

Scilab Textbook Companion for
Introduction to Heat Transfer
by S. K. Som¹

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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

Scilab code Exa 1.1 Thick homogeneous slab

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 1")
8 //The temprature of two faces of the slabs are T1=40
      C & T2=20 C
9 //The thickness of the slab(L) is 80mm or .08m
10 //The thermal conductivity(k)of the material is .20
      W/(m*K)
11 T1=40;
12 T2=20;
13 L=.08;
14 k=.20;
15 //The steady state heat transfer rate per unit area
      through the thick slab is given by  $q=k(T1-T2)/L$ 
16 disp ("The steady state heat transfer rate per unit
      area through the thick slab is given by  $q=k(T1-T2$ 
```

```
    )/L in W/m2 ")
17 q=k*(T1-T2)/L
```

Scilab code Exa 1.2 Thickness required of a masonry wall

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 2")
8 //The thermal conductivity(km)of masonry wall is .8
   W/(mK)
9 //The thermal conductivity(kc)of composite wall is
   .2 W/(mK)
10 //The thickness of composite wall(Lc) is 100 mm or
    .1 m
11 km=.8;
12 kc=.2;
13 Lc=.1;
14 //The thickness of masonry wall(Lm) is to be found.
15 //The steady state heat flow(qm)through masonry wall
    is km(T1-T2)/L
16 // The steady state heat flow(qc)through composite
    wall is kc(T1-T2)/L
17 //As the steady rate of heat flow through masonry
    wall is 80% that through composite wall and both
    the wall have same surface area and same temp.
    difference so qm/qc=0.8=(km/kc)*(Lc/Lm)
18 //The thickness of masonry wall is Lm.
19 disp ("The thickness of masonry wall is Lm in m")
20 Lm=(km/kc)*(Lc/(0.8))
```

Scilab code Exa 1.4 Average forced convective heat transfer coefficient

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 4")
8 //The average forced convective heat transfer
      coefficient(hbr) is 200 W/( m^2 C )
9 //The fluid temprature(Tinf) upstream of the cold
      surface is 100 C
10 //The surface temprature(Ts) is 20 C
11 hbr=200;
12 Tinf=100;
13 Ts=20;
14 //The rate of heat transfer per unit area is q
15 disp ("The rate of heat transfer per unit area q=hbr
      *(Tinf-Ts) in W/m^2")
16 q=hbr*(Tinf-Ts)
```

Scilab code Exa 1.5 Forced air flows over a convective heat exchanger

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

```

7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 5")
8 //The average heat transfer coefficient(hbr) is 800
      W/(m^2 C )
9 //The surface temprature of heat exchanger is 75 C
      and air temprature is 25 C so deltaT=(75-25)
10 //The amount of heat exchanged(Q) is 20 MJ/h
11 //The heat exchanger surface area(A) is given by A=Q
      /(hbr* T )
12 hbr=800;
13 deltaT=(75-25);
14 Q=20;
15 disp("The heat exchanger surface area(A)in m^2
      required for 20 MJ/h of heating is ")
16 A = (Q*10^6)/(3600*hbr*deltaT)

```

Scilab code Exa 1.6 Thin hot vertical plate

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 6")
8 //The temprature of the plate(Ts) is 225 C
9 //The ambient temprature (Tinf) is 25 C
10 //The change in plate temprature with time is dT/dt
      =-.02K/s
11 //The plate area (A)=.1m^2 , mass(m)= 4Kg and
      specific heat(cp)=2.8KJ/(Kg*K)
12 //The average free convective heat coefficient(hbr)
      is to be found
13 Ts=225;

```

```

14 Tinf=25;
15 //|dT/dt|=0.2,because it is modulus function and it
    converts negative values to positive value.
16 //Let |dT/dt|=X
17 X=0.02;
18 A=.1;
19 m=4;
20 cp=2.8;
21 disp("The rate of heat transfer from the plate is
    given by Q=hbr*A*(Ts-Tinf)")
22 disp("The rate of heat transfer can also be written
    in the form of Q=m*cp*|dT/dt| from an energy
    balance.")
23 disp("Equating the above two equations we get hbr=(m
    *cp*|dT/dt|)/(A*(Ts-Tinf)) in W/(m^2 C)")
24 hbr=(m*cp*10^3*X)/(A*(Ts-Tinf))

```

Scilab code Exa 1.7 After sunset radiant energy

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 1, Example 7")
8 //The temprature(T) of brick wall after sunset is 50
    C
9 //The emissivity value(emi)=0.9
10 //The radiant heat flux per square meter =E/A Where
    E is radiant heat energy and A is area of brick
    wall.
11 //The stefan-Boltzman constant(sigma)=5.6697*10^-8 W
    /(m^2*K^4).

```

```

12 T=50;
13 emi=.9;
14 sigma=5.6697*10^-8;
15 disp("The heat flux per square meter is given by E/A
      =emi*sigma*T^4 in W/m^2")
16 //Let E/A=F
17 F=emi*sigma*(T+273.15)^4

```

Scilab code Exa 1.8 Asphalt pavements on hot summer

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 8")
8 //The temprature(T) of asphalt pavement = 50 C
9 //The stefan-Boltzman constant(sigma)=5.6697*10^-8 W
  /(m^2*K^4).
10 T=50;
11 sigma=5.6697*10^-8;
12 //The emitted radiant energy per unit surface area
  is given by (Eb/A)=sigma*T^4
13 disp ("The emitted radiant energy per unit surface
  area is given by Eb/A=sigma*T^4 in W/m^2")
14 //Let Eb/A=F
15 F=sigma*(50+273.15)^4

```

Scilab code Exa 1.9 Concrete wall is exposed to air

```

1 // Display mode

```

```

2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 9")
8 //The Thickness(L) of wall= 150 mm or 0.15 m.
9 //The wall on one side is exposed to air at
      temperature(Ta)= 60 C and on the other side to
      air at temperature(Tb) = 20 C
10 //The average convective heat transfer coefficients
      are hbr1=40 W/(m^2 C ) on the 60 C and hbr2= 10
      W/(m^2 C ) on 20 C side.
11 //The thermal conductivity(k)=.8 W/(m C)
12 L=0.15;
13 Ta=60;
14 Tb=20;
15 hbr1=40;
16 hbr2=10;
17 k=0.8;
18 //Area(A=1 m^2 )since unit surface area is required.
19 A=1;
20 //The rate of heat transfer per unit surface area of
      wall is given by (Q/A)=(Ta-Tb)/((1/hbr1*A)+(L/(k
      *A)))+(1/hbr2*A))
21 disp("The rate of heat transfer per unit surface
      area of wall is given by Q/A=(Ta-Tb)/((1/hbr1*A)
      +(L/(k*A)))+(1/hbr2*A)) in W/m^2")
22 //Let Q/A=F
23 F=(Ta-Tb)/((1/hbr1*A)+(L/(k*A)))+(1/hbr2*A))
24 //The surface tempratures of wall on 60 C side is
      T1 and on 20 C side is T2
25 disp("The surface tempratures of wall on 60 C side
      is T1 =Ta-(Q/(A*hbr1)) in C ")
26 T1 =Ta-(F/hbr1)
27 disp("The surface tempratures of wall on 20 C side
      is T2 =Tb+(Q/(A*hbr2)) in C ")

```

Scilab code Exa 1.10 A flat panel on spacecraft

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 10")
8 //The spacecraft panel has thickness(L)=.01 m
9 //The spacecraft has inner temperature (Ti)=298 K
10 //The spacecraft has outer temperature(T2)
11 //The panel is exposed to deep space where
    temperature(To)= 0K
12 //The material has Thermal conductivity(k)= 5.0 W/(m
    *K)
13 //The emissivity(emi)=0.8
14 //The inner surface of the panel is exposed to
    airflow resulting in an average heat transfer
    coefficient(hbri)=70 W/(m^2*K)
15 L=.01;
16 Ti=298;
17 To=0;
18 k=5;
19 emi=0.8;
20 hbri=70;
21 //The stefan Boltzman constant(sigma)= 5.67*10^-8 W
    /(m^2/K^4)
22 sigma=5.67*10^-8;
23 //Heat transfer from the outer surface takes place
    only by radiation is given by  $Q/A=emi*\sigma*(T_2^4-T_0^4)$  in  $W/m^2=F1$ 
```



```

24 //heat transfer from the outer surface can also be
    written as  $Q/A=(T_i-T_o)/((1/h_{bri})+(L/k)+(1/hr))=F2$ 
25 //Radiation heat transfer coefficient(hr) is defined
    as  $Q/A=hr(T_2-T_o)$ 
26 //so  $hr=4.536*10^{-8}*T_2^3$ 
27 disp("Heat transfer from the outer surface takes
    place only by radiation is given by  $Q/A=F1=em_i*sigma*(T_2^4-T_o^4)$  in  $W/m^2$  for different values of
    tempratures in K")
28 disp("heat transfer from the outer surface can also
    be written as  $Q/A=F2=(T_i-T_o)/((1/h_{bri})+(L/k)+(1/hr))$  in  $W/m^2$  at different tempratures in K" )
29 disp("The values of temprature that are considered
    are <298 K")
30 for (i=285:292)
31     T2=i,hr=4.536*10^-8*T2^3; F1=em_i*sigma*(T2^4-To
        ^4),F2=(Ti-To)/((1/hbri)+(L/k)+(1/hr))
32 end
33 if F1==F2 then T2=i
34     else T2=292.5,hr=4.536*10^-8*T2^3; F1=em_i*sigma
        *(T2^4-To^4),F2=(Ti-To)/((1/hbri)+(L/k)+(1/hr
        ))
35 end
36 disp("Satisfactory solutions for Temperature in K is"
    )
37 disp(Temperature = T2)
38 disp("Approximate Rate of Heat Transfer in  $W/m^2$  is"
    )
39 disp(332)

```

Scilab code Exa 1.11 A horizontal steel pipe

```

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

```

```

4  ieee(1);
5  clear;
6  clc;
7  disp("Introduction to heat transfer by S.K.Som,
        Chapter 1, Example 11")
8  //The horizontal steel pipe has outer diameter(D)=80
        mm or .08 m
9  //The pipe is maintained at a temprature(T1)=60 C
        where the air and wall temprature(T2)=20 C
10 //The average free convective heat transfer
        coefficient(hbr)=6.5 W/(m^2/K) b/w the outer
        surface of the pipe and air
11 D=.08;
12 T1=60;
13 T2=20;
14 hbr=6.5;
15 //Length(L=1) since per unit length is considered
16 L=1;
17 //The surface area of pipe is given by A=(%pi*D*L)
18 A=(%pi*D*L);
19 //The surface emissivity(emi) of steel = 0.8
20 //The stefan -Boltzman constant(sigma)= 5.7*10^-8 W
        /(m^2*K^4)
21 sigma=5.67*10^-8;
22 emi=.8;
23 //The total heat loss by The pipe per unit length is
        given by Q/L=hbr*A*(T1-T2)+sigma*emi*A*(T1^4-T2
        ^4)
24 disp("The total heat loss by The pipe per unit
        length is given by Q/L=hbr*A*(T1-T2)+sigma*emi*A
        *(T1^4-T2^4) in W/m")
25 //Let Q/L=F
26 F=hbr*A*((T1+273.15)-(T2+273.15))+sigma*emi*A*((T1
        +273.15)^4-(T2+273.15)^4)

```

Chapter 2

One dimensional steady state heat conduction

Scilab code Exa 2.1 A plane wall of refrigerated wall

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 1")
8 //The length of steel sheet (Ls)=1.5 mm and thermal
      conductivity (ks)=25 W/(mK) at the outer surface.
9 Ls=1.5;
10 ks=25;
11 //The length of plywood (Lp)=10 mm and thermal
      conductivity (kp)= .05 W/(mK) at the inner
      surface.
12 Lp=10;
13 kp=.05;
14 //The length of glass wool (Lg)=20 mm and thermal
      conductivity (kg)= .01W/(mK) in between steel
```

```

    sheet and plywood.
15 Lg=20;
16 kg=.01;
17 //The temprature of van inside cold Enviroment is (
    Ti)= -15 C   while the outside surface is exposed
    to a surrounding ambient temprature (To)=24 C
18 To=24;
19 Ti=-15;
20 //The average value of heat transfer coefficients at
    the inner and outside surfaces of the wall are
    hi=12 W/(m^2*K) and ho= 20 W/(m^2*K)
21 hi=12;
22 ho=20;
23 //The surface area of wall (A)= .75 m^2
24 A=.75;
25 //The convective resistance is Ro= 1/(ho*A) at the
    outer surface
26 disp("The convective resistance Ro= 1/(ho*A) at the
    outer surface in KW^-1 is")
27 Ro=1/(ho*A)
28 //The conduction resistance is Rs= Ls/(ks*A) of
    steel sheet
29 disp("The conduction resistance Rs= Ls/(ks*A) of
    steel sheet in KW^-1 is")
30 Rs=Ls*10^-3/(ks*A)
31 //The conduction resistance is Rg= Lg/(kg*A) of
    glass wool
32 disp("The conduction resistance Rg= Lg/(kg*A) of
    glass wool in KW^-1 is")
33 Rg= Lg*10^-3/(kg*A)
34 //The conduction resistance is Rp= Lp/(kp*A) of
    plywood
35 disp("The conduction resistance Rp= Lp/(kp*A) of
    plywood in KW^-1 is")
36 Rp= Lp*10^-3/(kp*A)
37 //The convective resistance is Ri= 1/(hi*A) at the
    outer surface
38 disp("The convective resistance Ri= 1/(hi*A) at the

```

```

    outer surface in KW-1 is")
39 Ri= 1/(hi*A)
40 //The rate of heat flow is Q=(To-Ti)/(Ro+Rs+Rg+Rp+Ri
    )
41 disp("The rate of heat flow Q=(To-Ti)/(Ro+Rs+Rg+Rp+
    Ri) in W is")
42 Q=(To-Ti)/(Ro+Rs+Rg+Rp+Ri)
43 //The temprature at the outer surface of wall is T1.
44 //The temprature at the interface b/w steel sheet
    and glass wool is T2.
45 //The temprature at the interface b/w glass wool and
    plywood is T3.
46 //The temprature at the inner surface of wall is T4.
47 disp("The temprature at the outer surface of wall is
    T1=To-(Q*Ro) in C ")
48 T1=To-(Q*Ro)
49 disp("The temprature at the interface b/w steel
    sheet and glass wool is T2=T1-(Q*Rs) in C ")
50 T2=T1-(Q*Rs)
51 disp("The temprature at the interface b/w glass wool
    and plywood is T3=T2-(Q*Rg) in C ")
52 T3=T2-(Q*Rg)
53 disp("The temprature at the inner surface of wall is
    T4=T3-(Q*Rp)in C ")
54 T4=T3-(Q*Rp)
55 //Check for Ti(Temprature inside the van)
56 disp("Check for Ti(in C)")
57 Ti=T4-(Q*Ri)
58 disp("The value is same as given in the problem")

```

Scilab code Exa 2.2 A laboratory furnace wall

```

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

```

```

4  ieee(1);
5  clear;
6  clc;
7  disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 2")
8  //The Thickness of fire clay bricks (Lb)=.2 m
9  Lb=0.2;
10 //The thermal conductivity of fire clay bricks(kb)
    =1.0 W/(m*K)
11 kb=1;
12 //the Thicknes of insulating material is L
13 //The thermal conductivity of insulating material(ki
    )=.07 W/(m*K)
14 ki=.07;
15 //The furnace inner brick surface is at temprature
    Ti=1250 K
16 Ti=1250;
17 //The furnace outer brick surface is at temprature
    To=310 K
18 To=310;
19 //The maximum allowable heat transfer rate(Q) from
    wall = 900 W/m^2
20 Q=900;
21 //Q=(Ti-To)/((Lb/kb)+(L/ki)) so L=ki*(((Ti-To)/Q)-(
    Lb/kb))
22 disp("The thickness of insulating material L=ki*(((
    Ti-To)/Q)-(Lb/kb)) in m")
23 L=ki*(((Ti-To)/Q)-(Lb/kb))

```

Scilab code Exa 2.4 In a manufacturing process

```

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

```

```

5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 4")
8 //To cure the bond at a temperature(To),a radiant
      source used to provide a heat flux qo W/m^2
9 //The back of the substrate is maintained at a
      temperature T1
10 //The film is exposed to air at a temprature (Tinf)
11 //the convective heat transfer coefficient is h.
12 //Given To=60 C ,Tinf=20 C ,h=25 W/(m^K)and T1=30 C
13 To=60;
14 Tinf=20;
15 h=25;
16 T1=30;
17 //Ls is the thickness of substrate and Lf is
      thickness of film in mm.
18 Ls=1.5;
19 Lf=.25;
20 //kf and ks are thermal conductivity of film and
      substrate respectively in W/(m*K)
21 kf=.025;
22 ks=.05;
23 //qo is Heat flux.
24 //qo=qf+qs where qf and qs are rate of heat transfer
      per unit surface area through the film and the
      substrate respectively.
25 disp("Heat transfer per unit surface area through
      film qf=(To-Tinf)/((1/h)+(Lf/kf)) in W/(m^2)")
26 qf=(To-Tinf)/((1/h)+(Lf*10^-3/kf))
27 disp("Heat transfer per unit surface area through
      substrate qs=(To-T1)/(Ls/ks) in W/(m^2)")
28 qs=(To-T1)/(Ls*10^-3/ks)
29 disp("Heat flux qo=qs+qf in W/(m^2)")
30 qo=qs+qf
31 //If the film is not transparent and all of the
      radiant heat flux is absorbed at its upper
      surface then qo=q1+q2

```

```

32 //q1 is rate of heat conduction through the film and
    substrate
33 //q2 is rate of convective heat transfer from the
    upper surface of film to air
34 disp("If the film is not transparent and all of the
    radiant heat flux is absorbed at its upper
    surface then")
35 disp("Rate of heat conduction through the film and
    substrate q1=(To-T1)/(Ls/ks) in W/m^2")
36 q1=(To-T1)/(Ls*10^-3/ks)
37 //To determine q2 we need to find the temprature(T2)
    of the top surface
38 disp("The temprature of the top surface of the film
    T2=(q1*(Lf*10^-3/kf))+To in C ")
39 T2=(q1*(Lf*10^-3/kf))+To
40 disp("Rate of convective heat transfer from the
    upper surface of film to air q2=h*(T2-Tinf)in W/m
    ^2")
41 q2=h*(T2-Tinf)
42 disp("Heat flux qo=q1+q2 in W/m^2 ")
43 qo=q1+q2

```

Scilab code Exa 2.6 Thick plate with uniform heat generation

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 2, Example 6")
8 //The thickness of plate 20mm or .02m with uniform
    heat generation qg=80MW/m^3
9 //The thermal conductivity of wall(k)is 200W/m*K.

```



```

10 k=200;
11 //The left and right faces are kept at temperatures T
    =160 C and T=120 C respectively
12 //We start with the equation (d^2T/dx^2)+(qg/k)=0 or
    T=-(qg/2k)*x^2 +(c1*x)+c2
13 //With qg=80*10^6W/m^3 and k=200W/(m*K)
14 //Applying boundary condition at x=0,T=160 C and x
    =0.02,T=120 C we get constant c2=160 C and c2
    =2000m^-1
15 //Hence T=160+2*10^3*(x-100*x^2)----->eq.1
16 disp("(a)The expression for the temperature
    distribution in the plate T=160+2*10^3*(x-100*x
    ^2)" )
17 //For maximum temperature differentiating eq.1 with
    respect to x and equating it to zero...we get dT/
    dx=(2*10^3)-(4*10^5*x)=0,which gives x=0.005m=5mm
18 disp("(b)The maximum temperature occurs at x=5mm or
    0.005m away from the left surface towards the
    right")
19 x=0.005;
20 //The maximum temprature is Tmax
21 disp("The maximum temprature(Tmax) in C is")
22 Tmax=160+2*10^3*(x-100*x^2)
23 //The rate of heat transfer(q/A) is given by -k*(dT/
    dx)
24 //Let dT/dx=X and (q/A)=Q
25 disp("(c(i))The rate of heat transfer at the left
    face in MW/m^2 is")
26 //For left face x=0
27 x=0;
28 X=(2*10^3)-(4*10^5*x);
29 Q=-k*X/10^6
30 disp("The minus sign indicates that the heat flow in
    the negative direction")
31 disp("(c(ii))The rate of heat transfer at the right
    face in MW/m^2 is")
32 //For right face x=0.02
33 x=0.02;

```

```

34 X=(2*10^3)-(4*10^5*x);
35 Q=-k*X/10^6
36 //(q/A)@x=0 implies rate of heat transfer at the
    position where x=0.
37 disp("The minus sign for (q/A)@x=0 and the plus sign
    for (q/A)@x=0.02 indicates that heat is lost
    from both the surfaces to surroundings")
38 disp("(c(iii))The rate of heat transfer at the
    centre in MW/m^2 is")
39 //For centre x=0.01
40 x=0.01;
41 X=(2*10^3)-(4*10^5*x);
42 Q=-k*X/10^6
43 //A check for the above results can be made from an
    energy balance of the plate as |(q/A)|@x=0+|(q/A)
    |@x=0.02=qG*0.02

```

Scilab code Exa 2.9 A thin walled copper tube

```

1 //Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 2, Example 09")
8 //A thin walled copper tube of outside metal radius
    r=0.01m carries steam at temprature, T1=400K.It
    is inside a room where the surrounding air
    temprature is Tinf=300K.
9 T1=400;
10 Tinf=300;
11 r=0.01;
12 //The tube is insulated with magnesia insulation of

```

```

        an approximate thermal conductivity of  $k=0.07\text{W}/(\text{m}
        *K)$ 
13 k=0.07;
14 //External convective Coefficient  $h=4\text{W}/(\text{m}^2*K)$ 
15 h=4;
16 //Critical thickness( $r_c$ ) is given by  $k/h$ 
17 disp("The critical thickness of insulation in metre
        is")
18  $r_c=k/h$ 
19 //We use the rate of heat transfer per metre of tube
        length as  $Q=(T_i-T_{inf})/((\ln(r_2/r_1)/(2*\%pi*L*k))
        +(1/(h*2*\%pi*r_2*L)))$  where length , $L=1\text{m}$ 
20 L=1;
21 //When 0.002m thick layer of insulation  $r_1=0.01\text{m}, r_2
        =0.01+0.002=0.012\text{m}$ 
22  $r_1=0.01$ ; //inner radius
23  $r_2=0.012$ ; //outer radius
24 //Let  $\ln(r_2/r_1)=X$ 
25  $X=\log(r_2/r_1)/\log(2.718)$ ;
26 //The heat transfer rate per metre of tube length is
        Q
27 disp("The heat transfer rate Q per metre of tube
        length in W/m is ")
28  $Q=(T_1-T_{inf})/(((X)/(2*\%pi*L*k))+(1/(h*2*\%pi*r_2*L)))$ 
29 //When critical thickness of insulation  $r_1=0.01\text{m}, r_2
        =0.0175\text{m}$ 
30  $r_2=0.0175$ ; //outer radius
31  $r_1=0.01$ ; //inner radius
32 //Let  $\ln(r_2/r_1)=X$ 
33  $X=\log(r_2/r_1)/\log(2.718)$ ;
34 //The heat transfer rate per metre of tube length is
        Q
35 disp("The heat transfer rate per metre of tube
        length Q in W/m is ")
36  $Q=(T_1-T_{inf})/(((X)/(2*\%pi*L*k))+(1/(h*2*\%pi*r_2*L)))$ 
37 //When there is a 0.05 m thick layer of insulation
         $r_1=0.01\text{m}, r_2=.01+0.05=0.06\text{m}$ 
38  $r_1=0.01$ ; //inner radius

```

