Scilab Textbook Companion for Introduction to Heat Transfer by S. K. Som[1]

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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.

Contents

List of Scilab Codes

Chapter 1

Fundamental concepts

Scilab code Exa 1.1 Thick homogeneous slab

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

```
)/L in W/m^2 ")
q=k*(T1-T2)/L
```

Scilab code Exa 1.2 Thickness required of a masonry wall

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 1, Example 2")
//The thermal conductivity(km)of masonry wall is .8 W/(mK)
//The thermal conductivity(kc)of composite wall is .2 W/(mK)
//The thickness of composite wall(Lc) is 100 mm or .1 m
km=.8;
kc=.2;
Lc=.1;
//The thickness of masonry wall(Lm) is to be found.
//The steady state heat flow(qm)through masonry wall is km(T1-T2)/L
// The steady state heat flow(qc)through composite wall is kc(T1-T2)/L
//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)
//The thickness of masonry wall is Lm.
disp ("The thickness of masonry wall is Lm in m")
Lm=(km/kc)*(Lc/(0.8))
```

Scilab code Exa 1.4 Average forced convective heat transfer coefficient

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

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
```

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

Scilab code Exa 1.6 Thin hot vertical plate

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

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

Scilab code Exa 1.7 After sunset radiant energy

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

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

Scilab code Exa 1.8 Asphalt pavements on hot summer

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

Scilab code Exa 1.9 Concrete wall is exposed to air

```
// Display mode
```

```
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 1, Example 9")
//The Thickness(L) of wall= 150 mm or 0.15 m.
//The wall on one side is exposed to air at temprature(Ta)= 60 C and on the other side to air at temprature(Tb) = 20 C
//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.
//The thermal conductivity(k)=.8 W/( m C)
L=0.15;
Ta=60;
Tb=20;
hbr1=40;
hbr2=10;
k=0.8;
//Area(A=1 m^2 )since unit surface area is required.
A=1;
//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))
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")
//Let Q/A=F
F=(Ta-Tb)/((1/hbr1*A)+(L/(k*A))+(1/hbr2*A))
//The surface tempratures of wall on 60 C side is T1 and on 20 C side is T2
disp("The surface tempratures of wall on 60 C side is T1 =Ta-(Q/(A*hbr1)) in  C")
T1 =Ta-(F/hbr1)
disp("The surface tempratures of wall on 20 C side is T2 =Tb+(Q/(A*hbr2)) in  C")
```

```
T2 =Tb+(F/hbr2)
```

Scilab code Exa 1.10 A flat panel on spacecraft

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 1, Example 10")
//The spacecraft panel has thickness(L)=.01 m
//The spacecraft has inner temprature (Ti)=298 K
//The spacecraft has outer temprature(T2)
//The panel is exposed to deep space where temprature(To)= 0K
//The material has Thermal conductivity(k)= 5.0 W/(m*K)
//The emissivity(emi)=0.8
//The inner surface of the panel is exposed to airflow resulting in an average heat transfer coefficient(hbri)=70 W/(m^2*K)
L=.01;
Ti=298;
To=0;
k=5;
emi=0.8;
hbri=70;
//The stefan Boltzman constant(sigma)= 5.67*10^-8 W/(m^2/K^4)
sigma=5.67*10^-8;
//Heat transfer from the outer surface takes place only by radiation is given by  Q/A=emi*sigma*(T2^4-T0^4)in W/m^2=F1
```

```
//heat transfer from the outer surface can also be written as Q/A=(Ti-To)/((1/hbri)+(L/k)+(1/hr))=F2
//Radiation heat transfer coefficient(hr) is defined as Q/A=hr(T2-To)
//so hr=4.536*10^-8*T2^3
disp("Heat transfer from the outer surface takes place only by radiation is given by Q/A=F1=emi*sigma*(T2^4-T0^4)in W/m^2 for different values of tempratures in K")
disp("heat transfer from the outer surface can also be written as Q/A=F2=(Ti-To)/((1/hbri)+(L/k)+(1/hr)) in W/m^2 at different tempratures in K" )
disp("The values of temprature that are considered are <298 K")
for (i=285:292)
    T2=i,hr=4.536*10^-8*T2^3; F1=emi*sigma*(T2^4-To^4),F2=(Ti-To)/((1/hbri)+(L/k)+(1/hr))
end
if F1==F2 then T2=i
    else T2=292.5,hr=4.536*10^-8*T2^3; F1=emi*sigma*(T2^4-To^4),F2=(Ti-To)/((1/hbri)+(L/k)+(1/hr))
end
disp("Satisfactory solutions for Temprature in K is")
disp(Temprature = T2)
disp("Approximate Rate of Heat Transfer in W/m^2 is")
disp(332)
```

Scilab code Exa 1.11 A horizontal steel pipe

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

```
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 1, Example 11")
//The horizontal steel pipe has outer diameter(D)=80 mm or.08 m
//The pipe is maintained at a temprature(T1)=60  C where the air and wall temprature(T2)=20   C
//The average free convective heat transfer coefficient(hbr)=6.5 W/(m^2/K) b/w the outer surface of the pipe and air
D=.08;
T1=60;
T2=20;
hbr=6.5;
//Length(L=1) since per unit length is considered
L=1;
//The surface area of pipe is given by A=(%pi*D*L)
A=(%pi*D*L);
//The surface emissivity(emi) of steel = 0.8
//The stefan -Boltzman constant(sigma)= 5.7*10^-8 W/(m^2*K^4)
sigma=5.67*10^-8;
emi=.8;
//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)
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")
//Let Q/L=F
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

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

```
    sheet and plywood.
Lg=20;
kg=.01;
//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
To=24;
Ti=-15;
//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)
hi=12;
ho=20;
//The surface area of wall (A)= .75 m^2
A=.75;
//The convective resistance is Ro= 1/(ho*A) at the outer surface
disp("The convective resistance Ro= 1/(ho*A) at the outer surface in KW^-1 is")
Ro=1/(ho*A)
//The conduction resistance is Rs= Ls/(ks*A) of steel sheet
disp("The conduction resistance Rs= Ls/(ks*A) of steel sheet in KW^-1 is")
Rs=Ls*10^-3/(ks*A)
//The conduction resistance is Rg= Lg/(kg*A) of glass wool
disp("The conduction resistance Rg= Lg/(kg*A) of glass wool in KW^-1 is")
Rg= Lg*10^-3/(kg*A)
//The conduction resistance is Rp= Lp/(kp*A) of plywood
disp("The conduction resistance Rp= Lp/(kp*A) of plywood in KW^-1 is")
Rp= Lp*10^-3/(kp*A)
//The convective resistance is Ri= 1/(hi*A) at the outer surface
disp("The convective resistance Ri= 1/(hi*A) at the
```

```
outer surface in KW^-1 is")
Ri= 1/(hi*A)
//The rate of heat flow is Q=(To-Ti)/(Ro+Rs+Rg+Rp+Ri)
disp("The rate of heat flow Q=(To-Ti)/(Ro+Rs+Rg+Rp+Ri) in W is")
Q=(To-Ti)/(Ro+Rs+Rg+Rp+Ri)
//The tempraure at the outer surface of wall is T1.
//The temprature at the interface b/w steel sheet and glass wool is T2.
//The temprature at the interface b/w glass wool and plywood is T3.
//The tempraure at the inner surface of wall is T4.
disp("The temprature at the outer surface of wall is T1=To-(Q*Ro) in  C")
T1=To-(Q*Ro)
disp("The temprature at the interface b/w steel sheet and glass wool is T2=T1-(Q*Rs) in C")
T2=T1-(Q*Rs)
disp("The temprature at the interface b/w glass wool and plywood is T3=T2-(Q*Rg) in C")
T3=T2-(Q*Rg)
disp("The temprature at the inner surface of wall is T4=T3-(Q*Rp)in  C")
T4=T3-(Q*Rp)
//Check for Ti(Temprature inside the van)
disp("Check for Ti(in  C)")
Ti=T4-(Q*Ri)
disp("The value is same as given in the problem")
```

Scilab code Exa 2.2 A laboratory furnace wall

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

```
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 2, Example 2")
//The Thickness of fire clay bricks (Lb)=.2 m
Lb=0.2;
//The thermal conductivity of fire clay bricks(kb)
    =1.0 W/(m*K)
kb=1;
//the Thicknes of insulating material is L
//The thermal conductivity of insulating material(ki
    )=.07 W/(m*K)
ki=.07;
//The furnace inner brick surface is at temprature
    Ti=1250 K
Ti=1250;
//The furnace outer brick surface is at temprature
    To=310 K
To=310;
//The maximum allowable heat transfer rate(Q) from
    wall = 900 W/m^2
Q=900;
//Q=(Ti-To)/((Lb/kb)+(L/ki)) so L=ki*(((Ti-To)/Q)-(
    Lb/kb))
disp("The thickness of insulating material L=ki*(((
    Ti-To)/Q)-(Lb/kb)) in m")
L=ki*(((Ti-To)/Q)-(Lb/kb))
```

Scilab code Exa 2.4 In a manufacturing process

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

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

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

Scilab code Exa 2.6 Thick plate with uniform heat generation

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

```
k=200;
//The left and right faces are kept at tempratures T=160  C and T=120  C respectively
//We start with the equation (d^2T/dx^2)+(qg/k)=0 or T=-(qg/2k)*x^2 +(c1*x)+c2
//With qg=80*10^6W/m^3 and k=200W/(m*K)
//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
//Hence T=160+2*10^3*(x-100*x^2)------>eq.1
disp("(a)The expression for the temprature distribution in the plate T=160+2*10^3*(x-100*x^2)" )
//For maximum temprature 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
disp("(b)The maximum temprature occurs at x=5mm or 0.005m away from the left surface towards the right")
x=0.005;
//The maximum temprature is Tmax
disp("The maximum temprature(Tmax) in   C is")
Tmax=160+2*10^3*(x-100*x^2)
//The rate of heat transfer(q/A) is given by -k*(dT/dx)
//Let dT/dx=X and (q/A)=Q
disp("(c(i))The rate of heat transfer at the left face in MW/m^2 is")
//For left face x=0
x=0;
X=(2*10^3)-(4*10^5*x);
Q=-k*X/10^6
disp("The minus sign indicates that the heat flow in the negative direction")
disp("(c(ii))The rate of heat transfer at the right face in MW/m^2 is")
//For right face x=0.02
x=0.02;
```

```
X=(2*10^3)-(4*10^5*x);
Q=-k*X/10^6
//(q/A)@x=0 implies rate of heat transfer at the position where x=0.
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")
disp("(c(iii))The rate of heat transfer at the centre in MW/m^2 is")
//For centre x=0.01
x=0.01;
X=(2*10^3)-(4*10^5*x);
Q=-k*X/10^6
//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

```
//Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 2, Example 09")
//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.
T1=400;
Tinf=300;
r=0.01;
//The tube is insulated with magnesia insulation of
```

```
an approximate thermal conductivity of k=0.07W/(m*K)
k=0.07;
//External convective Coefficient h=4W/(m^2*K)
h=4;
//Critical thickness(rc) is given by k/h
disp("The critical thickness of insulation in metre is")
rc=k/h
//We use the rate of heat transfer per metre of tube length as Q=(Ti-Tinf)/((ln(r2/r1)/(2*%pi*L*k))+(1/(h*2*%pi*r2*L))) where length,L=1m
L=1;
//When 0.002m thick layer of insulation r1=0.01m,r2=0.01+0.002=0.012m
r1=0.01;//inner radius
r2=0.012;//outer radius
//Let ln(r2/r1)=X
X=log(r2/r1)/log(2.718);
//The heat transfer rate per metre of tube length is Q
disp("The heat transfer rate Q per metre of tube length in W/m is ")
Q=(T1-Tinf)/(((X)/(2*%pi*L*k))+(1/(h*2*%pi*r2*L)))
//When critical thickness of insulation r1=0.01m,r2=0.0175m
r2=0.0175;//outer radius
r1=0.01;//inner radius
//Let ln(r2/r1)=X
X=log(r2/r1)/log(2.718);
//The heat transfer rate per metre of tube length is Q
disp("The heat transfer rate per metre of tube length Q in W/m is ")
Q=(T1-Tinf)/(((X)/(2*%pi*L*k))+(1/(h*2*%pi*r2*L)))
//When there is a 0.05 m thick layer of insulation r1=0.01m,r2=.01+0.05=0.06m
r1=0.01;//inner radius
```

```
r2=0.06;//outer radius
//Let ln(r2/r1)=X
X=log(r2/r1)/log(2.718);
//The heat transfer rate per metre of tube length is Q
disp("The heat transfer rate per metre of tube length Q in W/m is ")
Q=(T1-Tinf)/(((X)/(2*%pi*L*k))+(1/(h*2*%pi*r2*L)))
//It is important to note that Q increases by 5.2% when the insulation thickness increases from 0.002m to critical thickness.
//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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 2, Example 10")
//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 temprature,T1=-182 C
//mass flow rate is ,mdot=0.06m^3/min.
Di=0.03;//in metre
Do=0.035;// in metre
T1=-182;
mdot=0.06;
//The ambient air is at temprature(Ta)=20 C and has
```

