2-T1) in KJ/kg")
27 Wc=Cp*(T2-T1)
28 disp(" turbine work ,Wt=Cp*(T3-T4) in KJ/kg")
29 Wt=Cp*(T3-T4)
30 disp(" thermal efficiency=net work/heat supplied=(Wt-
    Wc)/Q23")
31 (Wt-Wc)/Q23
32 disp(" so compressor work=301.5 KJ/kg ,turbine work
    =603 KJ/kg ,thermal efficiency=50%")

```

---

**Scilab code Exa 9.5** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 5

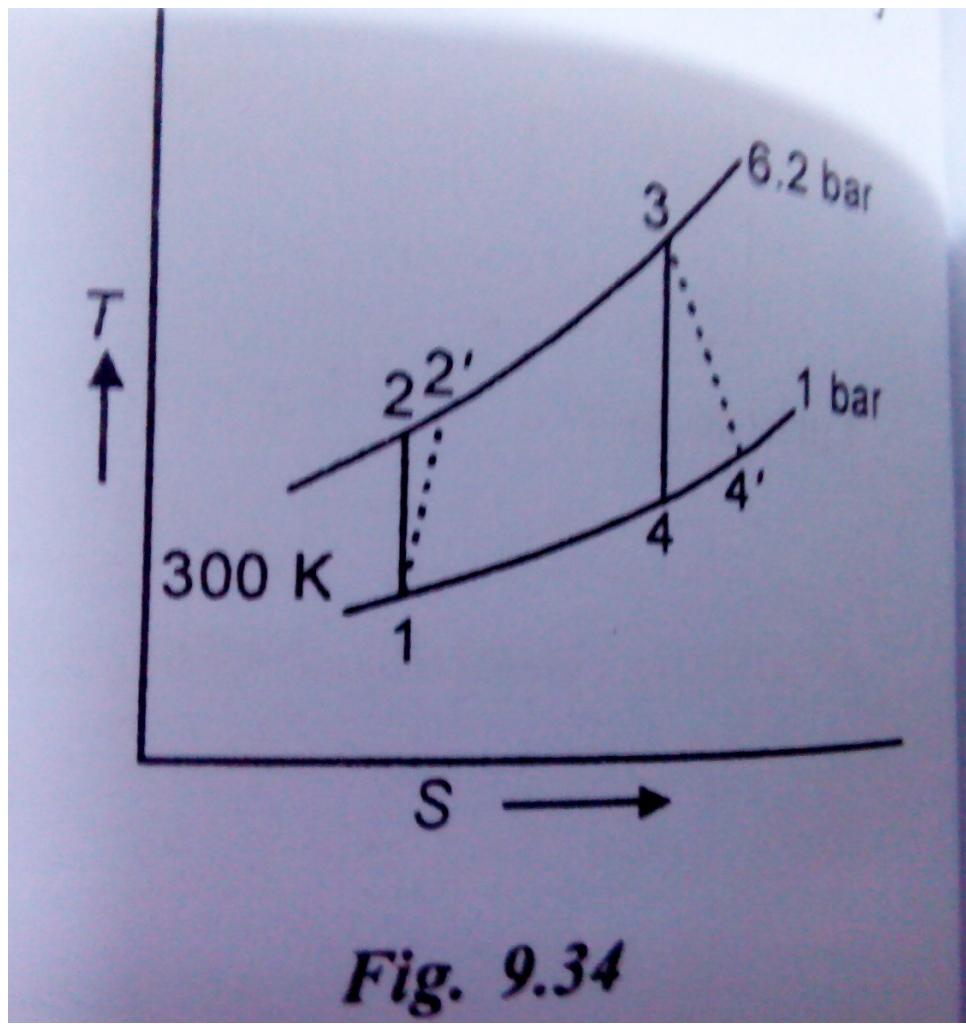


Figure 9.5: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 5")
8 P1=1*10^5; //initial pressure in Pa
9 P4=P1; //constant pressure process
10 T1=300; //initial temperature in K
11 P2=6.2*10^5; //pressure after compression in Pa
12 P3=P2; //constant pressure process
13 k=0.017; //fuel to air ratio
14 n_compr=0.88; //compressor efficiency
15 q=44186; //heating value of fuel in KJ/kg
16 n_turb=0.9; //turbine internal efficiency
17 Cp_comb=1.147; //specific heat of combustion at
    constant pressure in KJ/kg K
18 Cp_air=1.005; //specific heat of air at constant
    pressure in KJ/kg K
19 y=1.4; //expansion constant
20 n=1.33; //expansion constant for polytropic constant
21 disp("gas turbine cycle is shown by 1-2-3-4 on T-S
    diagram ,")
22 disp("for process 1-2 being isentropic ,")
23 disp("T2/T1=(P2/P1)^((y-1)/y)")
24 disp("so T2=T1*(P2/P1)^((y-1)/y) in K")
25 T2=T1*(P2/P1)^((y-1)/y)
26 disp("considering compressor efficiency ,n_compr=(T2-
    T1)/(T2_a-T1)")
27 disp("so T2_a=T1+((T2-T1)/n_compr) in K")
28 T2_a=T1+((T2-T1)/n_compr)
29 disp("during process 2-3 due to combustion of unit
    mass of compressed the energy balance shall be as
    under ,")
30 disp("heat added=mf*q")
31 disp("=((ma+mf)*Cp_comb*T3)-(ma*Cp_air*T2)" )

```

```

32 disp(" or ( mf/ma ) *q=(( 1+( mf/ma ) ) *Cp_comb*T3)-( Cp_air *
T2_a )")
33 disp(" so T3=(( mf/ma ) *q+( Cp_air*T2_a ) ) /(( 1+( mf/ma ) ) *
Cp_comb) in K")
34 T3=(( k)*q+(Cp_air*T2_a))/((1+(k))*Cp_comb)
35 disp(" for expansion 3-4 being")
36 disp("T4/T3=(P4/P3)^(( n-1)/n)")
37 disp(" so T4=T3*(P4/P3)^(( n-1)/n) in K")
38 T4=T3*(P4/P3)^((n-1)/n)
39 disp(" actual temperature at turbine inlet
considering internal efficiency of turbine ,")
40 disp(" n_turb=(T3-T4_a)/(T3-T4)")
41 disp(" so T4_a=T3-(n_turb*(T3-T4)) in K")
42 T4_a=T3-(n_turb*(T3-T4))
43 disp(" compressor work , per kg of air compressed (Wc)=
Cp_air*(T2_a-T1) in KJ/kg of air")
44 Wc=Cp_air*(T2_a-T1)
45 disp(" so compressor work=234.42 KJ/kg of air")
46 disp(" turbine work , per kg of air compressed (Wt)=
Cp_comb*(T3-T4_a) in KJ/kg of air")
47 Wt=Cp_comb*(T3-T4_a)
48 disp(" so turbine work=414.71 KJ/kg of air")
49 disp(" net work (W_net)=Wt-Wc in KJ/kg of air")
50 W_net=Wt-Wc
51 disp(" heat supplied (Q)=k*q in KJ/kg of air")
52 Q=k*q
53 disp(" thermal efficiency (n)=W_net/Q")
54 n=W_net/Q
55 disp(" in percentage")
56 n=n*100
57 disp(" so thermal efficiency=24%")

```

---

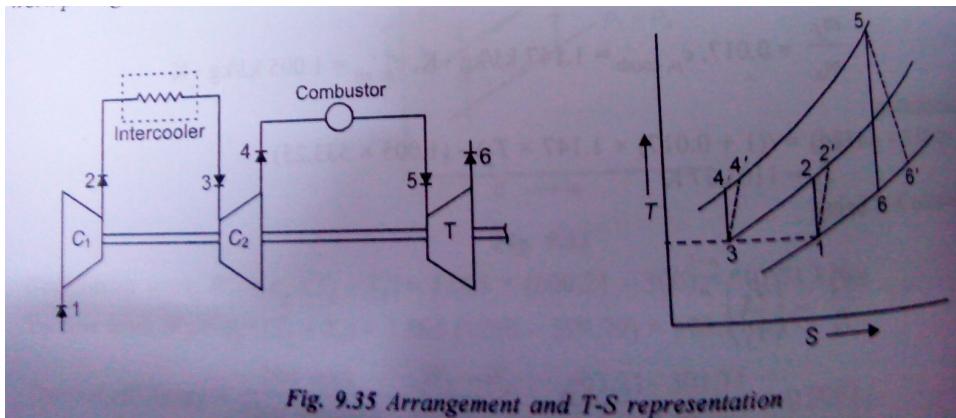


Figure 9.6: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 6

**Scilab code Exa 9.6** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 6

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 6")
8 T1=300; //minimum temperature in brayton cycle in K
9 T5=1200; //maximum temperature in brayton cycle in K
10 n_isen_c=0.85; //isentropic efficiency of compressor
11 n_isen_t=0.9; //isentropic efficiency of turbine
12 y=1.4; //expansion constant
13 disp("NOTE=>In this question formula for overall
pressure ratio is derived ,which cannot be done
using scilab ,so using this formula we proceed
further .")
14 disp("overall pressure ratio (rp)=(T1/(T5*n_isen_c *
n_isen_t )) ^((2*y)/(3*(1-y)))")

```

```
15 rp=(T1/(T5*n_isen_c*n_isen_t))^(2*y)/(3*(1-y)))
16 disp("so overall optimum pressure ratio=13.6")
```

---

**Scilab code Exa 9.7** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 7

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 7")
8 T1=313; //air entering temperature in K
9 P1=1*10^5; //air entering pressure in Pa
10 m=50; //flow rate through compressor in kg/s
11 R=0.287; //gas constant in KJ/kg K
12 disp("i> theoretically state of air at exit can be
determined by the given stage pressure ratio of
1.35. Let pressure at inlet to first stage P1 and
subsequent intermediate pressure be P2,P3,P4,P5,
P6,P7,P8 and exit pressure being P9.")
13 disp("therefore ,P2/P1=P3/P2=P4/P3=P5/P4=P6/P5=P7/P6=
P8/P7=P9/P8=r=1.35")
14 r=1.35; //compression ratio
15 disp("or P9/P1=k=(1.35)^8")
16 k=(1.35)^8
17 k=11.03; //approx.
18 disp("or theoretically ,the temperature at exit of
compressor can be predicted considering
isentropic compression of air (y=1.4)")
19 y=1.4; //expansion constant
20 disp("T9/T1=(P9/P1)^((y-1)/y)")
21 disp("so T9=T1*(P9/P1)^((y-1)/y) in K")
```

```

22 T9=T1*(k)^((y-1)/y)
23 disp(" considering overall efficiency of compression
     82% the actual temperature at compressor exit can
     be obtained")
24 disp("(T9-T1)/(T9_actual-T1)=0.82")
25 disp(" so T9_actual=T1+((T9-T1)/0.82) in K")
26 T9_actual=T1+((T9-T1)/0.82)
27 disp(" let the actual index of compression be n, then
     ")
28 disp("(T9_actual/T1)=(P9/P1)^((n-1)/n)")
29 disp(" so n=log(P9/P1)/(log(P9/P1)-log(T9-actual/T1))
     ")
30 n=log(k)/(log(k)-log(T9_actual/T1))
31 disp(" so state of air at exit of compressor , pressure
     =11.03 bar and temperature=689.18 K")
32 disp(" ii> let polytropic efficiency be n_polytropic
     for compressor then ,")
33 disp("(n-1)/n=((y-1)/y)*(1/n_polytropic)")
34 disp(" so n_polytropic=((y-1)/y)/((n-1)/n)")
35 n_polytropic=((y-1)/y)/((n-1)/n)
36 disp(" in percentage")
37 n_polytropic=n_polytropic*100
38 disp(" so ploytropic efficiency =86.88%")
39 disp(" iii> stage efficiency can be estimated for any
     stage.say first stage .")
40 disp(" ideal state at exit of compressor stage=T2/T1
     =(P2/P1)^((y-1)/y)")
41 disp(" so T2=T1*(P2/P1)^((y-1)/y) in K")
42 T2=T1*(r)^((y-1)/y)
43 disp(" actual temperature at exit of first stage can
     be estimated using polytropic index 1.49 .")
44 disp(" T2_actual/T1=(P2/P1)^((n-1)/n)")
45 disp(" so T2_actual=T1*(P2/P1)^((n-1)/n) in K")
46 T2_actual=T1*(r)^((n-1)/n)
47 disp(" stage efficiency for first stage , ns_1=(T2-T1)
     /(T2_actual-T1)")
48 ns_1=(T2-T1)/(T2_actual-T1)
49 disp(" in percentage")

```

```

50 ns_=ns_1*100
51 disp(" actual temperature at exit of second stage ,")
52 disp(" T3_actual/T2_actual=(P3/P2) ^((n-1)/n)")
53 disp(" so T3_actual=T2_actual*(P3/P2) ^((n-1)/n) in K"
)
54 T3_actual=T2_actual*(r)^((n-1)/n)
55 disp(" ideal temperature at exit of second stage")
56 disp("T3/T2_actual=(P3/P2) ^((n-1)/n)")
57 disp(" so T3=T2_actual*(P3/P2) ^((y-1)/y) in K")
58 T3=T2_actual*(r)^((y-1)/y)
59 disp(" stage efficiency for second stage , ns_2=(T3-
T2_actual)/(T3_actual-T2_actual)")
60 ns_2=(T3-T2_actual)/(T3_actual-T2_actual)
61 disp(" in percentage")
62 ns_2=ns_2*100
63 disp(" actual rtemperature at exit of third stage ,")
64 disp(" T4_actual/T3_actual=(P4/P3) ^((n-1)/n)")
65 disp(" so T4=T3_actual*(P4/P3) ^((n-1)/n) in K"
)
66 T4_actual=T3_actual*(r)^((n-1)/n)
67 disp(" ideal temperature at exit of third stage ,")
68 disp("T4/T3_actual=(P4/P3) ^((n-1)/n)")
69 disp(" so T4=T3_actual*(P4/P3) ^((y-1)/y) in K")
70 T4=T3_actual*(r)^((y-1)/y)
71 disp(" stage efficiency for third stage , ns_3=(T4-
T3_actual)/(T4_actual-T3_actual)")
72 ns_3=(T4-T3_actual)/(T4_actual-T3_actual)
73 disp(" in percentage")
74 ns_3=ns_3*100
75 disp(" so stage efficiency =86.4%")
76 disp(" iv> from steady flow energy equation ,")
77 disp("Wc=dw=dh and dh=du+p*dv+v*dp")
78 disp(" dh=dq+v*dp")
79 disp(" dq=0 in adiabatic process")
80 disp(" dh=v*dp")
81 disp("Wc=v*dp")
82 disp(" here for polytropic compression ")
83 disp("P*V^1.49=constant i.e n=1.49")

```

```

84 n=1.49;
85 disp("Wc=(n/(n-1))*m*R*T1*[((P9/P1)^(n-1)/n)-1] in
     KJ/s")
86 Wc=(n/(n-1))*m*R*T1*[((k)^(n-1)/n)-1]
87 disp("due to overall efficiency being 90% the actual
     compressor work(Wc_actual)=Wc*0.9 in KJ/s")
88 Wc_actual=Wc*0.9
89 disp("so power required to drive compressor
     =14777.89 KJ/s")

```

---

**Scilab code Exa 9.8** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 8

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 9 Example 8")
8 disp("In question no.8, expression for air standard
      cycle efficiency is derived which cannot be solve
      using scilab software.")

```

---

**Scilab code Exa 9.9** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 9

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

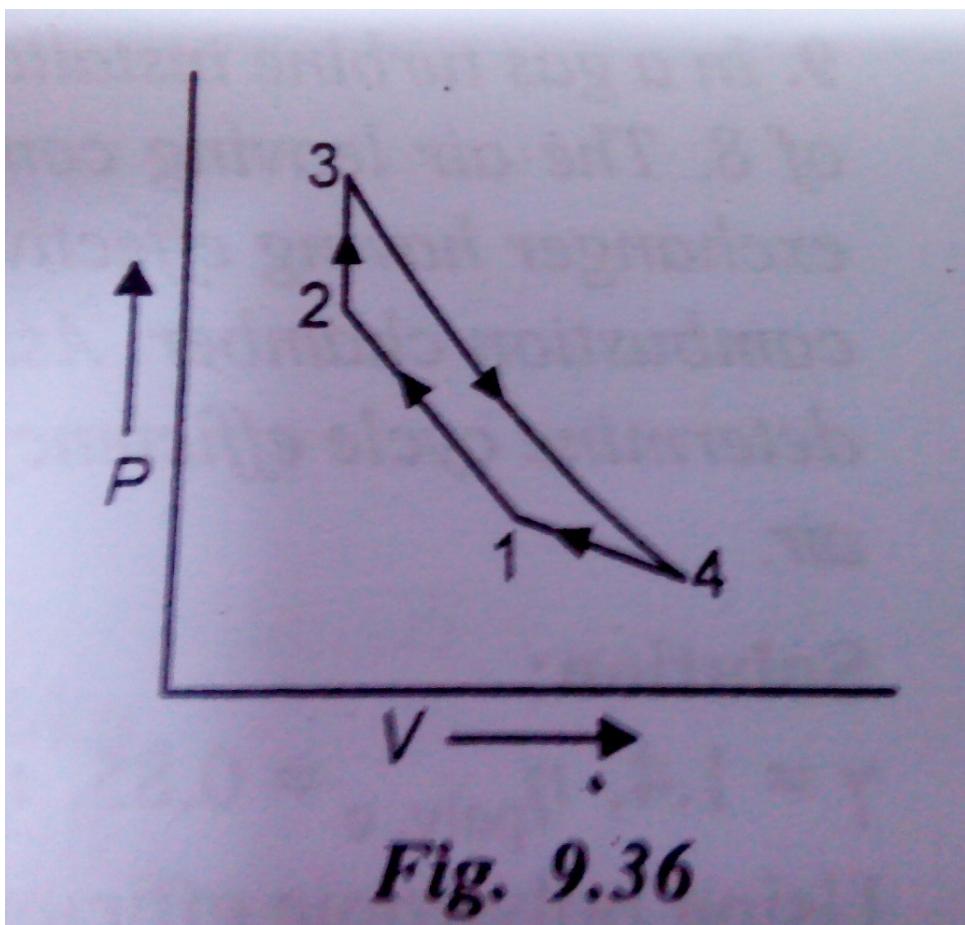


Figure 9.7: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 8

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 9")
8 y=1.4; //expansion constant
9 n_poly_c=0.85; //ploytropic efficiency of compressor
10 n_poly_T=0.90; //ploytropic efficiency of Turbine
11 r=8; //compression ratio
12 T1=(27+273); //temperature of air in compressor in K
13 T3=1100; //temperature of air leaving combustion
chamber in K
14 epsilon=0.8; //effectiveness of heat exchanger
15 Cp=1.0032; //specific heat at constant pressure in KJ
/kg K
16 disp("using polytropic efficiency the index of
compression and expansion can be obtained as
under ,")
17 disp(" let compression index be nc ,")
18 disp(" (nc-1)/nc=(y-1)/(y*n_poly_c)")
19 disp(" so nc=1/(1-((y-1)/(y*n_poly_c)))")
20 nc=1/(1-((y-1)/(y*n_poly_c)))
21 disp(" let expansion index be nt ,")
22 disp(" (nt-1)/nt=(n_poly_T*(y-1))/y")
23 disp(" so nt=1/(1-((n_poly_T*(y-1))/y))")
24 nt=1/(1-((n_poly_T*(y-1))/y))
25 disp("For process 1-2")
26 disp("T2/T1=(p2/p1)^((nc-1)/nc)")
27 disp(" so T2=T1*(p2/p1)^((nc-1)/nc) in K")
28 T2=T1*(r)^((nc-1)/nc)
29 disp(" also T4/T3=(p4/p3)^((nt-1)/nt)")
30 disp(" so T4=T3*(p4/p3)^((nt-1)/nt) in K")
31 T4=T3*(1/r)^((nt-1)/nt)
32 disp(" using heat exchanger effectivesss ,")
33 disp(" epsilon=(T5-T2)/(T4-T2)")
34 disp(" so T5=T2+(epsilon*(T4-T2)) in K")
35 T5=T2+(epsilon*(T4-T2))
36 disp("heat added in combustion chamber , q_add=Cp*(T3-

```

```

        T5) in KJ/kg" )
37 q_add=Cp*(T3-T5)
38 disp(" compressor work ,Wc=Cp*(T2-T1) in ")
39 Wc=Cp*(T2-T1)
40 disp(" turbine work ,Wt=Cp*( T3-T4) in KJ/kg" )
41 Wt=Cp*(T3-T4)
42 disp(" cycle efficiency=(Wt-Wc) / q_add" )
43 (Wt-Wc)/q_add
44 disp(" in percentage" )
45 (Wt-Wc)*100/q_add
46 disp(" work ratio ,(Wt-Wc) /Wt" )
47 (Wt-Wc)/Wt
48 disp(" specific work output=Wt-Wc in KJ/kg" )
49 Wt-Wc
50 disp(" so cycle efficiency =32.79%, work ratio =0.334 ,
    specific work output=152.56 KJ/kg" )

```

---

**Scilab code Exa 9.10** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 10

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
    Chapter 9 Example 10")
8 T1=(27+273); //temperature of air in compressor in K

```

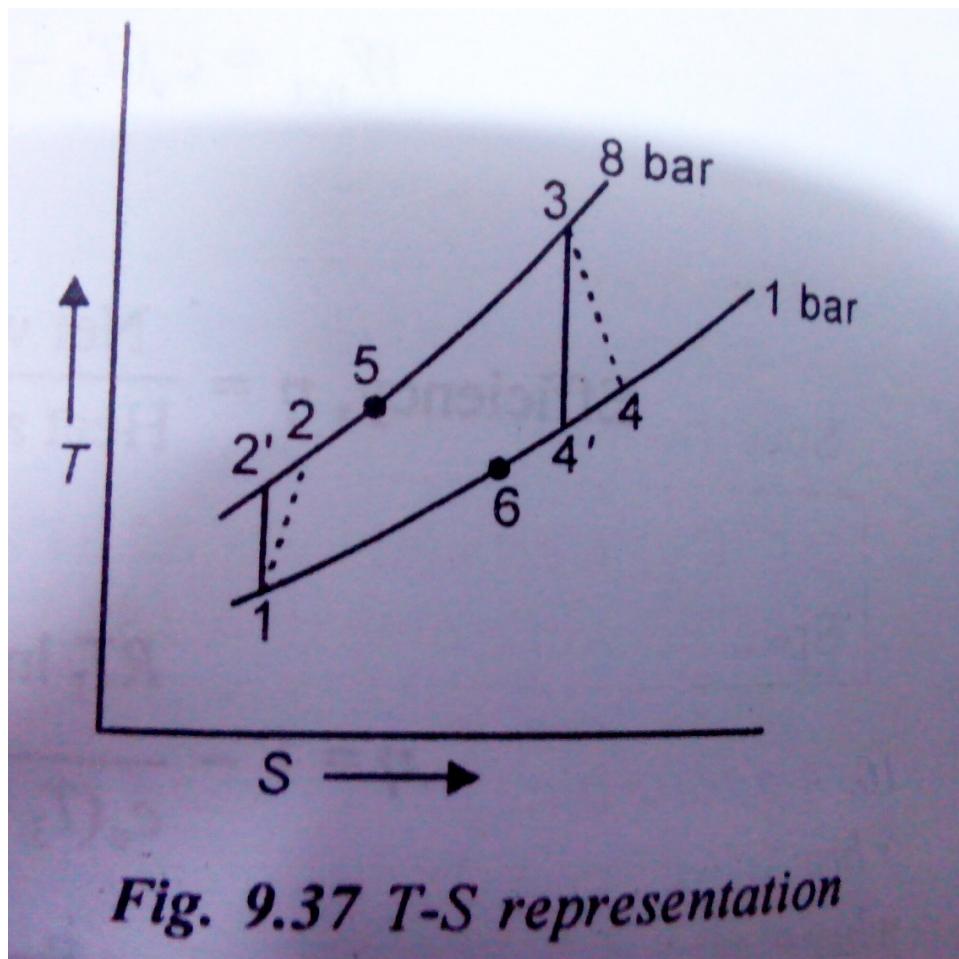
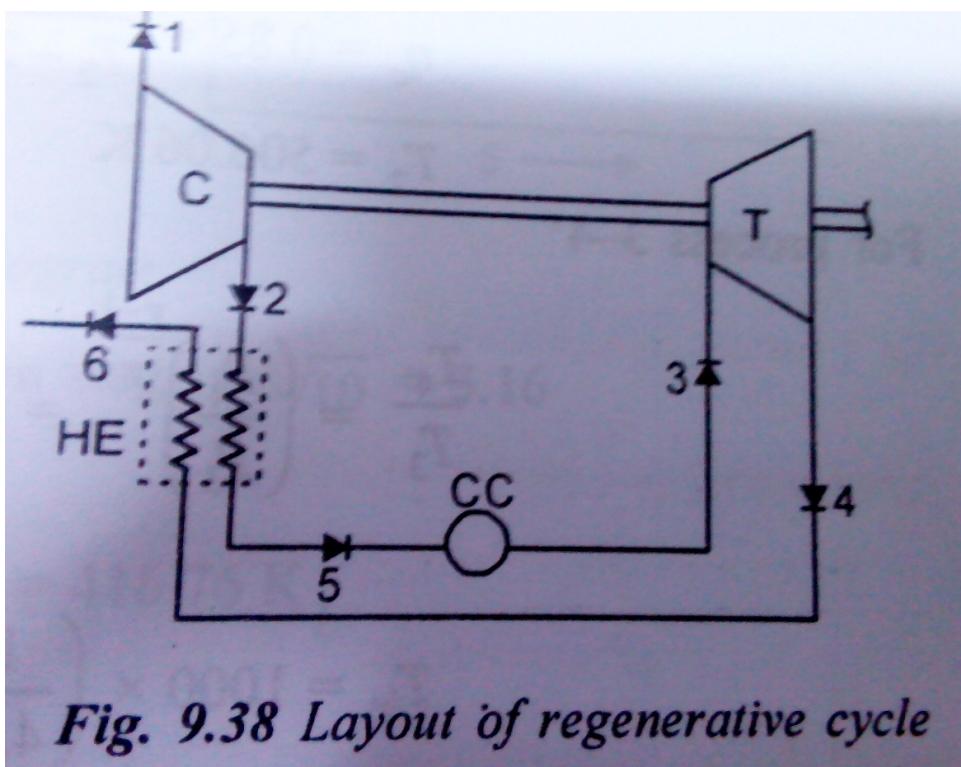


Figure 9.8: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 9



**Fig. 9.38 Layout of regenerative cycle**

Figure 9.9: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 9

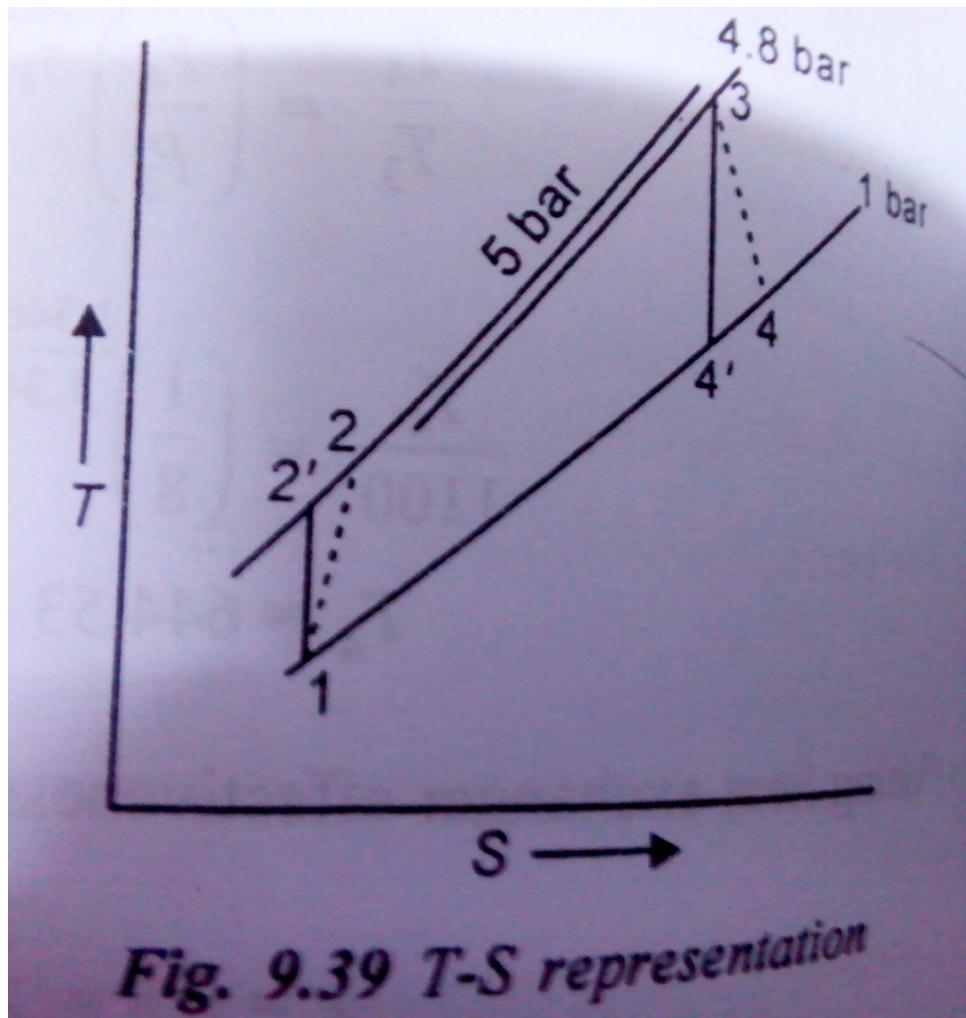


Figure 9.10: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 10