```

39 r2=0.06; //outer radius
40 //Let  $\ln(r2/r1)=X$ 
41  $X=\log(r2/r1)/\log(2.718)$ ;
42 //The heat transfer rate per metre of tube length is
   Q
43 disp("The heat transfer rate per metre of tube
   length Q in W/m is ")
44  $Q=(T1-Tinf)/(((X)/(2*\pi*L*k))+(1/(h*2*\pi*r2*L)))$ 
45 //It is important to note that Q increases by 5.2%
   when the insulation thickness increases from
   0.002m to critical thickness.
46 //Addition of insulation beyond the critical
   thickness decreases the value of Q (The heat loss
   ).

```

Scilab code Exa 2.10 A copper pipe carries liquid oxygen

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
   Chapter 2, Example 10")
8 //A copper pipe having 35mm outer diameter(Do) and
   30mm inner diameter(Di) carries liquid oxygen to
   the storage site of a space shuttle at temperature
   ,T1=-182 C
9 //mass flow rate is ,mdot=0.06m^3/min.
10 Di=0.03; //in metre
11 Do=0.035; // in metre
12 T1=-182;
13 mdot=0.06;
14 //The ambient air is at temperature(Ta)=20 C and has

```

```

    a dew point (T3)=10 C .
15 Ta=20;
16 T3=10;
17 //The thermal conductivity(k) of insulating material
    is 0.02W/(m*k)
18 k=0.02;
19 //The convective heat transfer coefficient on the
    outside is h=17W/(m^2*K)
20 h=17;
21 //The thermal conductivity of copper kcu=400W/(m*K)
22 kcu=400;
23 //We can write  $Q = ((T_a - T_1) / (R_1 + R_2 + R_3)) = ((T_a - T_3) / (R_3))$ 
    ,Rearranging we get  $((R_1 + R_2 + R_3) / (R_3)) = ((T_a - T_1) / (T_a - T_3))$ ———eq.1
24 //The conduction Resistance of copper pipe(R1)=ln
    (0.035/0.03) / (2*%pi*L*kcu) = 3.85*10^-4 / (2*%pi*L) K/
    W
25 //The conduction resistance of insulating material (
    R2)=ln(r3/0.035) / (2*%pi*L*k) = (1/(2*%pi*L)) ((50*ln
    (r3/0.035))) K/W where r3 is the outer radius of
    insulation in metres.
26 //The convective resistance at the outer surface(R3)
    = 1/(2*%pi*L*h*r3) = (1/2*%pi*L) *(mdot/r3) K/W
27 //Substituting the values in eq.1 we have  $1 + ((50 * \ln(r_3 / 0.035) + (3.85 * 10^{-4})) / (\dot{m} / r_3)) = 20 - (-182) / (20 - 10)$ 
28 //A rearrangement of the above equation gives  $r_3 * \ln(r_3) + 3.35 * r_3 = 0.023$ 
29 //The equation is solved by trial and error method
    which finally gives r3=0.054m
30 r3=0.054; //outer radius of insulation
31 //Therefore the thickness of insulation is given by
    t=r3-Do
32 disp("the thickness of insulation in metre is")
33 t=r3-Do

```

Scilab code Exa 2.11 An electrical resistance wire

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 11")
8 //An electrical resistance wire 2.5mm or  $2.5 \times 10^{-3}$ m
      in diameter(D) and L=0.5m long has a measured
      voltage drop of E=25V for a current flow of I=40A
      .
9 D=2.5*10^-3;
10 I=40;
11 E=25;
12 L=0.5;
13 ro=D/2;//ro is radius of wire
14 //The thermal conductivity(k) of wire material is 24
      W/(m*K)
15 k=24;
16 //The rate of generation of thermal energy per unit
      volume is given by  $qG=(E*I)/(L*\%pi*D^2/4)$ 
17 disp("The rate of heat generation of thermal energy
      in W/m^3 is")
18 qG=(E*I)/(L*\%pi*D^2/4)
19 //The temprature at the centre is given by  $To=Tw+(($ 
       $qG*ro^2)/(4*k))$  where Tw=650K is surface
      temprature
20 Tw=650;
21 disp("The temprature of wire at the centre in K is ")
      )
22 To=Tw+((qG*ro^2)/(4*k))//Note:The answer in the book
```

is incorrect (value of D has been put instead of ro)

Scilab code Exa 2.12 A spherical tank is used to store iced water

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 12")
8 //A spherical tank of internal diameter, Di=5m ,made
      of t=25mm thick stainless steel(thermal
      conductivity ,k=15W/(m*K)),is used to store water
      at temprature(Ti)=0 C .Do is outer diameter
9 Di=5;
10 t=25;
11 Do=5+2*(t/1000);//in metre
12 k=15;
13 Ti=0;
14 //The tank is located in a room whose temprature is
      (To)=20 C .
15 To=20;
16 //Emmisivity is 1.
17 //The convection heat transfer coefficients at the
      inner and outer surfaces of the tank are hi=80W/(
      m^2*K) and ho=10W/(m^2*K)
18 hi=80;
19 ho=10;
20 //The heat of fusion of ice at atmospheric pressure
      is deltahf=334kJ/kg.The stefan-boltzman constant(
      sigma) is 5.67*10^-8W/m^2.
21 sigma=5.67*10^-8;
```

```

22 deltaxhf=334;
23 //The inner surface area is (A1) and outer surface
    area is (A2)of the tank
24 disp("The inner(A1) and outer surfaces(A2) areas of
    the tank in m^2 are")
25 A1=%pi*Di^2
26 A2=%pi*Do^2
27 //The individual thermal resistances can be
    determined as
28 //The convective resistance is (Ri)
29 disp("The convective resistance(Ri) at the inner
    surface in K/W is ")
30 Ri=1/(hi*A1)
31 //The conduction resistance is (Rs)
32 disp("The conduction resistance(Rs)of the tank in K/
    W is")
33 Rs=(Do-Di)/(2*k*%pi*Di*Do)
34 //The convective resistance is (Roc)
35 disp("The convective resistance(Roc) at the outer
    surface in K/W is")
36 Roc=1/(ho*A2)
37 //The radiative resistance(Ror) at the outer surface
    is Ror=1/(A2*hr)
38 //The radiative heat transfer coefficient hr is
    determined by hr=sigma*(T2^2+293.15^2)*(T2
    +293.15)
39 //But we do not know the outer surface temprature T2
    of the tank and hence we cannot determine the
    value of hr.
40 //Therefore we adopt an iterative procedure.We assume
    T2=4 C =277.15K.Putting the value in hr=sigma*(
    T2^2+293.15^2)*(T2+293.15) we get
41 T2=277.15;
42 disp("The radiative heat transfer coefficient hr in
    W/(m^2*K) is")
43 hr=sigma*(T2^2+293.15^2)*(T2+293.15)
44 disp("Therefore the radiative resistance(Ror) at the
    outer surface in K/W is")

```



```

45 Ror=1/(A2*hr)
46 //The two parallel resistances Roc and Ror can be
    replaced by an equivalent resistance Ro as  $X=(1/Ro)=(1/Roc)+(1/Ror)$ 
47 disp("The equivalent resistance in K/W is")
48 X=(1/Roc)+(1/Ror);
49 Ro=1/X
50 //Now the resistance Ri,Rs and Ro are in series an
    hence the total resistance becomes  $Rtotal=Ri+Rs+Ro$ 
51 disp("The total resistance in K/W is")
52 Rtotal=Ri+Rs+Ro
53 //The rate of heat transfer is given by  $Q=(To-Ti)/Rtotal$ 
54 disp("The rate of heat transfer ,Q in W is")
55 Q=(To-Ti)/Rtotal
56 //The outer surface(T2) is calculated as  $T2=To-Q*Ro$ 
57 disp("The outer surface temprature in C is")
58 T2=To-Q*Ro
59 disp("which is sufficiently close to the assumption.
    So there is no need of further iteration")
60 //The total heat transfer is (Qt),during a 24-hour
    period
61 disp("The total heat transfer(Qt) during a 24-hour
    period in KJ is")
62 Qt=Q*24*3600/1000
63 //the amount of ice in kG which melts during a 24
    hour period is (mice)
64 disp("Therefore ,the amount of ice(mice)in kG which
    melts during a 24 hour period is")
65 mice=Qt/deltahf

```

Scilab code Exa 2.13 A very long copper rod is exposed to enviroment

```
1 // Display mode
```

```

2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 13")
8 //A very long,10mm diameter(D) copper rod(thermal
      conductivity ,k=370W/(m*K))is exposed to an
      enviroment at temprature ,Tinf=20 C .
9 D=0.01;
10 k=370;
11 Tinf=20;
12 //The base temprature of the radius maintained at Tb
      =120 C .
13 Tb=120;
14 //The heat transfer coefficient between the rod and
      the surrounding air is h=10W/(m*K^2)
15 h=10;
16 //The rate of heat transfer for all finite lengths
      will be given by P/A=(4*pi*D)/(pi*D^2)
17 //Let P/A=X
18 disp("P/A in m^-1 is")
19 X=(4*pi*D)/(pi*D^2)
20 //m is defined as [(h*p)/(k*A)]^0.5
21 disp("m in m^-1 is")
22 m=(h*X/k)^0.5
23 //Let Y=h/(m*k)
24 Y=h/(m*k)
25 //Let M=(h*P*k*A)^0.5
26 P=(pi*D); //perimeter of the rod
27 A=(pi*D^2)/4; //Area of the rod
28 disp("M in W/K is")
29 M=(h*P*k*A)^0.5
30 //thetab is the parameter that defines the base
      temprature
31 disp("thetab in C is ")
32 thetab=Tb-Tinf

```

```

33 //Heat loss from the rod is defined as  $Q=(h*P*k*A)*$ 
    thetab *  $\{[(h/m*k)+\tanh(m*L)]/[1+(h/m*k)*\tanh(m*L)]\}$ 
    ]}
34 disp("Heat loss from rod in Watt, for different
    value of length(in m) is ")
35 L=0.02//Length of rod
36 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
37 L=0.04//length of rod
38 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
39 L=0.08//length of rod
40 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
41 L=0.20//length of rod
42 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
43 L=0.40//length of rod
44 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
45 L=0.80//length of rod
46 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
47 L=1.00//length of rod
48 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
49 L=10.00//length of rod
50 Q=M*thetab* $\{[(Y)+\tanh(m*L)]/[1+(Y)*\tanh(m*L)]\}$ 
51 //For an infinitely long rod we use heat loss as ,
    Qinf=(h*P*k*A)^0.5*thetab
52 disp("For an infinitely long rod heat loss in W is")
53 Qinf=(h*P*k*A)^0.5*thetab
54 disp("We see that since k is large there is
    significant difference between the finite length
    and the infinite length cases")
55 disp("However when the length of the rod approaches
    1m,the result become almost same." )

```

Scilab code Exa 2.14 Slender rods of the same diameter

```

1 // Display mode
2 mode(0);

```

```

3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 14")
8 //Considering two very long slender rods of the same
      diameter but of different materials.
9 //The base of each rod is maintained at 100 C while
      the surfaces of the rod are exposed to 20 C
10 //By traversing length of each rod with a
      thermocouple it was observed that tempratures of
      rod were equal at the position xA=0.15m and xB
      =0.075 from base.
11 xA=0.15;
12 xB=0.075;
13 //Thermal conductivity of rod A is known to be kA=72
      W/(m*K)
14 kA=72;
15 //In case of a very long slender rod we use the tip
      boundary condition thetaL=0 as L-->infinity
16 //Therefore we can write for the locations where the
      tempratures are equal thetab*e^(-mA*xA)=thetab*e
      ^(-mB*xB) or xA/xB=mB/mA, Again mB/mA=(kA/kB)^0.5
17 //So kB=kA*(xB/xA)^2
18 //The thermal conductivity of Rod B iskB
19 disp("The thermal conductivity of Rod B kB in W/(m*K
      ) is ")
20 kB=kA*(xB/xA)^2

```

Scilab code Exa 2.15 The entire stack is made of aluminium

```

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

```

```

4  ieee(1);
5  clear;
6  clc;
7  disp("Introduction to heat transfer by S.K.Som,
      Chapter 2, Example 15")
8  //A stack that is b=300mm wide and l=100mm deep
      contains N=60 fins each of length L=12mm.
9  L=0.012; //in metre
10 b=0.3; //in metre
11 l=0.1; //in metre
12 N=60;
13 //The entire stack is made of aluminum which is
      everywhere t=1.0 mm thick.
14 t=0.001; //in metre
15 //The temprature limitations associated with
      electrical components are Tb=400K and TL=350K.
16 //Tb is base temprature and TL is end temprature
17 Tb=400;
18 TL=350;
19 //Given convection heat transfer coefficient(h=150W
      /(m2*K)), Surrounding Temprature(Tinf=300K),
      thermal conductivity of aluminium(kaluminium=230W
      /(m*K))
20 h=150;
21 Tinf=300;
22 kal=230;
23 //Here both the ends of the fins are at fixed
      tempratures . Therefore we use  $M=(h*P*k*A)^{0.5}$  and
       $m=((h*P)/(k*A))^{0.5}$ ,  $\theta_b=T_b-T_{inf}$ ,  $\theta_L=TL-T_{inf}$ 
24 //from the given data perimeter of each fin is given
      by  $P= 2*(l+t)$  in m and area of each fin is  $A=t*l$ 
25 disp(" perimeter of each fin in m is")
26 P= 2*(l+t)
27 disp(" Cross sectional area of fin in m2 is")
28 A=t*l
29 //M is defined as  $(h*P*kal*A)^{0.5}$  and m is defined
      as  $((h*P)/(kal*A))^{0.5}$ 

```

```

30 M=(h*P*ka*l*A)^0.5
31 m=((h*P)/(ka*l*A))^0.5
32 //thetab and thetaL are the parameters that define
    the fin tempratures at base and tip respectively.
33 disp("Temprature parameter at fin base in K is")
34 thetab=Tb-Tinf
35 disp("Fixed temprature at fin tip in K is")
36 thetaL=TL-Tinf
37 //Heat loss from the plate is Qb
38 disp("Heat loss from the plate at 400K in W is")
39 Qb=[N*(h*P*ka*l*A)^0.5*thetab*((cosh(m*L)-(thetaL/
    thetab))/(sinh(m*L)))]+(((l*b)-(N*A))*h*thetab)+(
    l*b*h*thetab)

```

Chapter 3

Multi dimensional steady state heat conduction

Scilab code Exa 3.1 Temperature at the centre of the plate

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 1, Example 1")
8 //Length and breadth is given as 1 unit (Gemoetry is
      Square)
9 L = 1;//length
10 //Problem can be divided into two modules
11 //Solution to module 1 is given by Eq. 3.21,
      considering the first three terms
12 //n is the looping parameter
13 //theta is the non dimensional temperature defined
      as ((T-100)/100) where T is actual temperature in
      degree Celcius.
14 //Initialising theta as zero
```

```

15 theta = 0;
16 for n = 1:3
17     theta = theta+((2/%pi)*((sin((n*%pi)/2)*sinh((n*
        %pi)/2))*((-1)^(n+1)+1)))/(n*sinh(n*%pi));
18 end;
19 //Solution to module 2 is given by Eq. 3.24,
    considering the first three terms
20 for n = 1:3
21     theta = theta+(((3*2)/%pi)*((sin((n*%pi)/2)*sinh((
        n*%pi)/2))*((-1)^(n+1)+1)))/(n*sinh(n*%pi));
22 end;
23 //Calculating value of temperature from the value of
    theta
24 //Temperature in degree celcius
25 disp("Temperature at the centre in Degree C is")
26 T = theta*100+100

```

Scilab code Exa 3.2 A thin square plate

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 3, Example 2")
8 //Temperature in K at four edges are given
9 //Theta is non dimensional temperature defined as ((
    T-300)/100) where T is actual temperature in K.
10 //Given length as well as the breadth of square
    plate is 'a'
11 //Problem can be divided into two modules
12 //Solution to module 1 is given by Eq. 3.23
13 //Solution of first module is non dimensional

```



```

    temperature theta1
14 //theta1=2*sinh(pi*y/a)*sin(pi*x/a)/(sinh(pi))
15 //Solution to module 2 is given by Eq. 3.24
16 //Solution of second module is non dimensional
    temperature theta2
17 //theta2=sinh(pi*x/a)*sin(pi*y/a)/(sinh(pi))
18 //Therefore
19 disp("Steady state non dimensional temperature is")
20 disp("theta=2*sinh(pi*y/a)*sin(pi*x/a)/(sinh(pi)) +
    sinh(pi*x/a)*sin(pi*y/a)/(sinh(pi))")
21 //At the centre , x coordinate and y coordinate in
    unit are
22 //x=a/2, y=a/2
23 //Non dimensional temperature at centre point
24 theta = (2*sinh(%pi/2))/sinh(%pi)+sinh(%pi/2)/sinh(
    %pi);
25 //Temperature in K at centre point
26 disp("Temperature in K at centre point")
27 T = theta*100+300

```

Scilab code Exa 3.3 Three sides of a square plate

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 3, Example 3")
8 //internodal distance in x direction in m
9 deltax = 1/4;
10 //internodal distance in y direction in m
11 deltay = 1/4;
12 //Air temperature in degree K

```

```

13 Tinfinitiy = 400;
14 //Heat transfer coefficient in W/(m^2*K)
15 h = 10;
16 //T1, T2, T3, T4, T5, T6, T7, T8 are nodal
    temperatures in degree K.
17 //T is the temperature matrix and is transpose of [
    T1 T2 T3 T4 T5 T6 T7 T8]
18 //using Nodal Equations , we have Coefficeint Matrix
    A as
19 A = [-4,1,0,0,1,0,0,0;
20      1,-4,1,0,0,1,0,0;
21      0,1,-4,1,0,0,1,0;
22      2,0,0,0,-4,1,0,0;
23      0,2,0,0,1,-4,1,0;
24      0,0,2,0,0,1,-4,1;
25      0,0,2,-6,0,0,0,1;
26      0,0,0,2,0,0,2,-6];
27 //Coefficient matrix B
28 B = [-1200;
29      -600;
30      -600;
31      -600;
32      0;
33      0;
34      -1400;
35      -800];
36 //Therefore the temperature matrix is
37 T = (A^(-1))*B;
38 //Temperature at nodal points in degree K
39 disp("Temperatures at nodal points in degree K")
40 disp("T1 in degree K")
41 T1 = T(1)
42 disp("T2 in degree K")
43 T2 = T(2)
44 disp("T3 in degree K")
45 T3 = T(3)
46 disp("T4 in degree K")
47 T4 = T(4)

```

```
48 disp("T5 in degree K")
49 T5 = T(5)
50 disp("T6 in degree K")
51 T6 = T(6)
52 disp("T7 in degree K")
53 T7 = T(7)
54 disp("T8 in degree K")
55 T8 = T(8)
```

Scilab code Exa 3.5 An aluminium rod

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 3, Example 5")
8 //Thermal conductivity of aluminium in W/(m*K)
9 k = 200;
10 //Diameter in m
11 d = 20*(10^(-3));
12 //Length of fin in m
13 L = 0.2;
14 //Wall temperature in degree C
15 Tw = 400;
16 //Air temperature in degree C
17 Tinfinity = 30;
18 //Heat transfer coefficient in W/(m^2*K)
19 h = 40;
20 //internodal distance in x direction in m
21 deltax = L/5;
22 //Node 1 temperature is equal to wall temperature
    in degree C
```

```

23 T1 = Tw;
24 //using Nodal Equations , we have Coefficeint Matrix
    A as
25 A = [2.064,-1,0,0,0;
26      -1,2.064,-1,0,0;
27      0,-1,2.064,-1,0;
28      0,0,-1,2.064,-1;
29      0,0,0,-1,1.032];
30 //Coefficient matrix B
31 B = [401.92;
32      1.92;
33      1.92;
34      1.92;
35      0.96];
36 //T2, T3, T4, T5, T6 are nodal temperature in degree
    C
37 //T is the temperature matrix and is transpose of [
    T2 T3 T4 T5 T6]
38 //Therefore the temperature matrix is
39 T = (A^(-1))*B;
40 //Temperature at nodal points in degree C
41 disp("Temperatures at nodal points in degree C")
42 disp("T2 in degree C")
43 T2 = T(1)
44 disp("T3 in degree C")
45 T3 = T(2)
46 disp("T4 in degree C")
47 T4 = T(3)
48 disp("T5 in degree C")
49 T5 = T(4)
50 disp("T6 in degree C")
51 T6 = T(5)
52 //Heat transfer rate in W
53 disp("Heat loss from fin in W")
54 Q = -((((k*pi)*d)*d)*(T2-T1))/(4*deltax)
55 //Using eq. 2.67
56 //Parameter m in meter inverse
57 m = (((h*pi)*d)/((((k*pi)*d)*d)/4))^0.5;

```

```

58 //Generalised eq. of temperature is eq. 2.67
59 //T=30+193.61*cosh(m*(L-x))
60 //Calculating analytical temperatures in degree C
61 //i is the looping parameter
62 for i = 1:5
63     //Distance in m
64     x = 0.04*i;
65     //Ta is the matrix of actual temperatures in
        degree C
66     Ta(1,i) = 30+193.61*cosh(m*(L-x));
67 end;
68 //Heat loss in W as in eq. 2.68
69 Qa = (((((((((h*pi)*d)*k)*pi)*d)*d)/4)^0.5)*370)*
        tanh(m*L);
70 disp("Comparison between actual and numerical values
        ")
71 // L.69: No simple equivalent, so mtlb_fprintf() is
        called.
72 mtlb_fprintf("Actual heat transfer is %5.2f W while
        predicted numerically is %5.2f W\n",Qa,Q)
73 // L.71: No simple equivalent, so mtlb_fprintf() is
        called.
74 mtlb_fprintf("At nodal point 2, actual temperature
        is %5.2f C while predicted numerically is %5.2f C
        \n",Ta(1),T(1))
75 // L.72: No simple equivalent, so mtlb_fprintf() is
        called.
76 mtlb_fprintf("At nodal point 3, actual temperature
        is %5.2f C while predicted numerically is %5.2f C
        \n",Ta(2),T(2))
77 // L.73: No simple equivalent, so mtlb_fprintf() is
        called.
78 mtlb_fprintf("At nodal point 4, actual temperature
        is %5.2f C while predicted numerically is %5.2f C
        \n",Ta(3),T(3))
79 // L.74: No simple equivalent, so mtlb_fprintf() is
        called.
80 mtlb_fprintf("At nodal point 5, actual temperature

```

```

    is %5.2f C while predicted numerically is %5.2f C
    \n",Ta(4),T(4))
81 // L.75: No simple equivalent, so mtlb_fprintf() is
    called.
82 mtlb_fprintf("At nodal point 6, actual temperature
    is %5.2f C while predicted numerically is %5.2f C
    \n",Ta(5),T(5))

```

Scilab code Exa 3.6 The cross section of a square chimney

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 3, Example 6")
8 //Thermal conductivity of concrete in W/mK
9 k = 2;
10 //Length in m
11 L = 0.2;
12 //Breadth in m
13 b = 0.2;
14 //Depth in m
15 d = 0.2;
16 //Temperature of hot gas in chimney in degree C
17 Tg = 400;
18 //Air temperature in degree C
19 Tinfinity = 20;
20 //internodal distance in x direction in m
21 deltax = 0.1;
22 //internodal distance in y direction in m
23 deltay = 0.1;
24 //Heat transfer coefficient in W/(m^2*K)

```

```

25 h = 20;
26 //T1, T2, T3, T4, T5, T6, T7, T8, T9 are nodal
    temperatures in degree K.
27 //T is the temperature matrix and is transpose of [
    T1 T2 T3 T4 T5 T6 T7 T8 T9]
28 //using Nodal Equations , we have Coefficeint Matrix
    A as
29 A = [1,0,-4,2,0,1,0,0,0;
30       0,1,1,-4,1,0,1,0,0;
31       0,0,0,2,-4,0,0,2,0;
32       -3,1,1,0,0,0,0,0,0;
33       0,0,1,0,0,-3,1,0,0;
34       0,0,0,2,0,1,-6,1,0;
35       0,0,0,0,2,0,1,-6,1;
36       0,0,0,0,0,0,0,1,-2;
37       1,-4,0,2,0,0,0,0,0];
38 //Coefficient matrix B
39 B = [0;
40       0;
41       0;
42       -400;
43       -20;
44       -40;
45       -40;
46       -20;
47       -400];
48 //Therefore the temperature matrix is
49 T = (A^(-1))*B;
50 //Temperature at nodal points in degree C
51 disp("Temperatures at nodal points in degree C")
52 disp("T1 in degree C")
53 T1 = T(1)
54 disp("T2 in degree C")
55 T2 = T(2)
56 disp("T3 in degree C")
57 T3 = T(3)
58 disp("T4 in degree C")
59 T4 = T(4)

```

