Scilab Textbook Companion for Principles Of Heat Transfer by F. Kreith, R. M. Manglik And M. S. Bohn[1]

Created by
Tanmay Agrawal
Heat Transfer
Mechanical Engineering
National Institute of Technology Hamirpur
College Teacher
Dr. Varun Goel
Cross-Checked by
Mukul Kulkarni

July 31, 2019

---

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

Book Description

Title: Principles Of Heat Transfer

Author: F. Kreith, R. M. Manglik And M. S. Bohn

Publisher: Cengage Learning

Edition: 7

Year: 2011

ISBN: 978-0-495-66770-4

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

List of Figures

Chapter 1

Basic Modes of Heat Transfer

Scilab code Exa 1.1 `Heat Loss Through a Brick Wall`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.1 ")

//Temperature Inside in F
Ti = 55;
//Temperature outside in F
To = 45;
//Thickness of the wall in ft
t = 1;
//Heat loss through the wall in Btu/h-ft2
q = 3.4;

```

```
//Converting Btu/h-ft2 to W/m2
disp("Heat loss through the wall in W/m2 is")
//Heat loss through the wall in W/m2
qdash = (q*0.2931)/0.0929

//Heat loss for a 100ft2 surface over a 24-h period
disp("Heat loss for a 100ft2 surface over a 24-h
    period in Btu is")
//Heat loss for a 100ft2 surface over a 24-h period
    in Btu
Q = (q*100)*24

//Q in SI units i.e. kWh
Q = (Q*0.2931)/1000;

//At price of 10c/kWh, the total price shall be
disp("So, the total price in c are")
//Total price in c
Price = 10*Q
```

Scilab code Exa 1.2 Heat Transfer Through a Window Glass

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 1 Example # 1.2 ")

//Thermal conductivity of window glass in W/m-K
```

```
k = 0.81;
//Height of the glass in m
h = 1;
//Width of the glass in m
w = 0.5;
//Thickness of the glass in m
t = 0.005;
//Outside temperature in C
T2 = 24;
//Inside temperature in C
T1 = 24.5;

//Assume that steady state exists and that the temperature is uniform over the inner and outer surfaces

//Cross sectional area in m2
A = h*w;

disp("Thermal resistance to conduction in K/W is")
//Thermal resistance to conduction in K/W
R = t/(k*A)

//The rate of heat loss from the interior to the exterior surface is
//obtained by dividing temperature difference from the thermal resistence

disp("Heat loss in W from the window glass is")
//Heat loss in W
q = (T1-T2)/R
```

Scilab code Exa 1.3 `Natural Convection Between Air and Roof`

```

```

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter – 1 Example # 1.3 ")

//Area of room in m2 is given as
A = 20*20;
//Air temperature in C
Tair = -3;
//Roof temperature in C
Troof = 27;
//Heat transfer coefficient in W/m2–K
h = 10;

//Assume that steady state exists and the direction of heat flow is from the
//roof to the air i.e higher to lower temperature (as it should be).

disp(" The rate of heat transfer by convection from the roof to the air in W")
//The rate of heat transfer by convection from the roof to the air in W
q = (h*A)*(Troof-Tair)
```

Scilab code Exa 1.4 `Analysis of Electrically Heated Rod`

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

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.4 ")

//Diameter of rod in m
d = 0.02;
// Emissivity and temperautre of rod in K
epsilon = 0.9;
T1 = 1000;
//Temperature of walls of furnace
T2 = 800;

//Assuming steady state has been reached.
//Since the walls of the furnace completely enclose the heating rod, all the radiant energy emitted by the surface of the rod is intercepted by the furnace walls

//From eq. 1.17, net heat loss can be given

disp("Net heat loss per unit length considering 1m length in W")
//Area in m2
A = (%pi*d)*1;
//Constant sigma in W/m2-K4
sigma = 0.0000000567;
//Net heat loss per unit length considering 1m length in W
q = ((A*sigma)*epsilon)*(T1^4-T2^4)

//From eq. 1.21 radiation heat transfer coefficient in W/m2-K is
```

```
disp("Radiation heat transfer coefficient in W/m2-K is")
//Radiation heat transfer coefficient in W/m2-K
hr = ((epsilon*sigma)*(T1^4-T2^4))/(T1-T2)
```