```
a dew point(T3)=10 C .
Ta=20;
T3=10;
//The thermal conductivity(k) of insulating material is 0.02W/(m*k)
k=0.02;
//The convective heat transfer coefficient on the outside is h=17W/(m^2*K)
h=17;
//The thermal conductivity of copper kcu=400W/(m*K)
kcu=400;
//We can write Q=((Ta-T1)/(R1+R2+R3))=((Ta-T3)/(R3)),Rearranging we get ((R1+R2+R3)/(R3))=((Ta-T1)/(Ta-T3))----------eq.1
//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
//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.
//The convective resistance at the outer surface(R3)=1/(2*%pi*L*h*r3)=(1/2*%pi*L)*(mdot/r3)K/W
//Substituting the values in eq.1 we have 1+((50*ln(r3/0.035)+(3.85*10^-4))/(mdot/r3))=20-(-182)/(20-10)
//A rearrangement of the above equation gives r3*ln(r3)+3.35*r3=0.023
//The equation is solved by trial and error method which finally gives r3=0.054m
r3=0.054;//outer radius of insulation
//Therefore the thickness of insulation is given by t=r3-Do
disp("the thickness of insulation in metre is")
t=r3-Do
```

Scilab code Exa 2.11 An electrical resistance wire

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 2, Example 11")
//An electrical resistance wire 2.5mm or 2.5*10^-3m
    in diameter(D) and L=0.5m long has a measured
    voltage drop of E=25V for a current flow of I=40A
    .
D=2.5*10^-3;
I=40;
E=25;
L=0.5;
ro=D/2;//ro is radius of wire
//The thermal conductivity(k) of wire material is 24
    W/(m*K)
k=24;
//The rate of generation of thermal energy per unit
    volume is given by qG=(E*I)/(L*%pi*D^2/4)
disp("The rate of heat generation of thermal energy
    in W/m^3 is")
qG=(E*I)/(L*%pi*D^2/4)
//The temprature at the centre is given by To=Tw+((
    qG*ro^2)/(4*k)) where Tw=650K is surface
    temprature
Tw=650;
disp("The temprature of wire at the centre in K is "
    )
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 2, Example 12")
//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
Di=5;
t=25;
Do=5+2*(t/1000);//in metre
k=15;
Ti=0;
//The tank is located in a room whose temprature is
    (To)=20 C.
To=20;
//Emmisivity is 1.
//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)
hi=80;
ho=10;
//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.
sigma=5.67*10^-8;
```

```
deltahf=334;
//The inner surface area is (A1) and outer surface area is (A2)of the tank
disp("The inner(A1) and outer surfaces(A2) areas of the tank in m^2 are")
A1=%pi*Di^2
A2=%pi*Do^2
//The individual thermal resistances can be determined as
//The convective resistance is (Ri)
disp("The convective resistance(Ri) at the inner surface in K/W is ")
Ri=1/(hi*A1)
//The conduction resistance is(Rs)
disp("The conduction resistance(Rs)of the tank in K/W is")
Rs=(Do-Di)/(2*k*%pi*Di*Do)
//The convective resistance is(Roc)
disp("The convective resistance(Roc) at the outer surface in K/W is")
Roc=1/(ho*A2)
//The radiative resistance(Ror) at the outer surface is Ror=1/(A2*hr)
//The radiative heat transfer coefficient hr is determined by hr=sigma*(T2^2+293.15^2)*(T2+293.15)
//But we do not know the outer surface temprature T2 of the tank and hence we cannot determine the value of hr.
//Therfore 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
T2=277.15;
disp("The radiative heat transfer coefficient hr in W/(m^2*K) is")
hr=sigma*(T2^2+293.15^2)*(T2+293.15)
disp("Therefore the radiative resistance(Ror) at the outer surface in K/W is")
```

```
Ror=1/(A2*hr)
//The two parallel resistances Roc and Ror can be
   replaced by an equivalent resistance Ro as X=(1/
   Ro)=(1/Roc)+(1/Ror)
disp("The equivalent resistance in K/W is")
X=(1/Roc)+(1/Ror);
Ro=1/X
//Now the resistance Ri,Rs and Ro are in series an
   hence the total resistance becomes Rtotal=Ri+Rs+
   Ro
disp("The total resistance in K/W is")
Rtotal=Ri+Rs+Ro
//The rate of heat transfer is given by Q=(To-Ti)/
   Rtotal
disp("The rate of heat transfer ,Q in W is")
Q=(To-Ti)/Rtotal
//The outer surface(T2) is calculated as T2=To-Q*Ro
disp("The outer surface temprature in  C is")
T2=To-Q*Ro
disp("which is sufficiently close to the assumption.
   So there is no need of further iteration")
//The total heat transfer is (Qt),during a 24-hour
   period
disp("The total heat transfer(Qt) during a 24-hour
   period in KJ is")
Qt=Q*24*3600/1000
//the amount of ice in kG which melts during a 24
   hour period is (mice)
disp("Therefore,the amount of ice(mice)in kG which
   melts during a 24 hour period is")
mice=Qt/deltahf
```

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

```
// Display mode
```

```
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 2, Example 13")
//A very long,10mm diameter(D) copper rod(thermal conductivity,k=370W/(m*K))is exposed to an enviroment at temprature,Tinf=20 C.
D=0.01;
k=370;
Tinf=20;
//The base temprature of the radius maintained at Tb=120 C.
Tb=120;
//The heat transfer coefficient between the rod and the surrounding air is h=10W/(m*K^2)
h=10;
//The rate of heat transfer for all finite lengths will be given by P/A=(4*pi*D)/(pi*D^2)
//Let P/A=X
disp("P/A in m^-1 is")
X=(4*%pi*D)/(%pi*D^2)
//m is defined as [(h*p)/(k*A)]^0.5
disp("m in m^-1 is")
m=(h*X/k)^0.5
//Let Y=h/(m*k)
Y=h/(m*k)
//Let M=(h*P*k*A)^0.5
P=(%pi*D);//perimeter of the rod
A=(%pi*D^2)/4;//Area of the rod
disp("M in W/K is")
M=(h*P*k*A)^0.5
//thetab is the parameter that defines the base temprature
disp("thetab in  C is ")
thetab=Tb-Tinf
```

```
//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)]}
disp("Heat loss from rod in Watt, for different value of length(in m) is ")
L=0.02//Length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
L=0.04//length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
L=0.08//length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
L=0.20//length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
L=0.40//length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
L=0.80//length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
L=1.00//length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
L=10.00//length of rod
Q=M*thetab*{[(Y)+tanh(m*L)]/[1+(Y)*tanh(m*L)]}
//For an infinitely long rod we use heat loss as , Qinf=(h*P*k*A)^0.5*thetab
disp("For an infintely long rod heat loss in W is")
Qinf=(h*P*k*A)^0.5*thetab
disp("We see that since k is large there is significant difference  between the finite length  and the infinte length cases")
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

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

```
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 2, Example 14")
//Considering two very long slender rods of the same diameter but of different materials.
//The base of each rod is maintained at 100 C while the surfaces of the rod are exposed to 20 C
//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.
xA=0.15;
xB=0.075;
//Thermal conductivity of rod A is known to be kA=72 W/(m*K)
kA=72;
//In case of a very long slender rod we use the tip boundary condition thetaL=0 as L--->infinity
//Therfore 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
//So kB=kA*(xB/xA)^2
//The thermal conductivity of Rod B iskB
disp("The thermal conductivity of Rod B kB in W/(m*K) is ")
kB=kA*(xB/xA)^2
```

Scilab code Exa 2.15 The entire stack is made of aluminium

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

```
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 2, Example 15")
//A stack that is b=300mm wide and l=100mm deep
    contains N=60 fins each of length L=12mm.
L=0.012;//in metre
b=0.3;//in metre
l=0.1;//in metre
N=60;
//The entire stack is made of aluminum which is
    everywhere t=1.0 mm thick.
t=0.001;//in metre
//The temprature limitations associated with
    electrical components are  Tb=400K and TL=350K.
//Tb is base temprature and TL is end temprature
Tb=400;
TL=350;
//Given convection heat transfer coefficient(h=150W
    /(m^2*K)),Surrounding Temprature(Tinf=300K),
    thermal conductivity of aluminium(kaluminium=230W
    /(m*K))
h=150;
Tinf=300;
kal=230;
//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,thetab=Tb-Tinf,thetaL=TL-
    Tinf
//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
disp(" perimeter of each fin in m is")
P= 2*(l+t)
disp("Cross sectional area of fin in m^2 is")
A=t*l
//M is defined as (h*P*kal*A)^0.5 and m is defined
    as ((h*P)/(kal*A))^0.5
```

```
M=(h*P*kal*A)^0.5
m=((h*P)/(kal*A))^0.5
//thetab and thetaL are the parameters that define
    the fin tempratures at base and tip respectively.
disp("Temprature parameter at fin base in K is")
thetab=Tb-Tinf
disp("Fixed temprature at fin tip in K is")
thetaL=TL-Tinf
//Heat loss from the plate is Qb
disp("Heat loss from the plate at 400K in W is")
Qb=[N*(h*P*kal*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 Temprature at the centre of the plate

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

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

Scilab code Exa 3.2 A thin square plate

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

```
    temperature theta1
//theta1=2*sinh(pi*y/a)*sin(pi*x/a)/(sinh(pi))
//Solution to module 2 is given by Eq. 3.24
//Solution of second module is non dimensional
    temperature theta2
//theta2=sinh(pi*x/a)*sin(pi*y/a)/(sinh(pi))
//Therefore
disp("Steady state non dimensional temperature is")
disp("theta=2*sinh(pi*y/a)*sin(pi*x/a)/(sinh(pi)) +
    sinh(pi*x/a)*sin(pi*y/a)/(sinh(pi))")
//At the centre, x coordinate and y coordinate in
    unit are
//x=a/2, y=a/2
//Non dimensional temperature at centre point
theta = (2*sinh(%pi/2))/sinh(%pi)+sinh(%pi/2)/sinh(
    %pi);
//Temperature in K at centre point
disp("Temperature in K at centre point")
T = theta*100+300
```

Scilab code Exa 3.3 Three sides of a square plate

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

```
Tinfinity = 400;
//Heat transfer coefficient in W/(m^2*K)
h = 10;
//T1, T2, T3, T4, T5, T6, T7, T8 are nodal temperatures in degree K.
//T is the temperature matrix and is transpose of [T1 T2 T3 T4 T5 T6 T7 T8]
//using Nodal Equations, we have Coefficeint Matrix A as
A = [-4,1,0,0,1,0,0,0;
     1,-4,1,0,0,1,0,0;
     0,1,-4,1,0,0,1,0;
     2,0,0,0,-4,1,0,0;
     0,2,0,0,1,-4,1,0;
     0,0,2,0,0,1,-4,1;
     0,0,2,-6,0,0,0,1;
     0,0,0,2,0,0,2,-6];
//Coefficient matrix B
B = [-1200;
     -600;
     -600;
     -600;
     0;
     0;
     -1400;
     -800];
//Therefore the temperature matrix is
T = (A^(-1))*B;
//Temperature at nodal points in degree K
disp("Temperatures at nodal points in degree K")
disp("T1 in degree K")
T1 = T(1)
disp("T2 in degree K")
T2 = T(2)
disp("T3 in degree K")
T3 = T(3)
disp("T4 in degree K")
T4 = T(4)
```

```
disp("T5 in degree K")
T5 = T(5)
disp("T6 in degree K")
T6 = T(6)
disp("T7 in degree K")
T7 = T(7)
disp("T8 in degree K")
T8 = T(8)
```

Scilab code Exa 3.5 An aluminium rod

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

```
T1 = Tw;
//using Nodal Equations, we have Coefficeint Matrix A as
A = [2.064,-1,0,0,0;
     -1,2.064,-1,0,0;
     0,-1,2.064,-1,0;
     0,0,-1,2.064,-1;
     0,0,0,-1,1.032];
//Coefficient matrix B
B = [401.92;
     1.92;
     1.92;
     1.92;
     0.96];
//T2, T3, T4, T5, T6 are nodal temperature in degree C
//T is the temperature matrix and is transpose of [T2 T3 T4 T5 T6]
//Therefore the temperature matrix is
T = (A^(-1))*B;
//Temperature at nodal points in degree C
disp("Temperatures at nodal points in degree C")
disp("T2 in degree C")
T2 = T(1)
disp("T3 in degree C")
T3 = T(2)
disp("T4 in degree C")
T4 = T(3)
disp("T5 in degree C")
T5 = T(4)
disp("T6 in degree C")
T6 = T(5)
//Heat transfer rate in W
disp("Heat loss from fin in W")
Q = -((((k*%pi)*d)*d)*(T2-T1))/(4*deltax)
//Using eq. 2.67
//Parameter m in meter inverse
m = (((h*%pi)*d)/((((k*%pi)*d)*d)/4))^0.5;
```

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

```
    is %5.2f C while predicted numerically is %5.2f C
    \n",Ta(4),T(4))
// L.75: No simple equivalent, so mtlb_fprintf() is
    called.
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 3, Example 6")
//Thermal conductivity of concrete in W/mK
k = 2;
//Length in m
L = 0.2;
//Breadth in m
b = 0.2;
//Depth in m
d = 0.2;
//Temperature of hot gas in chimney in degree C
Tg = 400;
//Air temperature in degree C
Tinfinity = 20;
//internodal distance in x direction in m
deltax = 0.1;
//internodal distance in y direction in m
deltay = 0.1;
//Heat transfer coefficient in W/(m^2*K)
```

```
h = 20;
//T1, T2, T3, T4, T5, T6, T7, T8, T9 are nodal temperatures in degree K.
//T is the temperature matrix and is transpose of [T1 T2 T3 T4 T5 T6 T7 T8 T9]
//using Nodal Equations, we have Coefficeint Matrix A as
A = [1,0,-4,2,0,1,0,0,0;
     0,1,1,-4,1,0,1,0,0;
     0,0,0,2,-4,0,0,2,0;
     -3,1,1,0,0,0,0,0,0;
     0,0,1,0,0,-3,1,0,0;
     0,0,0,2,0,1,-6,1,0;
     0,0,0,0,2,0,1,-6,1;
     0,0,0,0,0,0,0,1,-2;
     1,-4,0,2,0,0,0,0,0];
//Coefficient matrix B
B = [0;
     0;
     0;
     -400;
     -20;
     -40;
     -40;
     -20;
     -400];
//Therefore the temperature matrix is
T = (A^(-1))*B;
//Temperature at nodal points in degree C
disp("Temperatures at nodal points in degree C")
disp("T1 in degree C")
T1 = T(1)
disp("T2 in degree C")
T2 = T(2)
disp("T3 in degree C")
T3 = T(3)
disp("T4 in degree C")
T4 = T(4)
```

```
disp("T5 in degree C")
T5 = T(5)
disp("T6 in degree C")
T6 = T(6)
disp("T7 in degree C")
T7 = T(7)
disp("T8 in degree C")
T8 = T(8)
disp("T9 in degree C")
T9 = T(9)
```

Chapter 4

Unsteady conduction

Scilab code Exa 4.1 An apple subject to a cold enviroment

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

```
if Bi<0.1 then
  disp("Problem is suitable for lumped parameter
      analysis")
else
  disp("Problem is not suitable for lumped parameter
       analysis")
end;
```

Scilab code Exa 4.2 The temprature of a gas stream

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 4, Example 2")
//Diameter of sphere in m
d = 1.5*(10^(-3));
//radius in m
r = d/2;
//Thermal conductivity of sphere in W/(m* C )
k = 40;
//Density in kg/m^3
rho = 8000;
//Specific heat in J/(Kg*K)
c = 300;
//Heat transfer coefficient in W/(m^2* C )
h = 75;
//Time constant in sec
tc = ((rho*c)*(((((4*%pi)*r)*r)*r)/3))/((((h*4)*%pi)
   *r)*r);
disp("Time constant in seconds is")
tc
```

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

Scilab code Exa 4.3 Maximum edge dimension

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

Scilab code Exa 4.4 Some hot milk

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 4, Example 4")
//Diameter of glass in m
d = 50*(10^(-3));
//radius in m
r = d/2;
//Height of milk in glass in m
H = 0.1;
//Initial temperature of milk in  C
T = 80;
//Cold water temperature in  C
Tf = 25;
//Heat transfer coefficient in W/(m^2* C)
h = 100;
//Thermal conductivity of milk in W/(m*K)
k = 0.6;
//Density of milk in kg/m^3
rho = 900;
//Specific heat in J/(Kg*K)
c = 4.2*(10^3);
//Since the milk temperature is always maintained as constant.
//Therefore it can be assumed as lumped paramteter analysis.
//Time constant n seconds
tcs = (((((rho*c)*%pi)*r)*r)*H)/(((h*%pi)*d)*H);
//Time constant in minutes
tc = tcs/60;
//Calculating from eq. 4.3 time taken to cool milk from 80 C to 30 C
t = -tc*log((30-Tf)/(T-Tf));
disp("Time required to cool milk in minutes")
```