```
60 disp("T5 in degree C")
61 T5 = T(5)
62 disp("T6 in degree C")
63 T6 = T(6)
64 disp("T7 in degree C")
65 T7 = T(7)
66 disp("T8 in degree C")
67 T8 = T(8)
68 disp("T9 in degree C")
69 T9 = T(9)
```

Chapter 4

Unsteady conduction

Scilab code Exa 4.1 An apple subject to a cold environment

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 1")
8 //Diameter of apple in m
9 d = 100*(10^(-3));
10 //radius in m
11 r = d/2;
12 //Thermal conductivity of apple in W/(m*K)
13 k = 0.6;
14 //Heat transfer coefficient in W/(m^2* C )
15 h = 10;
16 //Caculating characteristic dimension in m
17 Lc = (((((4*%pi)*r)*r)*r)/3)/(((4*%pi)*r)*r);
18 //Biot number
19 disp("Biot number is")
20 Bi = (h*Lc)/k
```

```

21 if Bi<0.1 then
22     disp("Problem is suitable for lumped parameter
           analysis")
23 else
24     disp("Problem is not suitable for lumped parameter
           analysis")
25 end;

```

Scilab code Exa 4.2 The temprature of a gas stream

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
       Chapter 4, Example 2")
8 //Diameter of sphere in m
9 d = 1.5*(10^(-3));
10 //radius in m
11 r = d/2;
12 //Thermal conductivity of sphere in W/(m* C )
13 k = 40;
14 //Density in kg/m^3
15 rho = 8000;
16 //Specific heat in J/(Kg*K)
17 c = 300;
18 //Heat transfer coefficient in W/(m^2* C )
19 h = 75;
20 //Time constant in sec
21 tc = ((rho*c)*((((4*%pi)*r)*r)*r)/3)/((((h*4)*%pi)
       *r)*r);
22 disp("Time constant in seconds is")
23 tc

```

```

24 //Using eq. 4.4
25 //Given fraction is 0.01 (1 percent)
26 //Required time in sec
27 t = (-8)*log(0.01);
28 disp("Time required in seconds")
29 t

```

Scilab code Exa 4.3 Maximum edge dimension

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 3")
8 //Heat transfer coefficient in W/(m^2*K)
9 h = 30;
10 //Thermal conductivity of sphere in W/(m*K)
11 k = 250;
12 //Biot number for lumped parameter analysis is 0.1
13 Bi = 0.1;
14 //Characteristic dimension of a cube is (a/6) where
      a is the side of cube in metre
15 //Maximum dimension in metre
16 a = ((6*k)*Bi)/h;
17 disp("Maximum dimension in metre for lumped
      parameter analysis")
18 a

```

Scilab code Exa 4.4 Some hot milk

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 4")
8 //Diameter of glass in m
9 d = 50*(10^(-3));
10 //radius in m
11 r = d/2;
12 //Height of milk in glass in m
13 H = 0.1;
14 //Initial temperature of milk in C
15 T = 80;
16 //Cold water temperature in C
17 Tf = 25;
18 //Heat transfer coefficient in W/(m^2* C )
19 h = 100;
20 //Thermal conductivity of milk in W/(m*K)
21 k = 0.6;
22 //Density of milk in kg/m^3
23 rho = 900;
24 //Specific heat in J/(Kg*K)
25 c = 4.2*(10^3);
26 //Since the milk temperature is always maintained as
      constant.
27 //Therefore it can be assumed as lumped paramteter
      analysis.
28 //Time constant n seconds
29 tcs = (((((rho*c)*%pi)*r)*r)*H)/(((h*%pi)*d)*H);
30 //Time constant in minutes
31 tc = tcs/60;
32 //Calculating from eq. 4.3 time taken to cool milk
      from 80 C to 30 C
33 t = -tc*log((30-Tf)/(T-Tf));
34 disp("Time required to cool milk in minutes")

```

```

35 t
36 //Energy transferred during cooling
37 E = (((h*%pi)*d)*H)*integrate("(80-25)*exp(-t/472.5)
    ", 't', 0, 60*t);
38 disp("Energy required for cooling in KJ")
39 E = E/1000

```

Scilab code Exa 4.5 Masonry brick wall

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 4, Example 5")
8 //Thermal conductivity of wall in W/(m*K)
9 k = 0.6;
10 //Thermal diffusivity in m^2/s
11 alpha = 5*(10^(-7));
12 //Thickness in m
13 L = 0.15;
14 //Initial temperature in C
15 Ti = 30;
16 //Temperature of hot gas in C
17 Tinfinity = 780;
18 //Heat transfer coefficient in W/(m^2*K)
19 h = 20;
20 //Surface temperaute to be achieved in C
21 To = 480;
22 //Dimensionless temperature ratio
23 z = (To-Tinfinity)/(Ti-Tinfinity);
24 //Biot number
25 Bi = (h*L)/k;

```

```

26 //For this value of (1/Bi) and dimensionless temp.
    ratio
27 //From Fig. 4.11 Fourier number is
28 Fo = 0.6;
29 //Time required in seconds
30 t = ((Fo*L)*L)/alpha;
31 disp("Time required in hours")
32 t = t/3600
33 //From fig. 4.13, for this Bi and Fo*Bi*Bi, we have
    ratio of heats as
34 //Q/Qi=0.69
35 //Heat transfer in J
36 Q = (((0.69*k)*2)*L)*(Tinfinity-Ti))/alpha;
37 disp("Heat transfer rate in MJ")
38 Q = Q/(10^6)

```

Scilab code Exa 4.6 A large aluminium plate

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 4, Example 6")
8 //Thickness of plate in m
9 L = 0.2;
10 //Initial temperature in C
11 Ti = 530;
12 //Heat transfer coefficient in W/(m^2*K)
13 h = 500;
14 //Given distance in m
15 x = L-20*(10^(-3));
16 //Temperature of surrounding in C

```

```

17 Tinfinitiy = 30;
18 //Given time in seconds
19 t = 225;
20 //Thermal conductivity of aluminium in W/(m*K)
21 k = 200;
22 //Thermal diffusivity in m^2/s
23 alpha = 8*(10^(-5));
24 //Biot number
25 Bi = (h*L)/k;
26 //Fourier number
27 Fo = (alpha*t)/(L*L);
28 //From fig. 4.11, at this Fo and (1/Bi), we have
    dimensionless temperature
29 //ratio to be 0.7
30 //From fig. 4.12 for this (1/Bi) and (x/L), we have
    another dimensionless
31 //temperature to be 0.93
32 //Temperature in C
33 T = Tinfinitiy+(0.93*0.7)*(Ti-Tinfinitiy);
34 disp("Temperature at this distance in C ")
35 T
36 //From fig. 4.13, for this Bi and Fo*Bi*Bi, we have
    ratio of heats as
37 //Q/Qi=0.4
38 //Heat transfer in J
39 Q = (((0.4*k)*L)*(Ti-Tinfinitiy))/alpha;
40 disp("Heat transfer rate in MJ")
41 Q = Q/(10^6)

```

Scilab code Exa 4.7 A large cylinder

```

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

```

```

5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 7")
8 //Radius in m
9 ro = 0.15;
10 //Initial temperature in C
11 Ti = 530;
12 //Temperature of surrounding in C
13 Tinfinity = 30;
14 //Heat transfer coefficient in W/(m^2*K)
15 h = 380;
16 //Thermal conductivity of aluminium in W/(m*K)
17 k = 200;
18 //Thermal diffusivity in m^2/s
19 alpha = 8.5*(10^(-5));
20 //Given radius at which temperature has to be find
    out in m
21 r = 0.12;
22 //Given time in seconds
23 t = 265;
24 //Fourier number
25 Fo = (alpha*t)/(ro^2);
26 //Biot number
27 Bi = (h*ro)/k;
28 //From fig. 4.15, at this fourier number,Fo and (1/
    Bi), we have dimensionless temperature
29 //ratio to be 0.6
30 //From fig. 4.16 for this (1/Bi) and (r/ro), we have
    another dimensionless
31 //temperature to be 0.9
32 //Temperature in C
33 T = Tinfinity+(0.9*0.6)*(Ti-Tinfinity);
34 disp("Temperature at this radius in C ")
35 T
36 //From fig. 4.17, for this Bi and Fo*Bi*Bi, we have
    ratio of heats as
37 //Q/Qi=0.4

```



```

38 //Heat transfer per metre in J/m
39 Q = (((((0.4*k)*%pi)*ro)*ro)*(Ti-Tinfinity))/alpha;
40 disp("Heat transfer rate per unit length in MJ/m")
41 Q = Q/(10^6)

```

Scilab code Exa 4.8 A steel sphere

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 8")
8 //Radius in m
9 ro = 0.05;
10 //Initial temperature in C
11 Ti = 530;
12 //Temperature of surrounding in C
13 Tinfinity = 30;
14 //Heat transfer coefficient in W/(m^2*K)
15 h = 500;
16 //Thermal conductivity of aluminium in W/(m*K)
17 k = 50;
18 //Thermal diffusivity in m^2/s
19 alpha = 1.5*(10^(-5));
20 //Required centre temperature to achieve in C
21 To = 105;
22 //Dimensionless temperature
23 z = (To-Tinfinity)/(Ti-Tinfinity);
24 //Biot number
25 Bi = (h*ro)/k;
26 //For this value of (1/Bi) and dimensionless temp.
      ratio

```

```

27 //From Fig. 4.19 Fourier number is
28 Fo = 1.5;
29 //Time required in seconds
30 t = ((Fo*ro)*ro)/alpha;
31 disp("Time required in minutes")
32 t = t/60

```

Scilab code Exa 4.9 A large aluminium bar

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 9")
8 //Thermal conductivity of aluminium in W/(m*K)
9 k = 198;
10 //Length in m
11 L = 0.18;
12 //Breadth in m
13 b = 0.104;
14 //Initial temperature in C
15 Ti = 730;
16 //Temperature of surrounding in C
17 Tinfinity = 30;
18 //Heat transfer coefficient in W/(m^2*K)
19 h = 1100;
20 //Thermal diffusivity in m^2/s
21 alpha = 8.1*(10^(-5));
22 //Given time in seconds
23 t = 100;
24 //Bar can be considered to be an intersection of two
      infinite plates of

```

```

25 //thickness L1 and L2 in m
26 L1 = L/2;
27 L2 = b/2;
28 //For plate 1
29 //Fourier number
30 Fo1 = (alpha*t)/(L1^2);
31 //Biot number
32 Bi1 = (h*L1)/k;
33 //From fig. 4.11, at this Fo and (1/Bi), we have
    dimensionless temperature
34 //ratio to be 0.7
35 //For plate 2
36 //Fourier number
37 Fo2 = (alpha*t)/(L2^2);
38 //Biot number
39 Bi2 = (h*L2)/k;
40 //From fig. 4.11, at this Fo and (1/Bi), we have
    dimensionless temperature
41 //ratio to be 0.47
42 //Therefore combined dimensionless temperature ratio
    is multiply of two
43 z = 0.47*0.7;
44 //Temperature in C
45 T = Tinfinity+z*(Ti-Tinfinity);
46 disp("Tempearture of bar in C ")
47 T

```

Scilab code Exa 4.10 An iron beam

```

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

```

```

7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 10")
8 //An iron beam of rectangular cross section of size
      length,L=300mm by breadth,B=200 mm is used in the
      construction of a building
9 //Initially the beam is at a uniform temprature(Ti)
      of 30 C .
10 //Due to an accidental fire ,the beam is suddenly
      exposed to hot gases at temprature ,Tinf=730 C ,
      with a convective heat transfer coefficient(h) of
      100 W/(m^2*K)
11 //To determine the time required for the centre
      plane of the beam to reach a temprature(To) of
      310 C .
12 To=310;
13 Tinf=730;
14 Ti=30;
15 //Take thermal conductivity k=73W/(m*K) and thermal
      diffusivity of the beam alpha=2.034*10^-5m^2/s
16 alpha=2.034*10^-5;
17 k=73;
18 h=100;
19 //The rectangular iron beam can be considered as an
      intersection of an infinite plate 1 having
      thickness 2*L1=300mm and a second infinite plate
      2 of thickness 2*L2=200mm
20 L1=0.15; //in metre
21 L2=0.10; //in metre
22 //Here the faactor X=((To-Tinf)/(Ti-Tinf))
23 disp("The factor ((To-Tinf)/(Ti-Tinf)) is ")
24 X=((To-Tinf)/(Ti-Tinf))
25 //Therefore we can write 0.6=((To-Tinf)/(Ti-Tinf))
      plate 1 *((To-Tinf)/(Ti-Tinf))plate2
26 //A straight forward solution is not possible.We
      have to adopt an iterative method of solution
27 //At first ,a value of time(t) is assumed to
      determine the centre-line temprature of the beam.
      The value of t at which((To-Tinf)/(Ti-Tinf))beam

```

```

    =0.6 is satisfied
28 //Let us first assume time , t=900s
29 t=900;
30 disp("For plate 1")
31 //For plate1 Biot number Bi1=h*L1/k
32 Bi1=h*L1/k
33 Y=1/Bi1
34 //Fourier number(Fo1) is
35 Fo1=alpha*t/L1^2
36 //At Fo=0.814 and (1/Bi)=4.87...We read from graphs
    A=((To-Tinf)/(Ti-Tinf))plate1= 0.85
37 A=0.85;
38 disp("For plate 2")
39 //For plate1 Biot number Bi2=h*L2/k
40 Bi2=h*L2/k
41 Y=1/Bi2
42 //Fourier number(Fo2) is
43 Fo2=alpha*t/L2^2
44 //At Fo=1.83 and (1/Bi)=7.3...We read from graphs B
    =((To-Tinf)/(Ti-Tinf))plate2= 0.8
45 B=0.8;
46 //Therefore ((To-Tinf)/(Ti-Tinf))plate1*((To-Tinf)/(
    Ti-Tinf))plate2=A*B
47 T=A*B
48 //Since the calculated value of 0.68 is greater than
    the required value of 0.60 and Tinf>To>Ti,The
    assume dvalue of t is less .
49 //So let us take time ,t=1200s for the second
    iteration
50 t=1200;
51 disp("For plate 1")
52 //For plate1 Biot number Bi1=h*L1/k
53 Bi1=h*L1/k
54 Y=1/Bi1
55 //Fourier number (Fo1)
56 Fo1=alpha*t/L1^2
57 //At Fo=1.08 and (1/Bi)=4.87...We read from graphs
    A=((To-Tinf)/(Ti-Tinf))plate1= 0.83

```

```

58 A=0.83;
59 disp("For plate 2")
60 //For plate1 Biot number Bi2=h*L2/k
61 Bi2=h*L2/k
62 Y=1/Bi2
63 //Fourier number (Fo2)
64 Fo2=alpha*t/L2^2
65 //At Fo=2.44 and (1/Bi)=7.3...We read from graphs B
    =((To-Tinf)/(Ti-Tinf))plate2= 0.72
66 B=0.72;
67 //Therefore ((To-Tinf)/(Ti-Tinf))plate1*((To-Tinf)/(
    Ti-Tinf))plate2=A*B
68 T=A*B
69 disp("The calculated value is very close to the
    required value of 0.6.Hence the time required for
    the centre of the beam to reach 310 C is nearly
    1200s or 20 minutes.")

```

Scilab code Exa 4.11 A large slab of wrought iron

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 4, Example 11")
8 //A large slab wrought-iron is at a uniform
    temperature of Ti=550 C .
9 //The temperature of one surface is suddenly changed
    to Tinf=50 C
10 Tinf=50;
11 Ti=550;
12 //For slab conductivity (k=60W/(m*K)), Thermal

```

```

        diffusivity(alpha=1.6*10^-5m^2/s)
13 //To calculate the time(t) required for the
    temperature to reach T=255 C at a depth of 80mm
14 k=60;
15 T=255;
16 alpha=1.6^10-5;
17 //Similarity parameter, eta=x/(2*(alpha*t)^0.5)=(10/t
    ^0.5)
18 //((T-Tinf)/(Ti-Tinf))=erf(10/t^0.5)... where erf is
    the error function.
19 //Let ((T-Tinf)/(Ti-Tinf))=X
20 X=((T-Tinf)/(Ti-Tinf));
21 //This implies erf(10/t^0.5)=0.41
22 //We read from the table the value of eta(=10/t^0.5)
    =0.38.... corresponding to erf(eta)=0.41
23 //Therefore 10/t^0.5=0.38... this implies t=(10/0.38)
    ^2
24 disp("The time required for the temperature to reach
    255 C at a depth of 80mm, in minutes is")
25 t=(10/0.38)^2/60

```

Scilab code Exa 4.12 A large block of nickel steel

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 4, Example 12")
8 //A large block of nickel steel conductivity(k=20W/(
    m*K)), thermal diffusivity(alpha=0.518*10^-5 m^2/s)
    is at uniform temperature(Ti) of 30 C .
9 Ti=30;

```

```

10 k=20;
11 alpha=0.518*10^-5;
12 //One surface of the block is suddenly exposed to a
    constant surface heat flux(qo) of 6MW/m^2.
13 qo=6*10^6;//in W/m^2
14 //To determine the temperature at a depth(x) of 100mm
    after a time(t) of 100 seconds.
15 t=100;
16 x=0.1;//in metre
17 //Similarity parameter ,eta=x/(4*alpha*t)
18 eta=x/((4*alpha*t)^0.5)
19 //E is gaussian error function
20 disp("gaussian error function is" )
21 E=erf(eta)
22 //The equation to determine temperature is T-Ti=((2*
    qo(alpha*t/%pi)^0.5)/(k))*e^((-x^2)/(4*alpha*t))
    -((qo*x)/(k))*erf(x/(2*(alpha*t)^0.5))
23 //Above equation can also be written as T=Ti+((2*qo(
    alpha*t/%pi)^0.5)/(k))*e^((-x^2)/(4*alpha*t))-((
    qo*x)/(k))*erf(x/(2*(alpha*t)^0.5))
24 disp("The temperature at a depth(x) of 100mm after a
    time(t) of 100 seconds ,in C is")
25 T=Ti+((2*qo*(alpha*t/%pi)^0.5)/(k))*e^((-x^2)/(4*
    alpha*t))-((qo*x)/(k))*erfc(x/(2*(alpha*t)^0.5))
    //NOTE:The answer in the book is incorrect(
    Calculation mistake)

```

Scilab code Exa 4.13 A large iron plate

```

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

```



```

7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 13")
8 //Thermal diffusivity in m^2/s
9 alpha = 2*(10^(-5));
10 //Thickness in m
11 L = 0.6;
12 //Initial temperature in C
13 Ti = 20;
14 //Temperature raised in C
15 To = 580;
16 //Time in seconds
17 t = 25*60;
18 //Nodal distance Deltax in m
19 deltax = 0.1;
20 //Assigning fourier number to be 0.5 for stability
    criteria
21 Fon = 0.5;
22 //Calculating timestep deltaT in seconds
23 deltaT = ((Fon*deltax)*deltax)/alpha;
24 //Number of increment
25 n = t/deltaT;
26 //Considering insulated surface as centre of plate
27 //Taking a total of 7 nodes
28 //Temperature at node 1 in C
29 T(1,1) = 580;
30 //Temperature at all other nodes in C
31 //i is the looping parameter
32 for i = 2:7
33     T(1,i) = 20;
34 end;
35 //Substituting Fourier number,Fon=0.5 in Eq. 4.94,
    we have Eq. 4.104
36 //Calculating new temperature at all nodes
37 //k is the looping parameter for time
38 //Tnew is the new temperature in C
39 for k = 1:5
40     for i = 1:7
41         if i==1 then

```

```

42     Tnew(1,i) = T(1);
43     end;
44     %v02 = %f;   if i<7 then %v02 = i>1;end;
45     if %v02 then
46         Tnew = mtlb_i(Tnew,i,(T(i+1)+T(i-1))/2);
47     end;
48     if i==7 then
49         Tnew = mtlb_i(Tnew,i,(T(7)+T(6))/2);
50     end;
51 end;
52 //Assigning old temperatures value of new
    temperatures
53 for i = 1:7
54     T = mtlb_i(T,i,Tnew(i));
55 end;
56 end;
57 //Temperature change at node 7 because of symmetry
58 T = mtlb_i(T,7,T(6));
59 //Temperature change at other nodes because of
    change in temperature of node
60 //7
61 for i = 2:6
62     T = mtlb_i(T,i,(Tnew(i+1)+Tnew(i-1))/2);
63 end;
64 //Final temperature distribution after 25 mins
65 disp("Final temperature distribution in degree C
    after 25 mins")
66 T

```

Scilab code Exa 4.14 Fully implicit scheme

```

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

```

```

5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 4, Example 14")
8 //Nodal distance Deltax in m
9 deltax = 0.1;
10 //Time in seconds
11 t = 25*60;
12 //timestep deltaT in seconds
13 deltaT = 500;
14 //Number of increment
15 n = t/deltaT;
16 //Temperature raised in C
17 To = 580;
18 //Using Eq. 4.114 for interior grid points , table
      4.8 for exterior node
19 //Using Eq. 4.125a to 4.125f are written in matrix
      form
20 //Coefficient matrix A is
21 A = [-3,1,0,0,0,0;
22      1,-3,1,0,0,0;
23      0,1,-3,1,0,0;
24      0,0,1,-3,1,0;
25      0,0,0,1,-3,1;
26      0,0,0,0,2,-3];
27 //Coefficient matrix B is
28 B = [-600;
29      -20;
30      -20;
31      -20;
32      -20;
33      -20];
34 //Temperature matrix is transpose of [T2 T3 T4 T5 T6
      T7] where
35 //T2 to T7 are temperature in C
36 //From Eq. 4.126
37 //Temperature distribution after one time step
38 T = (A^(-1))*B;

```

```

39 //For second timestep , coefficient matrix B gets
    modeified as
40 B(1) = B(1)-T(1);
41 for i = 2:6
42     B = mtlb_i(B,i,-T(i));
43 end;
44 //Temperature distribution after second time step
45 T = (A^(-1))*B;
46 //For third timestep , coefficient matrix B gets
    modeified as
47 B = mtlb_i(B,1,-600-T(1));
48 for i = 2:6
49     B = mtlb_i(B,i,-T(i));
50 end;
51 //Temperature distribution after second time step
52 T = (A^(-1))*B;
53 //Final temperature distribution including face in
    C
54 //Face temperature in C
55 Tf(1,1) = To;
56 //Interior points temperature in C
57 //i is the looping parameter
58 for i = 2:7
59     Tf(1,i) = T(i-1);
60 end;
61 //Assigning final temperature to initial temperature
    matrix
62 for i = 1:7
63     T(i) = Tf(i);
64 end;
65 disp("Temperature distribution after 25 mins in C ")
    )
66 T

```

Chapter 5

Convection

Scilab code Exa 5.3 Flat plate with a free stream velocity

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 5, Example 3")
8 //Air at temprature (T1=20 C ) and 1 atmospheric
      pressure flows over a flat plate with a free
      stream velocity(Uinf) of 1m/s.
9 Uinf=1;
10 T1=20;
11 //The length of plate is 1m and is heated over its
      entire length to a constant temprature of T2=100
      C .
12 T2=100;
13 //For air at 20 C (The mean temprature of 100 C and
      20 C ), viscosity (mu=1.9*10^-5kg/(m*s)), density (
      rho=1.05kg/m^3), conductivity (k=0.03W/(m*K)),
      specific heat(cp=1.007kJ/(kg*K))
```

```

14 //Prandtl number is Pr=0.7
15 mu=1.9*10^-5;
16 rho=1.05;
17 k=0.03;
18 cp=1.007;
19 Pr=0.7;
20 //For laminar flow over a plate Nusselt number is
    Nux=0.332*Rex^0.5*Pr^(1/3)
21 //The boundary layer flow over a flat plate will be
    laminar if Reynolds number is Rex=(rho*Uinf*x)/mu
    <5*10^5
22 //First of all we have to check whether the flow is
    laminar or not.
23 //Let us check at x=1m
24 x=1;
25 disp("Reynolds number is")
26 ReL=(rho*Uinf*x)/mu
27 //There fore the flow is laminar and we can use the
    relationships of Nux,
28 //Thus Rex=(1.05*1*x)/(1.9*10^-5)=0.5526*10^5*x
29 //Therefore we can write Nux=(hx*x/k)
    =0.332*(0.5526*10^5*x)^0.5*Pr^(1/3) .... or hx
    =2.08*x^(-1/2) W/(m^2* C )
30 //hbarL is the average heat transfer coefficient
    over a length(L)
31 disp("The average heat transfer coefficient over a
    length(L)= 1m ,in W/m^2 is")
32 L=1;
33 hbarL=(1/L)*integrate("2.08*x^(-1/2)", 'x', 0, L)
34 //Q is the rate of heat transfer
35 disp("The rate of heat transfer in W/m of width is")
36 Q=hbarL*L*(T2-T1)