```

9 p1=1*10^5; //pressure of air in compressor in Pa
10 p2=5*10^5; //pressure of air after compression in Pa
11 p3=p2-0.2*10^5; //pressure drop in Pa
12 p4=1*10^5; //pressure to which expansion occur in
    turbine in Pa
13 nc=0.85; //isentropic efficiency
14 T3=1000; //temperature of air in combustion chamber
    in K
15 n=0.2; //thermal efficiency of plant
16 y=1.4; //expansion constant
17 Cp=1.0032; //specific heat at constant pressure in KJ
    /kg K
18 disp(" for process 1-2_a")
19 disp(" T2_a/T1=(p2_a/p1) ^((y-1)/y)")
20 disp(" so T2_a=T1*(p2_a/p1) ^((y-1)/y) in K")
21 T2_a=T1*(p2/p1) ^((y-1)/y)
22 disp(" nc=(T2_a-T1)/(T2-T1)")
23 disp(" so T2=T1+((T2_a-T1)/nc) in K")
24 T2=T1+((T2_a-T1)/nc)
25 disp(" for process 3-4_a ,")
26 disp(" T4_a/T3=(p4/p3) ^((y-1)/y)")
27 disp(" so T4_a=T3*(p4/p3) ^((y-1)/y) in K")
28 T4_a=T3*(p4/p3) ^((y-1)/y)
29 disp(" Compressor work per kg ,Wc=Cp*(T2-T1) in KJ/kg"
    )
30 Wc=Cp*(T2-T1)
31 disp(" Turbine work per kg ,Wt=Cp*(T3-T4) in KJ/kg")
32 disp(" net output ,W_net=Wt-Wc={Wc-(Cp*(T3-T4))} in KJ
    /kg")
33 disp(" heat added ,q_add=Cp*(T3-T2) in KJ/kg")
34 q_add=Cp*(T3-T2)
35 disp(" thermal efficiency ,n=W_net/q_add")
36 disp(" n={Wc-(Cp*(T3-T4))}/q_add")
37 disp(" so T4=T3-((Wc-(n*q_add))/Cp) in K")
38 T4=T3-((Wc-(n*q_add))/Cp)
39 disp(" therefore ,isentropic efficiency of turbine ,nt
    =(T3-T4)/(T3-T4_a)")
40 nt=(T3-T4)/(T3-T4_a)

```

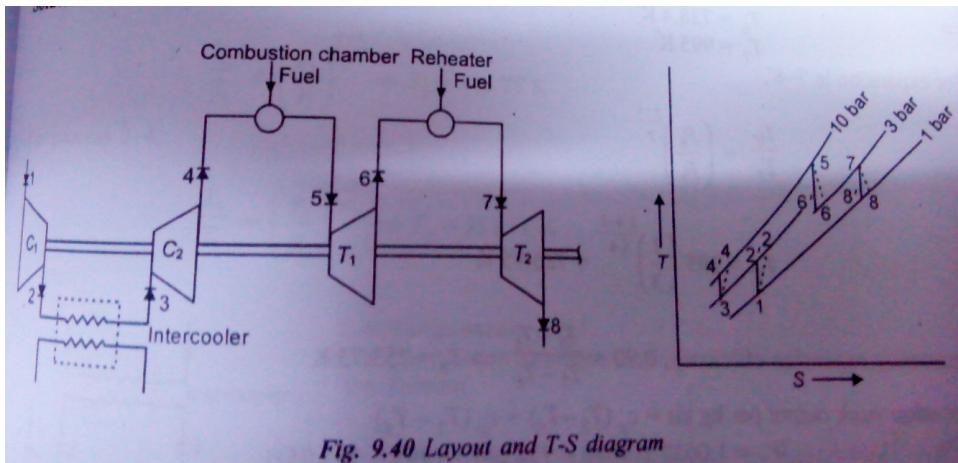


Figure 9.11: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 11

```

41 disp("in percentage")
42 nt=nt*100
43 disp("so turbine isentropic efficiency =29.69%")

```

---

**Scilab code Exa 9.11** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 11

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 9 Example 11")
8 P1=1*10^5; //initial pressure in Pa
9 T1=(27+273); //initial temperature in K

```

```

10 T3=T1;
11 r=10; //pressure ratio
12 T5=1000; //maximum temperature in cycle in K
13 P6=3*10^5; //first stage expansion pressure in Pa
14 T7=995; //first stage reheated temperature in K
15 C=42000; //calorific value of fuel in KJ/kg
16 Cp=1.0032; //specific heat at constant pressure in KJ
   /kg K
17 m=30; //air flow rate in kg/s
18 nc=0.85; //isentropic efficiency of compression
19 ne=0.9; //isentropic efficiency of expansion
20 y=1.4; //expansion constant
21 disp(" for perfect intercooling the pressure ratio of
      each compression stage(k)")
22 disp("k=sqrt(r)")
23 k=sqrt(r)
24 k=3.16; //approx.
25 disp(" for process 1-2_a , T2_a/T1=(P2/P1) ^((y-1)/y)")
26 disp(" so T2_a=T1*(k)^((y-1)/y) in K")
27 T2_a=T1*(k)^((y-1)/y)
28 disp(" considering isentropic efficiency of
      compression ,")
29 disp(" nc=(T2_a-T1)/(T2-T1)")
30 disp(" so T2=T1+((T2_a-T1)/nc) in K")
31 T2=T1+((T2_a-T1)/nc)
32 disp(" for process 3-4,")
33 disp(" T4_a/T3=(P4/P3) ^((y-1)/y)")
34 disp(" so T4_a=T3*(P4/P3) ^((y-1)/y) in K")
35 T4_a=T3*(k)^((y-1)/y)
36 disp(" again due to compression efficiency , nc=(T4_a-
      T3)/(T4-T3)")
37 disp(" so T4=T3+((T4_a-T3)/nc) in K")
38 T4=T3+((T4_a-T3)/nc)
39 disp(" total compressor work ,Wc=2*Cp*(T4-T3) in KJ/kg
      ")
40 Wc=2*Cp*(T4-T3)
41 disp(" for expansion process 5-6_a ,")
42 disp(" T6_a/T5=(P6/P5) ^((y-1)/y)")

```

```

43 disp(" so T6_a=T5*(P6/P5) ^((y-1)/y) in K")
44 P5=10*10^5; //pressure in Pa
45 T6_a=T5*(P6/P5) ^((y-1)/y)
46 disp(" considering expansion efficiency ,ne=(T5-T6)/(T5-T6_a)")
47 disp("T6=T5-(ne*(T5-T6_a)) in K")
48 T6=T5-(ne*(T5-T6_a))
49 disp(" for expansion in 7-8_a")
50 disp(" T8_a/T7=(P8/P7) ^((y-1)/y)") )
51 disp(" so T8_a=T7*(P8/P7) ^((y-1)/y) in K")
52 P8=P1; //constant pressure process
53 P7=P6; //constant pressure process
54 T8_a=T7*(P8/P7) ^((y-1)/y)
55 disp(" considering expansion efficiency ,ne=(T7-T8)/(T7-T8_a)")
56 disp(" so T8=T7-(ne*(T7-T8_a)) in K")
57 T8=T7-(ne*(T7-T8_a))
58 disp(" expansion work output per kg of air(Wt)=Cp*(T5-T6)+Cp*(T7-T8) in KJ/kg")
59 Wt=Cp*(T5-T6)+Cp*(T7-T8)
60 disp(" heat added per kg air (q_add)=Cp*(T5-T4)+Cp*(T7-T6) in KJ/kg")
61 q_add=Cp*(T5-T4)+Cp*(T7-T6)
62 disp(" fuel required per kg of air ,mf=q_add/C")
63 mf=q_add/C
64 disp(" air-fuel ratio=1/mf")
65 1/mf
66 disp(" net output (W)=Wt-Wc in KJ/kg")
67 W=Wt-Wc
68 disp("output for air flowing at 30 kg/s ,=W*m in KW")
69 W*m
70 disp(" thermal efficiency=W/q_add")
71 W/q_add
72 disp("in percentage")
73 W*100/q_add
74 disp("so thermal efficiency=27.87%, net output =6876.05 KW,A/F ratio=51.07")
75 disp("NOTE=>In this question ,expansion work is")

```

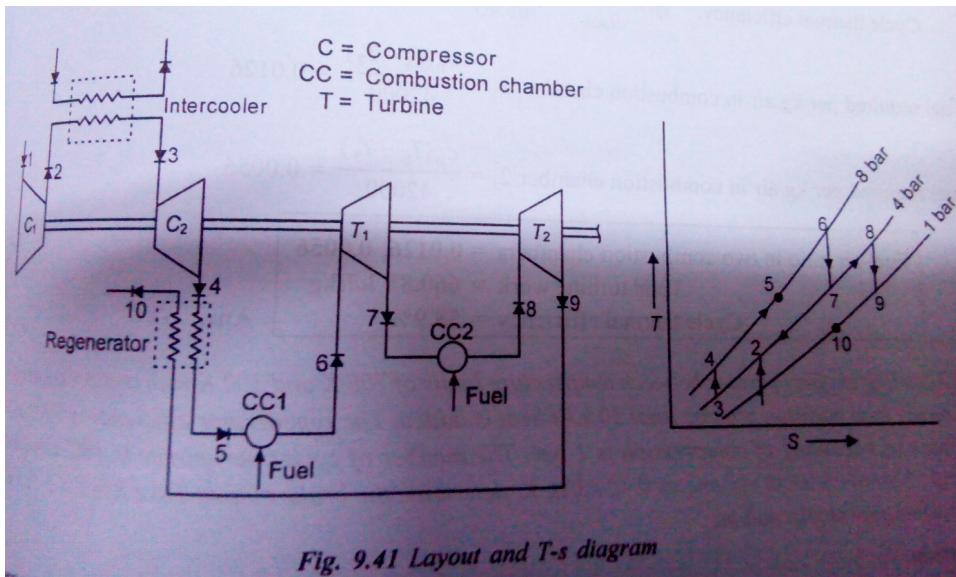


Figure 9.12: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 12

calculated wrong in book , so it is corrected above and answers vary accordingly . ” )

---

**Scilab code Exa 9.12** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 12

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 12")

```

```

8 P1=1*10^5; //initial pressure in Pa
9 P9=P1;
10 T1=300; //initial temperature in K
11 P2=4*10^5; //pressure of air in intercooler in Pa
12 P3=P2;
13 T3=290; //temperature of air in intercooler in K
14 T6=1300; //temperature of combustion chamber in K
15 P4=8*10^5; //pressure of air after compression in Pa
16 P6=P4;
17 T8=1300; //temperature after reheating in K
18 P8=4*10^5; //pressure after expansion in Pa
19 P7=P8;
20 C=42000; //heating value of fuel in KJ/kg
21 y=1.4; //expansion constant
22 ne=0.8; //effectiveness of regenerator
23 Cp=1.0032; //specific heat at constant pressure in KJ
    /kg K
24 disp("for process 1-2,")
25 disp("T2/T1=(P2/P1) ^((y-1)/y)" )
26 disp("so T2=T1*(P2/P1) ^((y-1)/y) in K")
27 T2=T1*(P2/P1) ^((y-1)/y)
28 disp("for process 3-4,")
29 disp("T4/T3=(P4/P3) ^((y-1)/y)" )
30 disp("so T4=T3*(P4/P3) ^((y-1)/y) in K")
31 T4=T3*(P4/P3) ^((y-1)/y)
32 disp("for process 6-7,")
33 disp("T7/T6=(P7/P6) ^((y-1)/y)" )
34 disp("so T7=T6*(P7/P6) ^((y-1)/y) in K")
35 T7=T6*(P7/P6) ^((y-1)/y)
36 disp("for process 8-9,")
37 disp("T9/T8=(P9/P8) ^((y-1)/y)" )
38 disp("T9=T8*(P9/P8) ^((y-1)/y) in K")
39 T9=T8*(P9/P8) ^((y-1)/y)
40 disp("in regenerator , effectiveness=(T5-T4)/(T9-T4)" )
41 disp("T5=T4+(ne*(T9-T4)) in K")
42 T5=T4+(ne*(T9-T4))
43 disp("compressor work per kg air ,Wc=Cp*(T2-T1)+Cp*(
    T4-T3) in KJ/kg")

```

```

44 Wc=Cp*(T2-T1)+Cp*(T4-T3)
45 disp(" turbine work per kg air ,Wt=Cp*(T6-T7)+Cp*(T8-
    T9) in KJ/kg")
46 Wt=Cp*(T6-T7)+Cp*(T8-T9)
47 disp(" heat added per kg air ,q_add=Cp*(T6-T5)+Cp*(T8-
    T7) in KJ/kg")
48 q_add=Cp*(T6-T5)+Cp*(T8-T7)
49 disp(" total fuel required per kg of air=q_add/C")
50 q_add/C
51 disp(" net work ,W_net=Wt-Wc in KJ/kg")
52 W_net=Wt-Wc
53 disp(" cycle thermal efficiency ,n=W_net/q_add")
54 n=W_net/q_add
55 disp(" in percentage")
56 n=n*100
57 disp(" fuel required per kg air in combustion chamber
    1 ,Cp*(T8-T7)/C")
58 Cp*(T8-T7)/C
59 disp(" fuel required per kg air in combustion
    chamber2 ,Cp*(T6-T5)/C")
60 Cp*(T6-T5)/C
61 disp(" so fuel-air ratio in two combustion chambers
    =0.0126 ,0.0056")
62 disp(" total turbine work=660.85 KJ/kg")
63 disp(" cycle thermal efficiency=58.9%")
64 disp("NOTE=>In this question ,fuel required per kg
    air in combustion chamber 1 and 2 are calculated
    wrong in book ,so it is corrected above and
    answers vary accordingly . ")

```

---

**Scilab code Exa 9.13** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 13

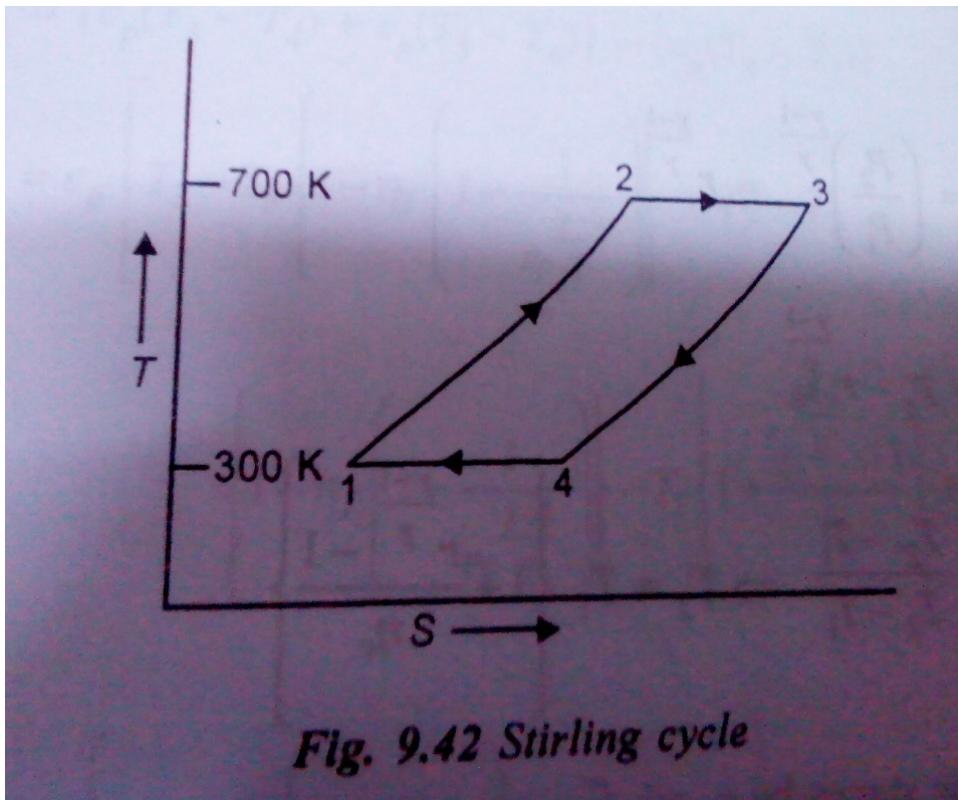


Figure 9.13: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 13

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 13")
8 T2=700; //highest temperature of stirling engine in K
9 T1=300; //lowest temperature of stirling engine in K
10 r=3; //compression ratio
11 q_add=30; //heat addition in KJ/s
12 epsilon=0.9; //regenerator efficiency
13 P=1*10^5; //pressure at begining of compression in Pa
14 n=100; //number of cycle per minute
15 Cv=0.72; //specific heat at constant volume in KJ/kg
    K
16 R=29.27; //gas constant in KJ/kg K
17 disp("work done per kg of air ,W=R*(T2-T1)*log (r) in
    KJ/kg")
18 W=R*(T2-T1)*log(r)
19 disp("heat added per kg of air ,q=R*T2*log (r)+(1-
    epsilon)*Cv*(T2-T1) in KJ/kg")
20 q=R*T2*log(r)+(1-epsilon)*Cv*(T2-T1)
21 disp("for 30 KJ/s heat supplied ,the mass of air/s(m)
    =q_add/q in kg/s")
22 m=q_add/q
23 disp("mass of air per cycle=m/n in kg/cycle")
24 m/n
25 disp("brake output=W*m in KW")
26 W*m
27 disp("stroke volume ,V=m*R*T/P in m^3")
28 m=1.33*10^-4; //mass of air per cycle in kg/cycle
29 T=T1;
30 V=m*R*T*1000/P
31 disp("brake output=17.11 KW")
32 disp("stroke volume=0.0116 m^3")

```

---

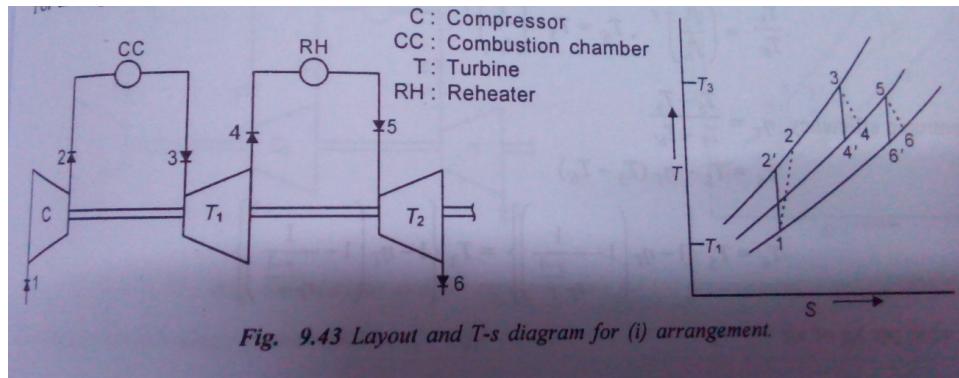


Figure 9.14: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 14

**Scilab code Exa 9.14** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 14

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 14")
8 disp("In question no.14 , various expression is
derived which cannot be solved using scilab
software .")

```

---

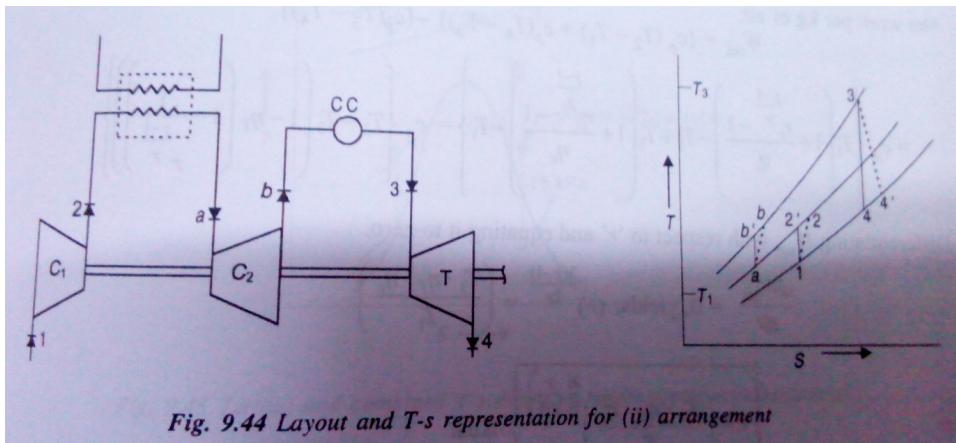


Fig. 9.44 Layout and T-s representation for (ii) arrangement

Figure 9.15: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 14

**Scilab code Exa 9.15** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 15

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 15")
8 r=10; //pressure ratio
9 Cp=1.0032; //specific heat of air in KJ/kg K
10 y=1.4; //expansion constant
11 T3=1400; //inlet temperature of gas turbine in K
12 T1=(17+273); //ambient temperature in K
13 P1=1*10^5; //ambient pressure in Pa
14 Pc=15; //condensor pressure in KPa
15 Pg=6*1000; //pressure of steam in generator in KPa

```

```

16 T5=420; //temperature of exhaust from gas turbine in
K
17 disp("In gas turbine cycle ,T2/T1=(P2/P1) ^((y-1)/y)")
18 disp("so T2=T1*(P2/P1) ^((y-1)/y) in K")
19 T2=T1*(r)^((y-1)/y)
20 disp("T4/T3=(P4/P3) ^((y-1)/y)")
21 disp("so T4=T3*(P4/P3) ^((y-1)/y) in K")
22 T4=T3*(1/r)^((y-1)/y)
23 disp("compressor work per kg,Wc=Cp*(T2-T1) in KJ/kg")
)
24 Wc=Cp*(T2-T1)
25 disp("turbine work per kg,Wt=Cp*(T3-T4) in KJ/kg ")
26 Wt=Cp*(T3-T4)
27 disp("heat added in combustion chamber per kg,q_add=
Cp*(T3-T2) in KJ/kg ")
28 q_add=Cp*(T3-T2)
29 disp("net gas turbine output ,W_net_GT=Wt-Wc in KJ/kg
air")
30 W_net_GT=Wt-Wc
31 disp("heat recovered in HRSG for steam generation
per kg of air")
32 disp("q_HRGC=Cp*(T4-T5) in KJ/kg")
33 q_HRGC=Cp*(T4-T5)
34 disp("at inlet to steam in turbine ,")
35 disp("from steam table ,ha=3177.2 KJ/kg ,sa=6.5408 KJ/
kg K")
36 ha=3177.2;
37 sa=6.5408;
38 disp("for expansion in steam turbine ,sa=sb")
39 sb=sa;
40 disp("let dryness fraction at state b be x")
41 disp("also from steam table ,at 15KPa, sf=0.7549 KJ/
kg K, sfg=7.2536 KJ/kg K, hf=225.94 KJ/kg ,hfg
=2373.1 KJ/kg")
42 sf=0.7549;
43 sfg=7.2536;
44 hf=225.94;
45 hfg=2373.1;

```

```

46 disp("sb=sf+x*sfg")
47 disp("so x=(sb-sf)/sfg ")
48 x=(sb-sf)/sfg
49 disp("so hb=hf+x*hfg in KJ/kg K")
50 hb=hf+x*hfg
51 disp("at exit of condenser ,hc=hf ,vc=0.001014 m^3/kg
      from steam table")
52 hc=hf;
53 vc=0.001014;
54 disp("at exit of feed pump,hd=hd-hc")
55 disp("hd=vc*(Pg-Pc)*100 in KJ/kg")
56 hd=vc*(Pg-Pc)*100
57 disp("heat added per kg of steam =ha-hd in KJ/kg")
58 ha-hd
59 disp("mass of steam generated per kg of air=q_HRGC/(
      ha-hd) in kg steam per kg air")
60 q_HRGC/(ha-hd)
61 disp("net steam turbine cycle output ,W_net_ST=(ha-hb
      )-(hd-hc) in KJ/kg")
62 W_net_ST=(ha-hb)-(hd-hc)
63 disp("steam cycle output per kg of air (W_net_ST)=
      W_net_ST*0.119 in KJ/kg air")
64 W_net_ST=W_net_ST*0.119
65 disp("total combined cycle output=(W_net_GT+W_net_ST
      ) in KJ/kg air ")
66 (W_net_GT+W_net_ST)
67 disp("combined cycle efficiency ,n_cc=(W_net_GT+
      W_net_ST)/q_add")
68 n_cc=(W_net_GT+W_net_ST)/q_add
69 disp("in percentage")
70 n_cc=n_cc*100
71 disp("In absence of steam cycle ,gas turbine cycle
      efficiency ,n_GT=W_net_GT/q_add")
72 n_GT=W_net_GT/q_add
73 disp("in percentage")
74 n_GT=n_GT*100
75 disp("thus ,efficiency is seen to increase in
      combined cycle upto 57.77% as compared to gas