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

Scilab code Exa 4.5 Masonry brick wall

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

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

Scilab code Exa 4.6 A large aluminium plate

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

```
Tinfinity = 30;
//Given time in seconds
t = 225;
//Thermal conductivity of aluminium in W/(m*K)
k = 200;
//Thermal diffusivity in m^2/s
alpha = 8*(10^(-5));
//Biot number
Bi = (h*L)/k;
//Fourier number
Fo = (alpha*t)/(L*L);
//From fig. 4.11, at this Fo and (1/Bi), we have dimensionless temperature
//ratio to be 0.7
//From fig. 4.12 for this (1/Bi) and (x/L), we have another dimensionless
//temperature to be 0.93
//Temperature in  C
T = Tinfinity+(0.93*0.7)*(Ti-Tinfinity);
disp("Temperature at this distance in  C")
T
//From fig. 4.13, for this Bi and Fo*Bi*Bi, we have ratio of heats as
//Q/Qi=0.4
//Heat transfer in J
Q = (((0.4*k)*L)*(Ti-Tinfinity))/alpha;
disp("Heat transfer rate in MJ")
Q = Q/(10^6)
```

Scilab code Exa 4.7 A large cylinder

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

```
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 4, Example 7")
//Radius in m
ro = 0.15;
//Initial temperature in  C
Ti = 530;
//Temperature of surrounding in  C
Tinfinity = 30;
//Heat transfer coefficient in W/(m^2*K)
h = 380;
//Thermal conductivity of aluminium in W/(m*K)
k = 200;
//Thermal diffusivity in m^2/s
alpha = 8.5*(10^(-5));
//Given radius at which temperature has to be find out in m
r = 0.12;
//Given time in seconds
t = 265;
//Fourier number
Fo = (alpha*t)/(ro^2);
//Biot number
Bi = (h*ro)/k;
//From fig. 4.15, at this fourier number,Fo and (1/Bi), we have dimensionless temperature
//ratio to be 0.6
//From fig. 4.16 for this (1/Bi) and (r/ro), we have another dimensionless
//temperature to be 0.9
//Temperature in  C
T = Tinfinity+(0.9*0.6)*(Ti-Tinfinity);
disp("Temperature at this radius in  C")
T
//From fig. 4.17, for this Bi and Fo*Bi*Bi, we have ratio of heats as
//Q/Qi=0.4
```

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

Scilab code Exa 4.8 A steel sphere

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

```
//From Fig. 4.19 Fourier number is
Fo = 1.5;
//Time required in seconds
t = ((Fo*ro)*ro)/alpha;
disp("Time required in minutes")
t = t/60
```

Scilab code Exa 4.9 A large aluminium bar

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

```
//thickness L1 and L2 in m
L1 = L/2;
L2 = b/2;
//For plate 1
//Fourier number
Fo1 = (alpha*t)/(L1^2);
//Biot number
Bi1 = (h*L1)/k;
//From fig. 4.11, at this Fo and (1/Bi), we have dimensionless temperature
//ratio to be 0.7
//For plate 2
//Fourier number
Fo2 = (alpha*t)/(L2^2);
//Biot number
Bi2 = (h*L2)/k;
//From fig. 4.11, at this Fo and (1/Bi), we have dimensionless temperature
//ratio to be 0.47
//Therefore combined dimensionless temperature ratio is multiply of two
z = 0.47*0.7;
//Temperature in  C
T = Tinfinity+z*(Ti-Tinfinity);
disp("Tempearture of bar in  C")
T
```

Scilab code Exa 4.10 An iron beam

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
```

```
disp("Introduction to heat transfer by S.K.Som, Chapter 4, Example 10")
//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
//Initially the beam is at a uniform temprature(Ti) of 30 C.
//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)
//To determine the time required for the centre plane of the beam to reach a temprature(To) of 310 C.
To=310;
Tinf=730;
Ti=30;
//Take thermal conductivity k=73W/(m*K) and thermal diffusivity of the beam alpha=2.034*10^-5m^2/s
alpha=2.034*10^-5;
k=73;
h=100;
//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
L1=0.15;//in metre
L2=0.10;//in metre
//Here the faactor X=((To-Tinf)/(Ti-Tinf))
disp("The factor((To-Tinf)/(Ti-Tinf)) is ")
X=((To-Tinf)/(Ti-Tinf))
//Therefore we can write 0.6=((To-Tinf)/(Ti-Tinf))plate 1 *((To-Tinf)/(Ti-Tinf))plate2
//A straight forward solution is not possible.We have to adopt an iterative method of solution
//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
//Let us first assume time, t=900s
t=900;
disp("For plate 1")
//For plate1 Biot number Bi1=h*L1/k
Bi1=h*L1/k
Y=1/Bi1
//Fourier number(Fo1) is
Fo1=alpha*t/L1^2
//At Fo=0.814 and (1/Bi)=4.87...We read from graphs A=((To-Tinf)/(Ti-Tinf))plate1= 0.85
A=0.85;
disp("For plate 2")
//For plate1 Biot number Bi2=h*L2/k
Bi2=h*L2/k
Y=1/Bi2
//Fourier number(Fo2) is
Fo2=alpha*t/L2^2
//At Fo=1.83 and (1/Bi)=7.3...We read from graphs B=((To-Tinf)/(Ti-Tinf))plate2= 0.8
B=0.8;
//Therefore ((To-Tinf)/(Ti-Tinf))plate1*((To-Tinf)/(Ti-Tinf))plate2=A*B
T=A*B
//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.
//So let us take time,t=1200s for the second iteration
t=1200;
disp("For plate 1")
//For plate1 Biot number Bi1=h*L1/k
Bi1=h*L1/k
Y=1/Bi1
//Fourier number (Fo1)
Fo1=alpha*t/L1^2
//At Fo=1.08 and (1/Bi)=4.87...We read from graphs A=((To-Tinf)/(Ti-Tinf))plate1= 0.83
```

```
A=0.83;
disp("For plate 2")
//For plate1 Biot number Bi2=h*L2/k
Bi2=h*L2/k
Y=1/Bi2
//Fourier number (Fo2)
Fo2=alpha*t/L2^2
//At Fo=2.44 and (1/Bi)=7.3...We read from graphs B =((To-Tinf)/(Ti-Tinf))plate2= 0.72
B=0.72;
//Therefore ((To-Tinf)/(Ti-Tinf))plate1*((To-Tinf)/(Ti-Tinf))plate2=A*B
T=A*B
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

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

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

Scilab code Exa 4.12 A large block of nickel steel

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

```
k=20;
alpha=0.518*10^-5;
//One surface of the block is suddenly exposed to a constant surface heat flux(qo) of 6MW/m^2.
qo=6*10^6;//in W/m^2
//To determine the temprature at a depth(x) of 100mm after a time(t) of 100 seconds.
t=100;
x=0.1;//in metre
//Similarity parameter,eta=x/(4*alpha*t)
eta=x/((4*alpha*t)^0.5)
//E is gaussian error function
disp("gaussian error function is" )
E=erf(eta)
//The equation to determine temprature 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))
//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))
disp("The temprature at a depth(x) of 100mm after a time(t) of 100 seconds,in  C is")
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
```

```
disp("Introduction to heat transfer by S.K.Som, Chapter 4, Example 13")
//Thermal diffusivity in m^2/s
alpha = 2*(10^(-5));
//Thickness in m
L = 0.6;
//Initial temperature in  C
Ti = 20;
//Temperature raised in  C
To = 580;
//Time in seconds
t = 25*60;
//Nodal distance Deltax in m
deltax = 0.1;
//Assigning fourier number to be 0.5 for stability criteria
Fon = 0.5;
//Calculating timestep deltaT in seconds
deltaT = ((Fon*deltax)*deltax)/alpha;
//Number of increment
n = t/deltaT;
//Considering insulated surface as centre of plate
//Taking a total of 7 nodes
//Temperature at node 1 in  C
T(1,1) = 580;
//Temperature at all other nodes in  C
//i is the looping parameter
for i = 2:7
  T(1,i) = 20;
end;
//Substituting Fourier number,Fon=0.5 in Eq. 4.94, we have Eq. 4.104
//Calculating new temperature at all nodes
//k is the looping parameter for time
//Tnew is the new temperature in  C
for k = 1:5
  for i = 1:7
    if i==1 then
```

```
      Tnew(1,i) = T(1);
    end;
    %v02 = %f;  if i<7 then %v02 = i>1;end;
    if %v02 then
      Tnew = mtlb_i(Tnew,i,(T(i+1)+T(i-1))/2);
    end;
    if i==7 then
      Tnew = mtlb_i(Tnew,i,(T(7)+T(6))/2);
    end;
  end;
  //Assigning old temperatures value of new
     temperatures
  for i = 1:7
    T = mtlb_i(T,i,Tnew(i));
  end;
end;
//Temperature change at node 7 because of symmetry
T = mtlb_i(T,7,T(6));
//Temperature change at other nodes because of
   change in temperature of node
//7
for i = 2:6
  T = mtlb_i(T,i,(Tnew(i+1)+Tnew(i-1))/2);
end;
//Final temperature distribution after 25 mins
disp("Final temperature distribution in degree C
   after 25 mins")
T
```

Scilab code Exa 4.14 Fully implicit scheme

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

```
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 4, Example 14")
//Nodal distance Deltax in m
deltax = 0.1;
//Time in seconds
t = 25*60;
//timestep deltaT in seconds
deltaT = 500;
//Number of increment
n = t/deltaT;
//Temperature raised in  C
To = 580;
//Using Eq. 4.114 for interior grid points, table 4.8 for exterior node
//Using Eq. 4.125a to 4.125f are written in matrix form
//Coefficient matrix A is
A = [-3,1,0,0,0,0;
     1,-3,1,0,0,0;
     0,1,-3,1,0,0;
     0,0,1,-3,1,0;
     0,0,0,1,-3,1;
     0,0,0,0,2,-3];
//Coefficient matrix B is
B = [-600;
     -20;
     -20;
     -20;
     -20;
     -20];
//Temperature matrix is transpose of [T2 T3 T4 T5 T6 T7] where
//T2 to T7 are temperature in  C
//From Eq. 4.126
//Temperature distribution after one time step
T = (A^(-1))*B;
```

```
//For second timestep, coefficient matrix B gets modeified as
B(1) = B(1)-T(1);
for i = 2:6
  B = mtlb_i(B,i,-T(i));
end;
//Temperature distribution after second time step
T = (A^(-1))*B;
//For third timestep, coefficient matrix B gets modeified as
B = mtlb_i(B,1,-600-T(1));
for i = 2:6
  B = mtlb_i(B,i,-T(i));
end;
//Temperature distribution after second time step
T = (A^(-1))*B;
//Final temperature distribution including face in C
//Face temperature in  C
Tf(1,1) = To;
//Interior points temperature in  C
//i is the looping parameter
for i = 2:7
  Tf(1,i) = T(i-1);
end;
//Assigning final temperature to initial temperature matrix
for i = 1:7
  T(i) = Tf(i);
end;
disp("Temperature distribution after 25 mins in  C")
T
```

Chapter 5

Convection

Scilab code Exa 5.3 Flat plate with a free stream velocity

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 5, Example 3")
//Air at temprature (T1=20 C ) and 1 atmospheric
    pressure flows over a flat plate with a free
    stream velocity(Uinf) of 1m/s.
Uinf=1;
T1=20;
//The length of plate is 1m and is heated over its
    entire length to a constant temprature of T2=100
     C .
T2=100;
//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))
```

```
//Prandtl number is Pr=0.7
mu=1.9*10^-5;
rho=1.05;
k=0.03;
cp=1.007;
Pr=0.7;
//For laminar flow over a plate Nusselt number is
    Nux=0.332*Rex^0.5*Pr^(1/3)
//The boundary layer flow over a flat plate will be
    laminar if Reynolds number is Rex=(rho*Uinf*x)/mu
    <5*10^5
//First of all we have to check whether the flow is
    laminar or not.
//Let us check at x=1m
x=1;
disp("Reynolds number is")
ReL=(rho*Uinf*x)/mu
//There fore the flow is laminar and we can use the
    relationships of Nux,
//Thus Rex=(1.05*1*x)/(1.9*10^-5)=0.5526*10^5*x
//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 )
//hbarL is the average heat transfer coefficient
    over a length(L)
disp("The average heat transfer coefficient over a
    length(L)= 1m ,in W/m^2 is")
L=1;
hbarL=(1/L)*integrate("2.08*x^(-1/2)",'x',0,L)
//Q is the rate of heat transfer
disp("The rate of heat transfer in W/m of width is")
Q=hbarL*L*(T2-T1)
```

Scilab code Exa 5.4 Circuit board to cool the electronic elements

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 5, Example 4")
//Air at atmospheric pressure is required to flow
   over a circuit board to cool the electronics
   element mounted on it.
//Chip has length (L)=3mm and width(B)=3mm located x
   =0.1m from the leading edge
L=0.003;//in metre
B=0.003;//in metre
x=0.1;
//The Nusselt no. is given by Nux=0.06*Rex^0.85*Pr
   ^0.33
//The chip has to dissipate E=50mW of energy while
   its surface temprature has to be kept below
   temprature,Ts=45 C and free strem Temptrature of
    air is Tinf=25 C
Ts=45;
Tinf=25;
E=50*10^-3;//in watt
//For air ,density(rho=1.2kg/m^3),viscosity(mu
   =1.8*10^5kg/(m*s)),conductivity(k=0.03W/(m*K))
   and specific heat(cp=1000J/(kg*K))
rho=1.2;
mu=1.8*10^5;
k=0.03;
cp=1000;
//Let the minimum flow velocity be U.
//The local heat transfer coefficient hx where the
   chip is mounted is determined as hx=(k/x)*0.06*(
   rho*U*x/mu)^0.85*(mu*cp/k)^0.33
disp("The local heat transfer coefficient hx is hx
   =27.063*U^0.85")
```

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

Scilab code Exa 5.6 Air enters a tube

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 5, Example 6")
//Air at 1atm pressure and temprature(Tin)=30 C
    enters a tube of 25mm diameter(D) with a velocity
    (U) of 10m/s
D=0.025;//in metre
U=10;
Tin=30;
//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
//Let Tw-Tb=T
q=2000;
deltaT=20;
//The length(L)= 2m
L=2;
//For air density(rho=1.2kg/m^3),specific heat(cp
    =1000J/(kg*K))
rho=1.2;
cp=1000;
//From an energy balance of a control volume of air
```

```
we get mdot*cp*(Tb+(dTb/dx)*deltax-Tb)=q*pi*D*deltax or (dTb/dx)=(q*pi*D)/(mdot*cp)
//mass flow rate=mdot
mdot=rho*%pi*D^2*U;
//let (dTb/dx)=Y
disp("(dTb/dx)in  C/m is")
Y=(4*q*%pi*D)/(mdot*cp)
//Tb2 is Exit bulk mean temprature
disp("Therefore Exit bulk mean temprature Tb2 in  C is")
Tb2=Tin+Y*2
//Again we can write at any section of the tube hx*(Tw-Tb)=q or hx=q/(Tw-Tb)
//hx is heat flux
disp("Heat flux(hx) in W/(m^2* C) is ")
hx=q/(deltaT)
//Since Tw-Tb remains the same,The heat transfer coefficient at all sections are the same
//Now Overall Nusselt number,NuL=hx*D/k
//The thermal conductivity of air at mean temprature of (30+83.4)/2=56.7  C is k=0.0285 W/(m*K)
k=0.0285;
disp("Overall Nusselt number is ")
NuL=hx*D/k
```

Scilab code Exa 5.7 Heat loss from a vertical wall

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