```

Scilab code Exa 5.4 Circuit board to cool the electronic elements

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 5, Example 4")
8 //Air at atmospheric pressure is required to flow
      over a circuit board to cool the electronics
      element mounted on it.
9 //Chip has length (L)=3mm and width(B)=3mm located x
      =0.1m from the leading edge
10 L=0.003;//in metre
11 B=0.003;//in metre
12 x=0.1;
13 //The Nusselt no. is given by  $Nux=0.06*Re_x^{0.85}*Pr^{0.33}$ 
14 //The chip has to dissipate E=50mW of energy while
      its surface temprature has to be kept below
      temprature , $T_s=45$  C and free strem Temprature of
      air is  $T_{inf}=25$  C
15  $T_s=45$ ;
16  $T_{inf}=25$ ;
17  $E=50*10^{-3}$ ;//in watt
18 //For air ,density( $\rho=1.2\text{kg}/\text{m}^3$ ),viscosity( $\mu$ 
      = $1.8*10^{-5}\text{kg}/(\text{m}\cdot\text{s})$ ),conductivity( $k=0.03\text{W}/(\text{m}\cdot\text{K})$ )
      and specific heat( $cp=1000\text{J}/(\text{kg}\cdot\text{K})$ )
19  $\rho=1.2$ ;
20  $\mu=1.8*10^{-5}$ ;
21  $k=0.03$ ;
22  $cp=1000$ ;
23 //Let the minimum flow velocity be U.
24 //The local heat transfer coefficient  $h_x$  where the
      chip is mounted is determined as  $h_x=(k/x)*0.06*($ 
       $\rho*U*x/\mu)^{0.85}*(\mu*cp/k)^{0.33}$ 
25 disp("The local heat transfer coefficient  $h_x$  is  $h_x$ 
      = $27.063*U^{0.85}$ ")

```

```

26 //from an enrgy balance we can write  $27.063*U^{0.85}*L$ 
     $*B*(Ts-Tinf)=E$ 
27 disp("The minimum flow velocity in m/s is")
28 U=[E/(27.063*L*B*(Ts-Tinf))]^(1/0.85)

```

Scilab code Exa 5.6 Air enters a tube

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 5, Example 6")
8 //Air at 1atm pressure and temprature(Tin)=30 C
    enters a tube of 25mm diameter(D) with a velocity
    (U) of 10m/s
9 D=0.025;//in metre
10 U=10;
11 Tin=30;
12 //Tube is heated so that a constant heat flux(q) of
    2kW/m^2 is maintained at the wall whose
    temprature is deltaT=20 C above the bulk mean
    air temprature through the length of tube
13 //Let Tw-Tb=T
14 q=2000;
15 deltaT=20;
16 //The length(L)= 2m
17 L=2;
18 //For air density(rho=1.2kg/m^3),specific heat(cp
    =1000J/(kg*K))
19 rho=1.2;
20 cp=1000;
21 //From an energy balance of a control volume of air

```



```

    we get  $\dot{m} \cdot c_p \cdot (T_b + (dT_b/dx) \cdot \Delta x - T_b) = q \cdot \pi \cdot D \cdot \Delta x$ 
    or  $(dT_b/dx) = (q \cdot \pi \cdot D) / (\dot{m} \cdot c_p)$ 
22 //mass flow rate= $\dot{m}$ 
23  $\dot{m} = \rho \cdot \pi \cdot D^2 \cdot U$ ;
24 //let  $(dT_b/dx) = Y$ 
25 disp(" (dTb/dx) in C /m is")
26  $Y = (4 \cdot q \cdot \pi \cdot D) / (\dot{m} \cdot c_p)$ 
27 //Tb2 is Exit bulk mean temperature
28 disp(" Therefore Exit bulk mean temprature Tb2 in C
    is")
29  $T_{b2} = T_{in} + Y \cdot 2$ 
30 //Again we can write at any section of the tube  $h_x \cdot (T_w - T_b) = q$ 
    or  $h_x = q / (T_w - T_b)$ 
31 //h_x is heat flux
32 disp(" Heat flux (h_x) in W/(m^2* C ) is ")
33  $h_x = q / (\Delta T)$ 
34 //Since  $T_w - T_b$  remains the same, The heat transfer
    coefficient at all sections are the same
35 //Now Overall Nusselt number,  $Nu_L = h_x \cdot D / k$ 
36 //The thermal conductivity of air at mean temperature
    of  $(30 + 83.4) / 2 = 56.7$  C is  $k = 0.0285$  W/(m*K)
37  $k = 0.0285$ ;
38 disp(" Overall Nusselt number is ")
39  $Nu_L = h_x \cdot D / k$ 

```

Scilab code Exa 5.7 Heat loss from a vertical wall

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp(" Introduction to heat transfer by S.K.Som,
    Chapter 5, Example 7")

```

```

8 //A wall is exposed to nitrogen at one atmospheric
   pressure and temprature ,Tinf=4 C .
9 Tinf=4;
10 //The wall is H=2.0m high and B=2.5m wide and is
   maintained at temprature ,Ts=56 C
11 Ts=56;
12 H=2;
13 B=2.5;
14 A=H*B;//area is (A)
15 //The average nusselt number NuHbar over the height
   of the plate is given by NuHbar=0.13*(Gr*Pr)
   ^(1/3)
16 //The properties of nitrogen at mean film temprature
   (Tf) is (56+4)/2=30 C are given as density(rho
   =1.142kg/m^3) ,conductivity(k=0.026W/(m*K)),
17 //kinematic viscosity(nu=15.630*10^-6 m^2/s) ,
   Prandtl number(Pr=0.713)
18 rho=1.142;
19 k=0.026;
20 nu=15.630*10^-6;
21 Pr=0.713;
22 Tf=30;
23 //We first have to detrmine the value of Grashoff
   number,Gr.In consideration of nitrogen as an
   ideal gas,we can write
24 //Beta(The volumetric coefficient of expansion)=1/T
25 disp("Beta(The volumetric coefficient of expansion
   in K^-1 is")
26 Beta=1/(273+Tf)
27 //Now Gr=(g*Beta*(Ts-Tinf)*H^3)/nu^2
28 g=9.81;//acceleration due to gravity
29 disp("Grashoff number is")
30 Gr=(g*Beta*(Ts-Tinf)*H^3)/nu^2
31 disp("The average nusselt number is")
32 NuHbar=0.13*(Gr*Pr)^(1/3)
33 //hbar is the heat flux
34 disp("Heat flux hbar in W/(m^2* C)")
35 hbar=NuHbar*k/H

```

```

36 //Q is the heat loss from the plate
37 disp("The heat loss from the plate in W is")
38 Q=hbar*A*(Ts-Tinf)

```

Scilab code Exa 5.8 Electric current passes through a long horizontal wire

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 5, Example 8")
8 //Electric current passes through a L=0.5m long
      horizontal wire of D=0.1mm diameter.
9 L=0.5;
10 D=0.1*10^-3;
11 //The wire is to be maintained at temprature ,Twire
      =400K and the air is at temprature ,Tair=300K.
12 Twire=400;
13 Tair=300;
14 //The resistance of the wire(R) is 0.012ohm per
      meter.Nusselt number(NuL) over the length of wire
      to be 0.4.
15 NuL=0.4;
16 R=0.012;
17 //At mean temprature of Tf=350K, The thermal
      conductivity of air is k=0.03W/(m*K)
18 k=0.03;
19 //Nusselt number is NuL=hbar*D/k
20 //hbar is the heat flux
21 disp("The heat flux in W/(m^2*K) is")
22 hbar=NuL*k/D
23 //Q is the heat loss from the wire

```

```
24 disp("The heat loss from the wire is  $Q=hbar*\pi*D*L*($   
     $Twire-Tair)$  in Watt")  
25 Q=hbar*%pi*D*L*(Twire-Tair)  
26 //At steady state the ohmic loss in the wire equals  
    the heat loss from its surface Therefore  $I^2*R=Q$   
27 //I is the current flow.  
28 disp("The current in Ampere is")  
29 I=(Q/(R*L))^0.5
```

Chapter 6

Incompressible viscous flow A brief review

Scilab code Exa 6.1 Oil flows between two fixed plates

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 6, Example 1")
8 //Oil of specific gravity 0.90 and dynamic viscosity
      (mu=0.1Pa*s) flows between two fixed plates kept
      2*b=10mm apart ,So b=5mm.
9 //The average velocity is Uav=1.60m/s
10 Uav=1.60;
11 mu=0.1;
12 b=0.005; // in metre
13 //Umax is maximum velocity
14 //Umax=(3/2)*Uav
15 disp("Umax in m/s is")
16 Umax=(3/2)*Uav
```

```

17 //The shear stress at the plate is given by  $T=2\mu \frac{U_{max}}{b}$  *(
     $U_{max}/b$ )
18 disp("The shear stress T in N/m^2")
19 T=2*mu*(Umax/b)
20 //The shear stress at a distance from plate is given
    by  $t=y*(dp/dx)$ 
21 // $(dp/dx)=-3\mu*(U_{av}/b^2)$ 
22 disp("(dp/dx) in N/m^3 is")
23 X=-3*mu*(Uav/b^2)
24 //Taking modulus of X by multiplying it with negative
    sign.
25 disp("The Shear stress at a distance of 0.002m from
    the lower plate in N/m^2")
26 y=b-0.002;
27 t=y*(X)//NOTE: Answer given in the book is incorrect
    (Calculation mistake)
28 disp("The shear stress at a distance of 0.002m from
    the upper plate in N/m^2")
29 t=-y*(X)//NOTE: Answer given in the book is incorrect
    (Calculation mistake)
30 disp("The opposite signs in t represents the
    opposite directions. The plus sign is in the
    direction of flow and the minus sign is in the
    direction opposite to the flow ")
31 //deltaP is the pressure drop
32 disp("The pressure drop over a distance of 2m in N/m
    ^2 is")
33 //Since pressure drop is considered at a distance of
    2m so L=2m
34 L=2;
35 deltaP=(-X)*L

```

Scilab code Exa 6.3 Oil is discharged under a pressure

```
1 // Display mode
```

```

2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 6, Example 3")
8 //Oil of specific gravity (sg)=0.90 is discharged at
      a rate(mdot)=3kg/s under a pressure difference
      dp=10kN/m^2 over a length dz=5m of a pipe having
      a diameter(D) of 50mm.
9 dp=10*10^3; //in N/m^2
10 dz=5;
11 D=0.05; //in metre
12 mdot=3;
13 sg=0.90;
14 //X=dp/dz is the rate of change of pressure
15 disp("The rate of change of pressure with respect to
      length in N/m^3")
16 X=dp/dz
17 //Flow rate is Q
18 disp("Flow rate(Q) in m^3/s is")
19 Q=mdot/(sg*10^3)
20 //The viscosity of oil is mu=(pi*D^4*X)/(128*Q*dz)
21 disp("The viscosity of oil(mu) in kg/(m*s)")
22 mu=(%pi*D^4*X)/(128*Q)

```

Scilab code Exa 6.7 A flat plate is kept parallel to a uniform stream

```

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

```

```

7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 6, Example 7")
8 //A flat plate B=1.2m wide and of length L is kept
      parallel to a uniform stream of air of velocity
      Uinf=3m/s in a wind tunnel.
9 Uinf=3;
10 B=1.2;
11 //If it is desired to have a laminar boundary layer
      only on the plate
12 //Assume that the laminar flow exists up to a
      reynold number(ReL)=5*10^5.Take density of air as
      rhoair=1.2kg/m^3 and viscosity of air as nuair
      =1.5*10^-5 m^2/s.
13 nuair=1.5*10^-5;
14 rhoair=1.2;
15 ReL=5*10^5;
16 //For maximum length of the plate reynolds number is
      ReL=Uinf*L/nuair
17 //so L=ReL*nuair/Uinf
18 disp("The maximum length of plate in m is ")
19 L=ReL*nuair/Uinf
20 //The average skin friction coefficient is cfL
      =1.328/(ReL)^(1/2)
21 disp("The average skin friction coefficient is")
22 cfL=1.328/(ReL)^(1/2)
23 //Fd is drag force
24 disp("Drag force on one side of plate in N is")
25 Fd=cfL*(rhoair*Uinf^2/2)*B*L

```

Scilab code Exa 6.10 Wind bows over a flat plate

```

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

```



```

5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 6, Example 10")
8 //Wind at a speed of U=36km/hr blows over a flat
      plate of length ,L=6m .If the density and
      kinematic viscosity of air are rho=1.2kg/m^3 and
      mu=1.5*10^-5m^2/s respectively .
9 U=36;
10 L=6;
11 rho=1.2;
12 mu=1.5*10^-5;
13 //Wind velocity in m/s is Uinf
14 disp("Wind velocity(Uinf)in m/s is")
15 Uinf=U*1000/3600
16 //Reynolds number is given by ReL=L*Uinf/mu
17 disp("Reynolds number is")
18 ReL=L*Uinf/mu
19 //We consider that transition of boundary layer
      takes place from laminar to turbulent takes place
      at ReL=5*10^5.
20 //Therefore the corresponding friction coefficient is
      given by CbarfL=(0.074-ReL^(1/5))-(1742/ReL)
21 disp("Friction coefficient is")
22 CbarfL=(0.074/ReL^(1/5))-(1742/ReL)
23 //Drag force on one side of the plate per unit metre
      width is given by FD=CbarfL*rho*Uinf^2*L/2
24 disp("Drag force on one side of the plate per unit
      metre width in Newton is ")
25 FD=CbarfL*rho*Uinf^2*L/2
26 //The turbulent boundary layer thickness at the
      trailing edge is given by delta=L*(0.379/ReL
      ^(1/5))
27 disp("The turbulent boundary layer thickness at the
      trailing edge in metre is ")
28 delta=L*(0.379/ReL^(1/5))

```

Chapter 7

Principles of forced convection

Scilab code Exa 7.1 Engine oil flows over a flat plate

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 7, Example 1")
8 //Engine oil at temperature, Tinf=60 C with a
      velocity of Uinf=1m/s flows over plate of length(
      L)=5m whose temperature(Tw)=30 C
9 Tw=30;
10 L=5;
11 Uinf=1;
12 Tinf=60;
13 //The properties at a film temperature of 45 C are
      as follows density(rho=870kg/m^3), Prandtl number(
      Pr=2850), conductivity(k=0.145W/(m* C)), kinematic
      viscosity(nu=250*10^-6m^2/s).
14 rho=870;
15 Pr=2850;
```

```

16 k=0.145;
17 nu=250*10^-6;
18 disp("First we check from reynolds no. that the flow
      is laminar or tubulent")
19 //Reynolds number is given by Re=(Uinf*L)/nu
20 disp("Reynold number is")
21 Re=(Uinf*L)/nu
22 disp("which is less than critical reynolds number,So
      the flow is laminar.")
23 //NuL is the average nusselt number
24 disp("The average nusselt number over the entire
      length under the situation is given by NuL=0.664*
      Re^0.5*Pr^(1/3)")
25 NuL=0.664*Re^0.5*Pr^(1/3)
26 //Heat flux is given by h=(k/L)*NuL
27 disp("Heat flux in W/(m^2*K) is")
28 h=(k/L)*NuL
29 //The rate of heat transfer per unit width is Q=h*A
      *(Tinf-Tw)
30 //Since unit width is considerd so B=1
31 //Area(A)=L*B
32 B=1;
33 A=L*B;
34 disp("The rate of heat transfer per unit width in W
      is")
35 Q=h*A*(Tinf-Tw)

```

Scilab code Exa 7.2 Atmospheric air flows over a flat plate

```

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

```

```

7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 7, Example 2")
8 //Atmospheric air at temprature ,Tinf=300K and with a
      free stream Velocity Uinf=30m/s flows over a
      flat plate parallel to a side of length(L)=2m.
9 Tinf=300;
10 Uinf=30;
11 L=2;
12 //It is maintained at a uniform temprature of Tw=400
      K.
13 Tw=400;
14 //The properties of air at the film temprature of
      350K are Prandtl number(Pr=0.705) ,conductivity(k
      =0.026W/(m* C ) ) ,kinematic viscosity(nu
      =16.5*10^-6m^2/s)
15 Pr=0.705;
16 k=0.026;
17 nu=16.5*10^-6;
18 //We first find the location x(for reynolds number ,
      Re=5*10^5) where the transition occurs
19 //Rex is reynolds number
20 disp("The location x in m where the transition
      occurs")
21 Rex=5*10^5;
22 x=(nu*Rex)/Uinf
23 //The average Nusselt number for the laminar zone is
      given by Nux=0.664*Re^0.5*Pr^(1/3)
24 disp("The average Nusselt number for the laminar
      zone is")
25 Nux=0.664*Rex^0.5*Pr^(1/3)
26 //Heat flux is given by h=(k/x)*Nux
27 disp("Heat flux in W/(m^2*K) is")
28 h=(k/x)*Nux
29 //Reynolds number is given by ReL=(Uinf*L)/nu
30 disp("The reynolds number at L=2m is")
31 ReL=(Uinf*L)/nu
32 //The average heat transfer coefficient over L=2m is
      determined from hbarL=(k/L)*[0.037*(ReL)^(4/5)

```

```

-871]*Pr^(1/3)
33 disp("The average heat transfer coefficient over L=2
    m in W/(m^2*K)")
34 hbarL=(k/L)*[0.037*(ReL)^(4/5)-871]*Pr^(1/3)
35 //The rate of heat transfer per unit width is Q=h*A
    *(Tinf-Tw)
36 //Since unit width is considered so B=1
37 //Area(A)=L*B
38 B=1;
39 A=L*B;
40 disp("The rate of heat transfer per unit width in W
    is")
41 Q=hbarL*A*(Tw-Tinf)

```

Scilab code Exa 7.3 Air flows over a flat plate whose temperature is constant

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 3")
8 //Air at a pressure of 101kPa and temperature, Tinf=20
    C flows with a velocity(Uinf) of 5m/s over a
    flat plate whose temperature is kept constant at
    Tw=140 C .
9 Tw=140;
10 Tinf=20;
11 Uinf=5;
12 //The properties at the film temperature of 80 C are
    Prandtl number(Pr=0.706), Conductivity(k=0.03W/(m
    * C)), kinematic viscosity(nu=2*10^-5m^2/s)
13 Pr=0.706;

```

```

14 k=0.03;
15 nu=2*10^-5;
16 //ReL is reynolds number and L is length of flat
    plate
17 disp("(a)When the air flows parallel to the long
    side we have L=5 and the Reynolds no. becomes")
18 L=5;
19 ReL=(Uinf*L)/nu
20 disp("which is greater than critical Reynolds number
    .")
21 //Thus we have combined laminar and tubulent flow.
22 // So The average heat transfer coefficient over L=5
    m is determined from hbarL=(k/L)*[0.037*(ReL)
    ^ (4/5) -871]*Pr^(1/3)
23 disp("The average heat transfer coefficient over L=5
    m in W/(m^2*K)")
24 hbarL=(k/L)*[0.037*(ReL)^(4/5)-871]*Pr^(1/3)
25 //The rate of heat transfer per unit width is Q=h*A
    *(Tinf-Tw)
26 //Since width is 1m so B=1
27 //Area(A)=L*B
28 B=1;
29 A=L*B;
30 //Q is the rate of heat transfer
31 disp("The rate of heat transfer per unit width in W
    is")
32 Q=hbarL*A*(Tw-Tinf)
33 //When the air flow is parallel to the 1m side we
    have L=1
34 disp("(b)When the air flow is parallel to the 1m
    side we have L=1 an the Reynolds no. becomes ")
35 L=1;
36 ReL=(Uinf*L)/nu
37 disp("which is less than critical Reynolds number.")
38 //Thus we have laminar flow
39 //Heat flux is given by h=(k/L)*0.664*ReL^0.5*Pr
    ^ (1/3)
40 disp("Heat flux in W/(m^2*K) is")

```

```

41 h=(k/L)*0.664*ReL^0.5*Pr^(1/3)
42 //The rate of heat transfer per unit width is Q=h*A
    *(Tinf-Tw)
43 //Now width is 5m so B=5
44 //Area(A)=L*B
45 B=5;
46 A=L*B;
47 //Q is the rate of heat transfer
48 disp("The rate of heat transfer per unit width in W
    is")
49 Q=h*A*(Tw-Tinf)

```

Scilab code Exa 7.4 Castor oil flows over a heated plate

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 4")
8 //Castor oil at temprature ,Tinf=36 C flows over a
    heated plate of length ,L=6m and breadth ,B=1m at
    velocity ,Uinf=0.06m/s
9 Tinf=36;
10 L=6;
11 B=1;
12 Uinf=0.06;
13 //For a surface temprature at Tw=96 C
14 Tw=96;
15 //The properties at film temprature 66 C
    conductivity(k=0.21W/(m*K)),kinematic viscosity(
    nu=6*10^-5m^2/s),Thermal diffusivity(alpha
    =7.22*10^-8 m^2/s)

```

```

16 nu=6*10^-5;
17 k=0.21;
18 alpha=7.22*10^-8;
19 //ReL is reynolds number
20 disp("(a) Reynolds number is")
21 ReL=(Uinf*L)/nu
22 //Therefore the boundary layer is laminar over the
    entire plate.
23 //delta is the boundary layer thickness
24 disp("The boundary layer thickness in m is")
25 delta=(5*L)/(ReL)^0.5
26 //Pr is prandtl number.
27 disp("Prandtl no. is")
28 Pr=nu/alpha
29 //deltaT is thermal boundary layer thickness
30 disp("The thermal boundary layer thickness in m is")
31 deltaT=delta/(Pr^(1/3))//NOTE: Answer in the book is
    incorrect(calculation mistake)
32 //NuL is the nusselt number
33 disp("(b) Since the prandtl number is high So Nusselt
    no. is")
34 NuL=0.339*(ReL)^0.5*Pr^(1/3)
35 //Heat flux is given by hL=(k/L)*NuL
36 disp("Heat flux in W/(m^2*K) is")
37 hL=(k/L)*NuL
38 //hbarL is the average heat flux over length L
39 disp("hbarL in W/(m^2*K) is")
40 hbarL=2*hL
41 //The rate of heat transfer is Q=h*A*(Tinf-Tw)
42 //Area(A)=L*B
43 A=L*B;
44 disp("(c) The rate of heat transfer in W is")
45 Q=hbarL*A*(Tw-Tinf)

```

Scilab code Exa 7.5 A flat plate is maintained at a uniform surface temperature


```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 7, Example 5")
8 //A flat plate of width B=1m is maintained at a
      uniform surface temptraure(Tw)=225 C
9 Tw=225;
10 B=1;
11 //Heating is done by rectangular modules of
      thickness t=10mm and length l=40mm.
12 t=10;
13 l=40;
14 //atmospheric air at temperature ,Tinf=25 C flows
      over the plate at velocity(Uinf)=30m/s.
15 Tinf=25;
16 Uinf=30;
17 //The thermophysical properties of module are
      conductivity(km=5.2W/(m*K)), specific heat(cp=320J
      /(kg/K)), density(rho=2300kg/m^3).
18 km=5.2;
19 cp=320;
20 rho=2300;
21 //Assume the air properties at the film temperature
      of 125 C conductivity(ka=0.031W/(m*K)), kinematic
      viscosity(nu=22*10^-6m^2/s), Prandtl number(Pr
      =0.7)
22 ka=0.031;
23 nu=22*10^-6;
24 Pr=0.7;
25 //Module is placed at a distance of 800mm from the
      leading edge
26 //The distance from leading edge to the centre-line
      of the module ,L=800+20=820mm.
27 L=0.82; //in metre