```

```
    turbine offering 48.21% efficiency.”)
76 disp(“overall efficiency=57.77%”)
77 disp(“steam per kg of air=0.119 kg steam per/kg air”
)
```

---

**Scilab code Exa 9.16** Engineering Thermodynamics by Onkar Singh Chapter 9 Example 16

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(“Engineering Thermodynamics by Onkar Singh
Chapter 9 Example 16”)
8 T1=(27+273); //temperature at begining of compression
in K
9 k=70; //ration of maximum to minimum pressures
10 r=15; //compression ratio
11 y=1.4; //expansion constant
12 disp(“here P4/P1=P3/P1 = 70 ..... eq1”)
13 disp(“compression ratio ,V1/V2=V1/V3 = 15 .....
eq2”)
14 disp(“heat added at constant volume= heat added at
constant pressure”)
15 disp(“Q23=Q34”)
16 disp(“m*Cv*(T3-T2)=m*Cp*(T4-T3)”)
17 disp(“(T3-T2)=y*(T4-T3)”)
```

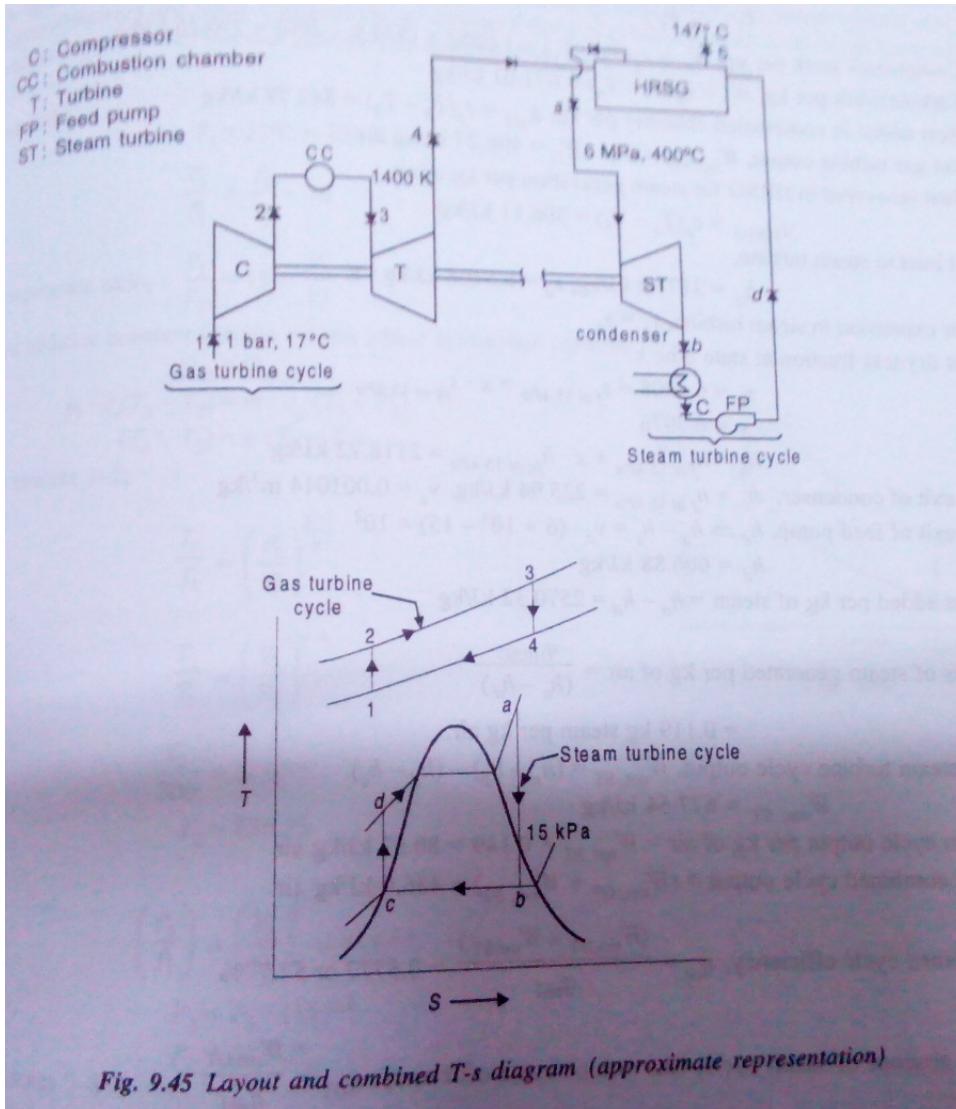


Fig. 9.45 Layout and combined T-s diagram (approximate representation)

Figure 9.16: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 15

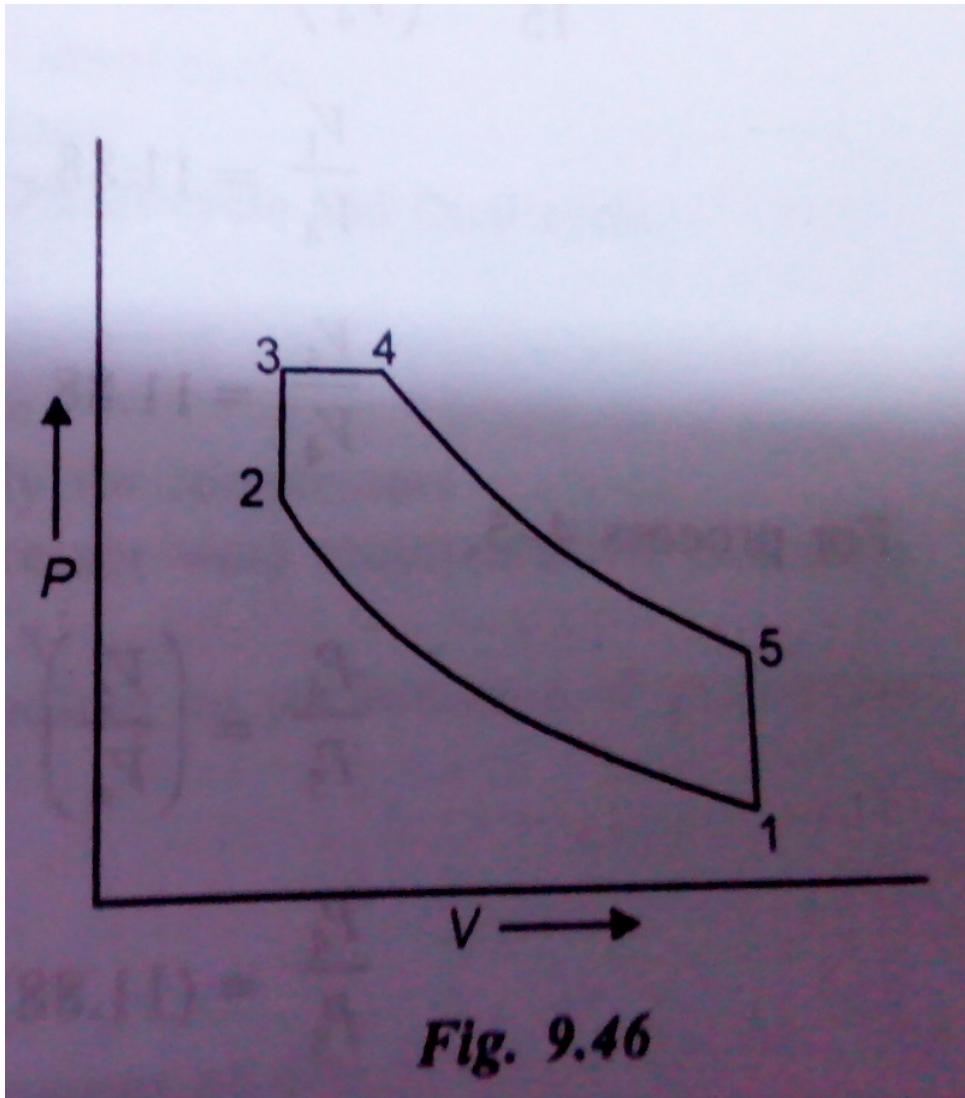


Figure 9.17: Engineering Thermodynamics by Onkar Singh Chapter 9 Example 16



- 53 **disp**(" Actual thermal efficiency may be different from theoretical efficiency due to following reasons")
- 54 **disp**("a> Air standard cycle analysis considers air as the working fluid while in actual cycle it is not air throughout the cycle. Actual working fluid which are combustion products do not behave as perfect gas.")
- 55 **disp**("b> Heat addition does not occur isochorically in actual process. Also combustion is accompanied by inefficiency such as incomplete combustion , dissociation of combustion products , etc .")
- 56 **disp**("c> Specific heat variation occurs in actual processes where as in air standard cycle analysis specific heat variation neglected .Also during adiabatic process theoretically no heat loss occur while actually these processes are accompanied by heat losses .")
-

# Chapter 10

## Introduction To Internal Combustion Engines

**Scilab code Exa 10.1** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 10 Example 1")
8 k=20*10^6; //spring constant in N/m^2
9 N=2000; //engine rpm
10 disp("from stroke to bore ratio i.e L/D=1.2 and
cylinder diameter=bore , i.e D=12 cm")
11 D=12*10^-2; //cylinder diameter in m
12 disp("stroke(L)=1.2*D in m")
13 L=1.2*D
14 disp("Area of indicator diagram(A)=30*10^-4 m^2")
15 A=30*10^-4;
16 disp("length of indicator diagram(l)=(1/2)*L in m")
```

```

17 l=(1/2)*L
18 disp("mean effective pressure(mep)=A*k/l in N/m^2")
19 mep=A*k/l
20 disp("cross-section area of piston(Ap)=%pi*D^2/4 in
m^2")
21 Ap=%pi*D^2/4
22 disp("for one cylinder indicated power(IP)=mep*Ap*L*
N/(2*60) in W")
23 IP=mep*Ap*L*N/(2*60)
24 disp("for four cylinder total indicated power(IP)=4*
IP in W")
25 IP=4*IP
26 disp("frictional power loss(FP)=0.10*IP in W")
27 FP=0.10*IP
28 disp("brake power available(BP)=indicated power-
frictional power=IP-FP in W")
29 BP=IP-FP
30 disp("therefore, mechanical efficiency of engine(n)=
brake power/indicated power=BP/IP")
31 n=BP/IP
32 disp("in percentage")
33 n=n*100
34 disp("so indicated power=90477.8 W")
35 disp("and mechanical efficiency=90%")

```

---

**Scilab code Exa 10.2** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh"

```

```

    Chapter 10 Example 2")
8 A=40*10^-4; //area of indicator diagram in m^2
9 l=8*10^-2; //length of indicator diagram in m
10 D=15*10^-2; //bore of cylinder in m
11 L=20*10^-2; //stroke in m
12 k=1.5*10^8; //spring constant in pa/m
13 N=100; //pump motor rpm
14 disp("reciprocating pump is work absorbing machine
        having its mechanism similar to the piston-
        cylinder arrangement in IC engine.")
15 disp("mean effective pressure(mep)=A*k/l in pa")
16 mep=A*k/l
17 disp("indicator power(IP)=Ap*L*mep*N*1*2/60 in W")
18 disp("(it is double acting so let us assume total
        power to be double of that in single acting)")
19 Ap=%pi*D^2/4
20 IP=Ap*L*mep*N*2/60
21 disp("so power required to drive=88.36 KW")

```

---

**Scilab code Exa 10.3** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 3

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
        Chapter 10 Example 3")
8 n=0.9; //mechanical efficiency of engine
9 BP=38; //brake power in KW
10 disp("indicated power(IP)=brake power/mechanical
        efficiency=BP/n in KW")
11 IP=BP/n

```

```

12 disp(" frictional power loss (FP)=IP-BP in KW")
13 FP=IP-BP
14 disp(" brake power at quater load (BPq)=0.25*BP in KW"
      )
15 BPq=0.25*BP
16 disp(" mechanical efficiency (n1)=BPq/IP" )
17 IP=BPq+FP;
18 n1=BPq/IP
19 disp(" in percentage")
20 n1=n1*100
21 disp(" so indicated power=42.22 KW")
22 disp(" frictional power loss=4.22 KW")
23 disp(" mechanical efficiency=69.24%")

```

---

**Scilab code Exa 10.4** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
          Chapter 10 Example 4")
8 m=0.25; //specific fuel consumption in kg/KWh
9 Pb_mep=1.5*1000; //brake mean effective pressure of
          each cylinder in Kpa
10 N=100; //engine rpm
11 D=85*10^-2; //bore of cylinder in m
12 L=220*10^-2; //stroke in m
13 C=43*10^3; //calorific value of diesel in KJ/kg
14 disp(" brake power of engine (BP)=Pb_mep*L*A*N/60 in
          MW")
15 A=%pi*D^2/4;

```

```

16 BP=Pb_mep*L*A*N/60
17 disp("so brake power is 3.121 MW")
18 disp("The fuel consumption in kg/hr(m)=m*BP in kg/hr
      ")
19 m=m*BP
20 disp("In order to find out brake thermal efficiency
      the heat input from fuel per second is required.")
21 disp("heat from fuel(Q) in KJ/s")
22 disp("Q=m*C/3600")
23 Q=m*C/3600
24 disp("energy to brake power=3120.97 KW")
25 disp("brake thermal efficiency (n)=BP/Q")
26 n=BP/Q
27 disp("in percentage")
28 n=n*100
29 disp("so fuel consumption=780.24 kg/hr ,brake thermal
      efficiency =33.49%")
30 disp("NOTE=>In book ,it is given that brake power in
      MW is 31.21 but in actual it is 3120.97 KW or
      3.121 MW which is corrected above.")

```

---

**Scilab code Exa 10.5** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 5

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 10 Example 5")
8 Pb_mep=6*10^5; //brake mean effective pressure in pa
9 N=600; //engine rpm

```

```

10 m=0.25; // specific fuel consumption in kg/KWh
11 D=20*10^-2; //bore of cylinder in m
12 L=30*10^-2; //stroke in m
13 k=26; //air to fuel ratio
14 C=43*10^3; //calorific value in KJ/kg
15 R=0.287; //gas constant in KJ/kg K
16 T=(27+273); //ambient temperature in K
17 P=1*10^2; //ambient pressure in Kpa
18 disp(" brake thermal efficiency (n)=3600/(m*C) ")
19 n=3600/(m*C)
20 disp(" in percentage")
21 n=n*100
22 disp(" brake power (BP) in KW")
23 disp("BP=4*Pb_mep*L*A*N/60000")
24 A=%pi*D^2/4;
25 BP=4*Pb_mep*L*A*N/60000
26 disp(" brake specific fuel consumption ,m=mf/BP")
27 disp(" so mf=m*BP in kg/hr")
28 mf=m*BP
29 disp(" air consumption (ma) from given air fuel ratio=k
*mf in kg/hr")
30 ma=k*mf
31 disp("ma in kg/min")
32 ma=ma/60
33 disp(" using perfect gas equation ,")
34 disp("P*Va=ma*R*T")
35 disp(" sa Va=ma*R*T/P in m^3/min")
36 Va=ma*R*T/P
37 disp(" swept volume(Vs)=%pi*D^2*L/4 in m^3")
38 Vs=%pi*D^2*L/4
39 disp(" volumetric efficiency , n_vol=Va/(Vs*(N/2)*no .
of cylinder)")
40 n_vol=Va/(Vs*(N/2)*4)
41 disp(" in percentage")
42 n_vol=n_vol*100
43 disp("NOTE=>In this question ,while calculating swept
volume in book ,values of D=0.30 m and L=0.4 m is
taken which is wrong.Hence above solution is

```

solve taking right values given in book which is  
D=0.20 m and L=0.3 m, so the volumetric efficiency  
vary accordingly.”)

---

**Scilab code Exa 10.6** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 6

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 10 Example 6")
8 N=3000; //engine rpm
9 m=5; //fuel consumption in litre/hr
10 r=19; //air-fuel ratio
11 sg=0.7; //specific gravity of fuel
12 V=500; //piston speed in m/min
13 P_imep=6*10^5; //indicated mean effective pressure in
      pa
14 P=1.013*10^5; //ambient pressure in pa
15 T=(15+273); //ambient temperature in K
16 n_vol=0.7; //volumetric efficiency
17 n_mech=0.8; //mechanical efficiency
18 R=0.287; //gas constant for gas in KJ/kg K
19 disp("let the bore diameter be (D) m")
20 disp("piston speed(V)=2*L*N")
21 disp("so L=V/(2*N) in m")
22 L=V/(2*N)
23 L=0.0833; //approx .
24 disp("volumetric efficiency ,n_vol=air sucked /(swept
      volume * no. of cylinder)")
25 disp("so air sucked/D^2=n_vol*(%pi*L/4)*N*2 in m^3/
```

```

        min")
26 n_vol*(%pi*L/4)*N*2
27 disp(" so air sucked = $274.78*D^2$  m $^3$ /min")
28 disp(" air requirement (ma), kg/min=A/F ratio*fuel
        consumption per min")
29 disp(" so ma=r*m in kg/min")
30 ma=r*m*sg/60
31 disp(" using perfect gas equation ,P*Va=ma*R*T")
32 disp(" so Va=ma*R*T/P in m $^3$ /min")
33 Va=ma*R*T*1000/P
34 disp(" ideally , air sucked=Va")
35 disp(" so  $274.78*D^2=0.906$ ")
36 disp("D=sqrt(0.906/274.78) in m")
37 D=sqrt(0.906/274.78)
38 disp(" indicated power(IP)=P_imep*L*A*N*no . of
        cylinders in KW")
39 IP=P_imep*L*(%pi*D $^2$ /4)*(N/60)*2/1000
40 disp(" brake power=indicated power*mechanical
        efficiency")
41 disp("BP=IP*n_mech in KW")
42 BP=IP*n_mech
43 disp(" so brake power=10.34 KW")

```

---

**Scilab code Exa 10.7** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
        Chapter 10 Example 7")
8 M=20; //load on dynamometer in kg

```

```

9 r=50*10^-2; //radius in m
10 N=3000; //speed of rotation in rpm
11 D=20*10^-2; //bore in m
12 L=30*10^-2; //stroke in m
13 m=0.15; //fuel supplying rate in kg/min
14 C=43; //calorific value of fuel in MJ/kg
15 FP=5; //friction power in KW
16 g=9.81; //acceleration due to gravity in m/s^2
17 disp("After switching off fuel supply the capacity
       of motor required to run engine will be the
       friction power required at this speed of engine."
      )
18 disp("friction power(FP)=5 KW")
19 disp("brake power(BP)=2*%pi*N*T in KW")
20 BP=2*%pi*N*(M*g*r)*10^-3/60
21 disp("indicated power(IP)=brake power(BP)+friction
       power(FP) in KW")
22 IP=BP+FP
23 disp("mechanical efficiency (n_mech)=BP/IP")
24 n_mech=BP/IP
25 disp("in percentage")
26 n_mech=n_mech*100
27 disp("brake specific fuel consumption(bsfc)=specific
       fuel consumption/brake power in kg/KW hr")
28 bsfc=m*60/BP
29 disp("brake thermal efficiency (n_bte)=3600/(brake
       specific fuel consumption*calorific value)")
30 n_bte=3600/(bsfc*C*1000)
31 disp("in percentage")
32 n_bte=n_bte*100
33 disp("also , mechanical efficiency (n_mech)=brake
       thermal efficiency/indicated thermal efficiency")
34 disp("indicated thermal efficiency (n_ite)=n_bte/
       n_mech")
35 n_ite=n_bte/n_mech
36 disp("in percentage")
37 n_ite=n_ite*100
38 disp("indicated power(IP)=P_imep*L*A*N")

```

```

39 disp(" so P_imep=IP/(L*(%pi*D^2/4)*N) in Kpa")
40 P_imep=IP/(L*(%pi*D^2/4)*N/60)
41 disp(" Also , mechanical efficiency=P_bmep/P_imep")
42 disp(" so P_bmep=P_imep*n_mech in Kpa")
43 n_mech=0.8604; // mechanical efficiency
44 P_bmep=P_imep*n_mech
45 disp(" brake power=30.82 KW")
46 disp(" indicated power=35.82 KW")
47 disp(" mechanical efficiency=86.04%")
48 disp(" brake thermal efficiency=28.67%")
49 disp(" indicated thermal efficiency=33.32%")
50 disp(" brake mean effective pressure=65.39 Kpa")
51 disp(" indicated mean effective pressure=76.01 Kpa")

```

---

**Scilab code Exa 10.8** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 8

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
Chapter 10 Example 8")
8 N=300; //engine rpm
9 BP=250; //brake power in KW
10 D=30*10^-2; //bore in m
11 L=25*10^-2; //stroke in m
12 m=1; //fuel consumption in kg/min
13 r=10; //airfuel ratio
14 P_imep=0.8; //indicated mean effective pressure in pa
15 C=43*10^3; //calorific value of fuel in KJ/kg
16 P=1.013*10^5; //ambient pressure in K
17 R=0.287; //gas constant in KJ/kg K

```

```

18 T=(27+273) ; //ambient temperature in K
19 disp(" indicated power(IP)=P_imep*L*A*N*4/60 in KW")
20 IP=P_imep*L*(%pi*D^2/4)*N*4*10^3/60
21 disp(" mechanical efficiency (n_mech)=brake power/
indicated power")
22 disp(" so n_mech=BP/IP")
23 n_mech=BP/IP
24 disp(" in percentage ")
25 n_mech=n_mech*100
26 disp(" brake specific fuel consumption (bsfc)=m*60/BP
in kg/KW hr")
27 bsfc=m*60/BP
28 disp(" brake thermal efficiency (n_bte)=3600/(bsfc*C)")
)
29 n_bte=3600/(bsfc*C)
30 disp(" in percentage")
31 n_bte=n_bte*100
32 disp(" swept volume(Vs)=%pi*D^2*L/4 in m^3")
33 Vs=%pi*D^2*L/4
34 disp(" mass of air corresponding to above swept
volume ,using perfect gas equation")
35 disp("P*Vs=ma*R*T")
36 disp(" so ma=(P*Vs)/(R*T) in kg")
37 ma=(P*Vs)/(R*T*1000)
38 ma=0.02; //approx.
39 disp(" volumetric effeciency (n_vol)=mass of air taken
per minute/mass corresponding to swept volume
per minute")
40 disp(" so mass of air taken per minute in kg/min ")
41 1*10
42 disp(" mass corresponding to swept volume per minute
in kg/min")
43 ma*4*N/2
44 disp(" so volumetric efficiency ")
45 10/12
46 disp(" in percentage")
47 (10/12)*100
48 disp(" so indicated power =282.74 KW, mechanical

```

<i>Energy input, kJ/s</i>	<i>Energy consumed, kJ/s</i>	<i>in %</i>
Heat from fuel = 84 kJ/s, 100%		
	Energy consumed as brake power = 4.62 kW	5.5%
	Energy carried by coolant = 14.63 kW	17.42%
	Energy carried by exhaust gases = 30 kW	35.71%
	Unaccounted losses = 34.75 kW	41.37%

Figure 10.1: Engineering Thermodynamics by Onkar Singh Chapter 10 Example 9

```

efficiency =88.42%" )
49 disp("brake thermal efficiency =34.88%, volumetric
efficiency =83.33%" )

```

---

**Scilab code Exa 10.9** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 9

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 10 Example 9")
8 h=10; //height of indicator diagram in mm
9 k=25; //indicator constant in KN/m^2 per mm
10 N=300; //engine rpm
11 Vs=1.5*10^-2; //swept volume in m^3
12 M=60; //effective brake load upon dynamometer in kg
13 r=50*10^-2; //effective brake drum radius in m
14 m=0.12; //fuel consumption in kg/min
15 C=42*10^3; //calorific value in KJ/kg
16 mw=6; //circulating water rate in kg/min

```

```

17 T1=35; //cooling water entering temperature in degree
          celcius
18 T2=70; //cooling water leaving temperature in degree
          celcius
19 Eg=30; //exhaust gases leaving energy in KJ/s
20 Cw=4.18; //specific heat of water in KJ/kg K
21 g=9.81; //acceleration due to gravity in m/s^2
22 disp("indicated mean effective pressure(P_imeb)=h*k
          in Kpa")
23 P_imeb=h*k
24 disp("indicated power(IP)=P_imeb*L*A*N/2 in KW")
25 IP=P_imeb*Vs*N/(2*60)
26 disp("brake power(BP)=2*pi*N*T in KW")
27 BP=2*pi*N*(M*g*r*10^-3)/(2*60)
28 disp("mechanical efficiency(n_mech)=BP/IP")
29 n_mech=BP/IP
30 disp("in percentage")
31 n_mech=n_mech*100
32 disp("so indicated power=9.375 KW")
33 disp("brake power=4.62 KW")
34 disp("mechanical efficiency=49.28%")
35 disp("energy liberated from fuel(Ef)=C*m/60 in KJ/s")
            )
36 Ef=C*m/60
37 disp("energy available as brake power(BP)=4.62 KW")
38 disp("energy to coolant(Ec)=(mw/M)*Cw*(T2-T1) in KW")
            )
39 Ec=(mw/M)*Cw*(T2-T1)
40 disp("energy carried by exhaust gases(Eg)=30 KJ/s")
41 disp("unaccounted energy loss=Ef-BP-Ec-Eg in KW")
42 Ef-BP-Ec-Eg
43 disp("NOTE=>overall energy balance sheet is attached
          as jpg file with this code.")