```
//A wall is exposed to nitrogen at one atmospheric pressure and temprature ,Tinf=4  C .
Tinf=4;
//The wall is H=2.0m high and B=2.5m wide and is maintained at temprature ,Ts=56  C
Ts=56;
H=2;
B=2.5;
A=H*B;//area is(A)
//The average nusselt number NuHbar over the height of the plate is given by NuHbar=0.13*(Gr*Pr)^(1/3)
//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)),
//kinematic viscosity(nu=15.630*10^-6 m^2/s)  , Prandtl number(Pr=0.713)
rho=1.142;
k=0.026;
nu=15.630*10^-6;
Pr=0.713;
Tf=30;
//We first have to detrmine the value of Grashoff number,Gr.In consideration of nitrogen as an ideal gas,we can write
//Beta(The volumetric coefficient of expansion)=1/T
disp("Beta(The volumetric coefficient of expansion in K^-1 is")
Beta=1/(273+Tf)
//Now Gr=(g*Beta*(Ts-Tinf)*H^3)/nu^2
g=9.81;//acceleration due to gravity
disp("Grashoff number is")
Gr=(g*Beta*(Ts-Tinf)*H^3)/nu^2
disp("The average nusselt number is")
NuHbar=0.13*(Gr*Pr)^(1/3)
//hbar is the heat flux
disp("Heat flux hbar in W/(m^2*  C )")
hbar=NuHbar*k/H
```

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

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

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

```
disp("The heat loss from the wire is Q=hbar*pi*D*L*(Twire-Tair) in Watt")
Q=hbar*%pi*D*L*(Twire-Tair)
//At steady state the ohmic loss in the wire equals the heat loss from its surface Therfore I^2*R=Q
//I is the current flow.
disp("The current in Ampere is")
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 6, Example 1")
//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.
//The average velocity is Uav=1.60m/s
Uav=1.60;
mu=0.1;
b=0.005;// in metre
//Umax is maximum velocity
//Umax=(3/2)*Uav
disp("Umax in m/s is")
Umax=(3/2)*Uav
```

```
//The shear stress at the plate is given by T=2*  *(Umax/b)
disp("The shear stress T in N/m^2")
T=2*mu*(Umax/b)
//The shear sress at a distance from plate is given by t=y*(dp/dx)
//(dp/dx)=X=-3*mu*(Uav/b^2)
disp("(dp/dx) in N/m^3 is")
X=-3*mu*(Uav/b^2)
//Taking modulus of X by multipying it with negative sign.
disp("The Shear stress at a distance of 0.002m from the lower plate in N/m^2")
y=b-0.002;
t=y*(X)//NOTE:Answer given in the book is incorrect(Calculation mistake)
disp("The shear stress at a distance of 0.002m from the upper plate in N/m^2")
t=-y*(X)//NOTE:Answer given in the book is incorrect(Calculation mistake)
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 ")
//deltaP is the pressure drop
disp("The pressure drop over a distance of 2m in N/m^2 is")
//Since pressure drop is considered at a distance of 2m so L=2m
L=2;
deltaP=(-X)*L
```

Scilab code Exa 6.3 Oil is discharged under a pressure

```
// Display mode
```

```
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 6, Example 3")
//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.
dp=10*10^3;//in N/m^2
dz=5;
D=0.05;//in metre
mdot=3;
sg=0.90;
//X=dp/dz is the rate of change of pressure
disp("The rate of change of pressure with respect to length in N/m^3")
X=dp/dz
//Flow rate is Q
disp("Flow rate(Q) in m^3/s is)")
Q=mdot/(sg*10^3)
//The viscosity of oil is mu=(pi*D^4*X)/(128*Q*dz)
disp("The viscosity of oil(mu)in kg/(m*s)")
mu=(%pi*D^4*X)/(128*Q)
```

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
```

```
disp("Introduction to heat transfer by S.K.Som, Chapter 6, Example 7")
//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.
Uinf=3;
B=1.2;
//If it is desired to have a laminar boundary layer only on the plate
//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.
nuair=1.5*10^-5;
rhoair=1.2;
ReL=5*10^5;
//For maximum length of the plate reynolds number is ReL=Uinf*L/nuair
//so L=ReL*nuair/Uinf
disp("The maximum length of plate in m is ")
L=ReL*nuair/Uinf
//The average skin friction coefficient is cfL=1.328/(ReL)^(1/2)
disp("The average skin friction coefficient is")
cfL=1.328/(ReL)^(1/2)
//Fd is drag force
disp("Drag force on one side of plate in N is")
Fd=cfL*(rhoair*Uinf^2/2)*B*L
```

Scilab code Exa 6.10 Wind bows over a flat plate

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

```
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 6, Example 10")
//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.
U=36;
L=6;
rho=1.2;
mu=1.5*10^-5;
//Wind velocity in m/s is Uinf
disp("Wind velocity(Uinf)in m/s is")
Uinf=U*1000/3600
//Reynolds number is given by ReL=L*Uinf/mu
disp("Reynolds number is")
ReL=L*Uinf/mu
//We consider that transition of boundary layer takes place from laminar to turbulent takes place at ReL=5*10^5.
//Therfore the corresponding friction coefficient is given by  CbarfL=(0.074-ReL^(1/5))-(1742/ReL)
disp("Friction coefficient is")
CbarfL=(0.074/ReL^(1/5))-(1742/ReL)
//Drag force on one side of the plate per unit metre width is given by FD=CbarfL*rho*Uinf^2*L/2
disp("Drag force on one side of the plate per unit metre width in Newton is ")
FD=CbarfL*rho*Uinf^2*L/2
//The turbulent boundary layer thickness at the trailing edge is given by delta=L*(0.379/ReL^(1/5))
disp("The turbulent boundary layer thickness at the trailing edge in metre is ")
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 1")
//Engine oil at temprature,Tinf=60 C with a
    velocity of Uinf=1m/s flows over plate of length(
    L)=5m whose temprature(Tw)=30 C
Tw=30;
L=5;
Uinf=1;
Tinf=60;
//The properties at a film temprature 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).
rho=870;
Pr=2850;
```

```
k=0.145;
nu=250*10^-6;
disp("First we check from reynolds no. that the flow is laminar or tubulent")
//Reynolds number is given by Re=(Uinf*L)/nu
disp("Reynold number is")
Re=(Uinf*L)/nu
disp("which is less than critical reynolds number,So the flow is laminar.")
//NuL is the average nusselt number
disp("The average nusselt number over the entire length under the situation is given by NuL=0.664*Re^0.5*Pr^(1/3)")
NuL=0.664*Re^0.5*Pr^(1/3)
//Heat flux is given by h=(k/L)*NuL
disp("Heat flux in W/(m^2*K) is")
h=(k/L)*NuL
//The rate of heat transfer per unit width is Q=h*A*(Tinf-Tw)
//Since unit width is considerd so B=1
//Area(A)=L*B
B=1;
A=L*B;
disp("The rate of heat transfer per unit width in W is")
Q=h*A*(Tinf-Tw)
```

Scilab code Exa 7.2 Atmospheric air flows over a flat plate

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
```

```
disp("Introduction to heat transfer by S.K.Som, Chapter 7, Example 2")
//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.
Tinf=300;
Uinf=30;
L=2;
//It is maintained at a uniform temprature of Tw=400 K.
Tw=400;
//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)
Pr=0.705;
k=0.026;
nu=16.5*10^-6;
//We first find the location x(for reynolds number,Re=5*10^5) where the transition occurs
//Rex is reynolds number
disp("The location x in m where the transition occurs")
Rex=5*10^5;
x=(nu*Rex)/Uinf
//The average Nusselt number for the laminar zone is given by Nux=0.664*Re^0.5*Pr^(1/3)
disp("The average Nusselt number for the laminar zone is")
Nux=0.664*Rex^0.5*Pr^(1/3)
//Heat flux is given by h=(k/x)*Nux
disp("Heat flux in W/(m^2*K) is")
h=(k/x)*Nux
//Reynolds number is given by ReL=(Uinf*L)/nu
disp("The reynolds number at L=2m is")
ReL=(Uinf*L)/nu
//The average heat transfer coefficient over L=2m is determined from hbarL=(k/L)*[0.037*(ReL)^(4/5)
```

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

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

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

```
Pr=0.706;
k=0.03;
nu=2*10^-5;
//ReL is reynolds number and L is length of flat plate
disp("(a)When the air flows parallel to the long side we have L=5 and the Reynolds no. becomes")
L=5;
ReL=(Uinf*L)/nu
disp("which is greater than critical Reynolds number.")
//Thus we have combined laminar and tubulent flow.
// 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)
disp("The average heat transfer coefficient over L=5 m in W/(m^2*K)")
hbarL=(k/L)*[0.037*(ReL)^(4/5)-871]*Pr^(1/3)
//The rate of heat transfer per unit width is Q=h*A*(Tinf-Tw)
//Since width is 1m so B=1
//Area(A)=L*B
B=1;
A=L*B;
//Q is the rate of heat transfer
disp("The rate of heat transfer per unit width in W is")
Q=hbarL*A*(Tw-Tinf)
//When the air flow is parallel to the 1m side we have L=1
disp("(b)When the air flow is parallel to the 1m side we have L=1 an the Reynolds no. becomes ")
L=1;
ReL=(Uinf*L)/nu
disp("which is less than critical Reynolds number.")
//Thus we have laminar flow
//Heat flux is given by h=(k/L)*0.664*ReL^0.5*Pr^(1/3)
```

```
disp("Heat flux in W/(m^2*K) is")
h=(k/L)*0.664*ReL^0.5*Pr^(1/3)
//The rate of heat transfer per unit width is Q=h*A*(Tinf-Tw)
//Now width is 5m so B=5
//Area(A)=L*B
B=5;
A=L*B;
//Q is the rate of heat transfer
disp("The rate of heat transfer per unit width in W is")
Q=h*A*(Tw-Tinf)
```

Scilab code Exa 7.4 Castor oil flows over a heated plate

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 7, Example 4")
//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
Tinf=36;
L=6;
B=1;
Uinf=0.06;
//For a surface temprature at Tw=96 C
Tw=96;
//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)
nu=6*10^-5;
k=0.21;
alpha=7.22*10^-8;
//ReL is reynolds number
disp("(a)Reynolds number is")
ReL=(Uinf*L)/nu
//Therefore the boundary layer is laminar over the
    entire plate.
//delta is the boundary layer thickness
disp("The boundary layer thickness in m is")
delta=(5*L)/(ReL)^0.5
//Pr is prandtl number.
disp("Prandtl no. is")
Pr=nu/alpha
//deltaT is thermal boundary layer thickness
disp("The thermal boundary layer thickness in m is")
deltaT=delta/(Pr^(1/3))//NOTE: Answer in the book is
    incorrect(calculation mistake)
//NuL is the nusselt number
disp("(b)Since the prandtl number is high So Nusselt
    no. is")
NuL=0.339*(ReL)^0.5*Pr^(1/3)
//Heat flux is given by hL=(k/L)*NuL
disp("Heat flux in W/(m^2*K) is")
hL=(k/L)*NuL
//hbarL is the average heat flux over length L
disp("hbarL in W/(m^2*K) is")
hbarL=2*hL
//The rate of heat transfer is Q=h*A*(Tinf-Tw)
//Area(A)=L*B
A=L*B;
disp("(c)The rate of heat transfer in W is")
Q=hbarL*A*(Tw-Tinf)
```

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 5")
//A flat plate of width B=1m is maintained at a
    uniform surface temprtaure(Tw)=225 C
Tw=225;
B=1;
//Heating is done by rectangular modules of
    thickness t=10mm and length l=40mm.
t=10;
l=40;
//atmospheric air at temprature,Tinf=25 C flows
    over the plate at velocity(Uinf)=30m/s.
Tinf=25;
Uinf=30;
//The thermophysical properties of module are
    conductivity(km=5.2W/(m*K)),specific heat(cp=320J
    /(kg/K)),density(rho=2300kg/m^3).
km=5.2;
cp=320;
rho=2300;
//Assume the air properties at the film temprature
    of 125 C conductivity(ka=0.031W/(m*K)),kinematic
     viscosity(nu=22*10^-6m^2/s),Prandtl number(Pr
    =0.7)
ka=0.031;
nu=22*10^-6;
Pr=0.7;
//Module is placed at a distance of 800mm from the
    leading edge
```

```
//The distance from leading edge to the centre-line
    of the module,L=800+20=820mm.
L=0.82;//in metre
//ReL is the reynolds number
disp("Reynolds number is")
ReL=(Uinf*L)/nu
disp("Therefore the flow is turbulent over the
    module ")
//The local heat transfer coefficient at L is
    calculated using hL=(k/L)*0.0296*(ReL)^(4/5)*(Pr)
    ^(1/3)
disp("The local heat transfer coefficient at L in W
    /(m^2*K)is")
hL=(ka/L)*0.0296*(ReL)^(4/5)*(Pr)^(1/3)
//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
//If qm be the power generation in W/m^2 within the
    module ,we can write from energy balance qm*(t
    /1000)*(l/1000)*(B)=hbarL*(t/1000)*(B)*(Tw-Tinf)
disp("The required power generation in W/m^3 is")
qm=(hL*(l/1000)*(B)*(Tw-Tinf))/((t/1000)*(l/1000)*(B
    ))
```

Scilab code Exa 7.6 Top surface of wing absorbs solar radiation

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 6")
//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 .
Tinf=-5;
Uinf=150;
//The top surface of the wing absorbs solar radiation at a rate of Qr=900W/m^2.
Qr=900;
//Considering the wing as a flat plate of length(L)=2m and to be of solid construction with a single uniform surface temprature .
L=2;
//The properties of air at 268K and 0.7 bar are conductivity(k=0.024W/(m*K)),kinematic viscosity(nu=2*10^-5m^2/s),Prandtl number(Pr=0.72)
k=0.024;
nu=2*10^-5;
Pr=0.72;
//ReL is reynolds number
disp("Reynolds number is")
ReL=Uinf*L/nu
//Rec is critical reynolds number
disp("Since ReL>Rec(=5*10^5) the flow is approximated as turbulent over the entire surface of the wing ")
//Nusselt number is given by Nux=0.0308*ReL^(4/5)*Pr^(1/3)
Nux=0.0308*ReL^(4/5)*Pr^(1/3);
//NubarL is average nusselt number over length L
disp("Nusselt number is ")
NubarL=(5/4)*Nux
//Average heat transfer coefficient is given by hbarL=(k/L)*NubarL
disp("Average heat transfer coefficient in W/(m^2*K) is")
hbarL=(k/L)*NubarL
//From an energy balance the airfoil at steady state ,Qr*As=2*hbarL*As*(Tw-Tinf) where Qr=radiation flux ,As=upper or lower surface area.
```

```
//Therefore we can write Surface temprature of wing, Tw=Tinf+(Qr/(2*hbarL))
disp("Surface temprature of wing in kelvin is")
Tw=(273+Tinf)+(Qr/(2*hbarL))
```