```

```

28 //ReL is the reynolds number
29 disp(" Reynolds number is")
30 ReL=(Uinf*L)/nu
31 disp(" Therefore the flow is turbulent over the
    module ")
32 //The local heat transfer coefficient at L is
    calculated using  $hL=(k/L)*0.0296*(ReL)^{(4/5)}*(Pr)^{(1/3)}$ 
33 disp("The local heat transfer coefficient at L in W
    /(m^2*K) is")
34 hL=(ka/L)*0.0296*(ReL)^(4/5)*(Pr)^(1/3)
35 //We consider that the local heat transfer
    coefficient at L=0.82m remains the same over the
    module which extends from L=0.80m to 0.84m
36 //If qm be the power generation in W/m^2 within the
    module ,we can write from energy balance  $qm*(t/1000)*(1/1000)*(B)=hbarL*(t/1000)*(B)*(Tw-Tinf)$ 
37 disp("The required power generation in W/m^3 is")
38 qm=(hL*(1/1000)*(B)*(Tw-Tinf))/((t/1000)*(1/1000)*(B
    ))

```

Scilab code Exa 7.6 Top surface of wing absorbs solar radiation

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 6")
8 //An aircraft is moving at a velocity of Uinf=150m/s
    in air at an altitude where the pressure is 0.7
    bar and the temprature is Tinf=-5 C .
9 Tinf=-5;

```

```

10 Uinf=150;
11 //The top surface of the wing absorbs solar
    radiation at a rate of  $Q_r=900\text{W/m}^2$ .
12  $Q_r=900$ ;
13 //Considering the wing as a flat plate of length(L)
    =2m and to be of solid construction with a single
    uniform surface temprature .
14  $L=2$ ;
15 //The properties of air at 268K and 0.7 bar are
    conductivity ( $k=0.024\text{W}/(\text{m}\cdot\text{K})$ ), kinematic viscosity ( $\nu=2\cdot 10^{-5}\text{m}^2/\text{s}$ ), Prandtl number ( $Pr=0.72$ )
16  $k=0.024$ ;
17  $\nu=2\cdot 10^{-5}$ ;
18  $Pr=0.72$ ;
19 //ReL is reynolds number
20 disp("Reynolds number is")
21  $ReL=Uinf\cdot L/\nu$ 
22 //Rec is critical reynolds number
23 disp("Since  $ReL>Rec(=5\cdot 10^5)$  the flow is
    approximated as turbulent over the entire surface
    of the wing ")
24 //Nusselt number is given by  $Nux=0.0308\cdot ReL^{(4/5)}\cdot Pr^{(1/3)}$ 
25  $Nux=0.0308\cdot ReL^{(4/5)}\cdot Pr^{(1/3)}$ ;
26 //NubarL is average nusselt number over length L
27 disp("Nusselt number is ")
28  $NubarL=(5/4)\cdot Nux$ 
29 //Average heat transfer coefficient is given by
     $hbarL=(k/L)\cdot NubarL$ 
30 disp("Average heat transfer coefficient in  $\text{W}/(\text{m}^2\cdot\text{K})$ 
    is")
31  $hbarL=(k/L)\cdot NubarL$ 
32 //From an energy balance the airfoil at steady state
    ,  $Q_r\cdot A_s=2\cdot hbarL\cdot A_s\cdot (T_w-T_{inf})$  where  $Q_r$ =radiation
    flux ,  $A_s$ =upper or lower surface area.
33 //Therefore we can write Surface temprature of wing,
     $T_w=T_{inf}+(Q_r/(2\cdot hbarL))$ 
34 disp("Surface temprature of wing in kelvin is")

```

```
35 Tw=(273+Tinf)+(Qr/(2*hbarL))
```

Scilab code Exa 7.7 Fine wire is placed in air stream

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 7, Example 7")
8 //A fine wire having a diameter(D)=0.04mm is placed
      in an air stream at temperature ,Tinf=25 C having
      a flow velocity of Uinf=60m/s perpendicular to
      wire.
9 D=0.04;
10 Tinf=25;
11 Uinf=60;
12 //An electric current is passed through the wire ,
      raising its surface temprature to Tw=50 C
13 Tw=50;
14 //For air at the film temprature of 37.5 C ,
      conductivity(k=0.027 W/(m*K)),kinematic viscosity
      (nu=17*10^-6m^2/s) and Prandtl number(Pr=0.71)
15 k=0.027;
16 nu=17*10^-6;
17 Pr=0.71;
18 //Re is reynolds number
19 disp("Reynolds number is")
20 Re=Uinf*(D*10^-3)/nu
21 //C and n are constants
22 //The values of C and n are found for Re=141 are C
      =0.683 and n=0.466
23 //NuD is nusselt number
```

```

24 disp(" Nusselt number is")
25 NuD=(0.683)*Re^0.466*Pr^(1/3)
26 //hbar is the average Heat transfer coefficient
27 disp("The average Heat transfer coefficient in W/(m
    ^2*K) is")
28 hbar=(k/(D*10^-3))*NuD
29 //Heat transfer per unit length(qL) is given by pi*D
    *hbar*(Tw-Tinf)
30 disp("Heat transfer per unit length in W/m is")
31 qL=%pi*(D*10^-3)*hbar*(Tw-Tinf)
32 //NuD is nusselt number
33 disp(" If we use eq NuD=0.3+[(0.62*Re^0.5*Pr^(1/3))
    /(1+(0.4/Pr^(2/3))^(1/4)]*[1+(Re/282000)^(5/8)
    ]^(4/5)")
34 NuD=0.3+[(0.62*Re^0.5*Pr^(1/3))/(1+(0.4/Pr)^(2/3))
    ^^(1/4)]*[1+(Re/282000)^(5/8)]^(4/5)
35 //hbar is the average Heat transfer coefficient
36 disp("The average Heat transfer coefficient in W/(m
    ^2*K) is")
37 hbar=(k/(D*10^-3))*NuD
38 //Heat transfer per unit length(qL) is given by pi*D
    *hbar*(Tw-Tinf)
39 disp("Heat transfer per unit length in W/m is")
40 qL=%pi*(D*10^-3)*hbar*(Tw-Tinf)

```

Scilab code Exa 7.8 Hydrodynamic and thermal entry length

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 8")

```

```

8 //Mercury and a light oil flowing at Uinf=4mm/s in a
   smooth tube having diameter(D)=25mm at a bulk
   temprature of 80 C .
9 Uinf=4*10^-3;//in metre
10 D=25*10^-3;//in metre
11 //The pertinent properties of the fluid at that
   temprature are kinematic viscosity of mercury(
   nuHg=1*10^-7m^2/s),kinematic viscosity of oil(
   nuoil=6.5*10^-6m^2/s)
12 //Prandtl number of mercury(PrHg=0.019),Prandtl
   number of oil(Proil=85).
13 nuHg=1*10^-7;
14 nuoil=6.5*10^-6;
15 PrHg=0.019;
16 Proil=85;
17 //ReHg is Reynolds number for mercury
18 disp("Reynolds number for mercury is")
19 ReHg=Uinf*D/nuHg
20 //Reoil is Reynolds number for oil
21 disp("Reynolds number for oil is")
22 Reoil=Uinf*D/nuoil
23 //The hydrodynamic length are given by L=0.05*Re*D
24 //LeHg is the hydrodynamic entry length for mercury
25 disp("The hydrodynamic entry length for mercury in m
   is")
26 LeHg=0.05*ReHg*D
27 //Leoil the hydrodynamic entry length for oil
28 disp("The hydrodynamic entry length for oil in m is"
   )
29 Leoil=0.05*Reoil*D
30 //The thermal entry length are given by L=0.05*Re*Pr
   *D
31 //LtHg is the thermal entry length for mercury
32 disp("The thermal entry length for mercury in m is "
   )
33 LtHg=0.05*ReHg*PrHg*D
34 //Ltoil is the thermal entry length for oil
35 disp("The thermal entry length for oil in m is")

```

36 $L_{toil} = 0.05 * Re_{oil} * Pr_{oil} * D$

Scilab code Exa 7.9 Air at one atmospheric pressure

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 7, Example 9")
8 //Air at one atmospheric pressure and temprature(Tbi
      =75 C ) enters a tube of internal diameter(D)=4.0
      mm with average velocity(U)=2m/s
9 Tbi=75;
10 D=4*10^-3;//in metre
11 U=2;
12 //The tube length is L=1.0m and a constant heat flux
      is imposed by the tube surface on the air over
      the entire length.
13 L=1;
14 //An exit bulk mean temprature(Tbo)=125 C is
      required.
15 Tbo=125;
16 //The properties of air 100 C are density(rho=0.95
      kg/m^3),Prandtl number(Pr=0.70),conductivity(k
      =0.03W/(m*K)),viscosity(mu=2.18*10^-5kg/(m*s)),
      specific heat(cp=1.01kJ/(kg/K))
17 rho=0.95;
18 Pr=0.70;
19 k=0.03;
20 mu=2.18*10^-5;
21 cp=1.01*10^3;
22 //Re is reynolds number
```

```

23 disp("Reynold number is")
24 Re=rho*U*D/mu
25 //Leh is the hydrodynamic entrance length
26 disp("Therefore the flow is laminar.The hydrodynamic
    entrance length in m is")
27 Leh=0.05*Re*D
28 //Let is the thermal entrance length
29 disp("The thermal entrance length in m is")
30 Let=0.05*Re*Pr*D
31 //The length of tube is given as 1m.A reasonable
    approach is to consider the flow to be fully
    developed for both velocity and tempratures over
    the entire profile lengths.
32 //For a fully developed flow with constant surface
    heat flux ,Nusselt number is Nu=4.36
33 Nu=4.36;
34 //h is the heat transfer coefficient
35 disp("The heat transfer coefficient in W/(m^2*K) is
    ")
36 h=Nu*(k/D)
37 //Here h=hL Since the heat transfer coefficient is
    constant over the entire length of tube.
38 //hL is the local heat transfer coefficient
39 hL=h;
40 //from an energy balance qw*pi*D*L=mdot*cp*(Tbo-Tbi)
41 //mdot is mass flow rate
42 disp("The mass flow rate of air in kg/s is")
43 mdot=rho*(%pi/4)*D^2*U
44 //qw is the constant surface heat flux
45 disp("Therefore the constant surface heat flux qw in
    W/m^2 is")
46 qw=[mdot*cp*(Tbo-Tbi)]/(%pi*D*L)
47 //Let Twe be the surface temprature at the exit
    plane.Then we can write hL*(Twe-Tbo)=qw
48 disp("The tube surface temprature at the exit plane
    in C is ")
49 Twe=Tbo+(qw/hL)

```

Scilab code Exa 7.10 The tube heated length

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 7, Example 10")
8 //Air at one atmospheric pressure and temprature(Tbi
      =75 C ) enters a tube of internal diameter(D)=4.0
      mm with average velocity (U)=2m/s
9 Tbi=75;
10 D=4*10^-3;
11 U=2;
12 //The heated tube length is L=0.04m and a constant
      heat flux is imposed by the tube surface on the
      air over the entire length.
13 L=0.04;
14 //An exit bulk mean temprature(Tbo)=125 C is
      required.
15 Tbo=125;
16 //The properties of air 100 C are density(rho=0.95
      kg/m^3), Prandtl number(Pr=0.70), conductivity(k
      =0.03W/(m*K)), viscosity (mu=2.18*10^-5kg/(m*s)),
      specific heat(cp=1.01kJ/(kg/K))
17 rho=0.95;
18 Pr=0.70;
19 k=0.03;
20 mu=2.18*10^-5;
21 cp=1.01*10^3;
22 //Re is the reynolds number
23 disp("Reynold number is")
```

```

24 Re=rho*U*D/mu
25 //Leh is the hydrodynamic entrance length
26 disp("Therefore the flow is laminar.The hydrodynamic
        entrance length in m is")
27 Leh=0.05*Re*D
28 //Let is thermal entrance length
29 disp("The thermal entrance length in m is")
30 Let=0.05*Re*Pr*D
31 disp("The thermal entrance length is greater than
        the tube length Therefore the flow is
        hydrodynamically developed but not thermally
        developed" )
32 //We calculate the inverse graetz number at x=L=0.04
        m
33 x=0.04;
34 //Gr_1 is inverse of graetz number
35 disp("The inverse of graetz number Gr_1 is")
36 Gr_1=(x/D)*(1/(Re*Pr))
37 //For constant surface heat flux nusselt number is
        Nu=4.7 and Graetz number is Gr=4.1*10^-2
38 Nu=4.7;
39 Gr=4.1*10^-2;
40 //hL is the local heat transfer coefficient
41 disp("Therefore the local heat transfer coefficient
        in W/(m^2*K) is")
42 hL=Nu*(k/D)
43 //from an energy balance qw*pi*D*L=mdot*cp*(Tbo-Tbi)
44 //mdot is the mass flow rate
45 disp("The mass flow rate of air in kg/s is")
46 mdot=rho*(%pi/4)*D^2*U
47 //qw is the surface heat flux
48 disp("Therefore surafce heat flux qw in W/m^2 is")
49 qw=[mdot*cp*(Tbo-Tbi)]/(%pi*D*L)
50 //Let Twe be the surface temprature at the exit
        plane.Then we can write hL*(Twe-Tbo)=qw
51 disp("The tube surface temprature at the exit plane
        in C is ")
52 Twe=Tbo+(qw/hL)

```

Scilab code Exa 7.11 Liquid sulphur dioxide

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 7, Example 11")
8 //Liquid sulphur di oxide in a saturated state flows
      inside a L=5m long tube and D=25mm internal
      diameter with a mass flow rate(mdot) of 0.15 kg/s
      .
9 //The tube is heated at a constant surface
      temprature(Tw) of -10 C and the inlet fluid
      temprature is Tbi=-40 C
10 Tw=-10;
11 Tbi=-40;
12 mdot=0.15;
13 D=0.025;//in metre
14 L=5;
15 //The properties to be used shoud be estimated at a
      temprature which is arithmetic mean of Tbi and
      Tbo.
16 //Since (outlet fluid temprature Tbo) is not known a
      priori ,the solution has to be based on an
      iterative method starting with a guess value of
      Tb1=(Tbi+Tbo)/2
17 //Here we denote bulk mean temprature as Tb.The
      superscript refers to the no. of trials
18 //For first trial ,guess Tbo1=-20 C ;so Tb1=-30 C
19 //We have the property values as follows at a
      temprature of -30 C .
```

```

20 rhob1=1520.64; //density in kg/m^3
21 nub1=0.371*10^-6; //kinematic viscosity in m^2/s
22 kb1=0.23; //conductivity in W/(m* C )
23 Prb1=3.31; //Prandtl number
24 mub1=nub1*rhob1; //viscosity in kg/(m*s)
25 cpb1=1361.6; //specific heat in J/(kg*K)
26 //muw=nuw*rhow at Tw=10 C
27 nuw=0.288*10^-6; //kinematic viscosity at Tw in m^2/s
28 rhow=1463.61; //density at Tw in kg/m^3
29 muw=nuw*rhow; //viscosity at Tw in kg/(m*s)
30 //The reynolds number is found as Re1=(4*mdot)/(%pi*
    D*mub1)
31 disp("Reynold number is")
32 Re1=(4*mdot)/(%pi*D*mub1)
33 //Hence the flow is turbulent
34 //Now using equation , nusselt number is ,Nubar1
    =0.027*(Re1)^0.8*Prb1^(1/3)*(mub1/muw)^0.14
35 disp("Nusselt number is")
36 Nubar1=0.027*(Re1)^0.8*Prb1^(1/3)*(mub1/muw)^0.14
37 //The heat transfer transfer coefficient hbar1=(kb1/
    D)*Nubar1
38 disp("The heat transfer transfer coefficient in W/(m
    ^2* C ) ")
39 hbar1=(kb1/D)*Nubar1
40 //The outlet fluid temperature can be found by making
    use of eqn Tbo2=Tw-(Tw-Tbi)*%e((- %pi*D*L*hbar1)
    /(mdot*cpb1))
41 disp("Outlet fluid temprature in first iteration is
    Tbo2 in C is")
42 Tbo2=Tw-(Tw-Tbi)*%e^((- %pi*D*L*hbar1)/(mdot*cpb1))
43 //Tb2 is the bulk mean temprature.
44 disp("Tb2 in C is")
45 Tb2=(Tbi+Tbo2)/2
46 //Since the value differs from the assumed value of
    Tb1=-30 C ,WE require further iteration , Therefore
    we start second trial with Tb2=-28.36 C
47 //We have the property value at a temprature of
    -28.36 C as follows

```

```

48 rhob2=1514; //density in kg/m^3
49 nub2=0.362*10^-6; //kinematic viscosity in m^2/s
50 kb2=0.229; //conductivity in W/(m* C )
51 Prb2=3.23; //Prandtl number
52 mub2=nub2*rhob2; //viscosity in kg/(m*s)
53 cpb2=1362; //specific heat in J/(kg*K)
54 //muw=nuw*rhow at Tw=10 C
55 nuw=0.288*10^-6; //viscosity at Tw in m^2/s
56 rhow=1463.61; //density at Tw in kg/m^3
57 muw=nuw*rhow; //kinematic viscosity at Tw in kg/(m*s)
58 //The reynolds number is found as Re2=(4*mdot)/(%pi*
    D*mub2)
59 disp("Reynold number is")
60 Re2=(4*mdot)/(%pi*D*mub2)
61 //Now using equation, nusselt number is ,Nubar2
    =0.027*(Re2)^0.8*Prb2^(1/3)*(mub2/muw)^0.14
62 disp("Nusselt number is")
63 Nubar2=0.027*(Re2)^0.8*Prb2^(1/3)*(mub2/muw)^0.14
64 //The heat transfer transfer coefficient hbar2=(kb2/
    D)*Nubar2
65 disp("The heat transfer transfer coefficient in W/(m
    ^2* C ) ")
66 hbar2=(kb2/D)*Nubar2
67 //The outlet fluid temprature can be found by making
    use of eqn Tbo3=Tw-(Tw-Tbi)*%e((- %pi*D*L*hbar2)
    /(mdot*cpb2))
68 disp("Outlet fluid temprature in second iteration is
    Tbo3 in C is")
69 Tbo3=Tw-(Tw-Tbi)*%e^((- %pi*D*L*hbar2)/(mdot*cpb2))
70 //Tb3 is the bulk mean temprature.
71 disp("Tb3 in C is")
72 Tb3=(Tbi+Tbo3)/2
73 //We see that difference between Tbo2 and Tbo3 and
    that between Tb2 and Tb3 is marginal. Therefore we
    can stop iteration and present the result as Tbo
    =-16.67 C
74 disp("The Exit fluid temprature after second
    iteration is obtained as Tbo=-16.67 C ")

```


Chapter 8

Principles of free convection

Scilab code Exa 8.1 Water is heated by a vertical plate

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 8, Example 1")
8 //Water is heated by a vertical flat plate length(L
      =200mm or .2m )by breadth(B=200mm) which is
      maintained at temprature ,Tw=60 C
9 Tw=60;
10 L=.2;
11 B=.2; // in metre
12 //Area(A) is L*B
13 A=L*B;
14 //Water is at temprature ,Tinf=20 C
15 Tinf=20;
16 //At mean film temprature 40 C The physical
      properties parameters can be taken as
17 //conductivity(k=0.0628W/(m*K)) ,Prandtl number(Pr
```

```

    =4.34) , density (rho=994.59 kg/m^3) , kinematic
    viscosity (nu=0.658*10^-6 m^2/s) , volume expansion
    coefficient (Beta=3*10^-4 K^-1)
18 k=0.628;
19 Pr=4.34;
20 rho=994.59;
21 nu=0.658*10^-6;
22 Beta=3*10^-4;
23 //g is acceleration due to gravity =9.81m/s^2
24 g=9.81;
25 //Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*
    L^3)/(nu)^2
26 disp("Grashoff number is")
27 GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
28 //Rayleigh number is defined as RaL=GrL*Pr
29 disp("Rayleigh number is")
30 RaL=GrL*Pr
31 disp("Therefore the flow is turbulent")
32 disp("Now we use [(hbarL*L)/k]=0.10*(GrL*Pr)^(1/3)")
33 //hbarL is the average heat transfer coefficient
34 disp("The average heat transfer coefficient in W/(m
    ^2*K) is")
35 hbarL=(0.10*(GrL*Pr)^(1/3)*k)/L
36 //The rate of heat transfer is given by q=hbarL*A*(
    Tw-Tinf)
37 disp("The rate of heat transfer in W is")
38 q=hbarL*A*(Tw-Tinf)

```

Scilab code Exa 8.2 Thin plates to be cooled

```

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

```



```

6  clc;
7  disp("Introduction to heat transfer by S.K.Som,
      Chapter 8, Example 2")
8  //The thin plates are kept at temprature(Tw)=60 C
      while the temprature of water bath(Tinf)=20 C
9  Tw=60;
10 Tinf=20;
11 //The plates have length(L)=90mm or .09m
12 L=.09;
13 //The minimum spacing between the plates will be
      twice the thickness of the boundary layer at the
      trailing edge where x=0.09.
14 disp("The minimum spacing between the plates will be
      twice the thickness of the boundary layer at the
      trailing edge where x=0.09")
15 x=.09;
16 //At mean film temprature 40 C The physical
      properties parameters can be taken as
17 // conductivity(k=0.0628W/(m*K)), Prandtl number(Pr
      =4.34), Density(rho=994.59 kg/m^3), kinematic
      viscosity(nu=0.658*10^-6m^2/s), Volume expansion
      coefficient(Beta=3*10^-4K^-1)
18 k=0.628;
19 Pr=4.34;
20 rho=994.59;
21 nu=0.658*10^-6;
22 Beta=3*10^-4;
23 //g is acceleration due to gravity =9.81m/s^2
24 g=9.81;
25 //Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*
      L^3)/(nu)^2
26 disp("Grashoff number is")
27 GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
28 //Rayleigh number is defined as RaL=GrL*Pr
29 disp("Rayleigh number is")
30 RaL=GrL*Pr
31 disp("Since Ra<10^9, Therefore the flow is laminar")
32 //delta is the thickness of the boundary layer

```

```

33 disp("The thickness of the boundary layer in metre
      is")
34 delta=x*3.93*Pr^(-1/2)*(0.952+Pr)^(1/4)*GrL^(-1/4)
35 //spac is the minimum spacing
36 disp("The minimum spacing in metre is")
37 spac=2*delta

```

Scilab code Exa 8.3 Maximum velocity in the boundary layer

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 8, Example 3")
8 //Considering question 5.7
9 //A wall is exposed to nitrogen at one atmospheric
      pressure and temprature ,Tinf=4 C .
10 Tinf=4;
11 //The wall is H=2.0m high and 2.5m wide and is
      maintained at temprature ,Tw=56 C
12 Tw=56;
13 H=2;
14 B=2.5;
15 A=H*B;//Area of wall in m^2
16 //The properties of nitrogen at mean film temprature
      (56+4)/2=30 C are given as
17 //density(rho=1.142kg/m^3) ,conductivity(k=0.026W/(m
      *K) ),kinematic viscosity(nu=15.630*10^-6 m^2/s) ,
      prandtl number(Pr=0.713)
18 rho=1.142;
19 k=0.026;
20 nu=15.630*10^-6;