Scilab code Exa 1.5 Heat Loss From a Composite Wall

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.5 ")

//Thickness of inside steel in m and thermal conductivity in W/m-k
t1 = 0.005;
k1 = 40;
//Thickness of outside brick in m and thermal conductivity in W/m-k
t2 = 0.1;
k2 = 2.5;

//Inside temperature in C
T1 = 900;
//Outside temperature in C
To = 460;

//Assuming the condition of steady state and using Eq. 1.24
```

```
disp("The rate of heat loss per unit area  in W/m2 is")
//The rate of heat loss per unit area  in W/m2
qk = (T1-To)/(t1/k1+t2/k2)

disp("Temperature at the interface in K is given as")
//Temperature at the interface in K
T2 = T1-(qk*t1)/k1
```

Scilab code Exa 1.6 `Analysis of Aluminium Plates`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.6 ")

//Thermal conductivity of aluminium in W/m-K
k = 240;
//Thickness of each plate in m
t = 0.01;
//Temperature at the surfaces of plates in C is given as
Ts1 = 395;
Ts3 = 405;
//From Table 1.6 the contact resistance at the interface in K/W is
R2 = 0.000275;
```

```
//Thermal resistance of the plates in K/W is
R1 = t/k;
R3 = t/k;

disp(”Heat flux in W/m2–K is”)
//Heat flux in W/m2–K
q = (Ts3-Ts1)/(R1+R2+R3)

//Since the temperature drop in each section of this one−dimensional system is propor−tional to the resistance.

disp(”Temperature drop due to contact resistance in degree C is”)
//Temperature drop due to contact resistance in degree C
deltaT = (R2/(R1+R2+R3))*(Ts3-Ts1)
```

Scilab code Exa 1.7 `Heat flow in Firebrick Steel System`

```


// Display mode
mode(0);

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

clc;
disp(”Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter − 1 Example # 1.7 ”)

//Because of symmetry, we need to calculate for only one half of the system

```

```
//Thickness of firebrick in inches
L1 = 1;
//Thermal conductivity of firebrick in Btu/h-ft-F
kb = 1;
//Thickness of steel plate in inches
L3 = 1/4;
//Thermal conductivity of steel in Btu/h-ft-F
ks = 30;
//Average height of asperities in inches is given as
L2 = 1/32;
//Temperature difference between the steel plates in
    F is
deltaT = 600;


//The thermal resistance of the steel plate is, on
   the basis of a unit wall area, equal to
R3 = L3/(12*ks);//12 is added to convert ft to in

//The thermal resistance of the brick asperities is,
    on the basis of a unit wall area, equal to
R4 = L2/((0.3*12)*kb);//Considering the 30 percent
   area

//At temperature of 300F, thermal conductivity of
   air in Btu/h-ft-F is
ka = 0.02;

// Thermal resistance of the air trapped between the
    asperities, is, on the basis of a unit area,
   equal to
R5 = L2/((0.7*12)*ka);//Considering the other 70
   percent area

//Since R4 and R5 are in parallel, so there combined
    resistance is
R2 = (R4*R5)/(R4+R5);

```

```
//The thermal resistance of half of the solid brick is
R1 = L1/(12*kb);

//The overall unit conductance for half the composite wall in Btu/h-ft2-F is then
kk = 0.5/(R1+R2+R3);

disp("The rate of heat flow per unit area in Btu/h-ft2 is")
//The rate of heat flow per unit area in Btu/h-ft2
q = kk*deltaT
```

Scilab code Exa 1.8 `Heat Dissipation in Instrument Circuit`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.8 ")

//Length for heat transfer for stainless steel in m
Lss = 0.1;

//Area for heat transfer for stainless steel in m2
A = 0.01;