Scilab code Exa 7.7 Fine wire is placed in air stream

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 7, Example 7")
//A fine wire having a diameter(D)=0.04mm is placed in an air stream at temprature,Tinf=25 C having a flow velocity of Uinf=60m/s perpendicular to wire.
D=0.04;
Tinf=25;
Uinf=60;
//An electric current is passed through the wire , raising its surface temprature to Tw=50 C
Tw=50;
//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)
k=0.027;
nu=17*10^-6;
Pr=0.71;
//Re is reynolds number
disp("Reynolds number is")
Re=Uinf*(D*10^-3)/nu
//C and n are constants
```

```
//The values of C and n are found  for Re=141 are C=0.683 and n=0.466
//NuD is nusselt number
disp("Nusselt number is")
NuD=(0.683)*Re^0.466*Pr^(1/3)
//hbar is the average Heat transfer coefficient
disp("The average Heat transfer coefficient in W/(m^2*K) is")
hbar=(k/(D*10^-3))*NuD
//Heat transfer per unit length(qL) is given by pi*D*hbar*(Tw-Tinf)
disp("Heat transfer per unit length in W/m is")
qL=%pi*(D*10^-3)*hbar*(Tw-Tinf)
//NuD is nusselt number
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)")
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)
//hbar is the average Heat transfer coefficient
disp("The average Heat transfer coefficient in W/(m^2*K) is")
hbar=(k/(D*10^-3))*NuD
//Heat transfer per unit length(qL) is given by pi*D*hbar*(Tw-Tinf)
disp("Heat transfer per unit length in W/m is")
qL=%pi*(D*10^-3)*hbar*(Tw-Tinf)
```

Scilab code Exa 7.8 Hydrodynamic and thermal entry length

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

```
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 7, Example 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.
Uinf=4*10^-3;//in metre
D=25*10^-3;//in metre
//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)
//Prandtl number of mercury(PrHg=0.019),Prandtl number of oil(Proil=85).
nuHg=1*10^-7;
nuoil=6.5*10^-6;
PrHg=0.019;
Proil=85;
//ReHg is Reynolds number for mercury
disp("Reynolds number for mercury is")
ReHg=Uinf*D/nuHg
//Reoil is Reynolds number for oil
disp("Reynolds number for oil is")
Reoil=Uinf*D/nuoil
//The hydrodynamic length are given by L=0.05*Re*D
//LeHg is the hydrodynamic entry length for mercury
disp("The hydrodynamic entry length for mercury in m is")
LeHg=0.05*ReHg*D
//Leoil the hydrodynamic entry length for oil
disp("The hydrodynamic entry length for oil in m is")
Leoil=0.05*Reoil*D
//The thermal entry length are given by L=0.05*Re*Pr*D
//LtHg is the thermal entry length for mercury
disp("The thermal entry length for mercury in m is ")
```

```
LtHg=0.05*ReHg*PrHg*D
//Ltoil is the thermal entry length for oil
disp("The thermal entry length for oil in m is")
Ltoil=0.05*Reoil*Proil*D
```

Scilab code Exa 7.9 Air at one atmospheric pressure

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 9")
//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
Tbi=75;
D=4*10^-3;//in metre
U=2;
//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.
L=1;
//An exit bulk mean temprature(Tbo)=125 C is
    required.
Tbo=125;
//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))
rho=0.95;
Pr=0.70;
k=0.03;
```

```
mu=2.18*10^-5;
cp=1.01*10^3;
//Re is reynolds number
disp("Reynold number is")
Re=rho*U*D/mu
//Leh is the hydrodynamic entrance length
disp("Therefore the flow is laminar.The hydrodynamic entrance length in m is")
Leh=0.05*Re*D
//Let is the thermal entrance length
disp("The thermal entrance length in m is")
Let=0.05*Re*Pr*D
//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.
//For a fully developed flow with constant surface heat flux,Nusselt number is Nu=4.36
Nu=4.36;
//h is the heat transfer coefficient
disp("The heat transfer coefficient in W/(m^2*K) is")
h=Nu*(k/D)
//Here h=hL Since the heat transfer coefficient is constant over the entire length of tube.
//hL is the local heat transfer coefficient
hL=h;
//from an energy balance qw*pi*D*L=mdot*cp*(Tbo-Tbi)
//mdot is mass flow rate
disp("The mass flow rate of air in kg/s is")
mdot=rho*(%pi/4)*D^2*U
//qw is the constant surface heat flux
disp("Therefore the constant surface heat flux qw in W/m^2 is")
qw=[mdot*cp*(Tbo-Tbi)]/(%pi*D*L)
//Let Twe be the surface temprature at the exit plane.Then we can write hL*(Twe-Tbo)=qw
disp("The tube surface temprature at the exit plane
```

```
    in  C is ")
Twe=Tbo+(qw/hL)
```

Scilab code Exa 7.10 The tube heated length

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 7, Example 10")
//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
Tbi=75;
D=4*10^-3;
U=2;
//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.
L=0.04;
//An exit bulk mean temprature(Tbo)=125 C is
    required.
Tbo=125;
//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))
rho=0.95;
Pr=0.70;
k=0.03;
mu=2.18*10^-5;
cp=1.01*10^3;
```

```
//Re is the reynolds number
disp("Reynold number is")
Re=rho*U*D/mu
//Leh is the hydrodynamic entrance length
disp("Therefore the flow is laminar.The hydrodynamic entrance length in m is")
Leh=0.05*Re*D
//Let is thermal entrance length
disp("The thermal entrance length in m is")
Let=0.05*Re*Pr*D
disp("The thermal entrance length is greater than the tube length Therefore the flow is hydrodynamically developed but not thermally developed" )
//We calculate the inverse graetz number at x=L=0.04 m
x=0.04;
//Gr_1 is inverse of graetz number
disp("The inverse of graetz number Gr_1 is")
Gr_1=(x/D)*(1/(Re*Pr))
//For constant surface heat flux nusselt number is Nu=4.7 and Graetz number is Gr=4.1*10^-2
Nu=4.7;
Gr=4.1*10^-2;
//hL is the local heat transfer coefficient
disp("Therefore the local heat transfer coefficient in W/(m^2*K) is")
hL=Nu*(k/D)
//from an energy balance qw*pi*D*L=mdot*cp*(Tbo-Tbi)
//mdot is the mass flow rate
disp("The mass flow rate of air in kg/s is")
mdot=rho*(%pi/4)*D^2*U
//qw is the surface heat flux
disp("Therefore surafce heat flux qw in W/m^2 is")
qw=[mdot*cp*(Tbo-Tbi)]/(%pi*D*L)
//Let Twe be the surface temprature at the exit plane.Then we can write hL*(Twe-Tbo)=qw
disp("The tube surface temprature at the exit plane
```

```
in C is ")
Twe=Tbo+(qw/hL)
```

Scilab code Exa 7.11 Liquid sulphur dioxide

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 7, Example 11")
//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.
//The tube is heated at a constant surface temprature(Tw) of -10 C and the inlet fluid temprature is Tbi=-40 C
Tw=-10;
Tbi=-40;
mdot=0.15;
D=0.025;//in metre
L=5;
//The properties to be used shoud be estimated at a temprature which is arithmetic mean of Tbi and Tbo.
//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
//Here we denote bulk mean temprature as Tb.The superscript refers to the no. of trials
//For first trial,guess Tbo1=-20 C;so Tb1=-30 C
```

```
//We have the property values as follows at a temprature of −30 C .
rhob1=1520.64;//density in kg/m^3
nub1=0.371*10^-6;//kinematic viscosity in m^2/s
kb1=0.23;//conductivity in W/(m* C)
Prb1=3.31;//Prandtl number
mub1=nub1*rhob1;//viscosity in kg/(m*s)
cpb1=1361.6;//specific heat in J/(kg*K)
//muw=nuw*rhow at Tw=10 C
nuw=0.288*10^-6;//kinematic viscosity at Tw in m^2/s
rhow=1463.61;//density at Tw in kg/m^3
muw=nuw*rhow;//viscosity at Tw in kg/(m*s)
//The reynolds number is found as Re1=(4*mdot)/(%pi*D*mub1)
disp("Reynold number is")
Re1=(4*mdot)/(%pi*D*mub1)
//Hence the flow is turbulent
//Now using equation, nusselt number is,Nubar1=0.027*(Re1)^0.8*Prb1^(1/3)*(mub1/muw)^0.14
disp("Nusselt number is")
Nubar1=0.027*(Re1)^0.8*Prb1^(1/3)*(mub1/muw)^0.14
//The heat transfer transfer coefficient hbar1=(kb1/D)*Nubar1
disp("The heat transfer transfer coefficient in W/(m^2* C) ")
hbar1=(kb1/D)*Nubar1
//The outlet fluid temprature can be found by making use of eqn Tbo2=Tw−(Tw−Tbi)*%e((−%pi*D*L*hbar1)/(mdot*cpb1))
disp("Outlet fluid temprature in first iteration is Tbo2 in C is")
Tbo2=Tw-(Tw-Tbi)*%e^((-%pi*D*L*hbar1)/(mdot*cpb1))
//Tb2 is the bulk mean temprature.
disp("Tb2 in C is")
Tb2=(Tbi+Tbo2)/2
//Since the value differs from the assumed value of Tb1=−30 C ,WE require furtheriteration,Therfore we start second trial with Tb2=−28.36 C
```

```
//We have the property value at a temprature of −28.36 C as follows
rhob2=1514;//density in kg/m^3
nub2=0.362*10^-6;//kinematic viscosity in m^2/s
kb2=0.229;//conductivity in W/(m* C)
Prb2=3.23;//Prandtl number
mub2=nub2*rhob2;//viscosity in kg/(m*s)
cpb2=1362;//specific heat in J/(kg*K)
//muw=nuw*rhow at Tw=10 C
nuw=0.288*10^-6;//viscosity at Tw in m^2/s
rhow=1463.61;//density at Tw in kg/m^3
muw=nuw*rhow;//kinematic viscosity at Tw in kg/(m*s)
//The reynolds number is found as Re2=(4*mdot)/(%pi*D*mub2)
disp("Reynold number is")
Re2=(4*mdot)/(%pi*D*mub2)
//Now using equation, nusselt number is,Nubar2=0.027*(Re2)^0.8*Prb2^(1/3)*(mub2/muw)^0.14
disp("Nusselt number is")
Nubar2=0.027*(Re2)^0.8*Prb2^(1/3)*(mub2/muw)^0.14
//The heat transfer transfer coefficient hbar2=(kb2/D)*Nubar2
disp("The heat transfer transfer coefficient in W/(m^2* C) ")
hbar2=(kb2/D)*Nubar2
//The outlet fluid temprature can be found by making use of eqn Tbo3=Tw−(Tw−Tbi)*%e((−%pi*D*L*hbar2)/(mdot*cpb2))
disp("Outlet fluid temprature in second iteration is Tbo3 in C is")
Tbo3=Tw-(Tw-Tbi)*%e^((-%pi*D*L*hbar2)/(mdot*cpb2))
//Tb3 is the bulk mean temprature.
disp("Tb3 in C is")
Tb3=(Tbi+Tbo3)/2
//We see that difference between Tbo2 and Tbo3 and that between Tb2 and Tb3 is marginal.Therfore we can stop iteration and present the result as Tbo=−16.67 C
```

```
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 8, Example 1")
//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
Tw=60;
L=.2;
B=.2;// in metre
//Area(A) is L*B
A=L*B;
//Water is at temprature,Tinf=20 C
Tinf=20;
//At mean film temprature 40 C The physical properties parameters can be taken as
//conductivity(k=0.0628W/(m*K)),Prandtl number(Pr
```

```
=4.34),density(rho=994.59kg/m^3),kinematic viscosity(nu=0.658*10^-6m^2/s),volume expnasion coefficient(Beta=3*10^-4K^-1))
k=0.628;
Pr=4.34;
rho=994.59;
nu=0.658*10^-6;
Beta=3*10^-4;
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*L^3)/(nu)^2
disp("Grashoff number is")
GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
//Rayleigh number is defined as RaL=GrL*Pr
disp("Rayleigh number is")
RaL=GrL*Pr
disp("Therefore the flow is turbulent")
disp("Now we use [(hbarL*L)/k]=0.10*(GrL*Pr)^(1/3)")
//hbarL is the average heat transfer coefficient
disp("The average heat transfer coefficient in W/(m^2*K) is")
hbarL=(0.10*(GrL*Pr)^(1/3)*k)/L
//The rate of heat transfer is given by q=hbarL*A*(Tw-Tinf)
disp("The rate of heat transfer in W is")
q=hbarL*A*(Tw-Tinf)
```

Scilab code Exa 8.2 Thin plates to be cooled

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

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

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

Scilab code Exa 8.3 Maximum velocity in the boundary layer

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 8, Example 3")
//Considering question 5.7
//A wall is exposed to nitrogen at one atmospheric pressure and temprature,Tinf=4 C .
Tinf=4;
//The wall is H=2.0m high and 2.5m wide and is maintained at temprature,Tw=56 C
Tw=56;
H=2;
B=2.5;
A=H*B;//Area of wall in m^2
//The properties of nitrogen at mean film temprature (56+4)/2=30 C are given as
//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)
rho=1.142;
k=0.026;
nu=15.630*10^-6;
```

```
Pr=0.713;
Tf=30;//mean film temprature
Beta=1/(273+Tf);//volume expansion coefficient:unit K^-1
//Now Grashoff number is Grx=(g*Beta*(Tw-Tinf)*x^3)/nu^2
g=9.81;//acceleration due to gravity
disp("Grashoff number is")
x=0.8;//distance from the bottom of wall
Grx=(g*Beta*(Tw-Tinf)*x^3)/nu^2
//Using equation delta=x*Pr^(-0.5)*(0.952+Pr)^(0.25)*Grx^(-0.25)
//delta is the boundary layer thickness
disp("The boundary layer thickness in metre is")
delta=x*3.93*Pr^(-0.5)*(0.952+Pr)^(0.25)*Grx^(-0.25)
//Now using equation ux=(g*Beta*delta^2*(Tw-Tinf))/(4*nu)
//ux is the velocity at point x
disp("The velocity at point x is ux in m/s is")
ux=(g*Beta*delta^2*(Tw-Tinf))/(4*nu)
// (u/ux)=(y/delta)*(1-y/delta)^2
//Putting value of ux we get velovity function,u=465.9*(y-116*y^2+3341*y^3)
//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
a=10023;
b=232;
c=1;
//Solution for quadratic equation is given by y=(-b+-(b^2-4ac)^0.5)/2*a
disp("For maximum value of velocity,u")
y=(b+(b^2-4*a*c)^0.5)/(2*a)//root of the quadratic equation
y=(b-(b^2-4*a*c)^0.5)/(2*a)//root of the quadratic equation
//The value of 0.0173 is at the edge of boundary layer,where u=0
```