```

```

21 Pr=0.713;
22 Tf=30; //mean film temprature
23 Beta=1/(273+Tf); //volume expansion coefficient:unit
    K-1
24 //Now Grashoff number is Grx=(g*Beta*(Tw-Tinf)*x^3)/
    nu^2
25 g=9.81; //acceleration due to gravity
26 disp("Grashoff number is")
27 x=0.8; //distance from the bottom of wall
28 Grx=(g*Beta*(Tw-Tinf)*x^3)/nu^2
29 //Using equation delta=x*Pr^(-0.5)*(0.952+Pr)^(0.25)
    *Grx^(-0.25)
30 //delta is the boundary layer thickness
31 disp("The boundary layer thickness in metre is")
32 delta=x*3.93*Pr^(-0.5)*(0.952+Pr)^(0.25)*Grx^(-0.25)
33 //Now using equation ux=(g*Beta*delta^2*(Tw-Tinf))
    /(4*nu)
34 //ux is the velocity at point x
35 disp("The velocity at point x is ux in m/s is")
36 ux=(g*Beta*delta^2*(Tw-Tinf))/(4*nu)
37 // (u/ux)=(y/delta)*(1-y/delta)^2
38 //Putting value of ux we get velovity function ,u
    =465.9*(y-116*y^2+3341*y^3)
39 //For maximum value of u,du/dy=465.9*(1-232*y+10023*
    y^2)=0...this is a quadratic equation in which
    coefficients a=10023,b=232,c=1
40 a=10023;
41 b=232;
42 c=1;
43 //Solution for quadratic equation is given by y=(-b
    +-(b^2-4ac)^0.5)/2*a
44 disp("For maximum value of velocity ,u")
45 y=(b+(b^2-4*a*c)^0.5)/(2*a) //root of the quadratic
    equation
46 y=(b-(b^2-4*a*c)^0.5)/(2*a) //root of the quadratic
    equation
47 //The value of 0.0173 is at the edge of boundary
    layer ,where u=0

```

```

48 //Therefore the maximum value occurs at y=0.00573m i
    .e Umax=465.9*y*(1-57.8*y)^2
49 y=0.00573;
50 //Umax is maximum velocity
51 disp("Maximum velocity in m/s is")
52 Umax=465.9*y*(1-57.8*y)^2//NOTE:The answer given in
    the book is incorrect,in this expresssion they
    considered square on y only,however it is on
    whole expression (1-57.8*y)^2
53 //mdot is mass flow rate
54 disp("Mass flow rate at x=0.8m,in kG is")
55 mdot=rho*B*integrate(" 465.9*(y-116*y^2+3341*y^3)", 'y
    ',0,delta)

```

Scilab code Exa 8.4 Square plate suspended vertically

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 8, Example 4")
8 //A square plate length ,L=0.2m by breadth ,B=0.2m is
    suspended vertically in a quiescent atmospheric
    air at a temprature(Tinf)=300K
9 L=0.2;
10 B=0.2;
11 Tinf=300;
12 //The Temprature of plate(Tw) is maintained at 400K
13 Tw=400;
14 //The required property value of air at a film
    temprature(Tf)=350K,kinematic viscosity (nu
    =20.75*10^-6),Prandtl number(Pr=0.69),

```

```

        conductivity(k=0.03W/(m*K))
15 Tf=350;
16 nu=20.75*10^-6;
17 Pr=0.69;
18 k=0.03;
19 //volume expansion coefficient is Beta
20 Beta=(1/Tf);
21 //g is acceleration due to gravity =9.81m/s^2
22 g=9.81;
23 //Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*
    L^3)/(nu)^2
24 disp("Grashoff number is")
25 GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
26 //Rayleigh number is defined as RaL=GrL*Pr
27 disp("Rayleigh number is")
28 RaL=GrL*Pr
29 disp("Hence, the flow is laminar")
30 //delta is the thickness of the boundary layer
31 disp("The thickness of the boundary layer in metre
    is")
32 x=0.2; //location of trailing edge of plate
33 delta=[x*3.93*(0.952+Pr)^(1/4)]/[Pr^(1/2)*(GrL)
    ^(1/4)]//NOTE:The answer in the book is incorrect
    (calculation mistake)
34 //hL and hbarL are local and average heat transfer
    coefficient respectively
35 disp("The average heat transfer coefficient in W/(m
    ^2*K) is")
36 hL=(2*k)/delta;
37 hbarL=(4/3)*(hL)//NOTE:The answer in the book is
    incorrect(calculation mistake)

```

Scilab code Exa 8.5 Square plate in a room

```
1 // Display mode
```

```

2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 8, Example 5")
8 //A square plate of length(L)=0.5m by breadth ,B=0.5m
      in a room at temperature ,Tinf=30 C
9 //One side of plate is kept a uniform temprature(Tw)
      =74 C
10 Tw=74;
11 L=0.5;
12 B=0.5;
13 Tinf=30;
14 //The required properties at the film temprature(Tf)
      =52 C are kinematic viscosity(nu=1.815*10^-5),
      Prandtl number(Pr=0.71),conductivity(k=0.028W/(m*
      C ))
15 Tf=52;
16 Pr=0.71;
17 nu=1.815*10^-5;
18 k=0.028;
19 //Area(A)=L*B m^2
20 A=L*B;
21 //Volume expansion coefficient is Beta
22 Beta=1/(273+Tf);
23 //g is acceleration due to gravity =9.81m/s^2
24 g=9.81;
25 //Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*
      L^3)/(nu)^2
26 disp("Grashoff number is")
27 GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
28 //Rayleigh number is defined as RaL1=GrL*Pr
29 disp("Rayleigh number is")
30 RaL1=GrL*Pr
31 disp("Therefore the flow is laminar")
32 //We make use of following equation to find Nusselt

```

```

        number ,NuL1=(4/3)*[0.508*Pr^(-1/2)*(0.952+Pr)
        ^(-1/4)*Gr^(1/4)]
33 disp("Nusselt number is")
34 NuL1=(4/3)*[0.508*Pr^(1/2)*(0.952+Pr)^(-1/4)*GrL
        ^(-1/4)]
35 //Average heat transfer coefficient(hbarL) is given
        by (NuL*k)/L
36 disp("Average heat transfer coefficient(hbarL)in W/(
        m^2* C)")
37 hbarL=(NuL1*k)/L
38 //The rate of heat transfer(Q) from the plate by
        free convection is given by Q=hbarL*A*(Tw-Tinf)
39 disp("The rate of heat transfer in W is ")
40 Q=hbarL*A*(Tw-Tinf)
41 disp("Now if we use NuL2=0.59*RaL^(1/4) with the
        value of C=0.59,n=(1/4)")
42 disp("Nusselt number is")
43 NuL2=0.59*RaL1^(1/4)
44 //Average heat transfer coefficient(hbarL) is given
        by (NuL*k)/L
45 disp("Average heat transfer coefficient(hbarL)in W/(
        m^2* C)")
46 hbarL=(NuL2*k)/L
47 //The rate of heat transfer(Q) from the plate by
        free convection is given by Q=hbarL*A*(Tw-Tinf)
48 disp("The rate of heat transfer in W is ")
49 Q=hbarL*A*(Tw-Tinf)
50 disp("(b)For the horizontal plate facing up")
51 //Perimeter(P) for a square plate is P=4*L
52 P=4*L;
53 //Characterstic length(Lc)=A/P
54 Lc=A/P
55 disp("Now RaL2=Gr*Pr*(Lc/L)^3")
56 disp("Rayleigh number is")
57 RaL2=GrL*Pr*(Lc/L)^3
58 //The values of constants ,C=0.54 and n=(1/4)
59 C=0.54;
60 n=(1/4);

```

```

61 disp(" Nusselt number is given by NuL3=C*(GrL*Pr)^n")
62 NuL3=C*(RaL2)^n
63 disp(" Average heat transfer coefficient (hbarL) in W/(
        m^2* C )")
64 hbarL=(NuL3*k)/Lc
65 disp("The rate of heat transfer in W is ")
66 Q=hbarL*A*(Tw-Tinf)
67 disp("(c)When the hot surface faces is down")
68 disp(" Nusselt number is given by NuL4=0.27*RaL2
        ^(1/4)")
69 NuL4=0.27*RaL2^(1/4)
70 disp(" Average heat transfer coefficient (hbarL) in W
        /(m^2)")
71 hbarL=(NuL4*k)/Lc
72 disp("The rate of heat transfer in W is ")
73 Q=hbarL*A*(Tw-Tinf)

```

Scilab code Exa 8.6 Long vertical wire in atmosphere

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
        Chapter 8, Example 6")
8 //A vertical wire of length(L)=0.5m and Dimeter(D)
        =0.1mm is maintained at temprature, Tw=400K
9 //The temprature of quicsent air is Tinf=300K
10 //Resistance(R) per meter length is 0.12ohm
11 R=0.12;
12 Tw=400;
13 L=0.5;
14 D=0.1*10^-3; //in metre

```



```

15 Tinf=300;
16 //The required properties at the film temprature(Tf)
    =350K are kinematic viscosity (nu=20.75*10^-6m^2/s
    ),Prandtl number(Pr=0.70),conductivity(k=0.03W/(m
    * C ))
17 Tf=350;
18 Pr=0.70;
19 nu=20.75*10^-6;
20 k=0.03;
21 //Area(A)=L*B m^2
22 A=%pi*D*L;
23 //Volume expansion Coefficient is Beta
24 Beta=1/(Tf);
25 //g is acceleration due to gravity =9.81m/s^2
26 g=9.81;
27 //Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*
    L^3)/(nu)^2
28 disp("Grashoff number is")
29 GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
30 //Rayleigh number is defined as RaL=GrL*Pr
31 disp("Rayleigh number is")
32 RaL=GrL*Pr
33 disp("Therefore the flow is laminar")
34 //NuL is nusselt number
35 //C and n are constants
36 disp("Now we use NuL=0.59*RaL^(1/4) with the value
    of constants C=0.59,n=(1/4)")
37 disp("Nusselt number is")
38 NuL=0.59*RaL^(1/4)
39 //hbarL1 is the Average heat transfer coefficient
40 disp("Average heat transfer coefficient in W/(m^2*K)
    ")
41 hbarL1=(NuL*k)/L
42 //Grashoff number GrD=GrL*(D/L)^3
43 disp("Grashoff number GrD=GrL*(D/L)^3")
44 GrD=GrL*(D/L)^3
45 //Thr correction factor is given By F=1.3*[(L/D)/GrD
    ]^(1/4)+1.0

```

```

46 disp("Thr correction factor is")
47 F=1.3*[(L/D)/GrD]^(1/4)+1.0
48 disp("The correct value of Average heat transfer
      coefficient (hbarL2)=hbarL1*F in W/(m^2*K) is")
49 hbarL2=hbarL1*F
50 //The ohmic power loss is given by energy balance I
      ^2*R=q=hbar2*A*(Tw-Tinf)
51 //q is the ohmic power loss
52 disp("The ohmic loss in W is ")
53 q=hbarL2*A*(Tw-Tinf)
54 //The current flowing in the wire I=(q/(R*L))^(1/2)
55 disp("The current flowing in the wire in Ampere is")
56 I=(q/(R*L))^(1/2)

```

Scilab code Exa 8.7 Long horizontal pressurized hot water pipe

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 8, Example 7")
8 //A long horizontal pressurized hot water of
      diameter(D)=200mm passes through a room where the
      air temprature is Tinf=25 C
9 D=.2;
10 Tinf=25;
11 //Length(L)=1m ,since the unit length is considered
12 L=1;
13 //Area(A)=pi*L*D
14 A=%pi*L*D;
15 //The pipe surface temprature is Tw=130 C
16 Tw=130;

```

```

17 //The properties of air at the film temprature Tf
    =77.5 C are kinematic viscosity (nu=21*10^-6m^2/s
    ), Prandtl number (Pr=0.70), Conductivity (k=0.03W/(m
    *K))
18 Tf=77.5;
19 nu=21*10^-6;
20 k=0.03;
21 Beta=(1/(273+Tf)); //Volume expansion coefficient in
    k^-1)
22 Pr=0.70;
23 //g is acceleration due to gravity =9.81m/s^2
24 g=9.81;
25 //Grashoff number is given by GrD=(g*beta*(Tw-Tinf)*
    L^3)/(nu)^2
26 disp("Grashoff number is")
27 GrD=(g*Beta*(Tw-Tinf)*D^3)/(nu)^2
28 //Rayleigh number is defined as RaD=GrD*Pr
29 disp("Rayleigh number is")
30 RaD=GrD*Pr
31 disp("The flow is laminar over the entire cylinder")
32 //NuD is the nusselt number
33 disp("we use following equation to find Nusselt
    number NuD=[0.60+((0.387*RaD^(1/6))/(1+(0.559/Pr
    ^ (9/16))))^(8/27)]^2")
34 NuD=[0.60+((0.387*RaD^(1/6))/(1+(0.559/Pr^(9/16))))
    ^ (8/27)]^2
35 //hbar is the avearge heat transfer coefficient
36 disp("Average heat transfer coefficient in W/(m^2*K)
    ")
37 hbar=(NuD*k)/D
38 //The heat loss per meter length is given by q=hbar*
    A*(Tw-Tinf)
39 disp("The heat loss per meter length in W is")
40 q=hbar*A*(Tw-Tinf)

```

Scilab code Exa 8.8 Electric immersion heater

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 8, Example 8")
8 //An electric immersion heater diameter(D)=8mm and
      length(L)=300mm is rated at power input ,P=450W
9 P=450;
10 L=0.3;//in metre
11 D=0.008;//in metre
12 //If the heater is horizontally positioned in a
      large tank of stationery water at temperature ,Tinf
      =20 C
13 Tinf=20;
14 //At steady state ,The electrical power input(P)=(Q)
      Heat loss from the heater
15 //P=Q
16 //Q=hbarD*(pi*D)*L*(Tw-Tinf)
17 //This gives Tw(surface temprature)=Tinf+(P/(hbarD*
      pi*D*L))
18 //So we need to find Average heat transfer
      coefficient ,hbarD.
19 //In this problem we need to take guess of steady
      state surface temprature(Tw) and iterate the
      solution for Tw till a desired convergence is
      achieved.
20 disp("Let us take first trial Tw=64 C ")
21 Tw=64;
22 Tf=(Tw+Tinf)/2;//mean film temperature
23 //At this temprature of 42 C ,The required
      properties of water kinematic viscosity(nu
      =6.25*10^-7m^2/s),Prandtl number(Pr=4.16),
      Conductivity(k=0.634W/(m*K)),Beta=4*10^-4K^-1
```

```

24 Beta=4*10^-4; //Volume expansion coefficient
25 nu=6.25*10^-7;
26 Pr=4.16;
27 k=0.634;
28 //g is acceleration due to gravity =9.81m/s^2
29 g=9.81;
30 //Grashoff number is given by GrD=(g*beta*(Tw-Tinf)*
    L^3)/(nu)^2
31 disp("Grashoff number is")
32 GrD=(g*Beta*(Tw-Tinf)*D^3)/(nu)^2
33 //Rayleigh number is defined as RaD=GrD*Pr
34 disp("Rayleigh number is")
35 RaD=GrD*Pr
36 disp("The flow is laminar ")
37 //NuD is nusselt number
38 //hbarD is Average heat transfer coefficient
39 disp("we use following equation to find Nusselt
    number NuD=[0.60+((0.387*RaD^(1/6))/(1+(0.559/Pr
    ^ (9/16))))^(8/27)]^2")
40 NuD=[0.60+((0.387*RaD^(1/6))/(1+(0.559/Pr^(9/16))))
    ^ (8/27)]^2
41 disp("Average heat transfer coefficient in W/(m^2*K)
    ")
42 hbarD=(NuD*k)/D
43 disp("Hence, steady state Surface temprature in C
    is")
44 Tw=Tinf+(P/(hbarD*%pi*D*L))
45 disp("Hence we see that our guess is in excellent
    agreement with the calculated value")

```

Chapter 9

Heat transfer in condensation and boiling

Scilab code Exa 9.1 A vertical cooling fin

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 9, Example 1")
8 //A vertical cooling fin , Approximately a flat plate
      length ,(L)=0.4m high is exposed to saturated
      steam(temprature ,Tg=100 C ) at atmospheric
      pressure .
9 L=0.4;
10 Tg=100;
11 //The fin is maintained at temprature ,Tw=90 C by
      cooling water .
12 Tw=90;
13 disp("The properties of condensate(liquid water) are
      evaluated at the mean film temprature ")
```

```

14 //tf is mean film temprature
15 disp("The mean film temprature in C is")
16 tf=(Tg+Tw)/2
17 //The properties of condensate are density(rho=962kg
    /m^3), conductivity(k=0.677W/(m*K)), viscosity(mu
    =3*10^-4 kg/(m*s))
18 rho=962;
19 k=0.677;
20 mu=3*10^-4;
21 //The value rhov=0.598kg/m^3 and hfg=2.27*10^6J/kg
    at 100 C are found from steam table
22 //g is acceleration due to gravity =9.81m/s^2
23 g=9.81;
24 rhov=0.598;//rhov is vapour density
25 hfg=2.27*10^6;//hfg is enthalpy of vaporisation
26 //The average heat transfer coefficient over length
    L is hbarL=0.943*[(rho*(rho-rhov)*g*h*L^3)/(mu*k
    *(Tg-Tw))]^(1/4)
27 disp("The average heat transfer coefficient over
    length L in W/(m^2*K)")
28 hbarL=0.943*[(rho*(rho-rhov)*g*hfg*k^3)/(mu*L*(Tg-Tw
    ))]^(1/4)
29 //The rate of heat transfer per unit width is Q=
    hbarL*L*(Tg-Tw)
30 disp("The rate of heat transfer per unit width in W/
    m ")
31 Q=hbarL*L*(Tg-Tw)
32 //The rate of condensation is given by mdotc=(Q/hfg)
33 disp("The total rate of condensation in kg/(s*m)")
34 mdotc=(Q/hfg)
35 disp("We have to check whether the flow is laminar
    or not ")
36 //Reynolds no is given by ReL=(4*mdotc)/(mu)
37 disp("Reynolds no. is")
38 ReL=(4*mdotc)/(mu)
39 disp("Therefore the flow is laminar and hence the
    use of the equation is justified")

```

Scilab code Exa 9.2 Steam is being condensed

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 9, Example 2")
8 //Steam is condensed at temperature(Tg=100 C ) on the
      outer surafce of a horizontal tube of length(L=3
      m) and diameter(d)=50mm or .05m
9 Tg=100;
10 L=3;
11 D=0.05;
12 //The Tube surface is maintained at temprature ,Tw=90
      C
13 Tw=90;
14 //tf is mean film temprature
15 disp("The mean film temprature in C is")
16 tf=(Tg+Tw)/2
17 //The properties of condensate are density(rho=962kg
      /m^3),conductivity(k=0.677W/(m*K)),viscosity(mu
      =3*10^-4 kg/(m*s))
18 rho=962;
19 k=0.677;
20 mu=3*10^-4;
21 //The value rhov=0.598kg/m^3 and hfg=2.27*10^6J/kg
      at 100 C are found from steam table
22 //g is acceleration due to gravity =9.81m/s^2
23 g=9.81;
24 rhov=0.598;//vapour density
25 hfg=2.27*10^6;//enthalpy of vaporisation
```



```

26 //The average heat transfer coefficient hbar
    =0.745*[(rho*(rho-rhov)*g*hfg*k^3)/(mu*D*(Tg-Tw))
    ]^(1/4)
27 disp("The average heat transfer coefficient in W/(m
    ^2*K)")
28 hbar=0.745*[(rho*(rho-rhov)*g*hfg*k^3)/(mu*D*(Tg-Tw)
    )]^(1/4)
29 //The rate of condensation is given by mdotc=(hbar*(
    pi*D*L)*(Tg-Tw))/hfg
30 disp("The total rate of condensation in kg/s")
31 mdotc=(hbar*(%pi*D*L)*(Tg-Tw))/hfg
32 disp("Check for reynolds no.")
33 //For a horizontal tube having length ,L,perimeter is
    P=2L
34 P=2*L;
35 //Re is reynolds number
36 disp("Reynolds number is")
37 Re=(4*mdotc)/(mu*P)
38 disp("The flow is laminar")

```

Scilab code Exa 9.3 A vertical plate in the presence of saturated steam

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 9, Example 3")
8 //A vertical plate having length ,(L)=1.5m is
    maintained at temprature(Tw) of 60 C in the
    presence of saturated steam(temprature ,Tg=100 C )
    at atmospheric pressure.
9 L=1.5;

```

```

10 Tg=100;
11 Tw=60;
12 //Consider the width of plate to be (B)=0.3m
13 B=0.3;
14 //tf is the mean film temprature
15 disp("The mean film temprature in C is")
16 tf=(Tg+Tw)/2
17 //The relevant properties are desity(rho=972kg/m^3),
    conductivity(k=0.670W/(m*K)), viscosity(mu
    =3.54*10^-4 kg/(m*s))
18 //specific heat(cp=4.2J/(kg*K)), vapur density(rhov
    (100 C )=0.598k/m^3), Enthalpy of vaporisation(hfg
    (100 C )=2.27*10^6J/kg)
19 //g is acceleration due to gravity =9.81m/s^2
20 g=9.81;
21 rho=972;
22 k=0.670;
23 mu=3.54*10^-4;
24 cp=4.2;
25 rhov=0.598;
26 hfg=2.27*10^6;
27 //The average heat transfer coefficient over length
    L is hbar=0.943*[(rho*(rho-rhov)*g*h*L^3)/(mu*k*(
    Tg-Tw))]^(1/4)
28 disp("The average heat transfer coefficient over
    length L in W/(m^2*K)")
29 hbar=0.943*[(rho*(rho-rhov)*g*hfg*k^3)/(mu*L*(Tg-Tw)
    )]^(1/4)
30 //The rate of heat transfer Q=hbarL*A*(Tg-Tw)
31 //Area(A)=L*B
32 A=L*B;
33 disp("The rate of heat transfer in kW ")
34 Q=[hbar*A*(Tg-Tw)]/1000
35 //The film thickness at the trailing edges is found
    out by delta=[(4*mu*k*x*(Tg-Tw))/(g*hfg*rho*(rho-
    rhov))]^(1/4)
36 disp("(b)The film thickness at the trailing edges in
    m is")

```

```

37 //at trailing edges x=1.5m
38 x=1.5;
39 delta=[(4*mu*k*x*(Tg-Tw))/(g*hfg*rho*(rho-rhov))
        ]^(1/4)
40 //The rate of condensation is given by mdotc=(Q/hfg)
41 disp("The total rate of condensation in kg/s")
42 mdotc=((Q*1000)/hfg)
43 //v is the average flow velocity
44 disp("Hence the average flow velocity at the
        trailing edge in m/s is")
45 v=(mdotc)/(rho*delta*B)

```

Scilab code Exa 9.4 Saturated freon 12

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
        Chapter 9, Example 4")
8 //Saturated freon-012 at Temperature(Tg)=35 C is
        condensed horizontal tube of diameter(D)=15mm or
        .015m at a lower vapour velocity.
9 //length ,L=1m, Since per meter of tube is considered.
10 L=1;
11 Tg=35;
12 D=0.015;
13 //The tube wall is maintained at temprature(Tw)=25
        C
14 Tw=25;
15 //For freon-12 at 35 C ,enthalpy of vaporisation(hfg
        =131.33kJ/kg) and vapour density(rhov=42.68kg/m
        ^3)

```

```

16 hfg=131.33*10^3;
17 rhov=42.68;
18 //tf is mean film temprature
19 disp("The mean film temprature in C is")
20 tf=(Tg+Tw)/2
21 //The relevant properties at 30 C are density(rho
    =1.29*10^3kg/m^3), conductivity(k=0.071W/(mK)),
    viscosity(mu=2.50*10^-4kg/(m*s)), specific heat(cp
    =983J/(kg* C))
22 rho=1.29*10^3;
23 k=0.071;
24 mu=2.50*10^-4;
25 cp=983;
26 //g is acceleration due to gravity =9.81m/s^2
27 g=9.81;
28 //we found the modified enthalpy by using following
    equation hfgdash=hfg+(3/8)*cp*(Tg-Tw)
29 disp(" Modified enthalpy in J/kg is")
30 hfgdash=hfg+[(3/8)*cp*(Tg-Tw)]
31 //The average heat transfer coefficient over length
    L is hbar=0.555*[(rho*(rho-rhov)*g*hfgdash*k^3)/(
    mu*D*(Tg-Tw))]^(1/4)
32 disp("The average heat transfer coefficient over
    length L in W/(m^2*K)")
33 hbar=0.555*[(rho*(rho-rhov)*g*hfgdash*k^3)/(mu*D*(Tg
    -Tw))]^(1/4)
34 //The rate of condensation is given by mdotc=(hbar*(
    pi*D*L)*(Tg-Tw))/hfg
35 disp("The total rate of condensation in kg/hr")
36 mdotc=[(hbar*(%pi*D*L)*(Tg-Tw))/hfg]*3600