//Thermal conductivity for stainless steel in W/m-K
kss = 144;
```

```

//Length for heat transfer for Duralumin in m
La1 = 0.02;

//Area for heat transfer for Duralumin in m2
A = 0.01;

//Thermal conductivity for Duralumin in W/m-K
ka1 = 164;

//Resistance in case of steel  in K/W
Rk1 = Lss/(A*kss);

//Resistance in case of Duralumin  in K/W
Rk2 = La1/(A*ka1);

//From Fig. 1.20, contact resistance in K/W
Ri = 0.05;

//Total resistance to heat transfer in K/W
Rtotal = Rk1+Rk2+Ri;

//Temperature diff. is given in K
deltaT = 40;

disp("Maximum allowable rate of heat dissipation in
   W is")
//Maximum allowable rate of heat dissipation in W
q = deltaT/Rtotal
```

Scilab code Exa 1.9 Heat Transfer Through Brick Wall

```


// Display mode
```

```
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 1 Example # 1.9 ")

//Cross sectional area in m2
A = 1;
//Heat transfer coefficient on hot side in W/m2-K
hchot = 10;
//Heat transfer coefficient on cold side in W/m2-K
hccold = 40;

//Length for heat transfer in m
L = 0.1;
//Thermal conductivity in W/m-K
k = 0.7;

//Resistances in K/w
R1 = 1/(hchot*A);
R2 = L/(k*A);
R3 = 1/(hccold*A);

//Total resistance
Rtotal = R1+R2+R3;

//Temperature on hot side in K
T1 = 330;
//Temperature on cold side in K
T2 = 270;

disp("Rate of heat transfer per unit area in W is")
//Rate of heat transfer per unit area in W
q = (T1-T2)/(R1+R2+R3)
```

Scilab code Exa 1.10 `Heat Loss From Pipe`

```
 

// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.10 ")

//diameter of pipe in m
d = 0.5;
//Epsilon is given as
epsilon = 0.9;
//sigma(constant) in SI units is
sigma = 0.0000000567;
//Temperatures in K are given as
T1 = 500;
T2 = 300;

//Radiation heat transfer coefficient in W/m2K
hr = ((sigma*epsilon)*(T1*T1+T2*T2))*(T1+T2);

//Convection heat transfer coefficient in W/m2K
hc = 20;

//total heat transfer coefficient in W/m2K
h = hc+hr;

disp("Rate of heat loss per meter in W/m is")
```

```
//Rate of heat loss per meter in W/m
q = ((%pi*d)*h)*(T1-T2)
```

Scilab code Exa 1.11 `Heat Exchanger Analysis`

```



// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.11 ")

//Hot-gas temperature in K
Tgh = 1300;
//Heat transfer coefficient on hot side in W/m2K
h1 = 200;
//Heat transfer coefficient on cold side in W/m2K
h3 = 400;
//Coolant temperature in K
Tgc = 300;
//Max temp. in C
Tsg = 800;
//Maximum permissible unit thermal resistance per square meter of the metal wall in K/W
R2 = (Tgh-Tgc)/((Tgh-Tsg)/(1/h1))-1/h1-1/h3;
disp("Maximum permissible unit thermal resistance per square meter of the metal wall in m2.K/W is")
R2
```

Scilab code Exa 1.12 Insulation in Gas Furnace

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 1 Example # 1.12 ")

// total length of metal sheet in m
L = 0.625/39.4;
//  we estimate the thermal conductivity of the
   metal sheets to be approximately 43 W/m K
k = 43;
// therefore the resistance in K/W offered by metal
   sheey
R = L/k;

//heat loss in W/m2 is given as
q = 1200;
// overall heat transfer coefficient between the gas
    and the door is given
// in W/m2K
U = 20;
//The temperature drop between the gas and the
   interior surface of the door at the specified
   heat flux is
deltaT1 = q/U;
//Hence, the temperature of the Inconel will be in
```

```
degree C
T = 1200-deltaT1;

//The heat transfer coefficient between the outer surface of the door and
//the surroundings at 20 C  in W/m2K
h = 5;
//The temperature drop at the outer surface in degree C is
deltaT2 = q/h;
//Selecting milled alumina-silica chips as insulator (Fig 1.31 on page 48)

// Hence, temperature difference across the insulation is
deltaT3 = T-deltaT1-deltaT2;

//thermal conductivity for milled alumina-silica chips in W/mK is
k = 0.27;

disp(”The insulation thickness in m is”)
//The insulation thickness in m
L = (k*deltaT3)/q
```