```
//Therefore the maximum value occurs at y=0.00573m i
    .e Umax=465.9*y*(1-57.8*y)^2
y=0.00573;
//Umax is maximum velocity
disp("Maximum velocity in m/s is")
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
//mdot is mass flow rate
disp("Mass flow rate at x=0.8m,in kG is")
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 8, Example 4")
//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
L=0.2;
B=0.2;
Tinf=300;
//The Temprature of plate(Tw) is maintained at 400K
Tw=400;
//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))
Tf=350;
nu=20.75*10^-6;
Pr=0.69;
k=0.03;
//volume expansion coefficient is Beta
Beta=(1/Tf);
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*L^3)/(nu)^2
disp("Grashoff number is")
GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
//Rayleigh number is defined as RaL=GrL*Pr
disp("Rayleigh number is")
RaL=GrL*Pr
disp("Hence,the flow is laminar")
//delta is the thickness of the boundary layer
disp("The thickness of the boundary layer in metre is")
x=0.2;//location of trailing edge of plate
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)
//hL and hbarL are local and average heat transfer coefficient respectively
disp("The average heat transfer coeficient in W/(m^2*K) is")
hL=(2*k)/delta;
hbarL=(4/3)*(hL)//NOTE:The answer in the book is incorrect(calculation mistake)
```

Scilab code Exa 8.5 Square plate in a room

```
// Display mode
```

```
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 8, Example 5")
//A square plate of length(L)=0.5m by breadth ,B=0.5m in a room at temprature ,Tinf=30 C
//One side of plate is kept a uniform temprature(Tw)=74 C
Tw=74;
L=0.5;
B=0.5;
Tinf=30;
//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))
Tf=52;
Pr=0.71;
nu=1.815*10^-5;
k=0.028;
//Area(A)=L*B m^2
A=L*B;
//Volume expansion coefficient is Beta
Beta=1/(273+Tf);
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*L^3)/(nu)^2
disp("Grashoff number is")
GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
//Rayleigh number is defined as RaL1=GrL*Pr
disp("Rayleigh number is")
RaL1=GrL*Pr
disp("Therefore the flow is laminar")
//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)]
disp("Nusselt number is")
NuL1=(4/3)*[0.508*Pr^(1/2)*(0.952+Pr)^(-1/4)*GrL^(1/4)]
//Average heat transfer coefficient(hbarL) is given by (NuL*k)/L
disp("Average heat transfer coefficient(hbarL)in W/(m^2* C )")
hbarL=(NuL1*k)/L
//The rate of heat transfer(Q) from the plate by free convection is given by Q=hbarL*A*(Tw-Tinf)
disp("The rate of heat transfer in W is ")
Q=hbarL*A*(Tw-Tinf)
disp("Now if we use NuL2=0.59*RaL^(1/4) with the value of C=0.59,n=(1/4)")
disp("Nusselt number is")
NuL2=0.59*RaL1^(1/4)
//Average heat transfer coefficient(hbarL) is given by (NuL*k)/L
disp("Average heat transfer coefficient(hbarL)in W/(m^2* C )")
hbarL=(NuL2*k)/L
//The rate of heat transfer(Q) from the plate by free convection is given by Q=hbarL*A*(Tw-Tinf)
disp("The rate of heat transfer in W is ")
Q=hbarL*A*(Tw-Tinf)
disp("(b)For the horizontal plate facing up")
//Perimeter(P) for a square plate is P=4*L
P=4*L;
//Characterstic length(Lc)=A/P
Lc=A/P
disp("Now RaL2=Gr*Pr*(Lc/L)^3")
disp("Rayleigh number is")
RaL2=GrL*Pr*(Lc/L)^3
//The values of constants,C=0.54 and n=(1/4)
C=0.54;
n=(1/4);
```

```
disp("Nusselt number is given by NuL3=C*(GrL*Pr)^n")
NuL3=C*(RaL2)^n
disp("Average heat transfer coefficient(hbarL)in W/(
    m^2* C)")
hbarL=(NuL3*k)/Lc
disp("The rate of heat transfer in W is ")
Q=hbarL*A*(Tw-Tinf)
disp("(c)When the hot surface faces is down")
disp("Nusselt number is given by NuL4=0.27*RaL2
    ^(1/4)")
NuL4=0.27*RaL2^(1/4)
disp("Average heat transfer coefficient(hbarL) in W
    /(m^2)")
hbarL=(NuL4*k)/Lc
disp("The rate of heat transfer in W is ")
Q=hbarL*A*(Tw-Tinf)
```

Scilab code Exa 8.6 Long vertical wire in atmosphere

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

```
Tinf=300;
//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))
Tf=350;
Pr=0.70;
nu=20.75*10^-6;
k=0.03;
//Area(A)=L*B m^2
A=%pi*D*L;
//Volume expansion Coefficient is Beta
Beta=1/(Tf);
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//Grashoff number is given by GrL=(g*beta*(Tw-Tinf)*L^3)/(nu)^2
disp("Grashoff number is")
GrL=(g*Beta*(Tw-Tinf)*L^3)/(nu)^2
//Rayleigh number is defined as RaL=GrL*Pr
disp("Rayleigh number is")
RaL=GrL*Pr
disp("Therefore the flow is laminar")
//NuL is nusselt number
//C and n are constants
disp("Now we use NuL=0.59*RaL^(1/4) with the value of constants C=0.59,n=(1/4)")
disp("Nusselt number is")
NuL=0.59*RaL^(1/4)
//hbarL1 is the Average heat transfer coefficient
disp("Average heat transfer coefficient in W/(m^2*K)")
hbarL1=(NuL*k)/L
//Grashoff number GrD=GrL*(D/L)^3
disp("Grashoff number GrD=GrL*(D/L)^3")
GrD=GrL*(D/L)^3
//Thr correction factor is given By F=1.3*[(L/D)/GrD]^(1/4)+1.0
```

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

Scilab code Exa 8.7 Long horizontal pressurized hot water pipe

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

```
//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))
Tf=77.5;
nu=21*10^-6;
k=0.03;
Beta=(1/(273+Tf));//Volume expansion coefficient in k^-1)
Pr=0.70;
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//Grashoff number is given by GrD=(g*beta*(Tw-Tinf)*L^3)/(nu)^2
disp("Grashoff number is")
GrD=(g*Beta*(Tw-Tinf)*D^3)/(nu)^2
//Rayleigh number is defined as RaD=GrD*Pr
disp("Rayleigh number is")
RaD=GrD*Pr
disp("The flow is laminar over the entire cylinder")
//NuD is the nusselt number
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")
NuD=[0.60+((0.387*RaD^(1/6))/(1+(0.559/Pr^(9/16)))^(8/27))]^2
//hbar is the avearge heat transfer coefficient
disp("Average heat transfer coefficient in W/(m^2*K)")
hbar=(NuD*k)/D
//The heat loss per meter length is given by q=hbar*A*(Tw-Tinf)
disp("The heat loss per meter length in W is")
q=hbar*A*(Tw-Tinf)
```

Scilab code Exa 8.8 Electric immersion heater

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 8, Example 8")
//An electric immersion heater diameter(D)=8mm and length(L)=300mm is rated at power input ,P=450W
P=450;
L=0.3;//in metre
D=0.008;//in metre
//If the heater is horizontally positioned in a large tank of stationery water at temprature ,Tinf =20 C
Tinf=20;
//At steady state ,The electrical power input(P)=(Q) Heat loss from the heater
//P=Q
//Q=hbarD*(pi*D)*L*(Tw-Tinf)
//This gives Tw(surface temprature)=Tinf+(P/(hbarD*pi*D*L))
//So we need to find Average heat transfer coefficient ,hbarD.
//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.
disp("Let us take first trial Tw=64 C")
Tw=64;
Tf=(Tw+Tinf)/2;//mean film temprature
//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
```

```
Beta=4*10^-4;//Volume expansion coefficient
nu=6.25*10^-7;
Pr=4.16;
k=0.634;
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//Grashoff number is given by GrD=(g*beta*(Tw-Tinf)*L^3)/(nu)^2
disp("Grashoff number is")
GrD=(g*Beta*(Tw-Tinf)*D^3)/(nu)^2
//Rayleigh number is defined as RaD=GrD*Pr
disp("Rayleigh number is")
RaD=GrD*Pr
disp("The flow is laminar ")
///NuD is nusselt number
//hbarD is Average heat transfer coefficient
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")
NuD=[0.60+((0.387*RaD^(1/6))/(1+(0.559/Pr^(9/16)))^(8/27))]^2
disp("Average heat transfer coefficient in W/(m^2*K)")
hbarD=(NuD*k)/D
disp("Hence,steady state Surface temprature in  C is")
Tw=Tinf+(P/(hbarD*%pi*D*L))
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 9, Example 1")
//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.
L=0.4;
Tg=100;
//The fin is maintained at temprature,Tw=90 C by
   cooling water.
Tw=90;
disp("The properties of condensate(liquid water) are
    evaluated at the mean film temprature ")
```

```
//tf is mean film temprature
disp("The mean film temprature in C is")
tf=(Tg+Tw)/2
//The properties of condensate are density(rho=962kg
    /m^3),conductivity(k=0.677W/(m*K)),viscosity(mu
    =3*10^-4 kg/(m*s))
rho=962;
k=0.677;
mu=3*10^-4;
//The value rhov=0.598kg/m^3 and hfg=2.27*10^6J/kg
    at 100 C are found from steam table
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
rhov=0.598;//rhov is vapour density
hfg=2.27*10^6;//hfg is enthalpy of vaporisation
//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)
disp("The average heat transfer coefficient over
    length L in W/(m^2*K)")
hbarL=0.943*[(rho*(rho-rhov)*g*hfg*k^3)/(mu*L*(Tg-Tw
    ))]^(1/4)
//The rate of heat transfer per unit width is Q=
    hbarL*L*(Tg-Tw)
disp("The rate of heat transfer per unit width in W/
    m ")
Q=hbarL*L*(Tg-Tw)
//The rate of condensation is given by mdotc=(Q/hfg)
disp("The total rate of condensation in kg/(s*m)")
mdotc=(Q/hfg)
disp("We have to check whether the flow is laminar
    or not ")
//Reynolds no is given by ReL=(4*mdotc)/(mu)
disp("Reynolds no. is")
ReL=(4*mdotc)/(mu)
disp("Therefore the flow is laminar and hence the
    use of the equation is justified")
```

Scilab code Exa 9.2 Steam is being condensed

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

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

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 9, Example 3")
//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.
L=1.5;
```

```
Tg=100;
Tw=60;
//Consider the width of plate to be (B)=0.3m
B=0.3;
//tf is the mean film temprature
disp("The mean film temprature in C is")
tf=(Tg+Tw)/2
//The relevant properties are desity(rho=972kg/m^3),conductivity(k=0.670W/(m*K)),viscosity(mu=3.54*10^-4 kg/(m*s))
//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)
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
rho=972;
k=0.670;
mu=3.54*10^-4;
cp=4.2;
rhov=0.598;
hfg=2.27*10^6;
//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)
disp("The average heat transfer coefficient over length L in W/(m^2*K)")
hbar=0.943*[(rho*(rho-rhov)*g*hfg*k^3)/(mu*L*(Tg-Tw))]^(1/4)
//The rate of heat transfer Q=hbarL*A*(Tg-Tw)
//Area(A)=L*B
A=L*B;
disp("The rate of heat transfer in kW ")
Q=[hbar*A*(Tg-Tw)]/1000
//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)
disp("(b)The film thickness at the trailing edges in m is")
```

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

Scilab code Exa 9.4 Saturated freon 12

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

```
hfg=131.33*10^3;
rhov=42.68;
//tf is mean film temprature
disp("The mean film temprature in C is")
tf=(Tg+Tw)/2
//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))
rho=1.29*10^3;
k=0.071;
mu=2.50*10^-4;
cp=983;
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//we found the modified enthalpy by using following equation hfgdash=hfg+(3/8)*cp*(Tg-Tw)
disp(" Modified enthalpy in J/kg is")
hfgdash=hfg+[(3/8)*cp*(Tg-Tw)]
//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)
disp("The average heat transfer coefficient over length L in W/(m^2*K)")
hbar=0.555*[(rho*(rho-rhov)*g*hfgdash*k^3)/(mu*D*(Tg-Tw))]^(1/4)
//The rate of condensation is given by mdotc=(hbar*(pi*D*L)*(Tg-Tw))/hfg
disp("The total rate of condensation in kg/hr")
mdotc=[(hbar*(%pi*D*L)*(Tg-Tw))/hfg]*3600
```

Scilab code Exa 9.5 Nickel wire is submerged horizontally in water

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

```
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 9, Example 5")
//A nickel wire of length(L)=0.1m,Diameter(D)=1mm or
    .001m
//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
L=0.1;
T1=110;
D=0.001;
I=150;
E=2.2;
//Area(A)=[%pi*D*L]
A=%pi*D*L;
//The saturation temprature of water at one
   atmospheric pressure(101kPa) is T2=100 C .
T2=100;
//We can write from energy balance E*I=h*A*(T1-T2),
   we can find heat transfer coefficient from it.
//h is heat transfer coefficient
disp("Heat transfer coefficient in W/m^2 is")
h=(E*I)/(A*(T1-T2))
```

Scilab code Exa 9.6 Nickel wire is submerged horizontally

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
```

```
disp("Introduction to heat transfer by S.K.Som, Chapter 9, Example 6")
//In a laboratory experiment ,A current(I)=100A burns out a nickel wire having Diameter(D)=1mm or 0.001mm, length(L)=0.3m
I=100;
D=.001;
L=0.3;
//It is submerged horizontally in water at one atmospheric pressure.
//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).
rhol=960;
rhov=0.60;
hfg=2.26*10^6;
sigma=0.055;
//Area(A)=[pi*D*L]
A=%pi*D*L;
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//The wire is burnt out when heat reaches its peak
//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)
disp("Critical Heat flux in W/m^2 is")
qc=0.149*hfg*rhov*[(sigma*g*(rhol-rhov))/rhov^2]^(1/4)*[(rhol+rhov)/rhol]^(1/2)
//From the energy balance E*I=qc*A
//E is the burn out voltage
disp("The burn out voltage in Volts is  ")
E=(qc*A)/I
```

Scilab code Exa 9.7 A heated nickel plate

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 9, Example 7")
//A heated nickel plate at temprature (T1)=110 C is
    submereged in water at one atmospheric pressure.
T1=110;
//For nucleate boiling coefficient(csf=0.006) and n
   =1
csf=0.006;
n=1;
//For saturated water at one atmospheric pressure,
   density of liquid(rhol=960kg/m^3),vapour density(
   rhov=0.60kg/m^3)
//enthalpy of vaporisation(hfg=2.26*10^6J/kg),
   surface tension(sigma=0.055N/m),saturation
   temprature(T2)=100 C
T2=100;
rhol=960;
rhov=0.60;
hfg=2.26*10^6;
sigma=0.055;
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//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))
cpl=4.216*10^3;
Prl=1.74;
mul=2.82*10^-4;
//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
disp("Heat flux q in W/m^2 is")
```