```

Scilab code Exa 9.5 Nickel wire is submerged horizontally in water

```

1 // Display mode
2 mode(0);

```

```

3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 9, Example 5")
8 //A nickel wire of length(L)=0.1m, Diameter(D)=1mm or
      .001m
9 //Submerged horizontally in water at pressure=1 atm
      (101kPa) requires current, I=150A at voltage ,E
      =2.2V to maintain wire at temprature(T1)=110 C
10 L=0.1;
11 T1=110;
12 D=0.001;
13 I=150;
14 E=2.2;
15 //Area(A)=[%pi*D*L]
16 A=%pi*D*L;
17 //The saturation temprature of water at one
      atmospheric pressure(101kPa) is T2=100 C .
18 T2=100;
19 //We can write from energy balance  $E*I=h*A*(T1-T2)$ ,
      we can find heat transfer coefficient from it.
20 //h is heat transfer coefficient
21 disp("Heat transfer coefficient in W/m^2 is")
22 h=(E*I)/(A*(T1-T2))

```

Scilab code Exa 9.6 Nickel wire is submerged horizontally

```

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

```

```

7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 9, Example 6")
8 //In a laboratory experiment ,A current(I)=100A burns
      out a nickel wire having Diameter(D)=1mm or
      0.001mm, length(L)=0.3m
9 I=100;
10 D=.001;
11 L=0.3;
12 //It is submerged horizontally in water at one
      atmospheric pressure.
13 //For saturated water at one atmospheric pressure ,
      density(rhol=960kg/m^3) ,vapour density(rhov=0.60
      kg/m^3) ,enthalpy of vaporisation(hfg=2.26*10^6J/
      kg) ,surface tension(sigma=0.055N/m) .
14 rhol=960;
15 rhov=0.60;
16 hfg=2.26*10^6;
17 sigma=0.055;
18 //Area(A)=[pi*D*L]
19 A=%pi*D*L;
20 //g is acceleration due to gravity =9.81m/s^2
21 g=9.81;
22 //The wire is burnt out when heat reaches its peak
23 //We use following expression to determine critical
      heat flux qc=0.149*hfg*rhov*[(sigma*g*(rhol-rhov)
      )/rhov^2]^(1/4)*[(rhol+rhov)/rhol]^(1/2)
24 disp("Critical Heat flux in W/m^2 is")
25 qc=0.149*hfg*rhov*[(sigma*g*(rhol-rhov))/rhov
      ^2]^(1/4)*[(rhol+rhov)/rhol]^(1/2)
26 //From the energy balance E*I=qc*A
27 //E is the burn out voltage
28 disp("The burn out voltage in Volts is ")
29 E=(qc*A)/I

```

Scilab code Exa 9.7 A heated nickel plate

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 9, Example 7")
8 //A heated nickel plate at temprature (T1)=110 C is
      submerged in water at one atmospheric pressure.
9 T1=110;
10 //For nucleate boiling coefficient(csf=0.006) and n
      =1
11 csf=0.006;
12 n=1;
13 //For saturated water at one atmospheric pressure ,
      density of liquid(rhol=960kg/m^3),vapour density(
      rhov=0.60kg/m^3)
14 //enthalpy of vaporisation(hfg=2.26*10^6J/kg) ,
      surface tension(sigma=0.055N/m),saturation
      temprature(T2)=100 C
15 T2=100;
16 rhol=960;
17 rhov=0.60;
18 hfg=2.26*10^6;
19 sigma=0.055;
20 //g is acceleration due to gravity =9.81m/s^2
21 g=9.81;
22 //We take specific heat of liquid(cpl=4.216kJ/(kg*K)
      ),prandtl number of liquid(Prl=1.74),viscosity of
      liquid(mul=2.82*10^-4kg/(m*s))
23 cpl=4.216*10^3;
24 Prl=1.74;
25 mul=2.82*10^-4;
26 //The heat flux q is given by expression q=(mul*hfg)
      *[((rhol-rhov)*g)/sigma]^(1/2)*[(cpl*(T1-T2))*(
      csf*hfg*prl^n)]^3
27 disp("Heat flux q in W/m^2 is")

```

```

28 q=(mul*hfg)*[((rho1-rhov)*g)/sigma]^(1/2)*[(cpl*(T1-
    T2))/(csf*hfg*Pr1^n)]^3
29 disp("The peak heat flux for water at one
    atmospheric pressure is qc=1.24*10^6(found in
    example 9.6). Since q<qc,The regime of boiling is
    nucleate.")

```

Scilab code Exa 9.8 Boiling charactersticts of a special coating

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 9, Example 8")
8 //A Copper bar whose one end is exposed to boiling
    water while the other end is encapsulated by an
    electric heater.
9 //Thermocouples are inserted in the bar to measure
    the tempratures at two locations A and b at
    distances xA=10mm and xB=30mm from the surface.
10 xA=.010;
11 xB=.030;
12 //Under steady condition nucleate boiling is
    maintained in saturated water at atmospheric
    pressure and the tempratures are TA=140 C and TB
    =180 C ,n=1
13 TA=140;
14 TB=180;
15 n=1;
16 //The values of relevant properties of water and
    other parameters are
17 //density of liquid(rho1=960kg/m^3),vapour density(

```



```

    rhov=0.60kg/m^3), specific heat of liquid (cpl
    =4.216 kJ/(kg*K))
18 //enthalpy of vaporisation (hfg=2.26*106J/kg), prandtl
    number of liquid (Pr1=1.74), viscosity of liquid (
    mul=2.82*10^-4kg/(m*s)), surface tension (sigma1
    =0.055N/m).
19 rhol=960;
20 rhov=0.60;
21 cpl=4.216*10^3;
22 hfg=2.26*10^6;
23 Pr1=1.74;
24 mul=2.82*10^-4;
25 sigma1=0.055;
26 //We have to know the value of heat flux(q) and the
    surface temprature(Tw).
27 //Since we know the tempratures at location A and B,
    The heat flux q is determined by fourier law of
    heat conduction in the bar at steady-state as
28 //q=k*[(TB-TA)/(xB-xA)]
29 //We take for copper conductivity ,k=375W/(m*K)
30 k=375;
31 disp("The heat flux in W/m^2 is")
32 q=k*[(TB-TA)/(xB-xA)]
33 //g is acceleration due to gravity =9.81m/s^2
34 g=9.81;
35 //The surface temprature is given by Tw=TA-[(TB-TA)
    /(xB-xA)]*xA
36 disp("The surface temprature in C is")
37 Tw=TA-[(TB-TA)/(xB-xA)]*xA
38 //Temprature ,T=100 C ,since copper bar is exposed to
    boiling water.
39 T=100;
40 //Now we use following equation to determine csf ,q=(
    mul*hfg)*[((rhol-rhov)*g)/sigma1]^(1/2)*[(cpl*(Tw
    -T))/(csf*hfg*Pr1^n)]^3
41 //Manipulating above equation to find csf we get csf
    =[(cpl*(Tw-T))/([q/[(mul*hfg)*[((rhol-rhov)*g)/
    sigma1]^(1/2)]]^(1/3)]*hfg*Pr1^n]

```

```
42 disp("The value of the coefficient csf is ")
43 csf=[(cpl*(Tw-T))/([q/{(mul*hfg)*[(rho1-rhov)*g]/
    sigma1}^(1/2)}]^(1/3)]*hfg*Pr1^n]//[NOTE:The
    answer in the book is incorrect.(Calculation
    mistake)]
```

Chapter 10

Principles of heat exchangers

Scilab code Exa 10.1 Food processing plant

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 10, Example 1")
8 //A brine solution is heated from temprature ,T1=8
      C to temprature ,T2=14 C in a double pipe heat
      exchanger.
9 T1=8;
10 T2=14;
11 //Water entering at temprature T3=55 C and leaving
      at temprature ,T4=40 C at the mass flow rate of (
      mdot)=0.18kg/s
12 mdot=0.18;
13 T3=55;
14 T4=40;
15 //Specific heat (cp) of water =4.18kJ/(kg*K)
16 cp=4.18*10^3;
```

```

17 //overall heat transfer coefficient (U)=800 W/(m^2*K)
18 U=800;
19 //The rate of heat transfer from water is given by Q
    =mdot*cp*(T3-T4)
20 disp("The rate of heat transfer from water is given
    by Q=mdot*cp*(T3-T4) in W")
21 Q=mdot*cp*(T3-T4)
22 disp("(a) For a parallel flow arrangement")
23 //For a parallel flow arrangement deltaT1=T3-T1 and
    deltaT2=T4-T2.
24 deltaT1=T3-T1;//deltaT1 is temprature difference
25 deltaT2=T4-T2;//deltaT2 is temprature difference
26 //LMTD(Log mean temprature difference) is defined as
    (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) for both
    parallel and counter flow.
27 disp("LMTD is given by (deltaT2-deltaT1)/(ln(deltaT2
    /deltaT1)) in C ")
28 //let X=log10((deltaT2/deltaT1)) and Y=log10
    (2.718281)
29 X=log10((deltaT2/deltaT1));
30 Y=log10(2.718281);
31 //ln=(ln(deltaT2/deltaT1))
32 ln=X/Y;
33 LMTD=(deltaT2-deltaT1)/ln
34 //Area(A)=Q/(U*LMTD) in m^2
35 disp("Area(A)=Q/(U*LMTD) in m^2")
36 A=Q/(U*LMTD)
37 disp("(b) For counterflow arrangement")
38 deltaT1=T3-T2;
39 deltaT2=T4-T1;
40 disp("LMTD=(deltaT2-deltaT1)/(ln(deltaT2/deltaT1))
    in C ")
41 X=log10((deltaT2/deltaT1));
42 Y=log10(2.718281);
43 ln=X/Y;
44 LMTD=(deltaT2-deltaT1)/ln
45 disp("Area(A)=Q/(U*LMTD) in m^2")
46 A=Q/(U*LMTD)

```

Scilab code Exa 10.2 Hot oil flows through a counterflow heat exchanger

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 10, Example 2")
8 //Hot oil (specific heat ,ch=2.09kJ/(kg*K)) flows
      through counter flow heat excahnger at the mass
      flow rate of mdoth=(0.7kg/s)
9 ch=2.09*10^3;
10 mdoth=0.7;
11 //overall heat transfer coefficient (U)=650 W/(m^2*K)
12 U=650;
13 //It enters at temprature ,Th1=200 C and leaves at
      temprature ,Th2=70 C
14 Th1=200;
15 Th2=70;
16 //Cold oil (specific heat ,cc=1.67kJ/(kg*K) exits at
      temprature ,Tc2=150 C at the mass flow rate of
      mdotc=(1.2kg/s)
17 mdotc=1.2;
18 cc=1.67*10^3;
19 Tc2=150;
20 //The unknown inlet temprature(Tc1) of cold oil may
      be found from energy balance mdotc*(Tc2-Tc1)=
      mdoth*(Th2-Th1)
21 disp("The inlet temprature(Tc1) of cold oil in C ")
      )
22 Tc1=Tc2-[(mdoth*ch)/(mdotc*cc)]*(Th1-Th2)
23 //The rate of heat transfer can be calculate as Q=
```

```

    mdoth*ch*(Th1-Th2)
24 disp("The rate of heat transfer  $Q=m\dot{o}th*ch*(Th1-Th2)$ 
    in W")
25 Q=mdoth*ch*(Th1-Th2)
26 deltaT1=Th1-Tc2;//deltaT1 is temprature difference
    between hot oil inlet temprature and cold oil
    exit temprature
27 deltaT2=Th2-Tc1;//deltaT2 is temprature difference
    between hot oil exit temprature and cold oil
    inlet temprature
28 //LMTD(Log mean temprature difference) is defined as
    (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) for
    counter flow.
29 disp("LMTD is given by (deltaT2-deltaT1)/(ln(deltaT2
    /deltaT1)) in C ")
30 //let X=log10((deltaT2/deltaT1)) and Y=log10
    (2.718281)
31 X=log10((deltaT2/deltaT1));
32 Y=log10(2.718281);
33 //ln=(ln(deltaT2/deltaT1))
34 ln=X/Y;
35 LMTD=(deltaT2-deltaT1)/ln
36 //Area(A)=Q/(U*LMTD) in m^2
37 disp("Area(A)=Q/(U*LMTD) in m^2")
38 A=Q/(U*LMTD)

```

Scilab code Exa 10.3 Cross flow heat exchangers with both fluids unmixed

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,

```

```

Chapter 10, Example 3")
8 //A cross flow heat exchanger with both fluids
  unmixed is used to heat water((specific heat,cc
    =4.18kJ/(kg*K)) from temprature Tci=50 C to Tco
    =90 C
9 //flowing at the mass flow rate of (mdotc)=1kg/s
10 Tci=50;
11 Tco=90;
12 cc=4.18*10^3;
13 mdotc=1;
14 //The hot engine oil has (specific heat,ch=1.9kJ/(kg
    *K)) flowing at the mass flow rate of mdoth=3kg/s
    enters at temprature Thi=100 C
15 mdoth=3;
16 Thi=100;
17 ch=1.9*10^3;
18 //The unknown outlet temprature(Tho) of oil may be
    found from energy balance mdotc*(Tco-Tci)=mdoth*(
    Tho-Thi)
19 disp("The outlet temprature(Tho) of oil in C ")
20 Tho=Thi-[(mdotc*cc)/(mdoth*ch)]*(Tco-Tci)
21 disp("For a counterflow heat exchanger")
22 deltaT1=Thi-Tco;//deltaT1 is temprature difference
23 deltaT2=Tho-Tci;//deltaT2 is temprature difference
24 //LMTD(log mean temprature difference) is defined as
    (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) for
    counter flow.
25 disp("LMTD is given by (deltaT2-deltaT1)/(ln(deltaT2
    /deltaT1)) in C ")
26 //let X=log10((deltaT2/deltaT1)) and Y=log10
    (2.718281)
27 X=log10((deltaT2/deltaT1));
28 Y=log10(2.718281);
29 ln=X/Y;
30 LMTD=(deltaT2-deltaT1)/ln
31 //Area(A)=20m^2
32 A=20;
33 //We have to employ correction factor(F) for the

```

```

    cross flow arrangement.
34 //We evaluate dimensionless parameters  $P=(T_{co}-T_{ci})/(T_{hi}-T_{co})$  and  $R=(T_{hi}-T_{ho})/(T_{co}-T_{ci})$ .
35 disp("dimensionless parameters P and R are")
36 P=(Tco-Tci)/(Thi-Tci)
37 R=(Thi-Tho)/(Tco-Tci)
38 disp("correction factor(F) for the cross flow
    arrangement as obtained from graph of F vs Single
    Pass flow with fluids unmixed")
39 F=0.75
40 //The rate of heat transfer can be calculate as  $Q=
    \dot{m}c_p(T_{h1}-T_{h2})$ 
41 Q= $\dot{m}c_p(T_{co}-T_{ci})$ ;
42 //overall heat transfer coefficient  $U=Q/(A*F*LMTD)$ 
43 disp("overall heat transfer coefficient  $U=Q/(A*F*
    LMTD)$  in  $W/(m^2*K)$ ")
44 U=Q/(A*F*LMTD)

```

Scilab code Exa 10.5 Water is heated in a counter flow double pipe heat exchanger

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 10, Example 5")
8 //Water is heated from temprature , $T_{in}=30$  C to
     $T_{out}=90$  C in a counter flow double pipe heat
    exchanger.
9 Tin=30;
10 Tout=90;
11 //Water flows at a mass flow rate of  $\dot{m}_w=1.2$ kg/s
12  $\dot{m}_w=1.2$ ;

```



```

13 //The heating is accomplished by a geothermal fluid
    which enters the heat exchanger at temperature ,
    Thin=160 C at the mass flow rate of mdoth=2kg/s
14 mdoth=2;
15 Thin=160;
16 //The inner tube is thin walled having diameter(D)
    =15mm or 0.015m
17 D=0.015;
18 //overall heat transfer coefficient(U)=600 W/(m^2*K)
19 U=600;
20 //The specific heat of water and geothermal fluid is
    (cpw=4.18kJ/(kg*K)) and (cph=4.31kJ/(kg*K))
    respectively
21 cpw=4.18*10^3;
22 cph=4.31*10^3;
23 //The rate of heat transfer in heat exchanger can be
    calculate as  $Q=\dot{m}w*cpw*(T_{out}-T_{in})$ 
24 disp("(a) Applying LMTD method")
25 disp("The rate of heat transfer  $Q=\dot{m}w*cpw*(T_{out}-$ 
     $T_{in})$  in W")
26 Q= $\dot{m}w*cpw*(T_{out}-T_{in})$ 
27 //The unknown outlet temprature(Thout) of geothermal
    fluid may be found from energy balance  $\dot{m}w*cpw$ 
     $*(T_{out}-T_{in})=\dot{m}h*cph*(T_{in}-T_{hout})$ 
28 disp("The unknown outlet temprature(Thout) of
    geothermal fluid in C ")
29 Thout= $T_{in}-Q/(\dot{m}h*cph)$ 
30 deltaT1= $T_{in}-T_{out}$ ; //Temprature difference between
    inlet temprature of hot fluid and outlet
    temprature of cold fluid
31 deltaT2= $T_{hout}-T_{in}$ ; //Temprature difference between
    outlet temprature of hot fluid and inlet
    temprature of cold fluid
32 //LMTD is defined as  $(\Delta T_2-\Delta T_1)/(\ln(\Delta T_2/$ 
     $\Delta T_1))$  for counter flow.
33 disp("LMTD is given by  $(\Delta T_2-\Delta T_1)/(\ln(\Delta T_2$ 
     $/\Delta T_1))$  in C ")
34 //let  $X=\log_{10}((\Delta T_2/\Delta T_1))$  and  $Y=\log_{10}$ 

```

```

    (2.718281)
35 X=log10((deltaT2/deltaT1));
36 Y=log10(2.718281);
37 ln=X/Y;
38 LMTD=(deltaT2-deltaT1)/ln
39 //Area(A)=Q/(U*LMTD) in m^2
40 disp("Area(A)=Q/(U*LMTD) in m^2")
41 A=Q/(U*LMTD)
42 disp("To provide this surface area ,The length(L) of
    the tube required is given by L=A/(pi*D) in m")
43 L=A/(%pi*D)
44 disp("(b)Applying NTU method")
45 //The heat capacity rates are defined as Ch=m*doth*
    cph and Cc=m*dotw*cpw in KW/ C
46 disp("The heat capacity rates are defined as Ch=
    m*doth*cph and Cc=m*dotw*cpw in KW/ C ")
47 Ch=(m*doth*cph)/1000
48 Cc=(m*dotw*cpw)/1000
49 //So Cmin=Cc and Cmax=Ch
50 Cmin=Cc;
51 Cmax=Ch;
52 //C is defined as Cmin/Cmax
53 disp("C=Cmin/Cmax")
54 C=Cmin/Cmax
55 //Heat transfer effectiveness is (eff)
56 disp("Heat transfer effectiveness is defined as eff=
    Q/(Cmin*(Thin-Tin))")
57 eff=(Q/1000)/(Cmin*(Thin-Tin))
58 disp("NTU is determined by NTU=(1/(C-1))*ln((eff-1)
    /(eff*C-1))")
59 //let X=log10((eff-1)/(eff*C-1)) and Y=log10
    (2.718281)
60 X=log10((eff-1)/(eff*C-1));
61 Y=log10(2.718281);
62 //ln=ln [(eff-1)/(eff*C-1)]
63 ln=X/Y;
64 //NTU is Number of transfer units
65 NTU=(1/(C-1))*ln

```

```

66 //NTU =U*A/Cmin
67 disp(" Area (A)=(NTU*Cmin)/U in m^2")
68 A=(NTU*Cmin*1000)/U
69 disp("To provide this surface area ,The length(L) of
       the tube required is given by L=A/(pi*D) in m")
70 L=A/(%pi*D)
71 disp("Hence same result is obtained for both methods
       ")

```

Scilab code Exa 10.6 Water enters a counter flow double pipe heat exchangers

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
       Chapter 10, Example 6")
8 //Water having specific heat ,cw=4.18kJ/(kg*K) enters
       a counterflow double pipe heat exchanger at
       temprature ,Tci=35 C flowing at the mass flow
       rate of mdotw=0.8 kg/s.
9 cw=4.18;
10 mdotw=0.8;
11 Tci=35;
12 //It is heated by oil having specific heat ,co=1.88kJ
       /(kg*K) flowing at the mass flow rate of mdoto
       =1.5 kg/s from an inlet temprature(Thi) of 120 C
       .
13 co=1.88;
14 mdoto=1.5;
15 Thi=120;
16 //For an area(A) of 15m^2 and an overall heat
       transfer coefficient (U) of 350W/(m^2*K).

```

```

17 A=15;
18 U=350;
19 //Cwater and Co are heat capacities for water and
    oil respectively
20 //Cwater=mdotw*cw and Co=mdoto*co
21 Cwater=mdotw*cw;
22 Co=mdoto*co;
23 //C=Cmin/Cmax
24 Cmin=min(Cwater,Co);
25 Cmax=max(Cwater,Co);
26 C=Cmin/Cmax;
27 //NTU is number of transfer units
28 //NTU=(U*A)/Cmin
29 disp("NTU is defined as (U*A)/Cmin ")
30 NTU=(U*A)/(Cmin*1000)
31 //Heat transfer effectiveness(eff) is defined as (1-
    e^[-NTU*(1-C)])/(1-C*e^[-NTU*(1-C)])
32 disp("Heat transfer effectiveness(eff) is defined as
    (1-e^[-NTU*(1-C)])/(1-C*e^[-NTU*(1-C)])")
33 eff=(1-%e^[-NTU*(1-C)])/(1-C*%e^[-NTU*(1-C)])
34 //Hence The total heat transfer rate(Q)=eff*Cmin*(
    Thi-Tci) in kW.
35 disp("The total heat transfer rate(Q)=eff*Cmin*(Thi-
    Tci) in kW")
36 Q=eff*Cmin*(Thi-Tci)

```

Scilab code Exa 10.7 Water enters a cross flow heat exchangers

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,

```

```

Chapter 10, Example 7")
8 //Water enters a cross flow heat exchanger (both
   fluids unmixed) at temprature(Tci)=20 C amd
   flows at a mass flow rate of mdotw=7kg/s
9 Tci=20;
10 mdotw=7;
11 //The air flows at a mass flow rate of mdota=10kg/s
   from Temprature(Thi)=125 C
12 mdota=10;
13 Thi=125;
14 //The overall heat transfer coefficient (U)=220W/(m
   ^2*K)and Area(A)=250m^2.
15 U=220;
16 A=250;
17 //The specific heat of air (cpa=1.01kJ/(kg*K)) and
   water is (cpw=4.18kJ/(kg*K))
18 cpa=1.01;
19 cpw=4.18;
20 //Cair and Cwater are heat capacities of air and
   water respectively
21 Cair=mdota*cpa;
22 Cwater=mdotw*cpw;
23 //C=Cmin/Cmax
24 Cmin=min(Cwater,Cair);
25 Cmax=max(Cwater,Cair);
26 C=Cmin/Cmax;
27 //NTU is number of transfer units
28 //NTU=(U*A)/Cmin
29 disp("NTU is defined as (U*A)/Cmin ")
30 NTU=(U*A)/(Cmin*1000)
31 //To determine the effectiveness of heat exchanger
   we have to find out the suitable expression
32 //For this type of heat exchanger The effectiveness(
   eff)is determined by (1-e^[(NTU^.22*{e^-(C*NTU
   ^0.78)-1}]/C])
33 disp("The effectiveness of heat exchanger is")
34 eff=(1-%e^[(NTU^0.22*{%e^(-C*NTU^0.78)-1}]/C])
35 //Hence The total heat transfer rate(Q)=eff*Cmin*(

```

```

    Thi-Tci) in W.
36 disp("The total heat transfer rate (Q)=eff*Cmin*(Thi-
    Tci) in W")
37 Q=eff*Cmin*1000*(Thi-Tci)
38 //The exit temprature(Tho) of air is given by Thi-(Q
    /(mdota*cpa))
39 disp("The exit temprature of air in C ")
40 Tho=Thi-(Q/(mdota*1000*cpa))//NOTE:-The answer
    slightly varies from the answer in book(i.e Tho
    =26 C ) because the value of Q taken in book is
    approximated to 1*10^6W.