```

---

<i>Heat input, kJ/min</i>	<i>%</i>	<i>Heat consumed, kJ/min,</i>	<i>%</i>
Heat from fuel = 11200	100%	1. Brake power = 2827.44	25.24%
		2. Cooling water = 1442.1	12.88%
		3. Exhaust gases = 4786.83	42.74%
		4. Unaccounted loss = 2143.63 (by difference)	19.14%
Total = 11200 kJ/min	100%	Total = 11200 kJ/min	100%

Figure 10.2: Engineering Thermodynamics by Onkar Singh Chapter 10 Example 10

**Scilab code Exa 10.10** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 10

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 10 Example 10")
8 m=4; //mass of fuel consumed in kg
9 N=1500; //engine rpm
10 mw=15; //water circulation rate in kg/min
11 T1=27; //cooling water inlet temperature in degree
celcius
12 T2=50; //cooling water outlet temperature in degree
celcius
13 ma=150; //mass of air consumed in kg
14 T_exhaust=400; //exhaust temperature in degree
celcius
15 T_atm=27; //atmospheric temperature in degree celcius
16 Cg=1.25; //mean specific heat of exhaust gases in KJ/
kg K
17 n_mech=0.9; //mechanical efficiency
18 T=300*10^-3; //brake torque in N
19 C=42*10^3; //calorific value in KJ/kg

```

```

20 Cw=4.18; // specific heat of water in KJ/kg K
21 disp(" brake power(BP)=2*pi*N*T in KW")
22 BP=2*pi*N*T/60
23 disp(" so brake power=47.124 KW")
24 disp(" brake specific fuel consumption( bsfc )=m*60/(mw
      *BP) in kg/KW hr")
25 bsfc=m*60/(mw*BP)
26 disp(" indicated power(IP)=BP/n_mech in Kw")
27 IP=BP/n_mech
28 disp(" indicated thermal efficiency( n_ite )=IP*mw
      *60/(m*C)")
29 n_ite=IP*mw*60/(m*C)
30 disp(" in percentage")
31 n_ite=n_ite*100
32 disp(" so indicated thermal efficiency =28.05%")
33 disp(" heat available from fuel(Qf)=(m/mw)*C in KJ/
      min")
34 Qf=(m/mw)*C
35 disp(" energy consumed as brake power(BP)=BP*60 in KJ
      /min")
36 BP=BP*60
37 disp(" energy carried by cooling water(Qw)=mw*Cw*(T2-
      T1) in KJ/min")
38 Qw=mw*Cw*(T2-T1)
39 disp(" energy carried by exhaust gases(Qg)=(ma+m)*Qg
      *(T_exhaust-T_atm)/mw in KJ/min")
40 Qg=(ma+m)*Cg*(T_exhaust-T_atm)/mw
41 disp(" unaccounted energy loss in KJ/min")
42 Qf-(BP+Qw+Qg)
43 disp("NOTE=>Heat balance sheet on per minute basis
      is attached as jpg file with this code.")

```

---

<i>No. of cylinders cut</i>	<i>Brake power, kW</i>
1	40.1
2	39.5
3	39.1
4	39.6
5	39.8
6	40

Figure 10.3: Engineering Thermodynamics by Onkar Singh Chapter 10 Example 11

**Scilab code Exa 10.11** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 11

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 10 Example 11")
8 BP=50; //brake power output at full load in KW
9 BP1=40.1; //brake power output of 1st cylinder in KW
10 BP2=39.5; //brake power output of 2nd cylinder in KW
11 BP3=39.1; //brake power output of 3rd cylinder in KW
12 BP4=39.6; //brake power output of 4th cylinder in KW
13 BP5=39.8; //brake power output of 5th cylinder in KW
14 BP6=40; //brake power output of 6th cylinder in KW
15 disp("indicated power of 1st cylinder=BP-BP1 in KW")
16 BP-BP1
17 disp("indicated power of 2nd cylinder=BP-BP2 in KW")
18 BP-BP2
19 disp("indicated power of 3rd cylinder=BP-BP3 in KW")

```

Heat balance sheet on per minute basis			
Energy in, kJ/min	%	Energy out, kJ/min,	%
Heat released by fuel = 8127	100%	(a) Brake power = 1177.8 (b) Exhaust gases = 1436.02 (c) Cooling water = 1730.52 (d) Unaccounted = 3782.66 (by difference)	14.50 17.67 21.29 40.54
Total = 8127, kJ/min	100%	Total = 8127 kJ/min	100%

Figure 10.4: Engineering Thermodynamics by Onkar Singh Chapter 10 Example 12

```

20 BP-BP3
21 disp(" indicated power of 4th cylinder=BP-BP4 in KW")
22 BP-BP4
23 disp(" indicated power of 5th cylinder=BP-BP5 in KW")
24 BP-BP5
25 disp(" indicated power of 6th cylinder=BP-BP6 in KW")
26 BP-BP6
27 disp(" total indicated power(IP) in KW")
28 IP=9.9+10.5+10.9+10.4+10.2+10
29 disp(" mechanical efficiency (n_mech)=BP/IP")
30 n_mech=BP/IP
31 disp(" in percentage")
32 n_mech=n_mech*100
33 disp(" so indicated power=61.9 KW")
34 disp(" mechanical efficiency=80.77%")

```

---

### Scilab code Exa 10.12 Engineering Thermodynamics by Onkar Singh Chapter 10 Example 12

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 10 Example 12")
8 N=1500; //engine rpm at full load
9 F=250; //brake load at full load in N
10 F1=175; //brake reading 1 in N
11 F2=180; //brake reading 2 in N
12 F3=182; //brake reading 3 in N
13 F4=170; //brake reading 4 in N
14 r=50*10^-2; //brake drum radius in m
15 m=0.189; //fuel consumption rate in kg/min
16 C=43*10^3; //fuel calorific value in KJ/kg
17 k=12; //air to fuel ratio
18 T_exhaust=600; //exhaust gas temperature in degree
celcius
19 mw=18; //cooling water flow rate in kg/min
20 T1=27; //cooling water entering temperature in degree
celcius
21 T2=50; //cooling water leaving temperature in degree
celcius
22 T_atm=27; //atmospheric air temperature
23 Cg=1.02; //specific heat of exhaust gas in KJ/kg K
24 Cw=4.18; //specific heat of water in KJ/kg K
25 disp("brake power output of engine(BP)=2*pi*N*T/60
in KW")
26 BP=2*pi*N*F*r*10^-3/60
27 disp("brake power when cylinder 1 is cut(BP1)=2*pi*
N*T/60 in KW")
28 BP1=2*pi*N*F1*r*10^-3/60
29 disp("so indicated power of first cylinder(IP1)=BP-
BP1 in KW")
30 IP1=BP-BP1
31 disp("brake power when cylinder 2 is cut(BP2)=2*pi*
N*T/60 in KW")
32 BP2=2*pi*N*F2*r*10^-3/60
33 disp("so indicated power of second cylinder(IP2)=BP-

```

```

        BP2 in KW")
34 IP2=BP-BP2
35 disp("brake power when cylinder 3 is cut (BP3)=2*pi*
      N*T/60 in KW")
36 BP3=2*pi*N*F3*r*10^-3/60
37 disp("so indicated power of third cylinder (IP3)=BP-
      BP3 in KW")
38 IP3=BP-BP3
39 disp("brake power when cylinder 4 is cut (BP4)=2*pi*
      N*T/60 in KW")
40 BP4=2*pi*N*F4*r*10^-3/60
41 disp("so indicated power of fourth cylinder (IP4)=BP-
      BP4 in KW")
42 IP4=BP-BP4
43 disp("now total indicated power (IP) in KW")
44 IP=IP1+IP2+IP3+IP4
45 disp("engine mechanical efficiency (n_mech)=BP/IP")
46 n_mech=BP/IP
47 disp("in percentage")
48 n_mech=n_mech*100
49 disp("so BP=19.63 KW, IP=23 KW, n_mech=83.35%")
50 disp("heat liberated by fuel (Qf)=m*C in KJ/min")
51 Qf=m*C
52 disp("heat carried by exhaust gases (Qg)=(k+1)*m*Cg*("
      T_exhaust-T_atm) in KJ/min")
53 Qg=(k+1)*m*Cg*(T_exhaust-T_atm)
54 disp("heat carried by cooling water (Qw)=mw*Cw*(T2-T1"
      ) in KJ/min")
55 Qw=mw*Cw*(T2-T1)
56 disp("energy to brake power (BP)=BP*60 in KJ/min")
57 BP=BP*60
58 disp("unaccounted losses in KJ/min")
59 Qf-(Qg+Qw+BP)
60 disp("NOTE=>Heat balance sheet on per minute basis
      is attached as jpg file with this code. ")

```

---

Input		Expenditure	
Heat, kJ/min	% , Percentage	Heat, kJ/min	% , Percentage
(A) Heat added by fuel = 3141.79	100	(B) Heat equivalent to brake power = 659.76	21%
		(C) Heat lost to cooling water = 862.13	27.44%
		(D) Heat carried by steam in exhaust gases = 299.86	9.54%
		(E) Heat carried by dry fuel gases in exhaust gases = 782.64	24.92%
		(F) Unaccounted losses = 537.4	17.10%

Figure 10.5: Engineering Thermodynamics by Onkar Singh Chapter 10 Example 13

**Scilab code Exa 10.13** Engineering Thermodynamics by Onkar Singh Chapter 10 Example 13

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 10 Example 13")
8 D=20*10^-2; //cylinder diameter in m
9 L=28*10^-2; //stroke in m
10 m=4.22; //mass of fuel used in kg
11 C=44670; //calorific value of fuel in KJ/kg
12 N=21000/60; //engine rpm
13 mep=2.74*10^5; //mean effective pressure in pa
14 F=600; //net brake load applied to a drum of 100 cm
           diameter in N
15 r=50*10^-2; //brake drum radius in m

```

```

16 mw=495; //total mass of cooling water in kg
17 T1=13; //cooling water inlet temperature in degree
           celcius
18 T2=38; //cooling water outlet temperature in degree
           celcius
19 ma=135; //mass of air used in kg
20 T_air=20; //temperature of air in test room in degree
           celcius
21 T_exhaust=370; //temperature of exhaust gases in
           degree celcius
22 Cp_gases=1.005; //specific heat of gases in KJ/kg K
23 Cp_steam=2.093; //specific heat of steam at
           atmospheric pressure in KJ/kg K
24 Cp_w=4.18; //specific heat of water in KJ/kg K
25 disp(" brake power(BP)=2*%pi*N*T in KW")
26 BP=2*%pi*N*F*r/60000
27 disp(" indicated power(IP)=(mep*L*A*N)/60000 in KW")
28 IP=(mep*L*(%pi*D^2/4)*N)/60000
29 disp("A> heat added(Q)=m*C/3600 in KJ/s")
30 Q=m*C/3600
31 disp(" or Q in KJ/min")
32 Q=Q*60
33 disp(" thermal efficiency (n_th)=IP/Q ")
34 Q=52.36; //heat added in KJ/s
35 n_th=IP/Q
36 disp(" in percentage")
37 n_th=n_th*100
38 disp("B> heat equivalent of brake power(BP)=BP*60 in
           KJ/min ")
39 BP=BP*60
40 disp("C> heat loss to cooling water(Qw)=mw*Cpw*(T2-
           T1) in KJ/min")
41 Qw=mw*Cpw*(T2-T1)/60
42 disp("heat carried by exhaust gases=heat carried by
           steam in exhaust gases+heat carried by fuel gases
           (dry gases) in exhaust gases")
43 disp("mass of exhaust gases(mg)=mass of air+mass of
           fuel in kg/min")

```

```

44 disp("mg=(ma+m)/60")
45 mg=(ma+m)/60
46 disp("mass of steam in exhaust gases in kg/min")
47 9*(0.15*m/60)
48 disp("mass of dry exhaust gases in kg/min")
49 mg-0.095
50 disp("D> heat carried by steam in exhaust in KJ/min"
      )
51 0.095*{Cpw*(100-T_air)+2256.9+Cp_steam*(T_exhaust
      -100)}
52 disp("E> heat carried by fuel gases(dry gases) in
      exhaust gases(Qg) in KJ/min")
53 Qg=2.225*Cp_gases*(T_exhaust-T_air)
54 disp("F> unaccounted loss=A-B-C-D-E in KJ/min")
55 3141.79-659.76-862.13-299.86-782.64
56 disp("NOTE>Heat balance sheet on per minute basis is
      attached as jpg file with this code.")

```

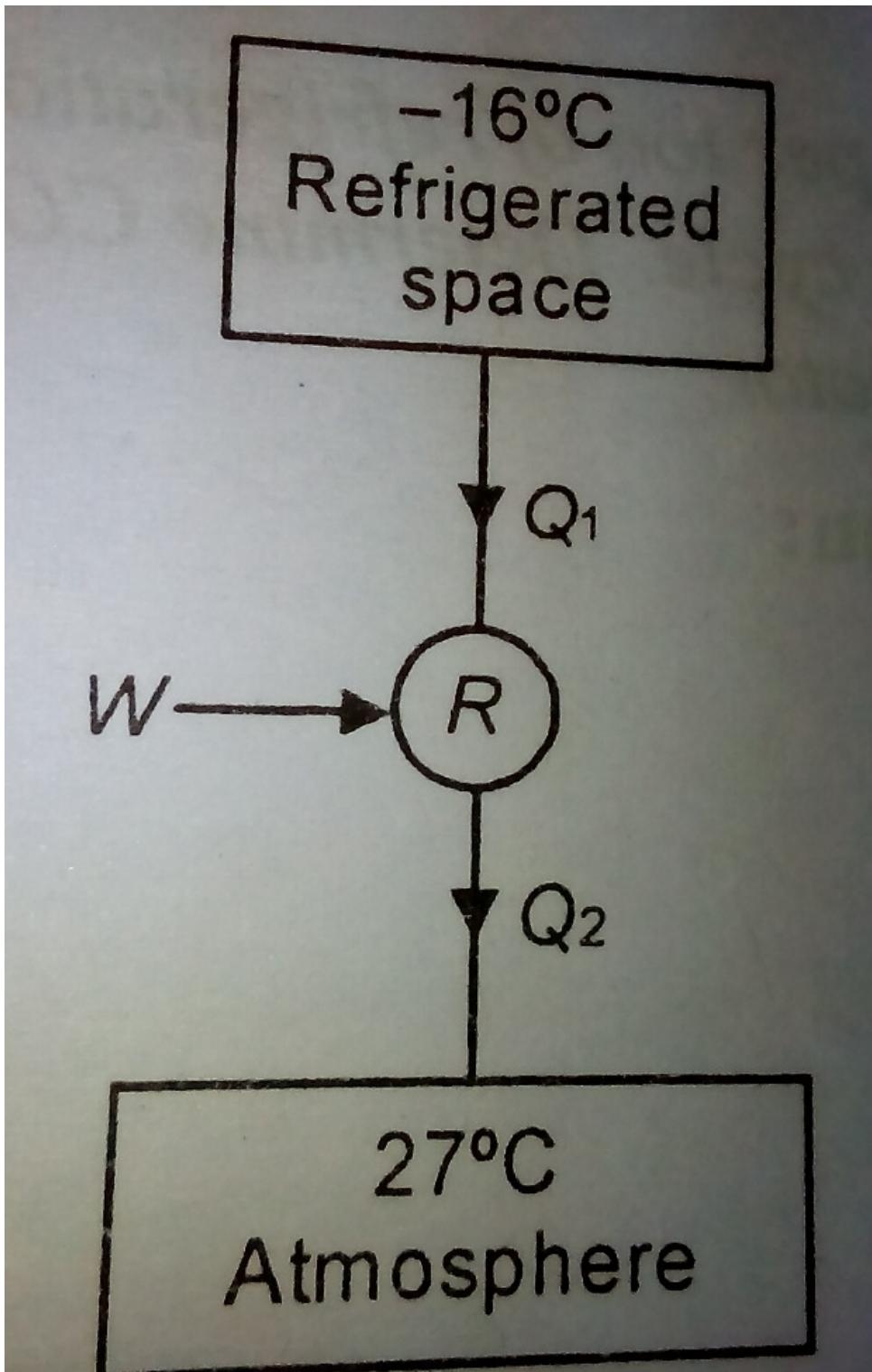
---

# Chapter 11

## Introduction To Refrigeration And Air Conditioning

**Scilab code Exa 11.1** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 1")
8 T1=(-16+273); //temperature of refrigerated space in
                  K
9 T2=(27+273); //temperature of atmosphere in K
10 Q1=500; //heat extracted from refrigerated space in
                KJ/min
11 disp("for refrigerator working on reversed carnot
      cycle.")
12 disp("Q1/T1=Q2/T2")
```



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Fig 11.22

```

13 disp(" so Q2=Q1*T2/T1 in KJ/min")
14 Q2=Q1*T2/T1
15 disp("and work input required ,W in KJ/min")
16 disp("W=Q2-Q1")
17 W=Q2-Q1

```

---

**Scilab code Exa 11.2** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 11 Example 2")
8 Q=800; //refrigeration capacity in tons
9 Q_latent=335; //latent heat for ice formation from
water in KJ/kg
10 T1=(-7+273); //temperature of reservoir 1 in K
11 T2=(27+273); //temperature of reservoir 2 in K
12 disp("refrigeration capacity or heat extraction rate
(Q) in KJ/s")
13 Q=Q*3.5
14 disp("let the ice formation rate be m kg/s")
15 disp("heat to be removed from per kg of water for
its transformation into ice(Q1) in KJ/kg .")
16 Q1=4.18*(27-0)+Q_latent
17 disp("ice formation rate(m) in kg=refrigeration
capacity/heat removed for getting per kg of ice")
18 m=Q/Q1
19 disp("COP of refrigerator ,=T1/(T2-T1)=refrigeration
capacity/work done")
20 COP=T1/(T2-T1)

```

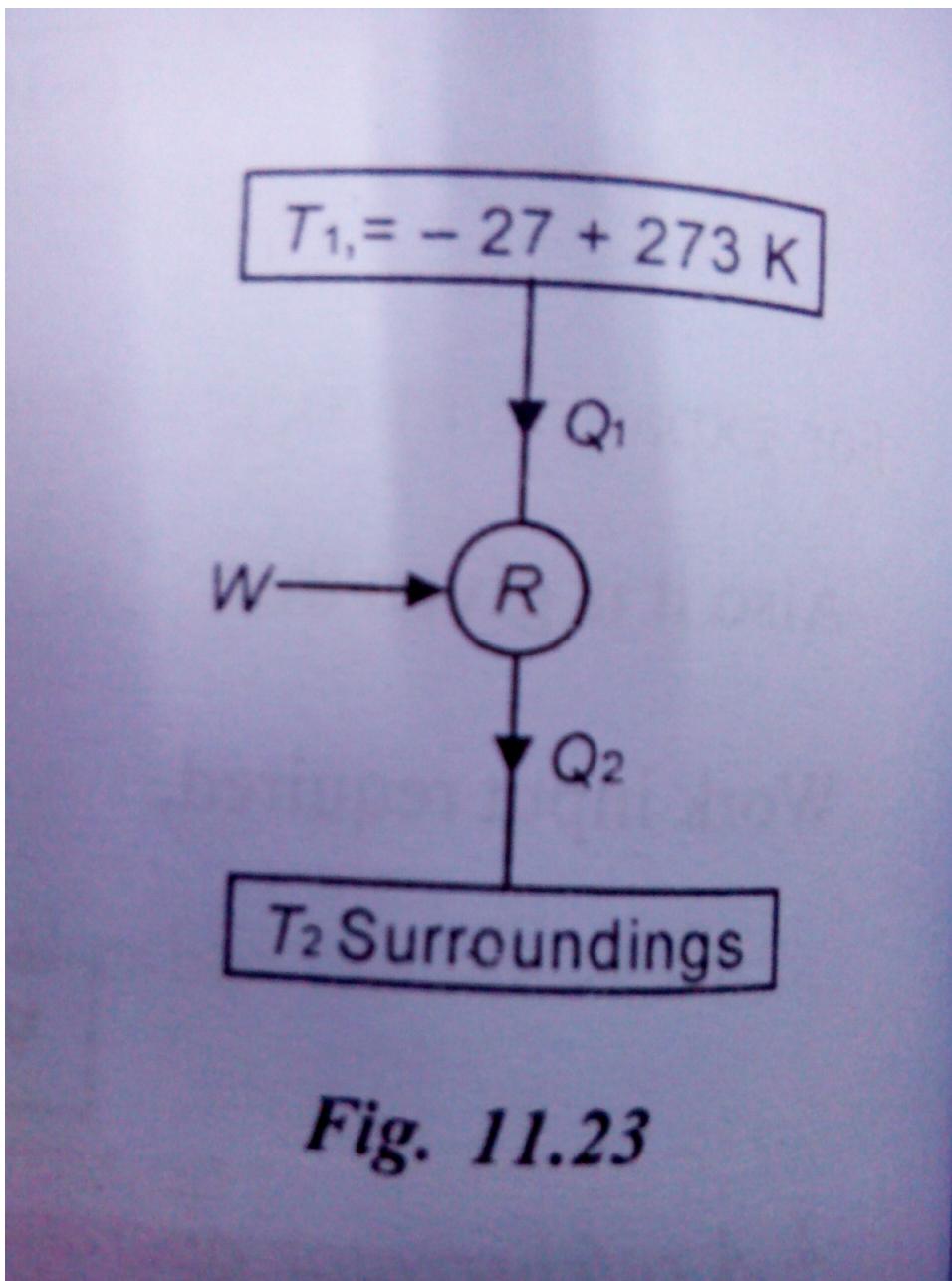
```
21 disp(" also COP=Q/W")
22 disp(" so W=Q/COP in KJ/s")
23 W=Q/COP
24 disp("HP required")
25 W=W/0.7457
26 disp("NOTE=>In book ,this question is solved by
    taking T1=-5 degree celcius ,but according to
    question T1=-7 degree celcius so this question is
    correctly solved above by considering T1=-7
    degree celcius.")
```

---

**Scilab code Exa 11.3** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 3

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
    Chapter 11 Example 3")
8 T1=(-27+273); //temperature of refrigerator in K
9 W=3*.7457; //work input in KJ/s
10 Q=1*3.5; //refrigeration effect in KJ/s
11 disp("COP=T1/(T2-T1)=Q/W")
12 COP=Q/W
13 COP=1.56; //approx.
14 disp(" equating ,COP=T1/(T2-T1) ")
15 disp(" so temperature of surrounding (T2) in K")
16 disp("T2=T1+(T1/COP)")
17 T2=T1+(T1/COP)
```

---

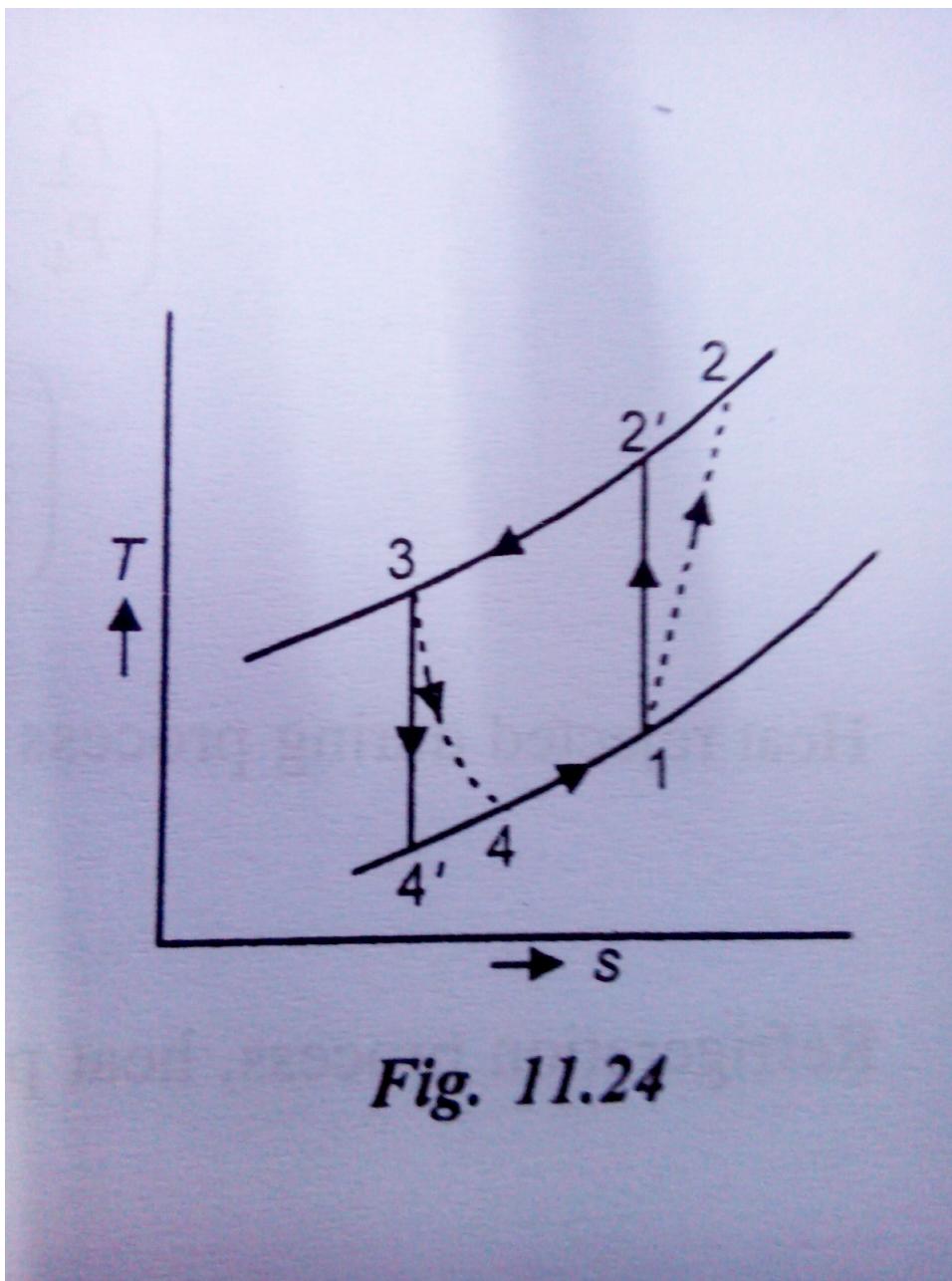


*Fig. 11.23*

Figure 11.2: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 3

**Scilab code Exa 11.4** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 4

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 4")
8 T1=(-30+273); //temperature of air at beginning of
                  compression in K
9 T3=(27+273); //temperature of air after cooling in K
10 r=8; //pressure ratio
11 Cp=1.005; //specific heat at constant pressure in KJ/
                 kg K
12 y=1.4; //expansion constant
13 m=1; //air flow rate in kg/s
14 n1=0.85; //isentropic efficiency for compression
                 process
15 n2=.9; //isentropic efficiency for expansion process
16 disp("during process 1-2_a")
17 disp("p2/p1=(T2_a/T1)^(y/(y-1))")
18 disp("so T2_a=T1*(p2/p1)^((y-1)/y) in K")
19 T2_a=T1*(r)^((y-1)/y)
20 disp("theoretical temperature after compression ,T2_a
      =440.18 K")
21 disp("for compression process ,")
22 disp("n1=(T2_a-T1)/(T2-T1)")
23 disp("so T2=T1+(T2_a-T1)/n1 in K")
24 T2=T1+(T2_a-T1)/n1
```