Scilab code Exa 1.13 `Energy Balance at Roof`

```


// Display mode
mode(0);

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

```

```
clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 1 Example # 1.13 ")

//Temperature of air in degree K
Tair = 300;
//Heat transfer coefficient in W/m2K
h = 10;

disp("Part a")
//Radiation solar flux in W/m2
q = 500;
//Ambient temperature in K
Tsurr = 50;

disp("Solving energy balance equaiton by trial and
   error for the roof temperature, we get temp. in
   degree K")
//Room temperature in degree K
Troof = 303

disp("Part b")

//No heat flux, energy balance equaiton is modified
disp("Room temperature in degree K")
//Room temperature in degree K
Troof = 270
```

Scilab code Exa 1.14 `Theoretical example`

```


// Display mode
mode(0);

```

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 1 Example # 1.14 ")

disp("The given example is theoretical and does not involve any numerical computation")
```

Chapter 2

Heat Conduction

Scilab code Exa 2.1 `Calculation of Heat Transfer Coeffcient`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 2 Example # 2.1 ")

//Heat generation rate in W/m3
qg = 1000000;
//Length along which heat will be dissipated in m (
   thickness)
L = 0.01;
//Thermal conductivity at the required temperature
   in W/mK
k = 64;

```

```
//Temperature of surrounding oil in degree C
Tinfinity = 80;
//Temperature of heater in degree C to be maintained
T1 = 200;

disp(”heat transfer coefficient in W/m2K from a heat balance”)
//Heat transfer coefficient in W/m2K
h = ((qg*L)/2)/(T1-Tinfinity)
```

Scilab code Exa 2.2 `Insulated vs Uninsulated Copper Pipe`

```


// Display mode
mode(0);

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

clc;
disp(”Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.2 ”)

disp(”Case of Uninsualted pipe”)
//Calculating resistance to heat flow at internal surface

//Internal radius in m
ri = 0.05;
//Heat transfer coefficient at inner surface for steam condensing in W/m2K
hci = 10000;
//Resistance in mK/W
R1 = 1/(((2*%pi)*ri)*hci);
```

```

//Calculating resistance to heat flow at external surface

//External radius in m
ro = 0.06;
//Heat transfer coefficient at outer surface in W/m2K
hco = 15;
//Resistance in mK/W
R3 = 1/(((2*%pi)*ro)*hco);

//Calcualting resistance to heat flow due to pipe

//Thermal conductivity of pipe in W/mK
kpipe = 400;
//Resistance in mK/W
R2 = log(ro/ri)/((2*%pi)*kpipe);

//Temperatures of steam(pipe) and surrounding(air) in degree C
Ts = 110;
Tinfinity = 30;

disp("Heat loss from uninsulated pipe in W/m is therefore")
//Heat loss from uninsulated pipe in W/m
q = (Ts-Tinfinity)/(R1+R2+R3)


disp("Case of insulated pipe")
//Calculating additional resistance between outer radius and new outer
//radius

//Thermal conductivity of insulation in W/mK
k = 0.2;
//New outer radius in m
```

```
r3 = 0.11;
//Resistance in mK/W
R4 = log(r3/ro)/((2*%pi)*k);

//Calculating new outer resistance
R0 = 1/(((2*%pi)*r3)*hco);


disp("Heat loss from insulated pipe in W/m is
    therefore")
//Heat loss from insulated pipe in W/m
q = (Ts-Tinfinity)/(R1+R2+R4+R0)
```

Scilab code Exa 2.3 `Hot Fluid Flowing Through Pipe`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 2 Example # 2.3 ")