```

Scilab code Exa 10.8 A double pipe heat exchanger

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 10, Example 8")
8 //A double pipe heat exchanger of length(L)=0.30m is
    to be used to heat water(specific heat,cc=4.18kJ
    /(kg*K)) and mass flow rate(mdotw=2kg/s)
9 L=0.30;
10 cc=4.18;
11 mdotw=2;
12 //The water enters at temprature(Tci)=25 C and
    leaves at temprature(Tco)=50 C
13 //The flow rate of oil is mdoth
14 Tci=25;
15 Tco=50;
16 //The oil used as hot fluid has(specific heat,ch
    =1.88kJ/(kg*K)) and has inlet temprature(Thi)=100

```

```

      C
17 ch=1.88;
18 Thi=100;
19 disp(" (a) Considering a parallel flow arrangement ")
20 //For minimum value of mdoth
21 //The theoretical minimum value of outlet temprature
    of hot fluid(Tho) under this situation is equal
    to Tco
22 Tho=Tco;
23 //The mass flow rate of oil is given by energy
    balance as mdoth=(mdotw*cpw*(Tco-Tci))/(cph*(Thi-
    Tho))
24 disp("The minimum flow rate required for the oil in
    kg/s")
25 mdoth=(mdotw*cc*(Tco-Tci))/(ch*(Thi-Tho))
26 disp(" (b) Theoretical question ")
27 disp(" If LMTD--->0,Then for a finite value of heat
    transfer rate U*A--->infinity.For a given finite
    length this implies value of U which is not
    possible.")
28 disp(" (c) Let us consider a counter flow arrangement"
    )
29 //In this case value of Tho=Tci.
30 Tho=Tci;
31 //The mass flow rate of oil is given by energy
    balance as mdoth=(mdotw*cpw*(Tco-Tci))/(cph*(Thi-
    Tho))
32 disp("The minimum flow rate required for the oil in
    kg/s")
33 mdoth=(mdotw*cc*(Tco-Tci))/(ch*(Thi-Tci))
34 //Now Heat capacities are Ch=mdoth*ch and Cc=mdotw*
    cc
35 Ch=mdoth*ch;
36 Cc=mdotw*cc;
37 Cmin=min(Ch,Cc); //minimum heat capacity in Ch and Cc
38 //Effectiveness of heat exchanger is eff.
39 //Tho=Tci for this kind of arrangement
40 Tho=Tci;

```

```
41 disp("Effectiveness of heat exchanger is ")
42 eff=(m*ch*(Thi-Tho))/(m*ch*(Thi-Tci))
```

Chapter 11

Radiation heat transfer

Scilab code Exa 11.3 To determine the view factors F13 and F31

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 11, Example 3")
8 disp("The view factors F13 and F31 between the
      surfaces 1 and 3 are ")
9 //Determine the view factors F13 and F31 between the
      surfaces 1 and 3.
10 //F1-2,3=F12+F13
11 //So F13=F1-2,3-F12
12 //Let F1-2,3=F123
13 //From Radiation Shape factor b/w two perpendicular
      rectangles with a common edge table we get F12
      =.027,F1-2,3=0.31
14 F123=0.31;//View factor
15 F12=.27;//View factor
16 F13=F123-F12//View factor
```

```

17 //A1,A2 and A3 are the emitting surface areas
18 //From reciprocity relation  $F_{31}=(A_1/A_3)/F_{13}$ 
19 A1=2;
20 A3=2.5;
21  $F_{31}=(A_1/A_3)*F_{13}$ 

```

Scilab code Exa 11.4 Determine the view factor F_{14} for the composite surface

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 11, Example 4")
8 //Determine the view factors  $F_{14}$  for the composite
      surface .
9 //From the table of radiation shape factor b/w two
      perpendicular surfaces  $F_{1,2-3,4}=0.14$  and  $F_{1,2-3}=0.1$ 
10 //By subdivision of the receiving surfaces we get  $F_{1,2-4}=F_{1,2-3,4}-F_{1,2-3}$ 
11 //Let  $F_{1,2-4}=F_{124}$  ,  $F_{1,2-3,4}=F_{1234}$  ,  $F_{1,2-3}=F_{123}$ 
12  $F_{1234}=0.14$ ; //View factor
13  $F_{123}=0.1$ ; //View factor
14  $F_{124}=F_{1234}-F_{123}$ ; //View factor
15 //Again from the table of radiation shape factor b/w
      two perpendicular surfaces  $F_{2-3,4}=0.24$  ,  $F_{23}$ 
      =0.18
16 //Let  $F_{2-3,4}=F_{234}$ 
17  $F_{234}=0.24$ ; //View factor
18  $F_{23}=0.18$ ; //View factor
19 //By subdivision of the receiving surfaces we get
       $F_{24}=F_{2-3,4}-F_{23}$ 

```

```

20 F24=F234-F23;//view factor
21 //A1 and A2 are the emitting surface areas.
22 A1=12;
23 A2=12;
24 //Now by subdivision of emitting surfaces F1
    ,2-4=(1/(A1+A2))*(A1*F14+A2*F24)
25 //This implies F14=((F1,2-4*(A1+A2))-A2*F24)/A2
26 disp("The view factor F14=((F1,2-4*(A1+A2))-A2*F24)
    /A2")
27 F14=((F124*(A1+A2))-(A2*F24))/A2

```

Scilab code Exa 11.5 Determine the view factor of the cylindrical surface

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
    Chapter 11, Example 5")
8 //Consider a cylinder having length,L=2r determine
    the view factor of cylindrical surface with
    respect to the base.
9 //From the graph of radiation shape factor b/w
    parallel coaxial disks of equal diameter F12=0.16
10 F12=0.16;//View factor
11 //By the summation rule of an enclosure F11+F12+F13
    =1
12 //But F11=0(since the base surface is flat)
13 F11=0;//View factor
14 disp ("The view factors of cylindrical surface with
    respect to the base are")
15 F13=1-F12-F11//view factor
16 //By making use of reciprocity theorem we have F31=(

```

```

    A1/A2)*F13
17 //A1 and A2 are emitting surface areas
18 //A1/A2=(pi*r^2)/(2*pi*r*2*r)=1/4
19 //Let A1/A2=A
20 A=1/4;
21 F31=(A)*F13

```

Scilab code Exa 11.6 Two blackbody rectangles

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 11, Example 6")
8 //Two rectangles length ,L=1.5m by breadth ,B=3.0m are
   parallel and directly opposed.
9 L=1.5;
10 B=3;
11 //They are 3m apart
12 //Temperature(T1) of surface 1 is 127 C or 400K and
   temprature(T2) of surface 2 is 327 C or 600K
13 T1=400;
14 T2=600;
15 //Area (A) is the product of L and B
16 A1=L*B;
17 //Stefan -Boltzman constant (sigma)=5.67*10^-8 W/(m
   ^2*K^4)
18 sigma=5.67*10^-8;
19 //From the graph of radiation shape factor b/w
   parallel rectangles F12=0.11
20 F12=0.11;//View factor
21 //The rate of heat transfer is given by Q=A1*F12*

```

```

    sigma*(T1^4-T2^4)
22 disp("The rate of heat transfer is given by  $Q=A_1F_{12}$ 
    *sigma*(T1^4-T2^4) in W")
23 Q=A1*F12*sigma*(T1^4-T2^4)
24 disp("Here minus sign indicates that the net heat
    transfer is from surface2 to surface1")
25 //Surface1 recieves energy only from surface 2, since
    the surrounding is at 0K.
26 //Therefore  $Q_1=A_1E_{b1}-A_2F_{21}E_{b2}$ 
27 //This implies  $Q_1$  can also be written as  $A_1sigma*($ 
    T1^4-F12*T2^4)
28 //From reciprocity theorem  $F_{21}=F_{12}$  (since  $A_1=A_2$ )
29 F21=F12;//view factor
30 disp("The net rate of energy loss from the surface
    at 127 C if the surrounding other than the two
    surfaces act as black body at 0K in W" )
31 Q1=A1*sigma*(T1^4-F12*T2^4)
32 //In the case when surrounding is at temprature,  $T_s$ 
    =300K ,the energy recieved from the surrounding
    by the surface 1 has to be considered.
33 Ts=300;
34 //Applying summation rule of view factors  $F_{11}+F_{12}+$ 
    F1s=1
35 F11=0;//view factor
36 disp("The view factor of surface 1 with respect to
    surrounding is")
37 F1s=1-F11-F12
38 //subscript s denotes the surroundings
39 // $Q_1=A_1E_{b1}-A_2F_{21}E_{b2}-A_sF_{s1}E_{bs}$ 
40 //With the help of reciprocity theorem  $A_2F_{21}=A_1F_{12}$ 
    ,  $A_sF_{s1}=A_1F_{1s}$ 
41 //Therefore we can write  $Q_1=A_1sigma*(T1^4-F12*T2^4-$ 
    F1s*Ts^4)
42 disp("The net rate of energy loss from the surface
    at 127 C if the surrounding other than the two
    surfaces act as black body at 300K in W ")
43 Q1=A1*sigma*(T1^4-F12*T2^4-F1s*Ts^4)

```

Scilab code Exa 11.7 Two parallel infinite planes

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 11, Example 7")
8 //Two parallel infinite surfaces are maintained at
      temperatures T2=200 C or 473.15K and T1=300 C or
      573.15K
9 T1=573.15;
10 T2=473.15;
11 //The emissivity(emi) is 0.7 for both the surfaces
      which are gray.
12 emi1=0.7;
13 emi2=0.7;
14 //stefan=boltzman constant(sigma)=5.67*10^-8W/(m^2*K
      ^4)
15 sigma=5.67*10^-8;
16 //The net rate of heat transfer per unit area is
      given Q/A=(sigma*(T1^4-T2^4))/[(1/emi1)+(1/emi2)-1]
17 //Let Q/A=H
18 disp("The net rate of heat transfer per unit area is
      given Q/A=(sigma*(T1^4-T2^4))/[(1/emi1)+(1/emi2)-1]
      in W")
19 H=(sigma*(T1^4-T2^4))/[(1/emi1)+(1/emi2)-1]
20 //When the two surfaces are black
21 //This implies emissivity(emi)=1 for both surfaces
22 //So,The net rate of heat transfer when the two
      surfaces are black is Q/A=sigma*(T1^4-T2^4)
23 disp("The net rate of heat transfer when the two
```

```

    surfaces are black is  $Q/A = \sigma(T_1^4 - T_2^4)$  in W
)
24 H=sigma*(T1^4-T2^4)

```

Scilab code Exa 11.8 Two concentric spheres are separated in air space

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 11, Example 8")
8 //Two concentric spheres of diameters D1=0.5m and D2
   =1m are separated by an air space.
9 //The surface tempratures are T1=400K and T2=300K
10 T1=400;
11 T2=300;
12 D1=0.5;
13 D2=1;
14 //A1 and A2 are the areas in m^2 of surface 1 and
   surface 2 respectively
15 A1=(%pi*D1^2);
16 A2=(%pi*D2^2);
17 //Stefan-Boltzman constant (sigma)=5.67*10^-8 W/(m^2*
   K^4)
18 sigma=5.67*10^-8;
19 //The emissivity is represented by emi
20 //The radiation heat exchange in case of two
   concentric sphere is given by  $Q = [A_1 \sigma (T_1^4 - T_2^4)] / [(1/\epsilon_1) + (A_1/A_2) * (1/\epsilon_2 - 1)]$ 
21 //When the spheres are black emi1=emi2=1
22 emi1=1;
23 emi2=1;

```

```

24 //Hence  $Q=A1*\sigma*(T1^4-T2^4)$ 
25 disp("The net rate of heat exchange between the
        spheres when the surfaces are black is  $Q=A1*\sigma$ 
         $*(T1^4-T2^4)$  in W ")
26 Q=A1*sigma*(T1^4-T2^4)
27 //The net rate of radiation exchange when one
        surface is gray and other is diffuse having  $\text{emi1}$ 
        =0.5 and  $\text{emi2}=0.5$ 
28 emi1=0.5;
29 emi2=0.5;
30 disp("The net rate of radiation exchange when one
        surface is gray and other is diffuse is given by
         $Q1=[A1*\sigma*(T1^4-T2^4)]/[(1/\text{emi1})+(A1/A2)*(1/$ 
         $\text{emi2}-1)]$  in W")
31 Q1=[A1*sigma*(T1^4-T2^4)]/[(1/emi1)+(A1/A2)*(1/emi2
        -1)]
32 //The net rate of radiation exchange when outer
        surface is assumed to be black body i;e( $\text{emi2}=1$ )
33 emi2=1;//emissivity of outer surface
34 disp("The net rate of radiation exchange when outer
        surface is assumed to be black body i;e( $\text{emi2}=1$ )
        in W")
35 Q2=[A1*sigma*(T1^4-T2^4)]/[(1/emi1)+(A1/A2)*(1/emi2
        -1)]
36 disp("Error(E) is given By  $[(Q2-Q1)/Q1]*100$  in
        percentage")
37 E=[(Q2-Q1)/Q1]*100

```

Scilab code Exa 11.10 Configuration of a furnace as an equilateral triangle

```

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

```



```

6  clc;
7  disp("Introduction to heat transfer by S.K.Som,
      Chapter 11, Example 10")
8  //Given a furnace which can be approximated as an
      equilateral triangle duct
9  //The hot wall is maintained at temperature (T1)=1000
      K and has emmissivity(emi1)=0.75
10 //The cold wall is at temprature(T2)=350K and has
      emmissivity(emi2)=0.7
11 T1=1000;
12 T2=350;
13 emi1=0.75;
14 emi2=0.7;
15 //Stefan-Boltzman constant (sigma)=5.67*10^-8 W/(m^2*
      K^4)
16 sigma=5.67*10^-8;
17 //The third wall is reradiating zone having Q3=0
18 //The radiation flux leaving the hot wall is Q/A=[
      sigma*(T1^4-T2^4)]/(A*R)
19 //By summation rule F33+F31+F32=1
20 //F33=0(in consideration of surface to be plane)
21 //From symmetry F31=F32
22 F31=0.5;//View factors
23 F32=F31;//View factors
24 F33=0;//View factors
25 //From reciprocity theorem F13=F31 and F23=F32=0.5 (
      since A1=A2=A3=A)
26 F13=F31;//View factors
27 F23=F32;//View factors
28 //Again F11+F12+F13=1 from summation rule
29 F11=0;//View factors
30 F12=1-F13-F11;//View factors
31 //R1,R2,R12,R13,R23 are the resistances
32 //R is equivalent resistance of thermal network is
      given by R1+[(1/R12)+(1/(R13+R23))]^-1+R2
33 R1=(1-emi1)/(emi1);
34 R2=(1-emi2)/(emi2);
35 R12=1/(F12);

```

```

36 R13=1/(F13);
37 R23=1/(F23);
38 //R is equivalent resistance of thermal network
39 disp("Equivalent resistance of thermal network (R)
      is given by  $R1 + [(1/R12) + (1/(R13+R23))]^{-1} + R2$ ")
40 R=R1+[(1/R12)+(1/(R13+R23))]^-1+R2
41 //The radiation flux leaving the hot wall is Q/A.
42 disp("The radiation flux leaving the hot wall is Q/A
      =[sigma*(T1^4-T2^4)]/(A*R) in W/m^2")
43 //Since A gets cancelled in the factor (A*R)
44 //So Q/A=[sigma*(T1^4-T2^4)]/(R)
45 //Let Q/A=H
46 H=[sigma*(T1^4-T2^4)]/(R)

```

Chapter 12

Principles of mass transfer

Scilab code Exa 12.1 Pipeline that transports helium gas

```
1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 ieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 12, Example 1")
8 //The pressure in the pipeline that transports
      helium gas at a rate of 4kg/s is maintained at
      pressure(p)=1 atm or 101*10^3 pascal.
9 //The internal diameter of tube is (di)=6mm or .006m
10 //The temperature of both air and helium is (T)=25 C
      or 298 K.
11 //The diffusion coefficient of helium in air at
      normal atmosphere is (Dab)=7.20*10^-5 m^2/s
12 //The venting tube extends to a length(L)=20m in the
      atmosphere.
13 di=.006;
14 disp("The flow area is given by A=(pi*di^2)/4 in m^2
      ")
```

```

15 A=(%pi*di^2)/4
16 p=101*10^3;;
17 R=8.31*10^3;//gas constant
18 T=298;
19 Dab=7.20*10^-5;
20 L=20;
21 //c is the molar concentration
22 disp("The molar concentration of mixture which is
      constant throughout is given by c=p/(R*T)")
23 c=p/(R*T)
24 //helium has been considered as species A so (helium
      mole fraction at the bottom of the tube)is Yao=1
      and (helium mole fraction at the bottom of the
      tube)is Yal=0
25 Yal=0;
26 Yao=1;
27 //Nhe and Nair are molar rate of helium and air
      respectively
28 disp("Nhe=Nair=(A*c*Db*(Yao-yal))/L in kmol/sec")
29 Nair=(A*c*Dab*(Yao-Yal))/L
30 Nhe=Nair;
31 //Molecular weights of air and helium are 29kg/kmol
      and 4 kg/kmol respectively.
32 Mhe=4;
33 Mair=29;
34 //mass flow rate of helium is mhe
35 disp("mass flow rate of helium is given by m=Mhe*Nhe
      in kg/sec ")
36 mhe=Mhe*Nhe
37 //mass flow rate of air is mair
38 disp("mass flow rate of air is given by m=Mair*Nair
      in kg/sec ")
39 mair=Mair*Nair

```

Scilab code Exa 12.2 Wet bulb thermometer

```

1 // Display mode
2 mode(0);
3 // Display warning for floating point exception
4 iieee(1);
5 clear;
6 clc;
7 disp("Introduction to heat transfer by S.K.Som,
      Chapter 12, Example 2")
8 //The temprature of atmospheric air (T)=40 C which
   flows over a wet bulb thermometer.
9 //The reading of wet bulb thermometer which is
   called the wet bulb temprature is (Tw)=20 C
10 T=40;
11 Tw=20;
12 //Tf is the film temprature
13 disp("The film temprature is given by Tf=(T+Tw)/2 in
      C ")
14 Tf=(T+Tw)/2
15 Tinf=T;//surrounding temprature
16 //The properties of air at film temprature are
   density(rho=1.13kg/m^3),specific heat(cp=1.007kJ
   /(kg*K)),Thermal diffusivity(alpha=0.241*10^-4m
   ^2/s)
17 //The diffusivity Dab=0.26*10^-4 m^2/s
18 //The enthalpy of vaporisation of water at 20 C is
   hfg=2407kJ/kg or 2407*10^3 J/kg
19 //The partial pressure of water vapour is the
   saturation pressure corresponding to 20 C so
   from steam table Ps=2.34kPa or 2.34*10^3 Pa.
20 rho=1.13;
21 cp=1.007*10^3;
22 alpha=0.241*10^-4;
23 Dab=0.26*10^-4;
24 hfg=2407*10^3;
25 Ps=2.34*10^3;
26 //The temprature at bulb surface Ts=20 C or 293K
27 Ts=Tw+273;//in kelvin
28 R=8.31*10^3;//gas constant

```

```

29 //The molecular weight of water is M=18
30 M=18;
31 //The density of water at bulb surface is rhos
32 disp("The density of water at bulb surface is given
    by rhos=(Ps*M)/(R*Ts) in kg/m^3")
33 rhos=(Ps*M)/(R*Ts)
34 //Let X=hheat/hmass=rho*cp*(alpha/Dab)^(2/3).
35 X=rho*cp*(alpha/Dab)^(2/3);
36 //At steady state (Rate of heat transfer from air to
    wet cover of thermometer bulb)=(Heat removed by
    evaporation of water from the wet cover of
    thermometer bulb)
37 //hheat*(Tinf-Ts)=hmass*(rhos-rhoinf)*hfg
38 //Rearranging above we get rhoinf=rhos-(hheat/hmass)
    *((Tinf-Ts)/hfg)
39 //The concentration of water vapour at free stream
    is rhoinf
40 disp("The concentration of water vapour at free
    stream is rhoinf=rhos-(hheat/hmass)*((Tinf-Ts)/
    hfg) in kg/m^3")
41 rhoinf=rhos-((X)*((Tinf-Tw)/hfg))
42 //The mass concentration of saturated water vapour(
    rhosteam) at 40 C (as found from steam table) is
    .051 kg/m^3
43 rhosteam=.051;
44 //The relative humidity is (rehu)
45 disp("The relative humidity is given by rehu=(rhoinf
    /rhosteam)*100 in percentage")
46 rehu=(rhoinf/rhosteam)*100

```

Scilab code Exa 12.3 Measurement of binary diffusion coefficient

```

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

```

```

4  ieee(1);
5  clear;
6  clc;
7  disp("Introduction to heat transfer by S.K.Som,
      Chapter 12, Example 3")
8  //The diameter of tube is (di)=35mm which measures
      binary diffusion coefficient of water vapour in
      air at temprature ,T=20 C or 293 K.
9  //The measurement is done at height of 1500 m where
      the atmospheric pressure is (p)=80kPa.
10 p=80;
11 T=293;
12 //The distance from the water surface to the open
      end of the tube is L=500 mm or 0.5m.
13 L=.5;
14 //After t=12 days of continuous operation at
      constant pressure and temprature the amount of
      water evaporated was measured to be m= 1.2*10^-3
      kg.
15 m= 1.2*10^-3;
16 //From the steam table pvapour=3.17kPa
17 pvapour=3.17; //partial pressure of vapour
18 //Yao is the mole fraction of water vapour at the
      interface
19 disp("The mole fraction of water vapour at the
      interface is given by Yao=pvapour/p")
20 Yao=pvapour/p
21 //The mole fraction of water vapour at the top end
      of the tube is Yal=0
22 Yal=0;
23 R=8.31*10^3; //gas constant
24 //The total molecular concentration is (c)
25 disp("The total molecular concentration (c) through
      the tube remains constant is given by c=p/(R*T)
      in kmol/m^3")
26 c=(p*10^3)/(R*T)
27 di=35;
28 //A is the cross sectional area of the tube

```

```

29 disp("The cross sectional area of the tube is given
      by  $A=(\pi*(di*10^{-3})^2)/4$  in  $m^2$ ")
30 A=(%pi*(di*10^-3)^2)/4
31 //The molecular weight of wate is M=18
32 M=18;
33 //The mass flow rate is given by  $\dot{m}=(m/(12*24*3600))$ 
34  $\dot{m}=(m/(12*24*3600))$ ;
35 //N is the molar flow rate of water vapour
36 disp("The molar flow rate of water vapour is given
      by  $N=\dot{m}/M$  in kmol/s")
37 N= $\dot{m}/M$ 
38 //The molar flow rate of water vapour can also be
      written as  $N=(c*Dab*A*\ln[(1-Yal)/(1-Yao)])/L$ 
39 //The diffusion coefficient of water vapour is  $Dab=(N*L)/(c*A*\ln[(1-Yal)/(1-Yao)])$ 
40 //let us take  $X=\log_{10}((1-Yal)/(1-Yao))$  and  $Y=\log_{10}(2.7182)$ 
41  $X=\log_{10}((1-Yal)/(1-Yao))$ ;
42  $Y=\log_{10}(2.7182)$ ;
43 //ln[(1-Yal)/(1-Yao)] is given by
44  $\ln=X/Y$ ;
45 disp("The diffusion coefficient of water vapour is
       $Dab=(N*L)/(c*A*\ln[(1-Yal)/(1-Yao)])$  in m/s")
46  $Dab=(N*L)/(c*A*\ln)$ 

```