**Fig. 11.24**

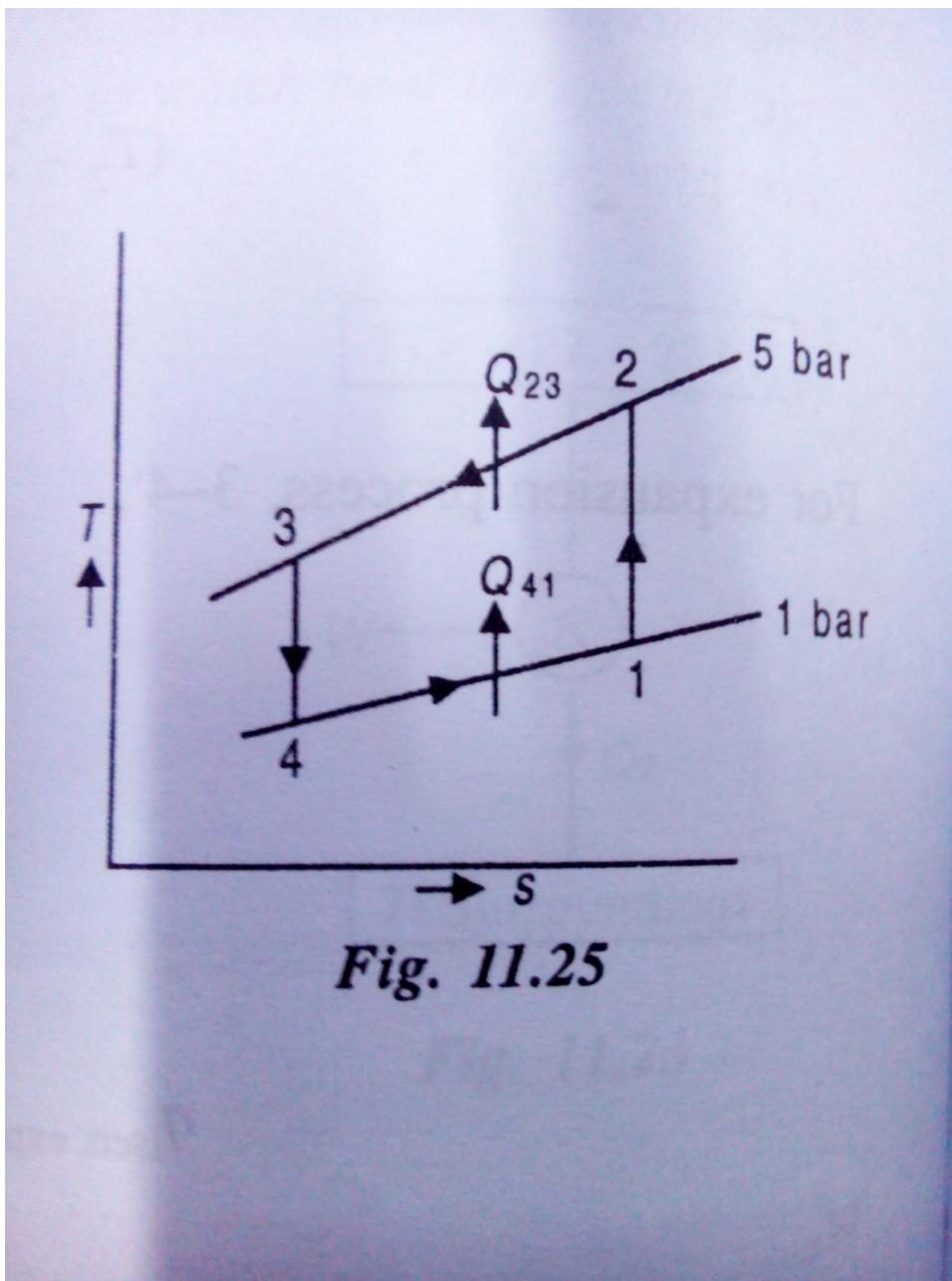
Figure 11.3: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 4

```

25 disp(" for expansion process ,3-4_a")
26 disp(" T4_a/T3=(p1/p2) ^((y-1)/y)")
27 disp(" so T4_a=T3*(p1/p2) ^((y-1)/y) in K")
28 T4_a=T3*(1/r) ^((y-1)/y)
29 disp(" n2=0.9=(T3-T4)/(T3-T4_a)")
30 disp(" so T4=T3-(n2*(T3-T4_a)) in K")
31 T4=T3-(n2*(T3-T4_a))
32 disp(" so work during compression ,W_C in KJ/s")
33 disp("W_C=m*Cp*(T2-T1)")
34 W_C=m*Cp*(T2-T1)
35 disp(" work during expansion ,W_T in KJ/s")
36 disp("W_T=m*Cp*(T3-T4)")
37 W_T=m*Cp*(T3-T4)
38 disp(" refrigeration effect is realized during
       process ,4-1.so refrigeration shall be ,")
39 disp(" Q_ref=m*Cp*(T1-T4) in KJ/s")
40 Q_ref=m*Cp*(T1-T4)
41 disp(" Q_ref in ton")
42 Q_ref=Q_ref/3.5
43 disp(" net work required (W)=W_C-W_T in KJ/s")
44 W=W_C-W_T
45 disp("COP=Q_ref/(W_C-W_T)")
46 Q_ref=64.26;
47 COP=Q_ref/(W_C-W_T)
48 disp(" so refrigeration capacity=18.36 ton or 64.26
       KJ/s")
49 disp("and COP=0.57")
50 disp("NOTE=>In book this question is solve by taking
       T1=240 K which is incorrect ,hence correction is
       made above according to question by taking T1=-30
       degree celcius or 243 K,so answer may vary
       slightly .")

```

---



**Fig. 11.25**

Figure 11.4: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 5

**Scilab code Exa 11.5** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 5

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 11 Example 5")
8 T1=(7+273); //temperature of refrigerated space in K
9 T3=(27+273); //temperature after compression in K
10 p1=1*10^5; //pressure of refrigerated space in pa
11 p2=5*10^5; //pressure after compression in pa
12 y=1.4; //expansion constant
13 Cp=1.005; //specific heat at constant pressure in KJ/
kg K
14 disp("for isentropic compression process:")
15 disp((p2/p1)^(y-1)/y)=T2/T1")
16 disp("so T2=T1*(p2/p1)^(y-1)/y in K")
17 T2=T1*(p2/p1)^(y-1)/y
18 disp("for isentropic expansion process:")
19 disp((p3/p4)^(y-1)/y)=(T3/T4)=(p2/p1)^(y-1)/y"
)
20 disp("so T4=T3/(p2/p1)^(y-1)/y in K")
21 T4=T3/(p2/p1)^(y-1)/y
22 disp("heat rejected during process 2-3,Q23=Cp*(T2-T3
) in KJ/kg")
23 Q23=Cp*(T2-T3)
24 disp("refrigeration process ,heat picked during
process 4-1,Q41=Cp*(T1-T4) in KJ/kg")
25 Q41=Cp*(T1-T4)
26 disp("so net work(W)=Q23-Q41 in KJ/kg")
27 W=Q23-Q41
28 disp("so COP=refrigeration effect / net work=Q41/W")
29 COP=Q41/W
```

---

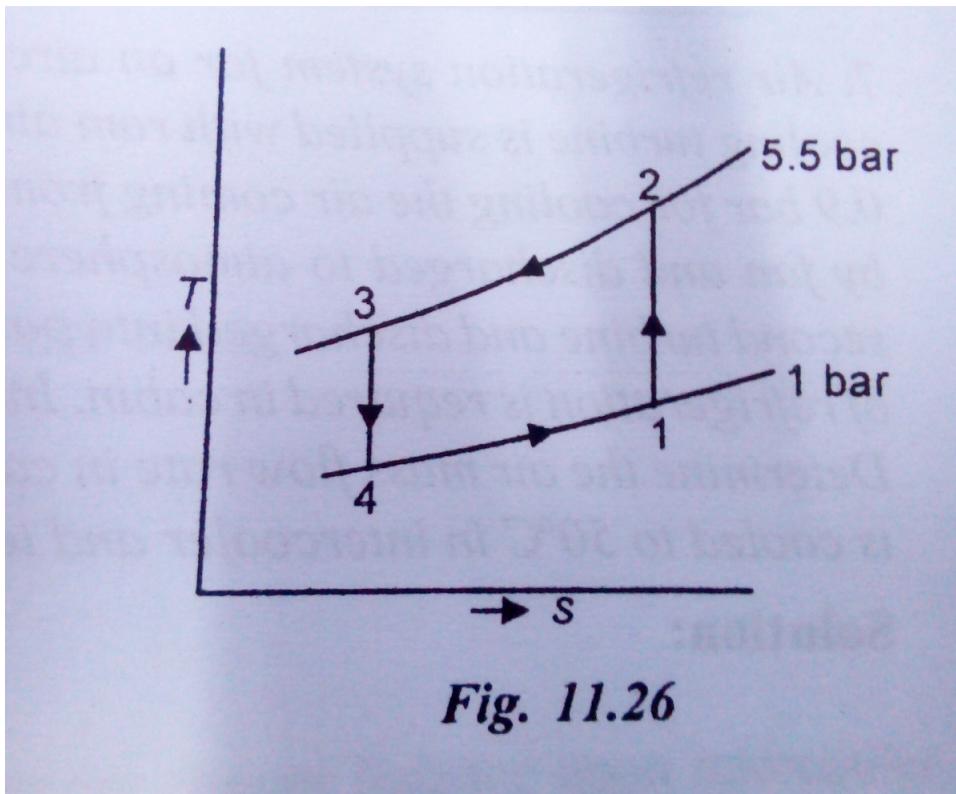


Figure 11.5: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 6

**Scilab code Exa 11.6** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 6

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;

```

```

6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 6")
8 T1=(-10+273); //air entering temperature in K
9 p1=1*10^5; //air entering pressure in pa
10 T3=(27+273); //compressed air temperature after
      cooling in K
11 p2=5.5*10^5; //pressure after compression in pa
12 m=0.8; //air flow rate in kg/s
13 Cp=1.005; //specific heat capacity at constant
      pressure in KJ/kg K
14 y=1.4; //expansion constant
15 R=0.287; //gas constant in KJ/kg K
16 disp("for process 1-2")
17 disp(" (p2/p1)^((y-1)/y)=T2/T1")
18 disp(" so T2=T1*(p2/p1)^((y-1)/y) in K")
19 T2=T1*(p2/p1)^((y-1)/y)
20 disp(" for process 3-4")
21 disp(" (p3/p4)^((y-1)/y)=T3/T4")
22 disp(" so T4=T3/(p3/p4)^((y-1)/y)=T3/(p2/p1)^((y-1)/y
      ) in K")
23 T4=T3/(p2/p1)^((y-1)/y)
24 disp(" refrigeration capacity (Q)=m*Cp*(T1-T4) in KJ/s
      ")
25 Q=m*Cp*(T1-T4)
26 disp("Q in ton")
27 Q=Q/3.5
28 disp("work required to run compressor (w)=(m*n)*(p2*
      v2-p1*v1)/(n-1)")
29 disp("w=(m*n)*R*(T2-T1)/(n-1) in KJ/s")
30 n=y;
31 w=(m*n)*R*(T2-T1)/(n-1)
32 disp("HP required to run compressor")
33 w/0.7457
34 disp("so HP required to run compressor=177.86 hp")
35 disp("net work input (W)=m*Cp*{(T2-T3)-(T1-T4)} in KJ/
      s")
36 W=m*Cp*{(T2-T3)-(T1-T4)}

```

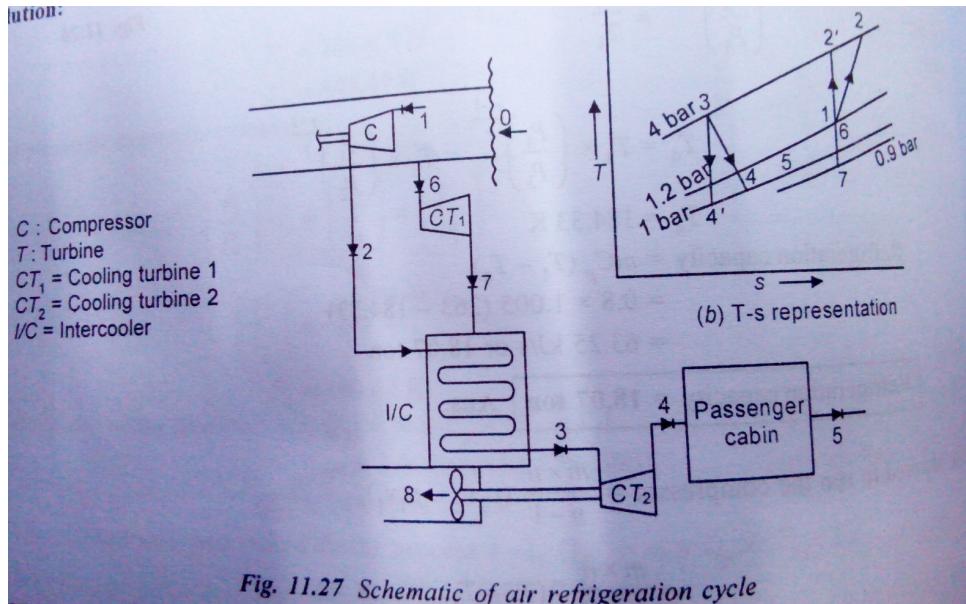


Fig. 11.27 Schematic of air refrigeration cycle

Figure 11.6: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 7

```

37 disp("COP=refrigeration capacity / work=Q/W")
38 Q=63.25; // refrigeration capacity in KJ/s
39 COP=Q/W

```

---

**Scilab code Exa 11.7** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;

```

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 11 Example 7")
8 p1=1.2*10^5; //pressure of ram air in pa
9 p6=p1;
10 T1=(15+273); //temperature of ram air in K
11 T6=T1;
12 p7=0.9*10^5; //pressure of ram air after expansion in
pa
13 p3=4*10^5; //pressure of ram air after compression in
pa
14 p2=p3;
15 p4=1*10^5; //pressure of ram air after expansion in
second turbine in pa
16 T5=(25+273); //temperature of air when exhausted
from cabin in K
17 T3=(50+273); //temperature of compressed air in K
18 T8=(30+273); //limited temperaure of ram air in K
19 Q=10*3.5; //refrigeration capacity in KJ/s
20 Cp=1.005; //specific heat capacity at constant
pressure in KJ/kg K
21 disp("for process 1-2,n=1.45")
22 n=1.45;
23 disp("T2/T1=(p2/p1) ^((n-1)/n)")
24 disp("so T2=T1*(p2/p1) ^((n-1)/n) in K")
25 T2=T1*(p2/p1) ^((n-1)/n)
26 disp("for process 3-4,n=1.3")
27 n=1.3;
28 disp("T4/T3=(p4/p3) ^((n-1)/n)")
29 disp("so T4=T3*(p4/p3) ^((n-1)/n) in K")
30 T4=T3*(p4/p3) ^((n-1)/n)
31 disp("refrigeration effect in passenger cabin with m
kg/s mass flow rate of air.")
32 disp("Q=m*Cp*(T5-T4)")
33 disp("m=Q/(Cp*(T5-T4)) in kg/s")
34 m=Q/(Cp*(T5-T4))
35 disp("so air mass flow rate in cabin=0.55 kg/s")
36 disp("let the mass flow rate through intercooler be
m1 kg/s then the energy balance upon intercooler")

```

```

        yields ,”)
37 disp(” $m_1 \cdot C_p \cdot (T_8 - T_7) = m \cdot C_p \cdot (T_2 - T_3)$ ”)
38 disp(” during process 6–7,  $T_7/T_6 = (p_7/p_6)^{((n-1)/n)}$ ”)
39 disp(” so  $T_7 = T_6 \cdot (p_7/p_6)^{((n-1)/n)}$  in K”)
40  $T_7 = T_6 \cdot (p_7/p_6)^{((n-1)/n)}$ 
41 disp(” substituting T2, T3, T7, T8 and m in energy
      balance on intercooler ,”)
42 disp(” $m_1 = m \cdot (T_2 - T_3) / (T_8 - T_7)$  in kg/s”)
43  $m_1 = m \cdot (T_2 - T_3) / (T_8 - T_7)$ 
44 disp(” total ram air mass flow rate= $m + m_1$  in kg/s”)
45  $m + m_1$ 
46 disp(” ram air mass flow rate=2.12 kg/s”)
47 disp(” work input to compressor (W)= $m \cdot C_p \cdot (T_2 - T_1)$  in KJ/
      s”)
48  $m = 0.55$ ; //approx.
49  $W = m \cdot C_p \cdot (T_2 - T_1)$ 
50 disp(”COP=refrigeration effect / work input=Q/W”)
51  $COP = Q/W$ 

```

---

**Scilab code Exa 11.8** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 8

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(” Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 8”)
8  $p_0 = 0.9 \cdot 10^5$ ; //atmospheric air pressure in pa
9  $T_0 = (3 + 273)$ ; //temperature of atmospheric air in K
10  $p_1 = 1 \cdot 10^5$ ; //pressure due to ramming air in pa

```

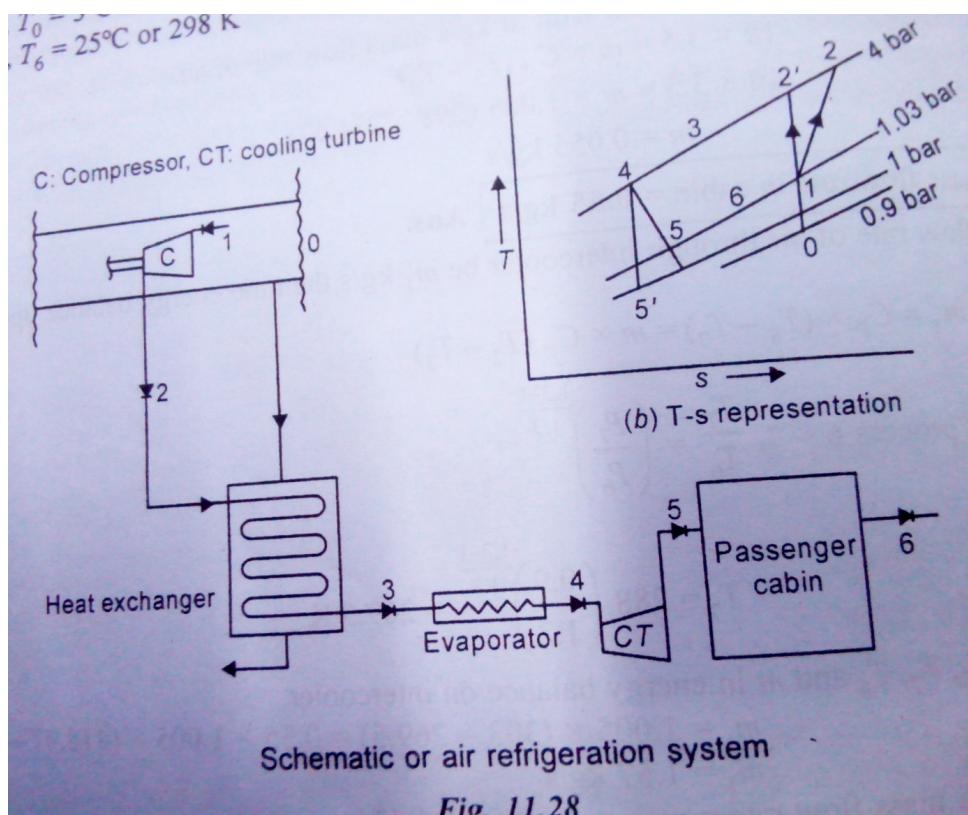


Figure 11.7: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 8

```

11 p2=4*10^5; // pressure when air leaves compressor in
   pa
12 p3=p2;
13 p4=p3;
14 p5=1.03*10^5; // pressure maintained in passenger
   cabin in pa
15 T6=(25+273); // temperature of air leaves cabin in K
16 Q=15*3.5; // refrigeration capacity of aeroplane in KJ
   /s
17 n1=0.9; // isentropic efficiency of compressor
18 n2=0.8; // isentropic efficiency of turbine
19 Cp=1.005; // specific heat at constant pressure in KJ/
   kg K
20 disp(" considering index of compression and expansion
   as 1.4")
21 y=1.4;
22 disp(" during ramming action , process 0-1,")
23 disp(" T1/To=(p1/po) ^((y-1)/y)")
24 disp(" T1=To*(p1/po) ^((y-1)/y) in K")
25 T1=To*(p1/po) ^((y-1)/y)
26 disp(" during compression process 1-2_a")
27 disp(" T2_a/T1=(p2/p1) ^((y-1)/y)")
28 disp(" T2_a=T1*(p2/p1) ^((y-1)/y) in K")
29 T2_a=T1*(p2/p1) ^((y-1)/y)
30 disp(" n1=(T2_a-T1)/(T2-T1)")
31 disp(" so T2=T1+(T2_a-T1)/n1 in K")
32 T2=T1+(T2_a-T1)/n1
33 disp(" In heat exchanger 66% of heat loss shall
   result in temperature at exit from heat exchanger
   to be ,T3=0.34*T2 in K")
34 T3=0.34*T2
35 disp(" subsequently for 10 degree celcius temperature
   drop in evaporator ,")
36 disp(" T4=T3-10 in K")
37 T4=T3-10
38 disp(" expansion in cooling turbine during process
   4-5;")
39 disp(" T5_a/T4=(p5/p4) ^((y-1)/y) ")

```

```

40 disp("T5_a=T4*(p5/p4)^(y-1)/y in K")
41 T5_a=T4*(p5/p4)^(y-1)/y
42 disp("n2=(T4-T5)/(T4-T5_a)")
43 disp("T5=T4-(T4-T5_a)*n2 in K")
44 T5=T4-(T4-T5_a)*n2
45 disp("let the mass flow rate of air through cabin be
        m kg/s. using refrigeration capacity heat balance
        yields .")
46 disp("Q=m*Cp*(T6-T5)")
47 disp("so m=Q/(Cp*(T6-T5)) in kg/s")
48 m=Q/(Cp*(T6-T5))
49 disp("work input to compressor(W)=m*Cp*(T2-T1) in KJ/
        s")
50 W=m*Cp*(T2-T1)
51 disp("W in Hp")
52 W=W/.7457
53 disp("COP=refrigeration effect / work input=Q/W")
54 W=41.37; // work input to compressor in KJ/s
55 COP=Q/W
56 disp("so COP=1.27")
57 disp("and HP required =55.48 hp")

```

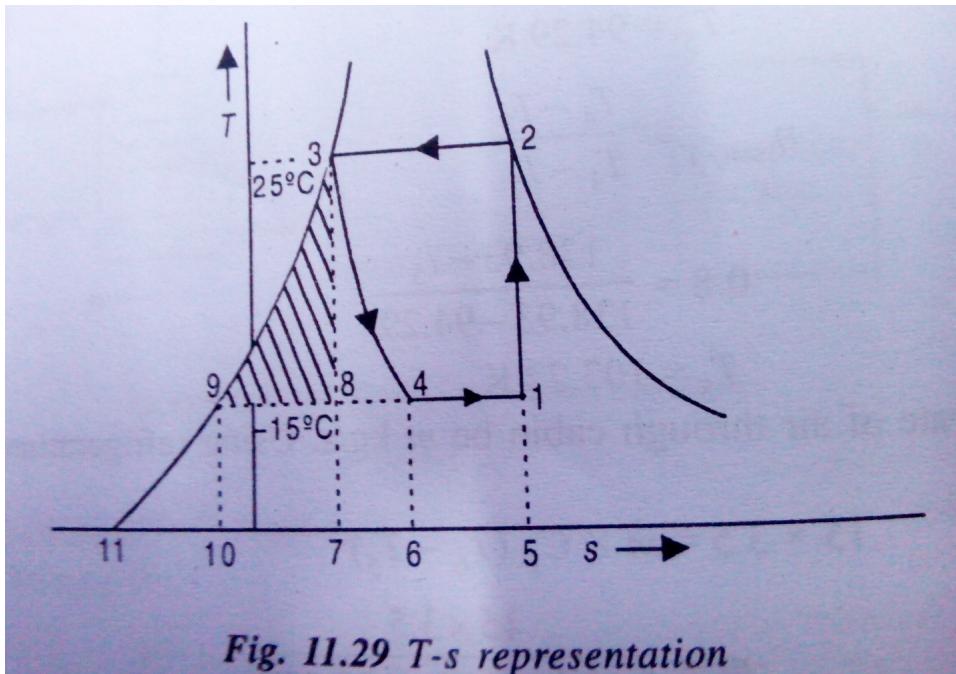
---

**Scilab code Exa 11.9** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 9

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 9")

```



*Fig. 11.29 T-s representation*

Figure 11.8: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 9

```

8 disp(" properties of NH3,")
9 disp(" at 15 degree celcius ,h9=-54.51 KJ/kg ,hg
      =1303.74 KJ/kg ,s9=-0.2132 KJ/kg K, sg=5.0536 KJ/kg
      K")
10 T1=(-15+273);
11 h9=-54.51;
12 hg=1303.74;
13 s9=-0.2132;
14 sg=5.0536;
15 disp(" and at 25 degree celcius ,h3=99.94 KJ/kg ,h2
      =1317.95 KJ/kg ,s3=0.3386 KJ/kg K, s2=4.4809 KJ/kg
      K")
16 T2=(25+273);
17 h3=99.94;
18 h2=1317.95;
19 s3=0.3386;
20 s2=4.4809;
21 disp(" here work done ,W=Area 1-2-3-9-1")
22 disp(" refrigeration effect=Area 1-5-6-4-1")
23 disp(" Area 3-8-9 =(Area 3-11-7)-(Area 9-11-10)-(Area
      9-8-7-10)")
24 disp(" so Area 3-8-9=h3-h9-T1*(s3-s9) in KJ/kg")
25 h3-h9-T1*(s3-s9)
26 disp(" during throttling process between 3 and 4 ,h3=
      h4")
27 disp(" (Area=3-11-7-3)=(Area 4-9-11-6-4)")
28 disp(" (Area 3-8-9)+(Area 8-9-11-7-8)=(Area
      4-6-7-8-4)+(Area 8-9-11-7-8)")
29 disp(" (Area 3-8-9)=(Area 4-6-7-8-4)")
30 disp(" so (Area 4-6-7-8-4)=12.09 KJ/kg")
31 disp(" also ,(Area 4-6-7-8-4)=T1*(s4-s8)")
32 disp(" so (s4-s8) in KJ/kg K=")
33 12.09/T1
34 disp(" also s3=s8=0.3386 KJ/kg K")
35 s8=s3;
36 disp(" so s4 in KJ/kg K=")
37 s4=s8+12.09/T1
38 disp(" also s1=s2=4.4809 KJ/kg K")

```

```

39 s1=s2;
40 disp(" refrigeration effect (Q)=Area (1-5-6-4-1)=T1*(
    s1-s4) in KJ/kg")
41 Q=T1*(s1-s4)
42 disp(" work done (W)=Area (1-2-3-9-1)=(Area 3-8-9)+((
    T2-T1)*(s1-s8)) in KJ/kg")
43 W=12.09+((T2-T1)*(s1-s8))
44 disp(" so COP=refrigeration effect / work done=Q/W")
45 COP=Q/W
46 disp(" so COP=5.94")

```

---

**Scilab code Exa 11.10** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 10

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Engineering Thermodynamics by Onkar Singh
        Chapter 11 Example 10")
8 Q=2.86*3.5; //refrigeration effect in KJ/s
9 N=1200; //compressor rpm
10 n=1.13; //compression index
11 disp(" properties of Freon-12,")
12 disp(" at -20 degree celcius ,P1=1.51 bar ,vg=0.1088 m
        ^3/kg , hf=17.8 KJ/kg , h1=178.61 KJ/kg , sf=0.0730 KJ/
        kg K, s1=0.7082 KJ/kg K,Cpg=0.605 KJ/kg K")
13 P1=1.51;
14 T1=(-20+273);
15 vg=0.1088;
16 h1=178.61;
17 s1=0.7082;
18 s2=s1;

```