//Outer radius in m
ro = 0.02;
//Inner radius in m
ri = 0.015;
//Thermal conductivity of plastic in W/mK
k = 0.5;
//Internal convection heat transfer coefficient in W
    /m2K
```

```
hc1 = 300;
//Temperature of fluid in pipe in degree C
Thot = 200;
//Temperature of outside in degree C
Tcold = 30;
//External convection heat transfer coefficient in W/m2K
hc0 = 10;

disp("Overall heat transfer coefficient in W/m2K is")
//Overall heat transfer coefficient in W/m2K
U0 = 1/(ro/(ri*hc1)+(ro*log(ro/ri))/k+1/hc0)

disp("The heat loss per unit length in W/m is")
//The heat loss per unit length in W/m
q = (((U0*2)*%pi)*ro)*(Thot-Tcold)
```

Scilab code Exa 2.4 Boiling Off Of Nitrogen

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.4 ")

//Temperature of liquid nitrogen in degree K
Tnitrogen = 77;
//Radius of container in m
```

```
ri = 0.25;
//Temperature of surrounding air in degree K
Tinfinity = 300;
//Thermal conductivity of insulating silica powder
   in W/mK
k = 0.0017;
//Outer radius of container with insulation in m
ro = 0.275;
//Latent heat of vaporization of liquid nitrogen in
   J/kg
hgf = 200000;
//convection coefficient at outer surface in W/m2K
hco = 20;

//Calcaulting heat transfer to nitrogen
q = (Tinfinity-Tnitrogen)/(1/((((4*%pi)*ro)*ro)*hco)
   +(ro-ri)/((((4*%pi)*k)*ro)*ri));

disp(" rate of liquid boil-off of nitrogen per hour
   is")
//rate of liquid boil-off of nitrogen per hour
m = (3600*q)/hgf
```

Scilab code Exa 2.5 `Analysis of Nuclear Reactor`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
```

```
    Kreith et. al Chapter - 2 Example # 2.5 ")

//Heat generation rate in W/m3
qg = 75000000;
//Outer radius of rods in m
ro = 0.025;
//Temperature of water in degree C
Twater = 120;
//Thermal cinductivity in W/mk
k = 29.5
//Heat transfer coefficient in W/m2K
hco = 55000;

//Since rate of flow through the surface of the rod equals the rate of internal heat generation
//and
//The rate of heat flow by conduction at the outer surface equals the rate
//of heat flow by convection from the surface to the water

//Surface Temperature in degree C
T0 = (qg*ro)/(2*hco)+Twater;

disp("Maximum temperature in degree C")
//Maximum temperature in degree C
Tmax = T0+((qg*ro)*ro)/(4*k)
```

Scilab code Exa 2.6 Analysis of Copper Pin Fin

```


// Display mode
mode(0);

```

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.6 ")

//diameter of fin in m
d = 0.0025;
//Perimeter in m
P = %pi*d;
//Area in m2
A = ((%pi*d)*d)/4;
//Surface temperature in degree C
Ts = 95;
//Ambient temperature in degree c
Tinfinity = 25;
//Heat transfer coefficient in W/m2K
hc = 10;
//From table 12, value of thermal conductivity in W/mK
k = 396;

disp("Case of an infinitely long fin")
disp("Heat loss for the   infintely   long  fin in W is")
//Heat loss for the   infintely   long  fin in W
qfin = ((((hc*P)*k)*A)^0.5)*(Ts-Tinfinity)

disp("Case 2: Fin length of 2.5cm")
//Length in cm
L = 2.5/100;
//Parameter m
m = ((hc*P)/(k*A))^0.5;
disp("Heat loss in this case in W is")
//Heat loss in this case in W
qfin = qfin*((sinh(m*L)+(hc/(m*k))*cosh(m*L))/(cosh(m*L)+(hc/(m*k))*sinh(m*L)))
```

```

disp("For the two solutions to be within 5%")
//((sinh(m*L)+(hc/(m*k))*cosh(m*L))/(cosh(m*L)+(hc/(m*k))*sinh(m*L))) must
//be less than 0.95
disp("L must be greater than 28.3cm")
```