```
q=(mul*hfg)*[((rhol-rhov)*g)/sigma]^(1/2)*[(cpl*(T1-T2))/(csf*hfg*Prl^n)]^3
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 characterstics of a special coating

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 9, Example 8")
//A Copper bar whose one end is exposed to boiling water while the other end is encapsulated by an electric heater.
//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.
xA=.010;
xB=.030;
//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
TA=140;
TB=180;
n=1;
//The values of relevant properties of water and other parameters are
//density of liquid(rhol=960kg/m^3),vapour density(
```

```
rhov=0.60kg/m^3),specific heat of liquid(cpl=4.216 kJ/(kg*K))
//enthalpy of vaporisation(hfg=2.26*106J/kg),prandtl number of liquiid(Prl=1.74),viscosity of liquid(mul=2.82*10^-4kg/(m*s)),surface tension(sigma1=0.055N/m).
rhol=960;
rhov=0.60;
cpl=4.216*10^3;
hfg=2.26*10^6;
Prl=1.74;
mul=2.82*10^-4;
sigma1=0.055;
//We have to know the value of heat flux(q) and the surface temprature(Tw).
//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
//q=k*[(TB-TA)/(xB-xA)]
//We take for copper conductivity,k=375W/(m*K)
k=375;
disp("The heat flux in W/m^2 is")
q=k*[(TB-TA)/(xB-xA)]
//g is acceleration due to gravity =9.81m/s^2
g=9.81;
//The surface temprature is given by Tw=TA-[(TB-TA)/(xB-xA)]*xA
disp("The surface temprature in  C is")
Tw=TA-[(TB-TA)/(xB-xA)]*xA
//Temprature,T=100 C ,since copper bar is exposed to boiling water.
T=100;
//Now we use following equation to determine csf,q=(mul*hfg)*[((rhol-rhov)*g)/sigma1]^(1/2)*[(cpl*(Tw-T))/(csf*hfg*Prl^n)]^3
//Manipulating above equation to find csf we get csf=[(cpl*(Tw-T))/([[q/{(mul*hfg)*[((rhol-rhov)*g)/sigma1]^(1/2)}]^(1/3)]*hfg*Prl^n)]
```

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

Chapter 10

Principles of heat exchangers

Scilab code Exa 10.1 Food processing plant

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

```
//overall heat transfer coefficient(U)=800 W/(m^2*K)
U=800;
//The rate of heat transfer from water is given by Q=mdot*cp*(T3-T4)
disp("The rate of heat transfer from water is given by Q=mdot*cp*(T3-T4) in W")
Q=mdot*cp*(T3-T4)
disp("(a) For a parallel flow arrangement")
//For a parallel flow arrangement deltaT1=T3-T1 and deltaT2=T4-T2.
deltaT1=T3-T1;//deltaT1 is temprature difference
deltaT2=T4-T2;//deltaT2 is temprature difference
//LMTD(Log mean temprature difference) is defined as (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) for both parallel and counter flow.
disp("LMTD is given by (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) in  C ")
//let X=log10((deltaT2/deltaT1)) and Y=log10(2.718281)
X=log10((deltaT2/deltaT1));
Y=log10(2.718281);
//ln=(ln(deltaT2/deltaT1))
ln=X/Y;
LMTD=(deltaT2-deltaT1)/ln
//Area(A)=Q/(U*LMTD) in m^2
disp("Area(A)=Q/(U*LMTD) in m^2")
A=Q/(U*LMTD)
disp("(b)For counterflow arrangement")
deltaT1=T3-T2;
deltaT2=T4-T1;
disp("LMTD=(deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) in C ")
X=log10((deltaT2/deltaT1));
Y=log10(2.718281);
ln=X/Y;
LMTD=(deltaT2-deltaT1)/ln
disp("Area(A)=Q/(U*LMTD) in m^2")
A=Q/(U*LMTD)
```

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 10, Example 2")
//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)
ch=2.09*10^3;
mdoth=0.7;
//overall heat transfer coefficient(U)=650 W/(m^2*K)
U=650;
//It enters at temprature,Th1=200 C and leaves at temprature,Th2=70 C
Th1=200;
Th2=70;
//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)
mdotc=1.2;
cc=1.67*10^3;
Tc2=150;
//The unknown inlet temprature(Tc1) of cold oil may be found from energy balance mdotc*(Tc2-Tc1)=mdoth*(Th2-Th1)
disp("The inlet temprature(Tc1) of cold oil in C ")
Tc1=Tc2-[(mdoth*ch)/(mdotc*cc)]*(Th1-Th2)
//The rate of heat transfer can be calculate as Q=
```

```
mdoth*ch*(Th1-Th2)
disp("The rate of heat transfer Q=mdoth*ch*(Th1-Th2) in W")
Q=mdoth*ch*(Th1-Th2)
deltaT1=Th1-Tc2;//deltaT1 is temprature difference between hot oil inlet temprature and cold oil exit temprature
deltaT2=Th2-Tc1;//deltaT2 is temprature difference between hot oil exit temprature and cold oil inlet temprature
//LMTD(Log mean temprature difference) is defined as (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) for counter flow.
disp("LMTD is given by (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) in  C ")
//let X=log10((deltaT2/deltaT1)) and Y=log10(2.718281)
X=log10((deltaT2/deltaT1));
Y=log10(2.718281);
//ln=(ln(deltaT2/deltaT1))
ln=X/Y;
LMTD=(deltaT2-deltaT1)/ln
//Area(A)=Q/(U*LMTD) in m^2
disp("Area(A)=Q/(U*LMTD) in m^2")
A=Q/(U*LMTD)
```

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
```

```
disp("Introduction to heat transfer by S.K.Som, Chapter 10, Example 3")
//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
//flowing at the mass flow rate of (mdotc)=1kg/s
Tci=50;
Tco=90;
cc=4.18*10^3;
mdotc=1;
//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
mdoth=3;
Thi=100;
ch=1.9*10^3;
//The unknown outlet temprature(Tho) of oil may be found from energy balance mdotc*(Tco-Tci)=mdoth*(Tho-Thi)
disp("The outlet temprature(Tho) of oil in C ")
Tho=Thi-[(mdotc*cc)/(mdoth*ch)]*(Tco-Tci)
disp("For a counterflow heat exchanger")
deltaT1=Thi-Tco;//deltaT1 is temprature difference
deltaT2=Tho-Tci;//deltaT2 is temprature difference
//LMTD(log mean temprature difference) is defined as (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) for counter flow.
disp("LMTD is given by (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) in C ")
//let X=log10((deltaT2/deltaT1)) and Y=log10(2.718281)
X=log10((deltaT2/deltaT1));
Y=log10(2.718281);
ln=X/Y;
LMTD=(deltaT2-deltaT1)/ln
//Area(A)=20m^2
A=20;
```

```
//We have to employ correction factor(F) for the
    cross flow arrangement.
//We evaluate dimensionless parameters P=(Tco-Tci)/(
    Thi-Tco) and R=(Thi-Tho)/(Tco-Tci).
disp("dimensionless parameters P and R are")
P=(Tco-Tci)/(Thi-Tci)
R=(Thi-Tho)/(Tco-Tci)
disp("correction factor(F) for the cross flow
    arrangement as obtained from graph of F vs Single
     Pass flow with fluids unmixed")
F=0.75
//The rate of heat transfer can be calculate as Q=
    mdoth*ch*(Th1-Th2)
Q=mdotc*cc*(Tco-Tci);
//overall heat transfer coefficient(U)=Q/(A*F*LMTD)
disp("overall heat transfer coefficient(U)=Q/(A*F*
    LMTD) in W/(m^2*K)")
U=Q/(A*F*LMTD)
```

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 10, Example 5")
//Water is heated from temprature ,Tin=30 C  to
    Tout=90 C  in a counter flow double pipe heat
    exchanger.
Tin=30;
Tout=90;
```

```
//Water flows at a mass flow rate of mdotw=1.2kg/s
mdotw=1.2;
//The heating is accomplished by a geothermal fluid which enters the heat exchanger at temprature , Thin=160 C at the mass flow rate of mdoth=2kg/s
mdoth=2;
Thin=160;
//The inner tube is thin walled having diameter(D)=15mm or 0.015m
D=0.015;
//overall heat transfer coefficient(U)=600 W/(m^2*K)
U=600;
//The specific heat of water and geothermal fluid is (cpw=4.18kJ/(kg*K))and(cph=4.31kJ/(kg*K)) respectively
cpw=4.18*10^3;
cph=4.31*10^3;
//The rate of heat transfer in heat exchanger can be calculate as Q=mdotw*cpw*(Tout-Tin)
disp("(a)Applying LMTD method")
disp("The rate of heat transfer Q=mdotw*cpw*(Tout-Tin) in W")
Q=mdotw*cpw*(Tout-Tin)
//The unknown outlet temprature(Thout) of geothermal fluid may be found from energy balance mdotw*cpw*(Tout-Tin)=mdoth*cph*(Thin-Thout)
disp("The unknown outlet temprature(Thout) of geothermal fluid in C ")
Thout=Thin-Q/(mdoth*cph)
deltaT1=Thin-Tout;//Temprature difference between inlet temprature of hot fluid and outlet temprature of cold fluid
deltaT2=Thout-Tin;//Temprature difference between outlet temprature of hot fluid and inlet temprature of cold fluid
//LMTD is defined as (deltaT2-deltaT1)/(ln(deltaT2/deltaT1)) for counter flow.
disp("LMTD is given by (deltaT2-deltaT1)/(ln(deltaT2
```

```
/deltaT1)) in  C ")
//let X=log10((deltaT2/deltaT1))and Y=log10(2.718281)
X=log10((deltaT2/deltaT1));
Y=log10(2.718281);
ln=X/Y;
LMTD=(deltaT2-deltaT1)/ln
//Area(A)=Q/(U*LMTD) in m^2
disp("Area(A)=Q/(U*LMTD) in m^2")
A=Q/(U*LMTD)
disp("To provide this surface area ,The length(L) of the tube required is given by L=A/(pi*D) in m")
L=A/(%pi*D)
disp("(b)Applying NTU method")
//The heat capacity rates are defined as Ch=mdoth*cph and Cc=mdotw*cw in KW/ C
disp("The heat capacity rates are defined as Ch=mdoth*cph and Cc=mdotw*cpw in KW/ C ")
Ch=(mdoth*cph)/1000
Cc=(mdotw*cpw)/1000
//So Cmin=Cc and Cmax=Ch
Cmin=Cc;
Cmax=Ch;
//C is defined as Cmin/Cmax
disp("C=Cmin/Cmax")
C=Cmin/Cmax
//Heat transfer effectiveness is (eff)
disp("Heat transfer effectiveness is defined as eff=Q/(Cmin*(Thin-Tin))")
eff=(Q/1000)/(Cmin*(Thin-Tin))
disp("NTU is determined by NTU=(1/(C-1))*ln((eff-1)/(eff*C-1))")
//let X=log10((eff-1)/(eff*C-1)) and Y=log10(2.718281)
X=log10((eff-1)/(eff*C-1));
Y=log10(2.718281);
//ln=ln[(eff-1)/(eff*C-1)]
ln=X/Y;
```

```
//NTU is Number of transfer units
NTU=(1/(C-1))*ln
//NTU =U*A/Cmin
disp("Area(A)=(NTU*Cmin)/U in m^2")
A=(NTU*Cmin*1000)/U
disp("To provide this surface area ,The length(L) of
    the tube required is given by L=A/(pi*D) in m")
L=A/(%pi*D)
disp("Hence same result is obtained for both methods
   ")
```

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 10, Example 6")
//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.
cw=4.18;
mdotw=0.8;
Tci=35;
//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
   .
co=1.88;
mdoto=1.5;
```

```
Thi=120;
//For an area(A) of 15m^2 and an overall heat transfer coefficient(U) of 350W/(m^2*K).
A=15;
U=350;
//Cwater and Co are heat capacities for water and oil respectively
//Cwater=mdotw*cw and Co=mdoto*co
Cwater=mdotw*cw;
Co=mdoto*co;
//C=Cmin/Cmax
Cmin=min(Cwater,Co);
Cmax=max(Cwater,Co);
C=Cmin/Cmax;
//NTU is number of transfer units
//NTU=(U*A)/Cmin
disp("NTU is defined as (U*A)/Cmin ")
NTU=(U*A)/(Cmin*1000)
//Heat transfer effectiveness(eff) is defined as (1-e^[-NTU*(1-C)])/(1-C*e^[-NTU*(1-C)])
disp("Heat transfer effectiveness(eff) is defined as (1-e^[-NTU*(1-C)])/(1-C*e^[-NTU*(1-C)])")
eff=(1-%e^[-NTU*(1-C)])/(1-C*%e^[-NTU*(1-C)])
//Hence The total heat transfer rate(Q)=eff*Cmin*(Thi-Tci)in kW.
disp("The total heat transfer rate(Q)=eff*Cmin*(Thi-Tci) in kW")
Q=eff*Cmin*(Thi-Tci)
```

Scilab code Exa 10.7 Water enters a cross flow heat exchangers

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

```
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 10, Example 7")
//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
Tci=20;
mdotw=7;
//The air flows at a mass flow rate of mdota=10kg/s from Temprature(Thi)=125 C
mdota=10;
Thi=125;
//The overall heat transfer coefficient(U)=220W/(m^2*K)and Area(A)=250m^2.
U=220;
A=250;
//The specific heat of air (cpa=1.01kJ/(kg*K)) and water is (cpw=4.18kJ/(kg*K))
cpa=1.01;
cpw=4.18;
//Cair and Cwater are heat capacities of air and water respectively
Cair=mdota*cpa;
Cwater=mdotw*cpw;
//C=Cmin/Cmax
Cmin=min(Cwater,Cair);
Cmax=max(Cwater,Cair);
C=Cmin/Cmax;
//NTU is number of transfer units
//NTU=(U*A)/Cmin
disp("NTU is defined as (U*A)/Cmin ")
NTU=(U*A)/(Cmin*1000)
//To determine the effectiveness of heat exchanger we have to find out the suitable expression
//For this type of heat exchanger The effectiveness(eff)is determined by (1-e^[(NTU^.22*{e^-(C*NTU^0.78)-1})/C])
```

```
disp("The effectiveness of heat exchanger is")
eff=(1-%e^[(NTU^0.22*{%e^(-C*NTU^0.78)-1})/C])
//Hence The total heat transfer rate(Q)=eff*Cmin*(Thi-Tci)in W.
disp("The total heat transfer rate(Q)=eff*Cmin*(Thi-Tci) in W")
Q=eff*Cmin*1000*(Thi-Tci)
//The exit temprature(Tho) of air is given by Thi-(Q/(mdota*cpa))
disp("The exit temprature of air in  C ")
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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 10, Example 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)
L=0.30;
cc=4.18;
mdotw=2;
//The water enters at temprature(Tci)=25 C  and leaves at temprature(Tco)=50 C
//The flow rate of oil is mdoth
Tci=25;
```