```

19 disp(" at 40 degree celcius ,P2=9.61 bar ,h3=74.53 KJ/
      kg ,hg=203.05 KJ/kg ,sf=0.2716 KJ/kg K, sg=0.682 KJ/
      kg K,Cpf=0.976 KJ/kg K,Cpg=0.747 KJ/kg K")
20 P2=9.61;
21 h3=74.53;
22 h4=h3;
23 hg=203.05;
24 sf=0.2716;
25 sg=0.682;
26 Cpf=0.976;
27 Cpg=0.747;
28 disp(" during expansion ( throttling ) between 3 and 4")
29 disp(" h3=h4=hf_40oc=74.53 KJ/kg=h4")
30 disp(" process 1-2 is adiabatic compression so ,")
31 disp(" s1=s2 ,s1=sg_-20oc=0.7082 KJ/kg K")
32 disp(" at 40 degree celcius or 313 K, s1=sg+Cpg*log (T2
      /313)")
33 disp("T2=313*exp((s1-sg)/Cpg) in K")
34 T2=313*exp((s1-sg)/Cpg)
35 disp(" so temperature after compression ,T2=324.17 K")
36 disp(" enthalpy after compression ,h2=hg+Cpg*(T2-313)
      in KJ/kg")
37 h2=hg+Cpg*(T2-313)
38 disp(" compression work required , per kg(Wc)=h2-h1 in
      KJ/kg")
39 Wc=h2-h1
40 disp(" refrigeration effect during cycle , per kg(q)=h1
      -h4 in KJ/kg")
41 q=h1-h4
42 disp(" mass flow rate of refrigerant ,m=Q/q in kg/s")
43 m=Q/q
44 m=0.096; //approx .
45 disp("COP=q/Wc")
46 COP=q/Wc
47 disp(" volumetric efficiency of reciprocating
      compressor , given C=0.02")
48 C=0.02;
49 disp(" n.vol=1+C-C*(P2/P1)^(1/n)")

```

Properties of Freon - 12								
Temperature °C	Saturation Pressure, bar	Specific Volume, $v_g m^3/kg$	Enthalpy, kJ/kg		Entropy, kJ/kg·K		specific heat kJ/kg·K	
			$h_f$	$h_g$	$s_f$	$s_g$	$C_{pf}$	$C_{pg}$
-20	1.51	0.1088	17.8	178.61	0.0730	0.7082	-	0.605
40	9.61	-	74.53	203.05	0.2716	0.682	0.976	0.747

Figure 11.9: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 10

```

50 n_vol=1+C-C*(P2/P1)^(1/n)
51 disp("let piston displacement by V,m^3")
52 disp("mass flow rate ,m=(V*n_vol*N)/(60*vg_-20oc)")
53 disp("so V=(m*60*vg_-20oc)*10^6/(N*n_vol) in cm^3")
54 V=(m*60*vg)*10^6/(N*n_vol)
55 disp("so COP=3.175")
56 disp("and piston displacement=569.45 cm^3")

```

---

### Scilab code Exa 11.11 Engineering Thermodynamics by Onkar Singh Chapter 11 Example 11

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 11")
8 Q=2; // refrigeration effect in KW
9 disp(" properties of CO2,")

```

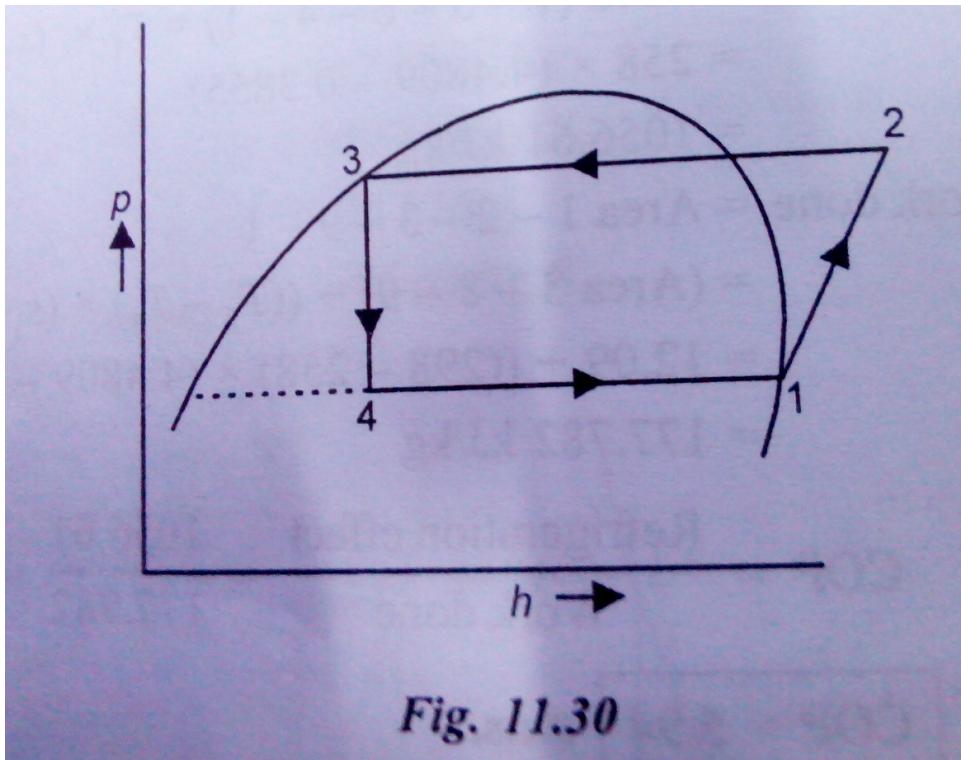


Figure 11.10: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 10

```

10 disp(" at 20 degree celcius ,P1=57.27 bar ,hf=144.11 KJ
      /kg ,hg=299.62 KJ/kg ,sf=0.523 KJ/kg K, sg_20oc
      =1.0527 KJ/kg K,Cpf=2.889 KJ/kg K,Cpg=2.135 KJ/kg
      K")
11 T1=(20+273); //condensation temperature in K
12 P1=57.27;
13 h3=144.11;
14 hg=299.62;
15 sf=0.523;
16 sg_20oc=1.0527;
17 Cpf=2.889;
18 Cpg=2.135;
19 disp(" at -10 degree celcius ,P2=26.49 bar ,vg=0.014 m
      ^3/kg ,hf=60.78 KJ/kg ,hg=322.28 KJ/kg ,sf=0.2381 KJ
      /kg K,sg=1.2324 KJ/kg K")
20 T2=(-10+273); //evaporator temperature in K
21 P2=26.49;
22 vg=0.014;
23 hf=60.78;
24 h1=322.28;
25 sf=0.2381;
26 sg=1.2324;
27 disp(" processes of vapour compression cycle are
      shown on T-s diagram")
28 disp("1-2:isentropic compression process")
29 disp("2-3-4:condensation process")
30 disp("4-5:isenthalpic expansion process")
31 disp("5-1:refrigeration process in evaporator")
32 disp("h1=hg at -10oc=322.28 KJ/kg")
33 disp("at 20 degree celcius ,h2=hg+Cpg*(40-20) in KJ/kg
      ")
34 h2=hg+Cpg*(40-20)
35 disp("entropy at state 2 ,at 20 degree celcius ,s2=
      sg_20oc+Cpg*log((273+40)/(273+20))in KJ/kg K")
36 s2=sg_20oc+Cpg*log((273+40)/(273+20))
37 disp("entropy during isentropic process ,s1=s2")
38 disp("at -10 degree celcius ,s2=sf+x1*sfg")
39 disp("so x1=(s2-sf)/(sg-sf)")

```

```

40 x1=(s2-sf)/(sg-sf)
41 disp("enthalpy at state 1,at -10 degree celcius ,h1=
        hf+x1*hfg in KJ/kg")
42 h1=hf+x1*(h1-hf)
43 disp("h3=hf at 20oc=144.11 KJ/kg")
44 disp("since undercooling occurs upto 10oc ,so ,h4=h3-
        Cpf*deltaT in KJ/kg")
45 h4=h3-Cpf*(20-10)
46 disp("also ,h4=h5=115.22 KJ/kg")
47 h5=h4;
48 disp("refrigeration effect per kg of refrigerant(q)
        =(h1-h5) in KJ/kg")
49 q=(h1-h5)
50 disp("let refrigerant flow rate be m kg/s")
51 disp("refrigerant effect(Q)=m*q")
52 disp("m=Q/q in kg/s")
53 m=Q/q
54 disp("compressor work ,Wc=h2-h1 in KJ/kg")
55 Wc=h2-h1
56 disp("COP=refrigeration effect per kg/compressor
        work per kg=q/Wc")
57 COP=q/Wc
58 disp("so COP=6.51, mass flow rate=0.01016 kg/s")
59 disp("NOTE=>In book ,mass flow rate(m) which is
        0.1016 kg/s is calculated wrong and it is
        correctly solve above and comes out to be m
        =0.01016 kg/s . ")

```

---

Properties of CO <sub>2</sub>								
Temperature °C	Saturation Pressure, bar	Specific Volume, v <sub>g</sub> m <sup>3</sup> /kg	Enthalpy, kJ/kg		Entropy, kJ/kg·K		Specific heat kJ/kg·K	
			h <sub>f</sub>	h <sub>g</sub>	s <sub>f</sub>	s <sub>g</sub>	C <sub>pf</sub>	C <sub>pg</sub>
20	57.27	—	144.11	299.62	0.523	1.0527	2.889	2.135
-10	26.49	0.014	60.78	322.28	0.2381	1.2324	—	—

Figure 11.11: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 11

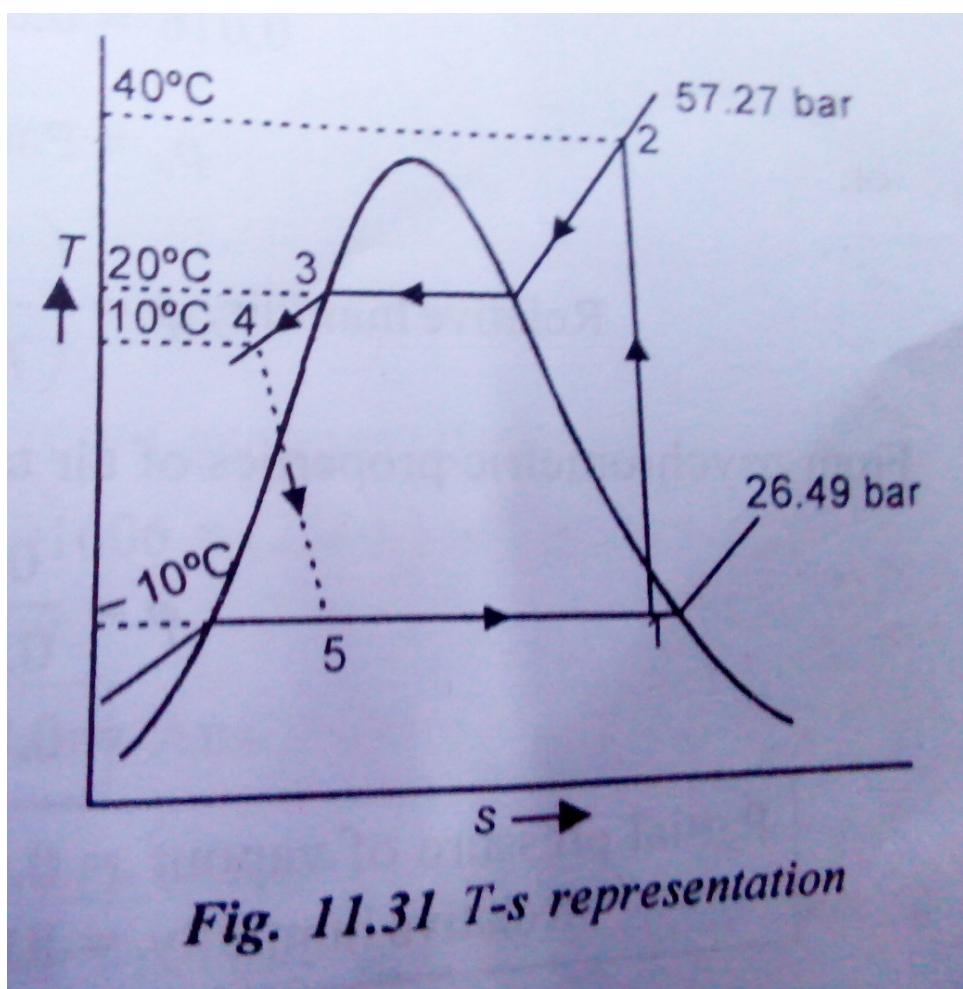


Figure 11.12: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 11

**Table 2 Saturated Steam (temperature) table**

Temp. °C <i>T</i>	Sat. press. kPa <i>P<sub>sat</sub></i>	Specific volume m <sup>3</sup> /kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid	Sat. vapour	Sat. <i>u<sub>f</sub></i>	Sat. <i>u<sub>fg</sub></i>	Sat. <i>u<sub>g</sub></i>	Sat. <i>h<sub>f</sub></i>	Sat. <i>h<sub>fg</sub></i>	Sat. <i>h<sub>g</sub></i>	Sat. <i>s<sub>f</sub></i>	Sat. <i>s<sub>fg</sub></i>	Sat. <i>s<sub>g</sub></i>
		<i>v<sub>f</sub></i>	<i>v<sub>g</sub></i>									
0.01	0.6113	0.001000	206.14	0.0	2375.3	2375.3	0.01	2501.4	2501.4	0.000	9.1562	9.1562
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	0.1510	8.7498	8.9000
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	0.2245	8.5569	8.7814
20	2.339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	0.2966	8.3706	8.6672
25	3.169	0.001003	43.36	104.88	2409.8	2309.8	104.89	2442.3	2547.2	0.3674	8.1905	8.5500
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	0.4369	8.0164	8.4533
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	0.5053	7.8478	8.3531
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	0.5725	7.6845	8.2570
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	0.6387	7.5261	8.1648
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0763
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8310
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7351
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6221
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.5000
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.3886
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.2769
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.96	2270.2	2668.1	1.2500	6.1639	7.1659

Figure 11.13: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 12

**Scilab code Exa 11.12** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 12

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 12")
8 omega=0.016; //specific humidity in gm/gm of air
9 disp("here pressure of atmospheric air(P)may be
      taken as 1.013 bar")
10 P=1.013; //pressure of atmospheric air in bar
11 disp(" specific humidity ,omega=0.622*(Pv/(P-Pv))")
12 disp("so partial pressure of vapour(Pv)in bar")
13 disp("Pv=P/(1+(0.622/omega)) in bar ")
14 Pv=P/(1+(0.622/omega))
15 Pv=0.0254; //approx.
16 disp("relative humidity(phi)=(Pv/Pv_sat)")
17 disp("from pychrometric properties of air Pv_sat at
      25 degree celcius=0.03098 bar")
18 Pv_sat=0.03098;
19 disp("so phi=Pv/Pv_sat")
20 phi=Pv/Pv_sat
21 disp("in percentage")
22 phi=phi*100
23 disp("so partial pressure of vapour=0.0254 bar")
24 disp("relative humidity=81.98 %")
```

---

**Scilab code Exa 11.13** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 13

Temp. °C	Sat. press. kPa	Table 2 Saturated Steam (temperature) table											
		Specific volume m³/kg			Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid $v_f$	Sat. vapour $v_g$	Sat. $u_f$	Sat. $u_{fg}$	Sat. $u_g$	Sat. $h_f$	Sat. $h_{fg}$	Sat. $h_g$	Sat. $s_f$	Sat. $s_{fg}$	Sat. $s_g$	
0.0	0.6113	0.001000	206.14	0.0	2375.3	2375.3	0.01	2501.4	2501.4	0.000	9.1562	9.1562	
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	0.0761	8.9496	9.0257	
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	0.1510	8.7498	8.9000	
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	0.2245	8.5569	8.7814	
20	2.339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	0.2966	8.3706	8.6672	
25	3.169	0.001003	43.36	104.88	2409.8	2309.8	104.89	2442.3	2547.2	0.3674	8.1905	8.5500	
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	0.4369	8.0164	8.4533	
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	0.5053	7.8478	8.3531	
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	0.5725	7.6845	8.2570	
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	0.6387	7.5261	8.1648	
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0763	
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913	
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096	
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8310	
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7351	
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6221	
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.5000	
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.3886	
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2866	7.2769	
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.96	2270.2	2668.1	1.2500	6.1639	7.1659	

Figure 11.14: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 13

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 11 Example 13")
8 r=0.6; //relative humidity
9 P=1.013; //total pressure of mixture in bar
10 R=0.287; //gas constant in KJ/kg K
11 Ta=(30+273); //room temperature in K
12 Cp=1.005; //specific heat at constant pressure in KJ/
kg degree celcius
13 disp("at 30 degree celcius from steam table ,
saturation pressure ,Pv_sat=0.0425 bar")
14 Pv_sat=0.0425;
15 disp("partial pressure of vapour(Pv)=relative
humidity*Pv_sat in bar")
16 Pv=r*Pv_sat
17 disp("partial pressure of air(Pa)=total pressure of
mixture-partial pressure of vapour")
18 Pa=P-Pv
19 disp("so partial pressure of air=0.9875 bar")
20 disp("humidity ratio ,omega=0.622*Pv/(P-Pv) in kg/kg
of dry air")
21 omega=0.622*Pv/(P-Pv)
22 disp("so humidity ratio=0.01606 kg/kg of air")
23 disp("Dew point temperature may be seen from the
steam table.The saturation temperature
corresponding to the partial pressure of vapour
is 0.0255 bar.Dew point temperature can be
approximated as 21.4oc by interpolation")
24 disp("so Dew point temperature=21.4 degree celcius")
25 disp("density of mixture(rho_m)=density of air(rho_a
)+density of vapour(rho_v)")
26 disp("rho_m=(rho_a)+(rho_v)=rho_a*(1+omega)")
27 disp("rho_m=P*100*(1+omega) /(R*Ta) in kg/m^3")

```

```

28 rho_m=P*100*(1+omega)/(R*Ta)
29 disp("so density = 1.1835 kg/m^3")
30 disp("enthalpy of mixture , h=Cp*T+omega*(hg
      +1.860*(30-21.4)) in KJ/kg of dry air")
31 T=30; //room temperature in degree celcius
32 hg=2540.1; //enthalpy at 30 degree celcius in KJ/kg
33 h=Cp*T+omega*(hg+1.860*(30-21.4))
34 disp("enthalpy of mixture =71.2 KJ/kg of dry air")

```

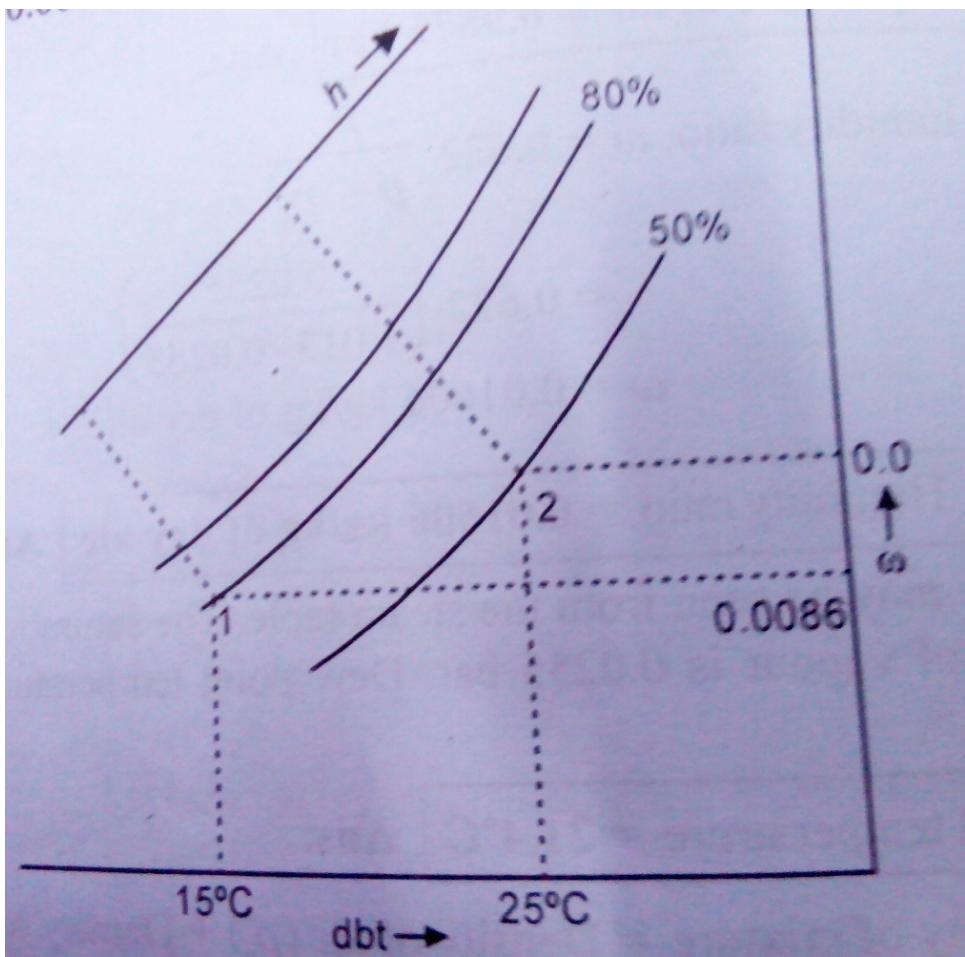
---

**Scilab code Exa 11.14** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 14

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 14")
8 disp("initial state at 15 degree celcius and 80%
      relative humidity is shown by point 1 and final
      state at 25 degree celcius and 50% relative
      humidity is shown by point 2 on psychrometric
      chart .")
9 disp("omega1=0.0086 kg/kg of air ,h1=37 KJ/kg ,omega2
      =0.01 kg/kg of air ,h2=50 KJ/kg ,v2=0.854 m^3/kg")
10 omega1=0.0086;
11 h1=37;
12 omega2=0.01;
13 h2=50;
14 v2=0.854;
15 disp("mass of water added between states 1 and 2")

```



**Fig. 11.32 Psychrometric chart**

Figure 11.15: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 14

Table 2 Saturated Steam (temperature) table												
Temp. T °C	Sat. press. kPa	Specific volume m³/kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)		
		Sat. liquid $v_f$	Sat. vapour $v_g$	Sat. liquid $u_f$	Evap. $u_{fg}$	Sat. vapour $u_g$	Sat. liquid $h_f$	Evap. $h_{fg}$	Sat. vapour $h_g$	Sat. liquid $s_f$	Evap. vapour $s_g$	Sat. vapour $s_g$
		0.6113	0.001000	206.14	0.0	2375.3	2375.3	0.01	2501.4	2501.4	0.000	9.1562
5	0.8721	0.001000	147.12	20.97	2361.3	2382.3	20.98	2489.6	2510.6	0.0761	8.9496	9.0257
10	1.2276	0.001000	106.38	42.00	2347.2	2389.2	42.01	2477.7	2519.8	0.1510	8.7498	8.9008
15	1.7051	0.001001	77.93	62.99	2333.1	2396.1	62.99	2465.9	2528.9	0.2245	8.5569	8.7814
20	2.339	0.001002	57.79	83.95	2319.0	2402.9	83.96	2454.1	2538.1	0.2966	8.3706	8.6672
25	3.169	0.001003	43.36	104.88	2409.8	2309.8	104.89	2442.3	2547.2	0.3674	8.1905	8.5280
30	4.246	0.001004	32.89	125.78	2290.8	2416.6	125.79	2430.5	2556.3	0.4369	8.0164	8.4533
35	5.628	0.001006	25.22	146.67	2276.7	2423.4	146.68	2418.6	2565.3	0.5053	7.8478	8.3551
40	7.384	0.001008	19.52	167.56	2262.6	2430.1	167.57	2406.7	2574.3	0.5725	7.6845	8.2570
45	9.593	0.001010	15.26	188.44	2248.4	2436.8	188.45	2394.8	2583.2	0.6387	7.5261	8.1648
50	12.349	0.001012	12.03	209.32	2234.2	2443.5	209.33	2382.7	2592.1	0.7038	7.3725	8.0768
55	15.758	0.001015	9.568	230.21	2219.9	2450.1	230.23	2370.7	2600.9	0.7679	7.2234	7.9913
60	19.940	0.001017	7.671	251.11	2205.5	2456.6	251.13	2358.5	2609.6	0.8312	7.0784	7.9096
65	25.03	0.001020	6.197	272.02	2191.1	2463.1	272.06	2346.2	2618.3	0.8935	6.9375	7.8110
70	31.19	0.001023	5.042	292.95	2176.6	2469.6	292.98	2333.8	2626.8	0.9549	6.8004	7.7223
75	38.58	0.001026	4.131	313.90	2162.0	2475.9	313.93	2321.4	2635.3	1.0155	6.6669	7.6232
80	47.39	0.001029	3.407	334.86	2147.4	2482.2	334.91	2308.8	2643.7	1.0753	6.5369	7.5222
85	57.83	0.001033	2.828	355.84	2132.6	2488.4	355.90	2296.0	2651.9	1.1343	6.4102	7.4212
90	70.14	0.001036	2.361	376.85	2117.7	2494.5	376.92	2283.2	2660.1	1.1925	6.2886	7.3202
95	84.55	0.001040	1.982	397.88	2102.7	2500.6	397.96	2270.2	2668.1	1.2500	6.1650	7.2192

Figure 11.16: Engineering Thermodynamics by Onkar Singh Chapter 11 Example 15