Scilab code Exa 2.7 `Heat Loss From Circumferential Fin`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.7 ")

//Thermal conductivity of alumunium in W/mK
k = 200;
//Outer radius of system in m
ro = 5.5/200;
//Inner radius of system in m
ri = 2.5/200;
//Thickness of fin in m
t = 0.1/100;

//Temperature of pipe in  degree C
Ts = 100;
//Temperature of surrounding in degree C
Tinfinity = 25;
//Heat transfer coefficient in W/m2K
```

```
h = 65;

//calculating fin efficiency
//From Fig. 2.22 on page 103, the fin efficiency is found to be 91%.

//Area of fin
A = (2*%pi)*((ro+t/2)^2-ri*ri);

disp("The rate of heat loss from a single fin in W is")
//The rate of heat loss from a single fin in W
q = ((0.91*h)*A)*(Ts-Tinfinity)
```

Scilab code Exa 2.8 Heat Loss From Buried Pipe

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.8 ")

//Diameter of pipe in m
D = 0.1;
//Depth under which it is sunk in m
z = 0.6;
//Temperature of pipe in degree C
Tpipe = 100;
//Temperature of soil in degree C
```

```
Tsoil = 20;
//Thermal conductivity in W/mK
k = 0.4;


//From table 2.2 on page 112, calculating shape factor
//Shape factor
S = (2*%pi)/acosh((2*z)/D);
disp(" rate of heat loss per meter length in W/m is")
//rate of heat loss per meter length in W/m
q = (k*S)*(Tpipe-Tsoil)
```

Scilab code Exa 2.9 Heat Loss From Cubic Furnace

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.9 ")

//Thermal conductivity in W/mC
k = 1.04;
//For square length and breadth are equal and are in m
D = 0.5;
//Area in m2
A = D*D;
```

```
//Thickness in m
L = 0.1;
//Inside temperature in degree C
Ti = 500;

//Outside temperature in degree C
To = 50;
//Shape factor for walls
Sw = A/L;
//Shape factor for corners
Sc = 0.15*L;
//Shape factor for edges
Se = 0.54*D;

//There are 6 wall sections , 12 edges , and 8 corners
    , so that the total
//shape factor is
S = 6*Sw+12*Se+8*Sc;

disp("Heat flow in W is")
//Heat flow in W
q = (k*S)*(Ti-To)
```

Scilab code Exa 2.10 `Transient Response of Thermocouple`

```


// Display mode
mode(0);

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

```

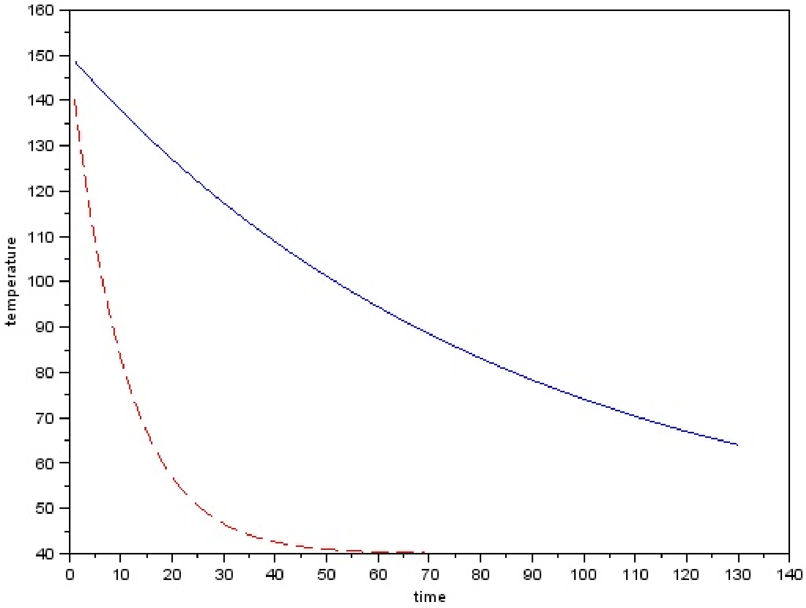

Figure 2.1: Transient Response of Thermocouple