```
Tco=50;
//The oil used as hot fluid has(specific heat,ch=1.88kJ/(kg*K)) and has inlet temprature(Thi)=100 C
ch=1.88;
Thi=100;
disp("(a)Considering a parallel flow arrangement ")
//For minimum value of mdoth
//The theoretical minimum value of outlet temprature of hot fluid(Tho) under this situation is equal to Tco
Tho=Tco;
//The mass flow rate of oil is given by energy balance as mdoth=(mdotw*cpw*(Tco-Tci))/(cph*(Thi-Tho))
disp("The minimum flow rate required for the oil in kg/s")
mdoth=(mdotw*cc*(Tco-Tci))/(ch*(Thi-Tho))
disp("(b)Theoretical question")
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.")
disp("(c)Let us consider a counter flow arrangement")
//In this case value of Tho=Tci.
Tho=Tci;
//The mass flow rate of oil is given by energy balance as mdoth=(mdotw*cpw*(Tco-Tci))/(cph*(Thi-Tho))
disp("The minimum flow rate required for the oil in kg/s")
mdoth=(mdotw*cc*(Tco-Tci))/(ch*(Thi-Tci))
//Now Heat capacities are Ch=mdoth*ch and Cc=mdotw*cc
Ch=mdoth*ch;
Cc=mdotw*cc;
Cmin=min(Ch,Cc);//minimum heat capacity in Ch and Cc
```

```
//Effectiveness of heat exchanger is eff.
//Tho=Tci for this kind of arrangement
Tho=Tci;
disp("Effectiveness of heat exchanger is ")
eff=(mdoth*ch*(Thi-Tho))/(mdoth*ch*(Thi-Tci))
```

Chapter 11

Radiation heat transfer

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

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

```
//A1,A2 and A3 are the emitting surface areas
//From reciprocity relation F31=(A1/A3)/F13
A1=2;
A3=2.5;
F31=(A1/A3)*F13
```

Scilab code Exa 11.4 Determine the view factor F14 for the composite surface

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
    Chapter 11, Example 4")
//Determine the view factors F14 for the composite
    surface .
//From the table of radiation shape factor b/w two
    perpendicular surfaces F1,2-3,4=0.14 and F1
    ,2-3=0.1
//By subdivision of the recieving surfaces we get F1
    ,2-4=F1,2-3,4-F1,2-3
//Let F1,2-4=F124 , F1,2-3,4=F1234 , F1,2-3=F123
F1234=0.14;//View factor
F123=0.1;//View factor
F124=F1234-F123;//View factor
//Again from the table of radiation shape factor b/w
     two perpendicular surfaces F2-3,4=0.24 , F23
    =0.18
//Let F2-3,4=F234
F234=0.24;//View factor
F23=0.18;//View factor
//By subdivision of the recieving surfaces we get
```

```
    F24=F2-3,4-F23
F24=F234-F23;//view factor
//A1 and A2 are the emitting surface areas.
A1=12;
A2=12;
//Now by subdivision of emitting surfaces F1
    ,2-4=(1/(A1+A2))*(A1*F14+A2*F24)
//This implies F14=((F1,2-4*(A1+A2))-A2*F24)/A2
disp("The view factor F14=((F1,2-4*(A1+A2))-A2*F24)
    /A2")
F14=((F124*(A1+A2))-(A2*F24))/A2
```

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

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

```
//By making use of reciprocity theorem we have F31=(
    A1/A2)*F13
//A1 and A2 are emitting surface areas
//A1/A2=(pi*r^2)/(2*pi*r*2*r)=1/4
//Let A1/A2=A
A=1/4;
F31=(A)*F13
```

Scilab code Exa 11.6 Two blackbody rectangles

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

```
//The rate of heat transfer is given by Q=A1*F12*sigma*(T1^4-T2^4)
disp("The rate of heat transfer is given by Q=A1*F12*sigma*(T1^4-T2^4) in W")
Q=A1*F12*sigma*(T1^4-T2^4)
disp("Here minus sign indicates that the net heat transfer is from surface2 to surface1")
//Surface1 recieves energy only from surface 2,since the surrounding is at 0K.
//Therefore Q1=A1*Eb1-A2*F21*Eb2
//This implies Q1 can also be written as A1*sigma*(T1^4-F12*T2^4)
//From reciprocity theorem F21=F12 (since A1=A2)
F21=F12;//view factor
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" )
Q1=A1*sigma*(T1^4-F12*T2^4)
//In the case when surrounding is at temprature, Ts=300K ,the energy recieved from the surrounding by the surface 1 has to be considered.
Ts=300;
//Applying summation rule of view factors F11+F12+F1s=1
F11=0;//view factor
disp("The view factor of surface 1 with respect to surrounding is")
F1s=1-F11-F12
//subscript s denotes the surroundings
//Q1=A1*Eb1-A2*F21*Eb2-As*Fs1*Ebs
//With the help of reciprocity theorem A2*F21=A1*F12, As*Fs1=A1*F1s
//Therefore we can write Q1=A1*sigma*(T1^4-F12*T2^4-F1s*Ts^4)
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 ")
Q1=A1*sigma*(T1^4-F12*T2^4-F1s*Ts^4)
```

Scilab code Exa 11.7 Two parallel infinite planes

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

```
surfaces are black is Q/A=sigma*(T1^4-T2^4) in W")
H=sigma*(T1^4-T2^4)
```

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

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 11, Example 8")
//Two concentric spheres of diameters D1=0.5m and D2=1m are separated by an air space.
//The surface tempratures are T1=400K and T2=300K
T1=400;
T2=300;
D1=0.5;
D2=1;
//A1 and A2 are the areas in m^2 of surface 1 and surface 2 respectively
A1=(%pi*D1^2);
A2=(%pi*D2^2);
//Stefan-Boltzman constant(sigma)=5.67*10^-8 W/(m^2*K^4)
sigma=5.67*10^-8;
//The emissivity is represented by emi
//The radiation heat exchange in case of two concentric sphere is given by Q=[A1*sigma*(T1^4-T2^4)]/[(1/emi1)+(A1/A2)*(1/emi2-1)]
//When the spheres are black emi1=emi2=1
emi1=1;
emi2=1;
```

```
//Hence Q=A1*sigma*(T1^4-T2^4)
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 ")
Q=A1*sigma*(T1^4-T2^4)
//The net rate of radiation exchange when one surface is gray and other is diffuse having emi1=0.5 and emi2=0.5
emi1=0.5;
emi2=0.5;
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/emi1)+(A1/A2)*(1/emi2-1)] in W")
Q1=[A1*sigma*(T1^4-T2^4)]/[(1/emi1)+(A1/A2)*(1/emi2-1)]
//The net rate of radiation exchange when outer surface is assumed to be black body i;e(emi2=1)
emi2=1;//emissivity of outer surface
disp("The net rate of radiation exchange when outer surface is assumed to be black body i;e(emi2=1) in W")
Q2=[A1*sigma*(T1^4-T2^4)]/[(1/emi1)+(A1/A2)*(1/emi2-1)]
disp("Error(E) is given By [(Q2-Q1)/Q1]*100 in percentage")
E=[(Q2-Q1)/Q1]*100
```

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

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

```
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 11, Example 10")
//Given a furnace which can be approximated as an equuilateral triangle duct
//The hot wall is maintained at temprature (T1)=1000 K and has emmisivity(emi1)=0.75
//The cold wall is at temprature(T2)=350K and has emmisivity(emi2)=0.7
T1=1000;
T2=350;
emi1=0.75;
emi2=0.7;
//Stefan-Boltzman constant(sigma)=5.67*10^-8 W/(m^2*K^4)
sigma=5.67*10^-8;
//The third wall is reradiating zone having Q3=0
//The radiation flux leaving the hot wall is Q/A=[sigma*(T1^4-T2^4)]/(A*R)
//By summation rule F33+F31+F32=1
//F33=0(in consideration of surface to be plane)
//From symmetry F31=F32
F31=0.5;//View factors
F32=F31;//View factors
F33=0;//View factors
//From reciprocity theorem F13=F31 and F23=F32=0.5 (since A1=A2=A3=A)
F13=F31;//View factors
F23=F32;//View factors
//Again F11+F12+F13=1 from summation rule
F11=0;//View factors
F12=1-F13-F11;//View factors
//R1,R2,R12,R13,R23 are the resistances
//R is equivalent resistance of thermal network is given by R1+[(1/R12)+(1/(R13+R23))]^-1+R2
R1=(1-emi1)/(emi1);
R2=(1-emi2)/(emi2);
```

```
R12=1/(F12);
R13=1/(F13);
R23=1/(F23);
//R is equivalent resistance of thermal network
disp("Equivalent resistance of thermal network (R)
    is given by R1+[(1/R12)+(1/(R13+R23))]^-1+R2")
R=R1+[(1/R12)+(1/(R13+R23))]^-1+R2
//The radiation flux leaving the hot wall is Q/A.
disp("The radiation flux leaving the hot wall is Q/A
    =[sigma*(T1^4-T2^4)]/(A*R) in W/m^2")
//Since A gets cancelled in the factor (A*R)
//So Q/A=[sigma*(T1^4-T2^4)]/(R)
//Let Q/A=H
H=[sigma*(T1^4-T2^4)]/(R)
```

Chapter 12

Principles of mass transfer

Scilab code Exa 12.1 Pipeline that transports helium gas

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som,
   Chapter 12, Example 1")
//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.
//The internal daimeter of tube is (di)=6mm or .006m
//The temprature of both air and helium is (T)=25 C
    or 298 K.
//The diffusion coefficient of helium in air at
   normal atmosphere is(Dab)=7.20*10^-5 m^2/s
//The venting tube extends to a length(L)=20m in the
    atmosphere.
di=.006;
disp("The flow area is given by A=(pi*di^2)/4 in m^2
   ")
```

```
A=(%pi*di^2)/4
p=101*10^3;;
R=8.31*10^3;//gas constant
T=298;
Dab=7.20*10^-5;
L=20;
//c is the molar concentration
disp("The molar concentration of mixture which is
    constant throughout is given by c=p/(R*T)")
c=p/(R*T)
//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
Yal=0;
Yao=1;
//Nhe and Nair are molar rate of helium and air
    respectively
disp("Nhe=Nair=(A*c*Db*(Yao-yal))/L in kmol/sec")
Nair=(A*c*Dab*(Yao-Yal))/L
Nhe=Nair;
//Molecular weights of air and helium are 29kg/kmol
    and 4 kg/kmol respectively.
Mhe=4;
Mair=29;
//mass flow rate of helium is mhe
disp("mass flow rate of helium is given by m=Mhe*Nhe
     in kg/sec ")
mhe=Mhe*Nhe
//mass flow rate of air is mair
disp("mass flow rate of air is given by m=Mair*Nair
    in kg/sec ")
mair=Mair*Nair
```

Scilab code Exa 12.2 Wet bulb thermometer

```
// Display mode
mode(0);
// Display warning for floating point exception
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 12, Example 2")
//The temprature of atmospheric air (T)=40 C which flows over a wet bulb thermometer.
//The reading of wet bulb thermometer which is called the wet bulb temprature is (Tw)=20 C
T=40;
Tw=20;
//Tf is the film temprature
disp("The film temprature is given by Tf=(T+Tw)/2 in C ")
Tf=(T+Tw)/2
Tinf=T;//surrounding temprature
//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)
//The diffusivity Dab=0.26*10^-4 m^2/s
//The enthalpy of vaporisation of water at 20 C is hfg=2407kJ/kg or 2407*10^3 J/kg
//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.
rho=1.13;
cp=1.007*10^3;
alpha=0.241*10^-4;
Dab=0.26*10^-4;
hfg=2407*10^3;
Ps=2.34*10^3;
//The temprature at bulb surface Ts=20 C or 293K
Ts=Tw+273;//in kelvin
R=8.31*10^3;//gas constant
```

```
//The molecular weight of water is M=18
M=18;
//The density of water at bulb surface is rhos
disp("The density of water at bulb surface is given
    by rhos=(Ps*M)/(R*Ts) in kg/m^3")
rhos=(Ps*M)/(R*Ts)
//Let X=hheat/hmass=rho*cp*(alpha/Dab)^(2/3).
X=rho*cp*(alpha/Dab)^(2/3);
//At steady atate (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)
//hheat*(Tinf-Ts)=hmass*(rhos-rhoinf)*hfg
//Rearranging above we get rhoinf=rhos-(hheat/hmass)
    *((Tinf-Ts)/hfg)
//The concentration of water vapour at free stream
    is rhoinf
disp("The concentration of water vapour at free
    stream is rhoinf=rhos-(hheat/hmass)*((Tinf-Ts)/
    hfg) in kg/m^3")
rhoinf=rhos-((X)*((Tinf-Tw)/hfg))
//The mass concentration of saturated water vapour(
    rhosteam) at 40 C(as found from steam table) is
    .051 kg/m^3
rhosteam=.051;
//The relative humidity is (rehu)
disp("The relative humidity is given by rehu=(rhoinf
    /rhosteam)*100 in percentage")
rehu=(rhoinf/rhosteam)*100
```

Scilab code Exa 12.3 Measurement of binary diffusion coefficient

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

```
ieee(1);
clear;
clc;
disp("Introduction to heat transfer by S.K.Som, Chapter 12, Example 3")
//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.
//The measurement is done at height of 1500 m where the atmospheric pressure is (p)=80kPa.
p=80;
T=293;
//The distance from the water surface to the open end of the tube is L=500 mm or 0.5m.
L=.5;
//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.
m= 1.2*10^-3;
//From the steam table pvapour=3.17kPa
pvapour=3.17;//partial pressure of vapour
//Yao is the mole fraction of water vapour at the interface
disp("The mole fraction of water vapour at the interface is given by Yao=pvapour/p")
Yao=pvapour/p
//The mole fraction of water vapour at the top end of the tube is Yal=0
Yal=0;
R=8.31*10^3;//gas constant
//The total molecular concentration is (c)
disp("The total molecular concentration (c) through the tube remains constant is given by c=p/(R*T) in kmol/m^3")
c=(p*10^3)/(R*T)
di=35;
//A is the cross sectional area of the tube
```

```
disp("The cross sectional area of the tube is given by A=(pi*(di*10^-3)^2)/4 in m^2")
A=(%pi*(di*10^-3)^2)/4
//The molecular weight of wate is M=18
M=18;
//The mass flow rate is given by mdot=(m/(12*24*3600))
mdot=(m/(12*24*3600));
//N is the molar flow rate of water vapour
disp("The molar flow rate of water vapour is given by N=mdot/M in kmol/s")
N=mdot/M
//The molar flow rate of water vapour can also be written as N=(c*Dab*A*ln[(1-Yal)/(1-Yao)])/L
//The diffusion coefficient of water vapour is Dab=(N*L)/(c*A*ln[(1-Yal)/(1-Yao)])
//let us take X=log10((1-Yal)/(1-Yao)) and Y=log10(2.7182)
X=log10((1-Yal)/(1-Yao));
Y=log10(2.7182);
//ln[(1-Yal)/(1-Yao)] is given by
ln=X/Y;
disp("The diffusion coefficient of water vapour is Dab=(N*L)/(c*A*ln[(1-Yal)/(1-Yao)]) in m/s")
Dab=(N*L)/(c*A*ln)
```