```

omega2-omega1 in kg/kg of air")
16 omega2-omega1
17 disp(" mass flow rate of air (ma)=0.8/v2 in kg/s")
18 ma=0.8/v2
19 disp(" total mass of water added=ma*(omega2-omega1) in
kg/s")
20 ma*(omega2-omega1)
21 disp(" heat transferred=ma*(h2-h1) in KJ/s")
22 ma*(h2-h1)
23 disp(" so mass of water added=0.001312 kg/s ,heat
transferred=12.18 KW")

```

---

**Scilab code Exa 11.15** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 15

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 11 Example 15")
8 P=1.013; //atmospheric pressure in bar
9 Cp_air=1.005; //specific heat of air at constant
pressure in KJ/kg K
10 Cp_stream=1.86; //specific heat of stream at constant
pressure in KJ/kg K
11 T1=30; //temperature of first stream of moist air in
K
12 m1=3; //mass flow rate of first stream in kg/s
13 T2=35; //temperature of second stream of moist air in
K
14 m2=2; //mass flow rate of second stream in kg/s
15 disp("Let temperature after mixing be Toc. For
getting final enthalpy after adiabatic mixing the
enthalpy of two streams are required.")
16 disp("For moist air stream at 30 degree celcius and
30% relative humidity.")
17 phi1=0.3;
18 disp("phi1=Pv1/Pv_sat_30oc")
19 disp("here Pv_sat_30oc=0.04246 bar")
20 Pv_sat_30oc=0.04246;
21 disp("so Pv1=phi1*Pv_sat_30oc in bar")
22 Pv1=phi1*Pv_sat_30oc
23 disp("corresponding to vapour pressure of 0.01274")
```

bar the dew point temperature shall be 10.5  
 degree celcius")

```

24 Tdp1=10.5;
25 disp(" specific humidity ,omega1=0.622*Pv1/(P-Pv1) in
    kg/kg of air")
26 omega1=0.622*Pv1/(P-Pv1)
27 disp("at dew point temperature of 10.5 degree
    celcius ,enthalpy ,hg at 10.5oc=2520.7 KJ/kg")
28 hg=2520.7; //enthalpy at 10.5 degree celcius in KJ/kg
29 disp("h1=Cp_air*T1+omega1*{hg-Cp_stream*(T1-Tdp1)} in
    KJ/kg of dry air")
30 h1=Cp_air*T1+omega1*{hg-Cp_stream*(T1-Tdp1)}
31 disp("for second moist air stream at 35oc and 85%
    relative humidity")
32 phi2=0.85;
33 disp("phi2=Pv2/Pv_sat_35oc")
34 disp("here Pv_sat_35oc=0.005628 bar")
35 Pv_sat_35oc=0.005628;
36 disp("so Pv2=phi2*Pv_sat_35oc in bar")
37 Pv2=phi2*Pv_sat_35oc
38 disp("specific humidity ,omega2=0.622*Pv2/(P-Pv2) in
    kg/kg of air")
39 omega2=0.622*Pv2/(P-Pv2)
40 disp("corresponding to vapour pressure of 0.004784
    bar the dew point temperature is 32 degree
    celcius")
41 Tdp2=32;
42 disp("so ,enthalpy of second stream ,")
43 disp("h2=Cp_air*T2+omega2*{hg+Cp_stream*(T2-Tdp2)} in
    KJ/kg of dry air")
44 hg=2559.9; //enthalpy at 32 degree celcius in KJ/kg
45 h2=Cp_air*T2+omega2*{hg+Cp_stream*(T2-Tdp2)}
46 disp("enthalpy of mixture after adiabatic mixing ,")
47 disp("=(1/(m1+m2))*(h1*m1/(1+omega1))+(h2*m2/(1+
    omega2))) in KJ/kg of moist air")
48 (1/(m1+m2))*((h1*m1/(1+omega1))+(h2*m2/(1+omega2)))
49 disp("mass of vapour per kg of moist air=(1/5)*(((
    omega1*m1/(1+omega1))+(omega2*m2/(1+omega2)))) in
    KJ/kg of moist air")
  
```

```

        kg/kg of moist air")
50 (1/5)*((omega1*m1/(1+omega1))+(omega2*m2/(1+omega2))
      )
51 disp(" specific humidity of mixture(omega) in kg/kg of
      dry air=")
52 omega=0.00589/(1-0.005893)
53 disp("omega=0.622*Pv/(P-Pv)" )
54 disp("Pv=omega*P/(omega+0.622) in bar" )
55 Pv=omega*P/(omega+0.622)
56 disp(" partial pressure of water vapour=0.00957 bar" )
57 disp("so specific humidity of mixture=0.00593 kg/kg
      dry air" )
58 disp("and partial pressure of water vapour in
      mixture=0.00957 bar" )

```

---

**Scilab code Exa 11.16** Engineering Thermodynamics by Onkar Singh Chapter 11 Example 16

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 11 Example 16")
8 m1=3; //rate at which moist air enter in heating coil
      in m^3/s
9 disp("The type of heating involved is sensible
      heating. Locating satte 1 on psychrometric chart
      corresponding to 15 degree celcius dbt and 80%
      relative humidity the other property values shall
      be ,")
10 disp("h1=36.4 KJ/kg ,omega1=0.0086 kg/kg of air ,v1
      =0.825 m^3/kg" )

```

```
11 h1=36.4;
12 omega1=0.0086;
13 v1=0.825;
14 disp(" final state 2 has ,h2=52 KJ/kg")
15 h2=52;
16 disp(" mass of air (m)=m1/v1 in kg/s")
17 m=m1/v1
18 m=3.64; //approx .
19 disp(" amount of heat added (Q) in KJ/s")
20 disp("Q=m*(h2-h1)")
21 Q=m*(h2-h1)
```

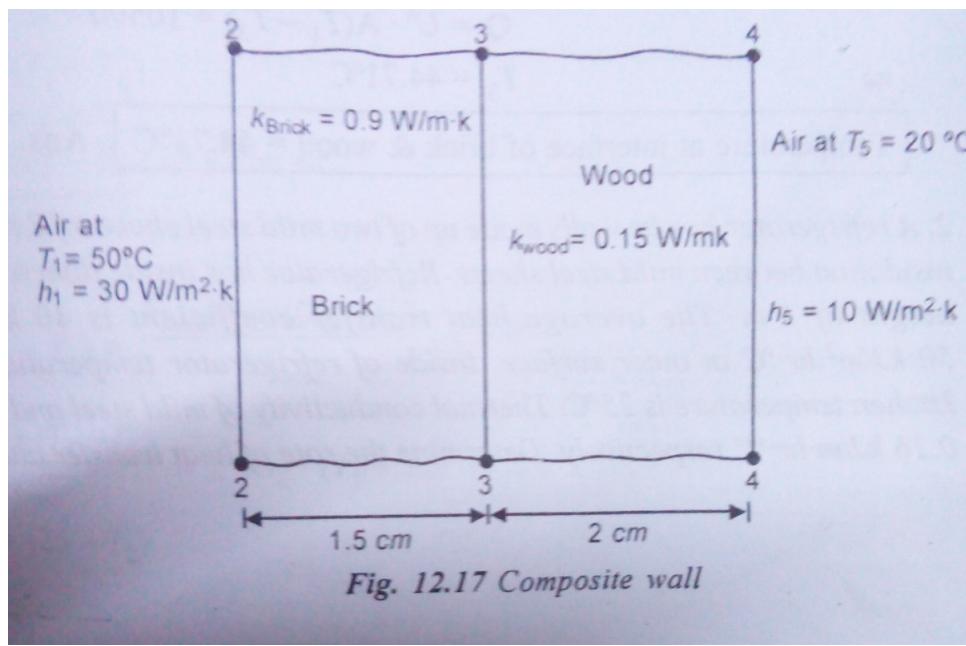
---

# Chapter 12

## Introduction To Heat Transfer

**Scilab code Exa 12.1** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 12 Example 1")
8 h1=30; //heat transfer coefficient on side of 50 oc
      in W/m^2 K
9 h5=10; //heat transfer coefficient on side of 20 oc
      in W/m^2 K
10 k_brick=0.9; //conductivity of brick in W/m K
11 k_wood=0.15; //conductivity of wood in W/m K
12 T1=50; //temperature of air on one side of wall in
      degree celcius
13 T5=20; //temperature of air on other side of wall in
      degree celcius
```



*Fig. 12.17 Composite wall*

Figure 12.1: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 1

```

14 A=100; //surface area in m^2
15 deltax_brick=1.5*10^-2; //length of brick in m
16 deltax_wood=2*10^-2; //length of wood in m
17 disp(" here for one dimentional heat transfer across
       the wall the heat transfer circuit shall
       comprises of thermal resistance due to convection
       between air & brick(R1), conduction in brick wall
       (R2), conduction in wood(R3), and convection
       between wood and air(R4). Let temperature at outer
       brick wall be T2 K, brick-wood interface be T3 K,
       outer wood wall be T4 K")
18 disp(" overall heat transfer coefficient for steady
       state heat transfer(U) in W/m^2 K")
19 disp("(1/U)=(1/h1)+(deltax_brick/k_brick)+(
       deltax_wood/k_wood)+(1/h5)")
20 disp(" so U=1/((1/h1)+(deltax_brick/k_brick)+(
       deltax_wood/k_wood)+(1/h5))")
21 U=1/((1/h1)+(deltax_brick/k_brick)+(deltax_wood/
       k_wood)+(1/h5))
22 U=3.53; //approx.
23 disp(" rate of heat transfer ,Q=U*A*(T1-T5) in W")
24 Q=U*A*(T1-T5)
25 disp(" so rate of heat transfer=10590 W")
26 disp(" heat transfer across states 1 and 3(at
       interface).")
27 disp("overall heat transfer coefficient between 1
       and 3")
28 disp("(1/U1)=(1/h1)+(deltax_brick/k_brick)")
29 disp(" so U1=1/((1/h1)+(deltax_brick/k_brick)) in W/m
       ^2 K")
30 U1=1/((1/h1)+(deltax_brick/k_brick))
31 disp("Q=U1*A*(T1-T3)")
32 disp(" so T3=T1-(Q/(U1*A)) in degree celcius")
33 T3=T1-(Q/(U1*A))
34 disp(" so temperature at interface of brick and wood
       =44.71 degree celcius")

```

---

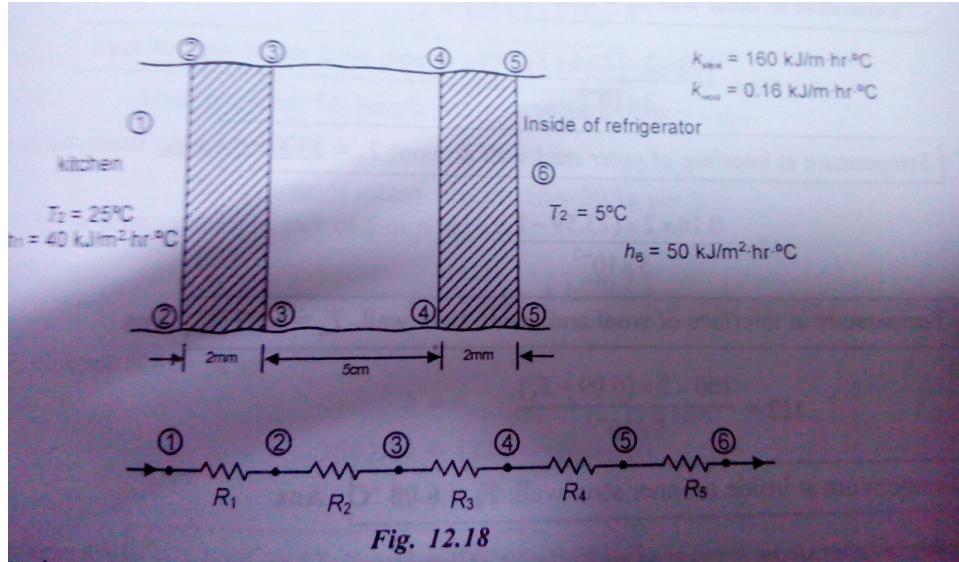


Figure 12.2: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 2

**Scilab code Exa 12.2** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 12 Example 2")
8 h1=40; //average heat transfer coefficient at inner
surface in KJ/m^2 hr oc
9 h6=50; //average heat transfer coefficient at outer

```

```

        surface in KJ/m^2 hr oc
10 deltax_stee=2*10^-3; //mild steel sheets thickness
    in m
11 deltax_wool=5*10^-2; //thickness of glass wool
    insulation in m
12 k_wool=0.16; //thermal conductivity of wool in KJ/m
    hr
13 k_stee=160; //thermal conductivity of steel in KJ/m
    hr
14 T1=25; //kitchen temperature in degree celcius
15 T6=5; //refrigerator temperature in degree celcius
16 disp("here thermal resistances are")
17 disp("R1=thermal resistance due to convection
    between kitchen air and outer surface of
    refrigerator wall(T1 & T2)")
18 disp("R2=thermal resistance due to conduction across
    mild steel wall between 2 & 3(T2 & T3)")
19 disp("R3=thermal resistance due to conduction across
    glass wool between 3 & 4(T3 & T4)")
20 disp("R4=thermal resistance due to conduction across
    mild steel wall between 4 & 5(T4 & T5)")
21 disp("R5=thermal resistance due to convection
    between inside refrigerator wall and inside of
    refrigerator between 5 & 6(T5 & T6)")
22 disp("overall heat transfer coefficient for one
    dimentional steady state heat transfer")
23 disp("(1/U)=(1/h1)+(deltax_stee/k_stee)+(
    deltax_wool/k_wool)+(deltax_stee/k_stee)+(1/h6)
    ")
24 disp("so U=1/((1/h1)+(deltax_stee/k_stee)+(
    deltax_wool/k_wool)+(deltax_stee/k_stee)+(1/h6)
    ) in KJ/m^2 hr oc")
25 U=1/((1/h1)+(deltax_stee/k_stee)+(deltax_wool/
    k_wool)+(deltax_stee/k_stee)+(1/h6))
26 U=2.8; //approx.
27 disp("rate of heat transfer (Q)=U*A*(T1-T6) in KJ/m^2
    hr")
28 disp("wall surface area (A) in m^2")

```

```

29 A=4*(1*0.5)
30 Q=U*A*(T1-T6)
31 disp("so rate of heat transfer=112 KJ/m^2 hr ")
32 disp("Q=A*h1*(T1-T2)=k_steel*A*(T2-T3)/deltax_steeel=
      k_wool*A*(T3-T4)/deltax_wool")
33 disp("Q=k_steeel*A*(T4-T5)/deltax_steeel=A*h6*(T5-T6)")
34 disp("substituting ,T2=T1-(Q/(A*h1)) in degree celcius
      ")
35 T2=T1-(Q/(A*h1))
36 disp("so temperature of outer wall ,T2=23.6 oc")
37 disp("T3=T2-(Q*deltax_steeel/(k_steeel*A)) in degree ")
38 T3=T2-(Q*deltax_steeel/(k_steeel*A))
39 disp("so temperature at interface of outer steel
      wall and wool ,T3=23.59 oc")
40 disp("T4=T3-(Q*deltax_wool/(k_wool*A)) in degree
      celcius")
41 T4=T3-(Q*deltax_wool/(k_wool*A))
42 disp("so temperature at interface of wool and inside
      steel wall ,T4=6.09 oc")
43 disp("T5=T4-(Q*deltax_steeel/(k_steeel*A)) in degree
      celcius")
44 T5=T4-(Q*deltax_steeel/(k_steeel*A))
45 disp("so temperature at inside of inner steel wall ,
      T5=6.08 oc")

```

---

**Scilab code Exa 12.3** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 3

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;

```

```

7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 12 Example 3")
8 k_insulation=0.3; //thermal conductivity of
      insulation in KJ/m hr oc
9 k_pipe=209; //thermal conductivity of pipe in KJ/m hr
      oc
10 T1=300; //temperature of inner surface of steam pipe
      in degree celcius
11 T3=50; //temperature of outer surface of insulation
      layer in degree celcius
12 r1=15*10^-2/2; //steam pipe inner radius without
      insulation in m
13 r2=16*10^-2/2; //steam pipe outer radius without
      insulation in m
14 r3=22*10^-2/2; //radius with insulation in m
15 m=0.5; //steam entering rate in kg/min
16 disp("here ,heat conduction is considered in pipe
      wall from 1 to 2 and conduction through
      insulation between 2 and 3 of one dimentional
      steady state type .")
17 disp("Q=(T1-T3)*2*%pi*L/((1/k_pipe)*log(r2/r1)+(1/
      k_insulation*log(r3/r2))) in KJ/hr")
18 L=1;
19 Q=(T1-T3)*2*%pi*L/((1/k_pipe)*log(r2/r1)+(1/
      k_insulation*log(r3/r2)))
20 disp("so heat loss per meter from pipe =1479.34 KJ/
      hr")
21 disp("heat loss from 5 m length(Q) in KJ/hr")
22 Q=5*Q
23 disp("enthalpy of saturated steam at 300 oc ,h_sat
      =2749 KJ/kg=hg from steam table")
24 hg=2749;
25 disp("mass flow of steam(m) in kg/hr")
26 m=m*60
27 disp("final enthalpy of steam per kg at exit of 5 m
      pipe(h)in KJ/kg")
28 h=hg-(Q/m)
29 disp("let quality of steam at exit be x ,")

```

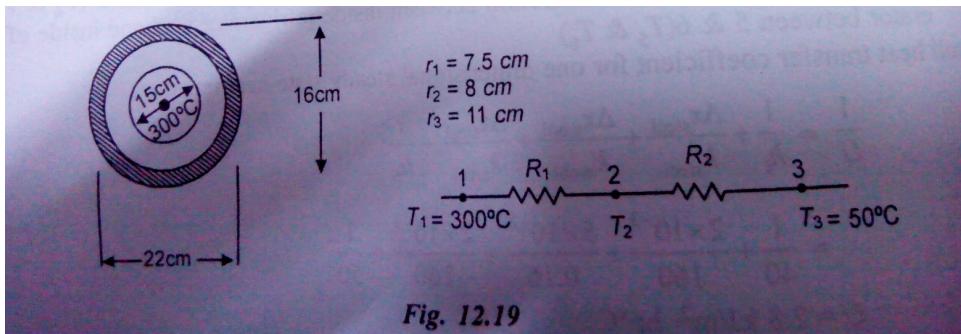


Fig. 12.19

Figure 12.3: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 3

```

30 disp(" also at 300oc , hf=1344 KJ/kg , hfg=1404.9 KJ/kg
      from steam table")
31 hf=1344;
32 hfg=1404.9;
33 disp("h=hf+x*hfg")
34 disp(" so x=(h-hf)/hfg")
35 x=(h-hf)/hfg
36 disp(" so quality of steam at exit=0.8245")

```

---

**Scilab code Exa 12.4** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 4

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;

```

Table 2 Saturated Steam (temperature) table

Temp. °C T	Sat. press. kPa $P_{sat}$	Specific volume m³/kg		Internal energy kJ/kg			Enthalpy kJ/kg			Entropy kJ/(kg K)			
		Sat. liquid $v_f$		Sat. vapour $v_g$	Sat. liquid $u_f$	Sat. Evap. $u_R$	Sat. vapour $u_g$	Sat. liquid $h_f$	Sat. Evap. $h_R$	Sat. vapour $h_g$	Sat. liquid $s_f$	Sat. Evap. vapour $s_{fg}$	Sat. vapour $s_g$
100	0.10135	0.001044	1.6729	418.94	2087.6	2506.5	419.04	2257.0	2676.1	1.3069	6.0480	7.3549	
105	0.12082	0.001048	1.4194	440.02	2072.3	2512.4	440.15	2243.7	2683.8	1.3630	5.9328	7.2958	
110	0.14327	0.001052	1.2102	461.14	2057.0	2518.1	461.30	2230.2	2691.5	1.4185	5.8202	7.2387	
115	0.16906	0.001056	1.0366	482.30	2041.4	2523.7	482.48	2216.5	2699.0	1.4734	5.7100	7.1833	
120	0.19853	0.001060	0.8919	503.50	2025.8	2529.3	503.71	2202.6	2706.3	1.5276	5.6020	7.1296	
125	0.2321	0.001065	0.7706	524.74	2009.5	2534.6	524.99	2188.5	2713.5	1.5813	5.4962	7.0775	
130	0.2701	0.001070	0.6685	546.02	1993.9	2539.9	546.31	2174.2	2720.5	1.6344	5.3925	7.0269	
135	0.3130	0.001075	0.5822	567.35	1977.7	2545.0	567.69	2159.6	2727.3	1.6870	5.2907	6.9777	
140	0.3613	0.001080	0.5089	588.74	1961.3	2550.0	589.13	2144.7	2733.9	1.7391	5.1908	6.9299	
145	0.4154	0.001085	0.4463	610.18	1944.7	2554.9	610.63	2129.6	2740.3	1.7907	5.0926	6.8833	
150	0.4758	0.001091	0.3928	631.68	1927.9	2559.5	632.20	2114.3	2746.5	1.8418	4.9960	6.8379	
155	0.5431	0.001096	0.3468	653.24	1910.8	2564.1	653.84	2098.6	2752.4	1.8925	4.9010	6.7935	
160	0.6178	0.001102	0.3071	674.87	1893.5	2568.4	675.55	2082.6	2758.1	1.9427	4.8075	6.7502	
165	0.7005	0.001108	0.2727	696.56	1876.0	2572.5	697.34	2066.2	2763.5	1.9925	4.7153	6.7078	
170	0.7917	0.001114	0.2428	718.33	1858.1	2576.5	719.21	2049.5	2768.7	2.0419	4.6244	6.6663	
175	0.8920	0.001121	0.2168	740.17	1840.0	2580.2	741.17	2032.4	2773.6	2.0909	4.5347	6.6256	
180	1.0021	0.001127	0.19405	762.09	1821.6	2583.7	763.22	2015.0	2778.2	2.1396	4.4461	6.5857	
185	1.1227	0.001134	0.17409	784.10	1802.9	2587.0	785.37	1997.1	2782.4	2.1879	4.3586	6.5465	
190	1.2544	0.001141	0.15654	806.19	1783.8	2590.0	807.62	1978.8	2786.4	2.2359	4.2720	6.5079	
195	1.3978	0.001149	0.14105	828.37	1764.4	2592.8	829.98	1960.0	2790.0	2.2835	4.1863	6.4698	
200	1.5538	0.001157	0.12736	850.65	1744.7	2595.3	852.45	1940.7	2793.2	2.3309	4.1014	6.4323	
205	1.7230	0.001164	0.11521	873.04	1724.5	2597.5	875.04	1921.0	2796.0	2.3780	4.0172	6.3952	
210	1.9062	0.001173	0.10441	895.53	1703.9	2599.5	897.76	1900.7	2798.5	2.4248	3.9337	6.3585	
215	2.104	0.001181	0.09479	918.14	1682.9	2601.1	920.62	1879.9	2800.5	2.4714	3.8507	6.3221	
220	2.318	0.001190	0.08619	940.87	1661.5	2602.4	943.62	1858.5	2802.1	2.5178	3.7683	6.2861	
225	2.548	0.001199	0.07849	963.73	1639.6	2603.3	966.78	1836.5	2803.3	2.5639	3.6863	6.2503	
230	2.795	0.001209	0.07158	986.74	1617.2	2603.9	990.12	1813.8	2804.0	2.6099	3.6047	6.2146	
235	3.060	0.001219	0.06537	1009.89	1594.2	2604.1	1013.62	1790.5	2804.2	2.6558	3.5233	6.1791	
240	3.344	0.001229	0.05976	1033.21	1570.8	2604.0	1037.32	1766.5	2803.8	2.7015	3.4422	6.1437	
245	3.648	0.001240	0.05471	1056.71	1546.7	2603.4	1061.23	1741.7	2803.0	2.7472	3.3612	6.1083	
250	3.973	0.001251	0.05013	1080.39	1522.0	2602.4	1085.36	1716.2	2801.5	2.7927	3.2802	6.0730	
255	4.319	0.001263	0.04598	1104.28	1506.7	2600.9	1109.73	1689.8	2799.5	2.8383	3.1992	6.0375	
260	4.688	0.001276	0.04221	1128.39	1470.6	2599.0	1134.37	1662.5	2796.9	2.8838	3.1181	6.0019	
265	5.081	0.001289	0.03877	1152.74	1443.9	2596.6	1159.28	1634.4	2793.6	2.9294	3.0368	5.9662	
270	5.499	0.001302	0.03564	1177.36	1416.3	2593.7	1184.51	1605.2	2789.7	2.9751	2.9551	5.9301	
275	5.942	0.001317	0.03279	1202.27	1387.9	2590.2	1210.07	1574.9	2785.0	3.0208	2.8730	5.8938	
280	6.412	0.001332	0.03017	1227.46	1358.7	2586.1	1235.99	1543.6	2779.6	3.0668	2.7903	5.8571	
285	6.909	0.001348	0.02777	1253.00	1328.4	2581.4	1262.31	1511.0	2773.3	3.1130	2.7070	5.8199	
290	7.436	0.001366	0.02557	1278.92	1297.1	2576.0	1289.07	1477.1	2766.2	3.1594	2.6227	5.7821	
295	7.993	0.001384	0.02354	1305.2	1264.7	2569.9	1316.3	1441.8	2758.1	3.2062	2.5375	5.7437	
300	8.581	0.001404	0.02167	1332.0	1231.0	2563.0	1344.0	1404.9	2749.0	3.2534	2.4511	5.7045	
305	9.202	0.001425	0.019948	1359.3	1195.9	2555.2	1372.4	1366.4	2738.7	3.3010	2.3633	5.6643	
310	9.856	0.001447	0.018350	1387.1	1159.4	2546.4	1401.3	1326.0	2727.3	3.3493	2.2737	5.6230	

Figure 12.4: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 3

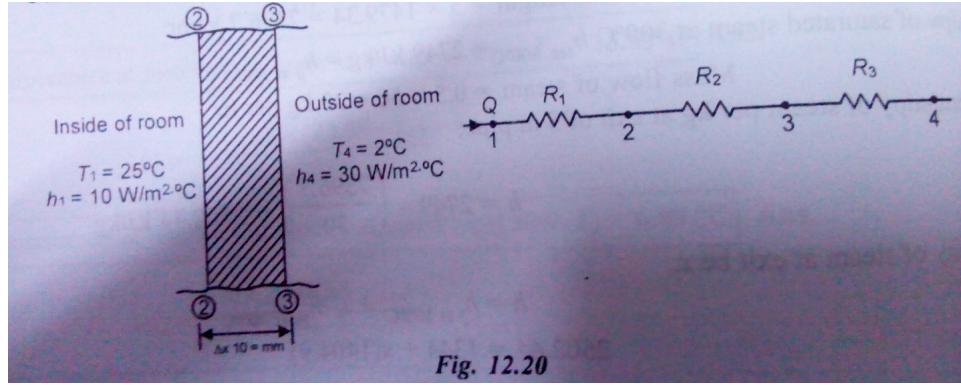


Fig. 12.20

Figure 12.5: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 5

```

7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 12 Example 4")
8 r1=150*10^-2/2; //inner radius in m
9 r2=200*10^-2/2; //outer radius in m
10 k=28; //thermal conductivity in KJ m hr oc
11 T1=200; //inside surface temperature in degree
celcius
12 T2=40; //outer surface temperature in degree celcius
13 disp("considering one dimensional heat transfer of
steady state type")
14 disp("for sphere(Q)=(T1-T2)*4*%pi*k*r1*r2/(r2-r1) in
KJ/hr")
15 Q=(T1-T2)*4*%pi*k*r1*r2/(r2-r1)
16 disp("so heat transfer rate=168892.02 KJ/hr")
17 disp("heat flux=Q/A in KJ/m^2 hr")
18 Q/(4*%pi*r1^2)
19 disp("so heat flux=23893.33 KJ/m^2 hr")

```

---

**Scilab code Exa 12.5** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 5

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 12 Example 5")
8 T1=25; //room temperature in degree celcius
9 T4=2; //winter outside temperature in degree celcius
10 h1=10; //heat transfer coefficient on inner window
surfaces in W/m^2 oc
11 h4=30; //heat transfer coefficient on outer window
surfaces in W/m^2 oc
12 k=0.78; //thermal conductivity of glass in W/m^2 oc
13 A=75*10^-2*100*10^-2; //area in m^2
14 deltax=10*10^-3; //glass thickness in m
15 disp("R1=thermal resistance for convection heat
transfer between inside room (1) and inside
surface of glass window(2)=1/(h1*A)")
16 disp("R2=thermal resistance for conduction through
glass between inside of glass window(2) to outside
surface of glass window(3)=deltax/(k*A)")
17 disp("R3=thermal resistance for convection heat
transfer between outside surface of glass window
(3) to outside atmosphere(4)=1/(h4*A)")
18 disp("total thermal resistance ,R_total=R1+R2+R3 in
oc/W")
19 R_total=1/(h1*A)+deltax/(k*A)+1/(h4*A)
20 disp("so rate of heat transfer ,Q=(T1-T4)/R_total in
W")
21 Q=(T1-T4)/R_total
22 disp("heat transfer rate from inside of room to
inside surface of glass window.")
23 disp("Q=(T1-T2)/R1")
```

```

24 disp(" so T2=T1-Q*R1 in degree celcius")
25 R1=(1/7.5);
26 T2=T1-Q*R1
27 disp("Thus, inside surface of glass window will be at
        temperature of 9.26 oc where as room inside
        temperature is 25 oc")