```
clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 2 Example # 2.10 ")

//Diameter of copper wire in m
D = 0.1/100;
//Initial temperature in degree C
To = 150;
//Final surrounding temperature in degree C of air
    and water
Tinfinity = 40;

//From table 12, appendix 2, we get the following
    data values for copper
//Thermal conductivity in W/mK
k = 391;
//Specific heat in J/kgK
c = 383;
//Density in kg/m3
rho = 8930;

//Surface area of wire per unit length in m
A = %pi*D;
//Volume of wire per unit length in m2
V = ((%pi*D)*D)/4;

//Heat transfer coefficient in the case of water in
    W/m2K
h = 80;
//Biot number in water
bi = (h*D)/(4*k);
//The temperature response is given by Eq. (2.84)

//For water Bi*Fo is 0.0936t
//For air Bi*Fo is 0.0117t

for i = 1:130
  //Position of grid
```

```
  x(1,i) = i;
  // Temperature of water in degree C
  Twater(1,i) = Tinfinity+(To-Tinfinity)*exp(-0.0936*i);
  // Temperature of air in degree C
  Tair(1,i) = Tinfinity+(To-Tinfinity)*exp(-0.0117*i);
end;
//Plotting curve
plot(x,Twater,"--r")
set(gca(),"auto_clear","off")
//Plotting curve
plot(x,Tair)
//Labelling axis
xlabel("time")
ylabel("temperature")
disp("Temperature drop in water is more than that of air")
```

Scilab code Exa 2.11 `Minimum Depth of Water Mains`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.11 ")

//Initial temperature of soil in degree C
Ti = 20;
```

```
//Surface temperature of soil
Ts = -15;
//Critical temperature (Freezing temperature) in degree C
Tc = 0;
//Time in days
t = 60;
//Density of soil in kg/m3
rho = 2050;
//Thermal conductivity of soil in W/mK
k = 0.52;
//Specific heat in J/kgK
c = 1840;
//Diffusivity in m2/sec
alpha = k/(rho*c);

//Finding the value of following to proceed further
//Z value
z = (Tc-Ts)/(Ti-Ts);

//From table 43, it corresponds to an error function value of 0.4,
//proceeding

disp("Minimum depth at which one must place a water main below the surface to avoid freezing in m is")
//Minimum depth at which one must place a water main below the surface to avoid freezing in m
xm = (0.4*2)*((((alpha*t)*24)*3600)^0.5)
```

Scilab code Exa 2.12 `Steel Component Fabrication Process`

```


```

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

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.12 ")

//Length of steel component in m
L = 2;
//Radius of steel component in m
ro = 0.1;
//Thermal conductivity of steel in W/mK
k = 40;
//Thermal diffusivity in m2/s
alpha = 0.00001;
//Initital temperature in degree C
Ti = 400;
//Surrounding temperature in degree C
Tinfinity = 50;
//Heat transfer coefficient in W/m2K
h = 200;
//time of immersion in mins
t = 20;

//Since the cylinder has a length 10 times the diameter, we can neglect end
//effects.

//Calculating biot number
bi = (h*ro)/k;
if bi>0.1 then
  //Calculating fourier number
  fo = ((alpha*t)*60)/(ro*ro);
  //The initial amount of internal energy stored in the cylinder per unit
```

```
  //length in Ws/m
  Q = ((((k*%pi)*ro)*ro)*(Ti-Tinfinity))/alpha;