```

---

**Scilab code Exa 12.6** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 6

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
        Chapter 12 Example 6")
8 D=4*10^-2; //inner diameter in m
9 L=3; //length in m
10 V=1; //velocity of water in m/s
11 T1=40; //mean temperature in degree celcius
12 T2=75; //pipe wall temperature in degree celcius
13 k=0.6; //conductivity of water in W/m
14 Pr=3; //prandtl no.
15 v=0.478*10^-6; //viscosity in m^2/s
16 disp(" reynolds number ,Re=V*D/v")
17 Re=V*D/v
18 disp(" subsituting in Nu=0.023*(Re)^0.8*(Pr)^0.4")
19 disp(" or (h*D/k)=0.023*(Re)^0.8*(Pr)^0.4")
20 disp(" so h=(k/D)*0.023*(Re)^0.8*(Pr)^0.4 in W/m^2 K"
)
21 h=(k/D)*0.023*(Re)^0.8*(Pr)^0.4
22 disp(" rate of heat transfer due to convection ,Q in W
")

```

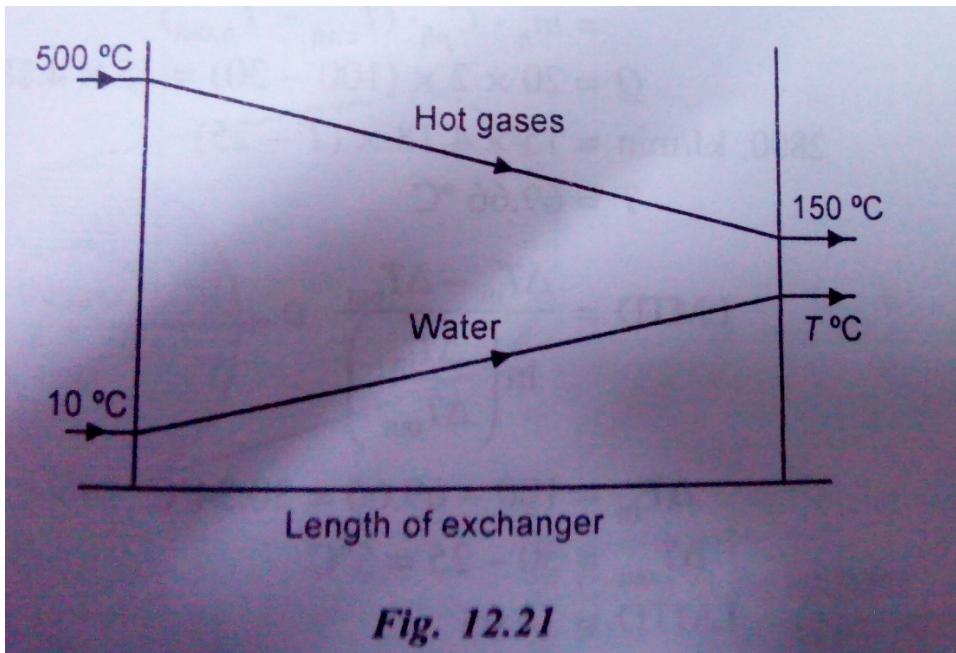


Figure 12.6: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 7

```

23 disp("Q=h*A*(T2-T1)")
24 Q=h*(%pi*D*L)*(T2-T1)
25 disp("so heat transfer rate=61259.38 W")
26 disp("Q in KW")
27 Q=Q/1000

```

---

**Scilab code Exa 12.7** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 7

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 12 Example 7")
8 m=0.5; //hot gases flowing rate in kg/s
9 T1=500; //initial temperature of gas in degree
celcius
10 T2=150; //final temperature of gas in degree celcius
11 Cg=1.2; //specific heat of gas in KJ/kg K
12 Cw=4.18; //specific heat of water in KJ/kg K
13 U=150; //overall heat transfer coefficient in W/m^2 K
14 mw=1; //mass of water in kg/s
15 T3=10; //water entering temperature in degree celcius
16 disp("Let the temperature of water at exit be T")
17 disp("Heat exchanger ,Q=heat rejected by glasses=heat
gained by water")
18 disp("Q=m*Cg*(T1-T2)=mw*Cw*(T-T3)")
19 disp("so T=T3+(m*Cg*(T1-T2) / (mw*Cw)) in degree
celcius")
20 T=T3+(m*Cg*(T1-T2) / (mw*Cw))
21 disp("and Q in KJ")
22 Q=m*Cg*(T1-T2)
23 disp("deltaT_in=T1-T3 in degree celcius")
24 deltaT_in=T1-T3
25 disp("deltaT_out=T2-T in degree celcius")
26 deltaT_out=T2-T
27 disp("for parallel flow heat exchanger ,")
28 disp("LMTD=(deltaT_in-deltaT_out)/log(deltaT_in/
deltaT_out) in degree celcius")
29 LMTD=(deltaT_in-deltaT_out)/log(deltaT_in/deltaT_out
)
30 disp("also ,Q=U*A*LMTD")
31 disp("so A=Q/(U*LMTD) in m^2")
32 A=Q*10^3/(U*LMTD)
33 disp("surface area ,A=5.936 m^2")

```

---

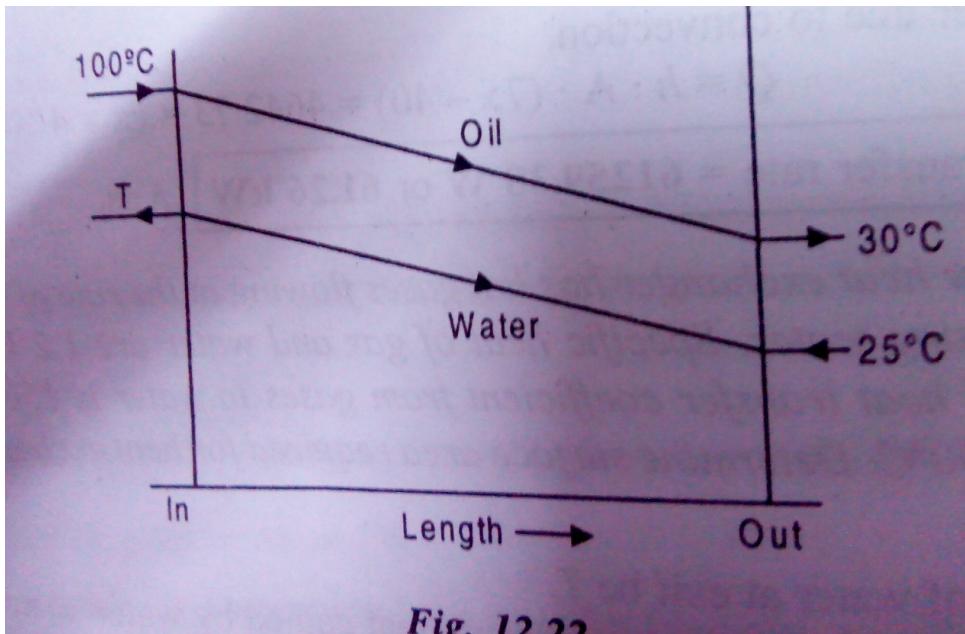


Figure 12.7: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 8

**Scilab code Exa 12.8** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 8

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 12 Example 8")
8 mc=20; //mass of oil in kg/min

```

```

9 Tc_out=100; //initial temperature of oil in degree celcius
10 Th_in=30; //final temperature of oil in degree celcius
11 Th_out=25; //temperature of water in degree celcius
12 Cpc=2; //specific heat of oil in KJ/kg K
13 Cph=4.18; //specific heat of water in KJ/kg K
14 mh=15; //water flow rate in kg/min
15 U=25; //overall heat transfer coefficient in W/m^2 K
16 disp("This oil cooler has arrangement similar to a counter flow heat exchanger .")
17 disp("by heat exchanger ,Q=U*A*LMTD=mc*Cpc*( Tc_out - Th_in )=mh*Cph*( Tc_in - Th_out )")
18 disp("so Q in KJ/min")
19 Q=mc*Cpc*(Tc_out - Th_in)
20 disp("and T=Th_out+(Q/(mh*Cph)) in degree celcius")
21 T=Th_out+(Q/(mh*Cph))
22 disp("LMTD=(deltaT_in-deltaT_out)/log( deltaT_in / deltaT_out ) in degree ")
23 disp("here deltaT_in=Tc_out-T in degree celcius")
24 deltaT_in=Tc_out-T
25 disp("deltaT_out=Th_in- Th_out in degree celcius")
26 deltaT_out=Th_in- Th_out
27 disp("so LMTD in degree celcius")
28 LMTD=(deltaT_in-deltaT_out)/log(deltaT_in/deltaT_out )
29 disp("substituting in ,Q=U*A*LMTD")
30 disp("A=(Q*10^3/60)/(U*LMTD) in m^2")
31 A=(Q*10^3/60)/(U*LMTD)
32 disp("so surface area=132.85 m^2")

```

---

**Scilab code Exa 12.9** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 9

```
1 // Display mode
```

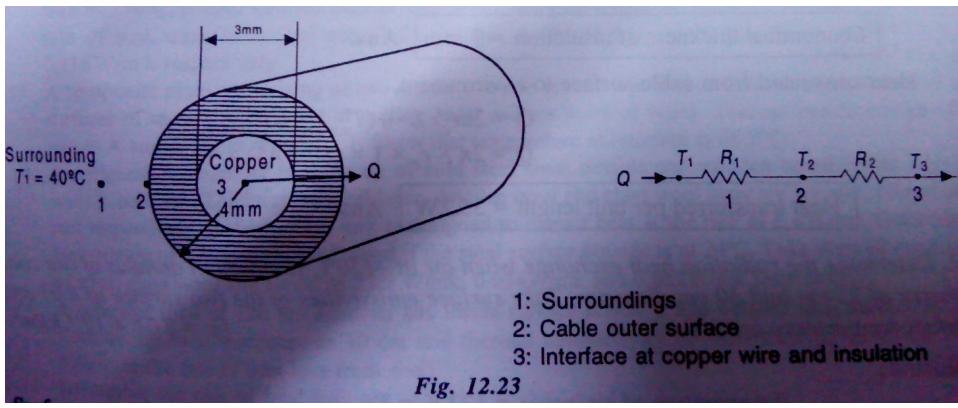


Figure 12.8: Engineering Thermodynamics by Onkar Singh Chapter 12 Example 10

```

2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 12 Example 9")
8 T1=(1200+273); //temperature of body in K
9 T2=(600+273); //temperature of black surrounding in K
10 epsilon=0.4; //emissivity of body at 1200 degree
celcius
11 sigma=5.67*10^-8; //stephen boltzman constant in W/m
^2 K^4
12 disp("rate of heat loss by radiation(Q)=wpsilon*
sigma*A*(T1^4-T2^4)") 
13 disp("heat loss per unit area by radiation(Q) in W")
14 disp("Q=epsilon*sigma*(T1^4-T2^4)")
15 Q=epsilon*sigma*(T1^4-T2^4)
16 disp("Q in KW")
17 Q=Q/1000

```

---

**Scilab code Exa 12.10** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 10

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 12 Example 10")
8 V=16; //voltage drop in V
9 I=5; //current in cable in A
10 r2=8*10^-3/2; //outer cable radius in m
11 r3=3*10^-3/2; //copper wire radius in m
12 k=0.16; //thermal conductivity of copper wire in W/m
    oc
13 L=5; //length of cable in m
14 h1=15; //heat transfer coefficient of cable in W/m^2
    oc
15 T1=40; //temperature of surrounding in degree celcius
16 disp("Let us carry out one dimentional analysis for
steady state.Due to flow of electricity the heat
generated can be given as:")
17 disp("Q=V*I in W")
18 Q=V*I
19 disp("For steady state which means there should be
no change in temperature of cable due to
electricity flow ,the heat generated should be
transferred out to surroundings .Therefore ,heat
transfer across table should be 80 W")
20 disp(" surface area for heat transfer ,A2=2*pi*r*L in
m^2")
21 A2=2*pi*r2*L
```

```

22 A2=0.125; //approx .
23 disp("R1=thermal resistance due to convection
      between surroundings and cable outer surface
      ,(1-2)=1/(h1*A2)") )
24 disp("R2=thermal resistance due to conduction across
      plastic insulation(2-3)=log (r2/r3)/(2*pi*k*L)" )
25 disp("Total resistance ,R_total=R1+R2 in oc/W")
26 R_total=(1/(h1*A2))+(log(r2/r3)/(2*pi*k*L))
27 disp("Q=(T3-T1)/R_total")
28 disp("so T3=T1+Q*R_total in degree celcius")
29 T3=T1+Q*R_total
30 disp("so temperature at interface=125.12 degree
      celcius")
31 disp("critical radius of insulation ,rc=k/h in m")
32 rc=k/h1
33 disp(" rc in mm")
34 rc=rc*1000
35 disp("This rc is more than outer radius of cable so
      the increase in thickness of insulation upon rc
      =110.66 mmwould increase rate of heat transfer .
      Doubling insulation thickness means new outer
      radius would be r1=1.5+5=6.5 mm. Hence doubling(
      increase) of insulation thickness would increase
      heat transfer and thus temperature at interface
      would decrease if other parameters reamins
      constant .")
36 disp("NOTE=>In this question value of R_total is
      calculated wrong in book ,hence it is correctly
      solve above ,so the values of R_total and T3 may
      vary .")

```

---

**Scilab code Exa 12.11** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 11

1 // Display mode

```

2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 12 Example 11")
8 r_wire=3; //radius of electric wire in mm
9 k=0.16; //thermal conductivity in W/m oc
10 T_surrounding=45; //temperature of surrounding in
      degree celcius
11 T_surface=80; //temperature of surface in degree
      celcius
12 h=16; //heat transfer cooefficient in W/m^2 oc
13 disp("for maximum heat transfer the critical radius
      of insulation should be used.")
14 disp("critical radius of insulation (rc)=k/h in mm")
15 rc=k*1000/h
16 disp("economical thickness of insulation (t)=rc-
      r_wire in mm")
17 t=rc-r_wire
18 disp("so economical thickness of insulation=7 mm")
19 disp("heat convected from cable surface to
      environment ,Q in W")
20 disp("Q=2*pi*rc*L*h*( T_surface-T_surrounding )")
21 L=1; //length in mm
22 Q=2*pi*rc*L*h*(T_surface-T_surrounding)*10^-3
23 disp("so heat transferred per unit length=35.2 W")

```

---

**Scilab code Exa 12.12** Engineering Thermodynamics by Onkar Singh Chapter 12 Example 12

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception

```

```

4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 12 Example 12")
8 T1=(-150+273); //temperature of air inside in K
9 T2=(35+273); //temperature of outer surface in K
10 epsilon1=0.03; //emissivity
11 epsilon2=epsilon1;
12 D1=25*10^-2; //diameter of inner sphere in m
13 D2=30*10^-2; //diameter of outer sphere in m
14 sigma=2.04*10^-4; //stephen boltzmann constant in KJ/
m^2 hr K^4
15 disp("heat transfer through concentric sphere ,Q in
KJ/hr ")
16 disp("Q=(A1*sigma*(T1^4-T2^4))/((1/ epsilon1)+((A1/A2
)*(1/ epsilon2)-1)))")
17 A1=4*pi*D1^2/4;
18 A2=4*pi*D2^2/4;
19 Q=(A1*sigma*(T1^4-T2^4))/((1/ epsilon1)+((A1/A2)*(1/
epsilon2)-1)))
20 disp("so heat exchange=6297.1 KJ/hr")

```

---

# Chapter 13

## One Dimensional Compressible Fluid Flow

**Scilab code Exa 13.1** Engineering Thermodynamics by Onkar Singh Chapter 13 Example 1

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 13 Example 1")
8 To=(27+273); //stagnation temperature in K
9 P=0.4*10^5; //static pressure in pa
10 m=3000/3600; //air flowing rate in kg/s
11 d=80*10^-3; //diameter of duct in m
12 R=287; //gas constant in J/kg K
13 y=1.4; //expansion constant
14 disp("mass flow rate (m)=rho*A*C")
15 disp("so rho*C=4*m/(%pi*d^2)")
16 4*m/(%pi*d^2)
17 disp("so rho=165.79/C")
```

```

18 disp("now using perfect gas equation , p=rho*R*T")
19 disp("T=P/(rho*R)=P/((165.79/C)*R)")
20 disp("C/T=165.79*R/P")
21 165.79*R/P
22 disp(" so C=1.19*T")
23 disp("we know , C^2=((2*y*R)/(y-1))*(To-T)")
24 disp("C^2=(2*1.4*287)*(300-T)/(1.4-1)")
25 disp("C^2=602.7*10^3-2009*T")
26 disp("C^2+1688.23*C-602.7*10^3=0")
27 disp(" solving we get ,C=302.72 m/s and T=254.39 K")
28 C=302.72;
29 T=254.39;
30 disp(" using stagnation property relation ,")
31 disp("To/T=1+(y-1)*M^2/2")
32 disp(" so M=sqrt(((To/T)-1)/((y-1)/2))")
33 M=sqrt(((To/T)-1)/((y-1)/2))
34 M=0.947; //approx.
35 disp("stagnation pressure ,Po=P*(1+(y-1)*M^2/2) in bar")
36 Po=P*(1+(y-1)*M^2/2)/10^5
37 disp("so mach number=0.947, stagnation pressure=0.472 bar , velocity =302.72 m/s")

```

---

**Scilab code Exa 13.2** Engineering Thermodynamics by Onkar Singh Chapter 13 Example 2

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh")

```

Table 14 Air table for isentropic flow of air, ( $\gamma = 1.4$ )

55

$M$	$\lambda$	$\frac{T}{T_0}$	$\frac{P}{P_0}$	$\frac{A}{A'}$	$\frac{l}{l'}$	$\frac{A}{A'} \frac{P}{P_0}$	$\frac{m\sqrt{C_p T_0}}{A P_0}$
1.20	1.158	0.776	0.412	1.030	1.010	0.425	1.243
1.22	1.173	0.771	0.402	1.037	1.013	0.416	1.236
1.24	1.188	0.765	0.391	1.043	1.015	0.408	1.228
1.26	1.203	0.759	0.381	1.050	1.017	0.400	1.220
1.28	1.217	0.753	0.371	1.058	1.019	0.392	1.211
1.30	1.231	0.747	0.361	1.066	1.022	0.385	1.201
1.32	1.245	0.742	0.351	1.075	1.024	0.378	1.192
1.34	1.259	0.736	0.342	1.084	1.027	0.37	1.181
1.36	1.273	0.730	0.332	1.094	1.029	0.364	1.171
1.38	1.286	0.724	0.323	1.104	1.032	0.357	1.160
1.40	1.300	0.718	0.314	1.115	1.035	0.350	1.149
1.42	1.313	0.713	0.305	1.126	1.037	0.344	1.138
1.44	1.326	0.706	0.297	1.138	1.040	0.338	1.126
1.46	1.330	0.701	0.288	1.150	1.043	0.332	1.114
1.48	1.352	0.695	0.280	1.163	1.046	0.326	1.102
1.50	1.365	0.689	0.272	1.176	1.048	0.320	1.089
1.52	1.377	0.684	0.265	1.189	1.052	0.315	1.077
1.54	1.389	0.678	0.257	1.204	1.055	0.309	1.064
1.56	1.402	0.673	0.249	1.219	1.057	0.304	1.051
1.58	1.414	0.667	0.242	1.234	1.061	0.300	1.038
1.60	1.425	0.661	0.235	1.250	1.063	0.294	1.025
1.62	1.437	0.656	0.228	1.267	1.067	0.289	1.011
1.64	1.448	0.650	0.222	1.284	1.069	0.285	0.998
1.66	1.460	0.645	0.215	1.301	1.073	0.280	0.985
1.68	1.471	0.639	0.208	1.319	1.076	0.275	0.971
1.70	1.483	0.634	0.203	1.337	1.078	0.271	0.958
1.72	1.494	0.628	0.196	1.357	1.082	0.267	0.944
1.74	1.504	0.623	0.191	1.376	1.085	0.262	0.931
1.76	1.515	0.617	0.185	1.397	1.087	0.258	0.917
1.78	1.526	0.612	0.179	1.418	1.091	0.254	0.904

Contd

Figure 13.1: Engineering Thermodynamics by Onkar Singh Chapter 13 Example 2

```

Chapter 13 Example 2")
8 To=(273+1100); //stagnation temperature in K
9 a=45; //mach angle over exit cross-section in degree
10 Po=1.01; //pressure at upstream side of nozzle in bar
11 P=0.25; //ststic pressure in bar
12 y=1.4; //expansion constant
13 R=287; //gas constant in J/kg K
14 disp(" mach number ,M_a=(1/sin(a))=sqrt(2)")
15 M_a=sqrt(2)
16 M_a=1.414; //approx .
17 disp(" here ,P/Po=0.25/1.01=0.2475. Corresponding to
      this P/Po ratio the mach number and T/To can be
      seen from air table as M=1.564 and T/To=0.6717")
18 M=1.564;
19 disp("T=To*0.6717 in K")
20 T=To*0.6717
21 disp("and C_max=M*sqrt(y*R*T) in m/s")
22 C_max=M*sqrt(y*R*T)
23 disp("corresponding to mach number(M_a=1.414) as
      obtained from experimental observation ,the T/To
      can be seen from air table and it comes out as (T
      /To)=0.7145")
24 disp(" so T=0.7145*To in K")
25 T=0.7145*To
26 disp("and C_av=M_a*sqrt(y*R*T) in m/s")
27 C_av=M_a*sqrt(y*R*T)
28 disp(" ratio of kinetic energy=((1/2)*C_av^2)/((1/2)*
      C_max^2)")
29 ((1/2)*C_av^2)/((1/2)*C_max^2)
30 disp("so ratio of kinetic energy=0.869")

```

---

**Scilab code Exa 13.3** Engineering Thermodynamics by Onkar Singh Chapter 13 Example 3

```
1 // Display mode
```

```

2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
Chapter 13 Example 3")
8 C=300; //aircraft flying speed in m/s
9 P=0.472*10^5; //altitude pressure in Pa
10 rho=0.659; //density in kg/m^3
11 y=1.4; //expansion constant
12 R=287; //gas constant in J/kg K
13 disp("From bernoulli equation ,Po-P=(1/2)*rho*C^2")
14 disp(" so Po=P+(1/2)*rho*C^2 in N/m^2")
15 Po=P+(1/2)*rho*C^2
16 disp(" speed indicator reading shall be given by mach
no.s")
17 disp("mach no .,M=C/sqrt(y*R*T") )
18 disp(" using perfect gas equation ,P=rho*R*T")
19 disp(" so T=P/(rho*R) in K")
20 T=P/(rho*R)
21 disp("so mach no .,M")
22 M=C/sqrt(y*R*T)
23 M=0.947; //approx .
24 disp(" considering compressibility effect ,Po/P=(1+(y
-1)*M^2/2)^(y/(y-1))")
25 disp(" so stagnation pressure ,Po=P*((1+(y-1)*M^2/2)^(y
/(y-1))) in N/m^2")
26 Po=P*((1+(y-1)*M^2/2)^(y/(y-1)))
27 disp(" also Po-P=(1+k)*(1/2)*rho*C^2")
28 disp(" substitution yields ,k=")
29 k=((Po-P)/((1/2)*rho*C^2))-1
30 disp(" so compressibility correction factor ,k=0.2437"
)

```

---

**Scilab code Exa 13.4** Engineering Thermodynamics by Onkar Singh Chapter 13 Example 4

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 13 Example 4")
8 Po=2; //total pressure in bar
9 P=0.3; //static pressure in bar
10 y=1.4; //expansion constant
11 disp("we know that ,Po/P=(1+(y-1)*M^2/2)^((y)/(y-1))")
12 disp(" so M=sqrt (( exp ( log (Po/P) /(y/(y-1))) -1)/((y-1)
      /2))")
13 M=sqrt((exp(log(Po/P)/(y/(y-1)))-1)/((y-1)/2))
14 disp(" so mach number ,M=1.89")
```

---

**Scilab code Exa 13.5** Engineering Thermodynamics by Onkar Singh Chapter 13 Example 5

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Engineering Thermodynamics by Onkar Singh
      Chapter 13 Example 5")
8 To=305; //stagnation temperature of air stream in K
9 y=1.4; //expansion constant
10 R=287; //gas constant in J/kg K
```

```

11 disp(" actual static pressure (P)=1+0.3 in bar")
12 P=1+0.3
13 disp(" It is also given that ,Po-P=0.6 ,")
14 disp(" so Po=P+0.6 in bar")
15 Po=P+0.6
16 disp(" air velocity ,ao=sqrt(y*R*To) in m/s")
17 ao=sqrt(y*R*To)
18 disp(" density of air ,rho_o=Po/(R*To) in ")
19 rho_o=Po*10^5/(R*To)
20 disp(" considering air to be in-compressible ,")
21 disp(" Po=P+rho_o*C^2/2")
22 disp(" so C=sqrt((Po-P)*2/rho_o) in m/s")
23 C=sqrt((Po-P)*10^5*2/rho_o)
24 disp(" for compressible fluid ,Po/P=(1+(y-1)*M^2/2)^(y
   /(y-1))")
25 disp(" so M=sqrt((exp(log(Po/P)/(y/(y-1)))-1)/((y-1)
   /2))")
26 M=sqrt(exp(log(Po/P)/(y/(y-1)))-1)/((y-1)/2))
27 M=0.7567; //approx.
28 disp(" compressibility correction factor ,k")
29 disp(" k=(M^2/4)+((2-y)/24)*M^4")
30 k=(M^2/4)+((2-y)/24)*M^4
31 disp(" stagnation temperature ,To/T=1+((y-1)/2)*M^2")
32 disp(" so T=To/(1+((y-1)/2)*M^2) in K")
33 T=To/(1+((y-1)/2)*M^2)
34 disp(" density ,rho=P/(R*T) in kg/m^3")
35 rho=P*10^5/(R*T)
36 disp(" substituting Po-P=(1/2)*rho*C^2(1+k)")
37 disp(" C=sqrt((Po-P)/((1/2)*rho*(1+k))) in m/s")
38 C=sqrt((Po-P)*10^5/((1/2)*rho*(1+k)))
39 disp(" so C=250.95 m/s")

```

---