  //The dimensionless centerline temperature for 1/
     Bi= 2.0 and Fo= 1.2 from
  //Fig. 2.43(a)
  //Centreline temperature in degree C
  T = Tinfinity+0.35*(Ti-Tinfinity);
  disp("Centreline temperature in degree C is")
  T
  //The surface temperature at r/r0= 1.0 and t= 1200
      s is obtained from Fig. 2.43(b) in terms of
     the centerline temperature
  //Surface temperature in degree C
  Tr = Tinfinity+0.8*(T-Tinfinity);
  disp("Surface temperature in degree C is")
  Tr
  //Then the amount of heat transferred from the
     steel rod to the water can be obtained from Fig
     . 2.43(c). Since Q(t)/Qi= 0.61,
  disp("The heat transferred to the water during the
       initial 20 min in Wh is")
  //The heat transferred to the water during the
     initial 20 min in Wh
  Q = ((0.61*L)*Q)/3600
end;
```

Scilab code Exa 2.13 `Analysis of Concrete Wall`

```


// Display mode
mode(0);

// Display warning for floating point exception
```

```
ieee(1);

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.13 ")

//Thickness of wall in m
L = 0.5;
//Initial temperature in degree C
Ti = 60;
//Combustion gas (Surrounding) temperature in degree C
Tinfinity = 900;
//Heat transfer coefficient in W/m2K
h = 25;
//Thermal conductivity in W/mk
k = 1.25;
//Specific heat in J/KgK
c = 837;
//Density in kg/m3
rho = 500;
//Thermal diffusivity in m2/s
alpha = 0.000003;
//Required temperature to achieve in degree C
Ts = 600;

//Calculating temperature ratio
z = (Ts-Tinfinity)/(Ti-Tinfinity);
//Reciprocal biot number
bi = k/(h*L);


//From Fig. 2.42(a) we find that for the above conditions the Fourier number= 0.70 at the midplane.
//Time in hours
t = ((0.7*L)*L)/alpha;
disp("Time in hours is")
```

```
//Time in hours
t = t/3600

//The temperature distribution in the wall 16 h after the transient was
//initiated can be obtained from Fig. 2.42(b) for various values of x/L

disp(”Temperature distribution in degree C is”)
disp(”  (x/l)  = 1.00 0.80 0.60 0.40 0.20”)
disp(”Fraction = 0.13 0.41 0.64 0.83 0.96”)

//The heat transferred to the wall per square meter of surface area during
//the transient can be obtained from Fig. 2.42(c).
disp(”Heat transfer in J/m2 is”)
//Heat transfer in J/m2
Q = ((c*rho)*L)*(Ti-Tinfinity)
```

Scilab code Exa 2.14 `Cylinder Places in Hot Oven`

```


// Display mode
mode(0);

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

clc;
disp(”Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 2 Example # 2.14 ”)

//Radius of cylinder in m
ro = 0.05;
```

```
//Length of cylinder in m
L = 0.16;
//Thermal conductivity in W/mK
k = 0.5;
//Thermal diffusivity in m2/s
alpha = 0.0000005;
//Initial temperature in degree C
Ti = 20;
//Surrounding temperature in degree C
Tinfinity = 500;
//Heat transfer coefficient in W/m2K
h = 30;
//Time in mins
t = 30;

//Biot number
bi = (h*ro)/k;
//Fourier number
fo = ((alpha*t)*60)/((L*L)/4);

//From fig. 2.42(a)
//Po
P0 = 0.9;
//From fig. 2.42(a) and (b)
//Pl
PL = 0.243;
//From fig. 2.43(a)
//Co
C0 = 0.47;
//From fig. 2.43(a) and (b)
//Cr
CR = 0.155;
disp(”Minimum temperature in degree C”)
//Minimum temperature in degree C
Tmin = Tinfinity+((Ti-Tinfinity)*P0)*C0
```

Chapter 3

Numerical Analysis of Heat Conduction

Scilab code Exa 3.1 `Temperature Distribution in Heating Element`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 3 Example # 3.1 ")

//Cross section of the element in m is given as
b = 0.1; //breadth in m
H = 0.01; //height in m
//Temperature of surrrounding oil in C is given as
Tinfinity = 80;
//Correspoding heat transfer coefficient in W/m2-K
   is given as:
```

```
h = 42;
//Heat generation rate is given in W/m3 as
qg = 10^6;
//Temperature below which element needed to maintain in C is
T = 200;
// Thermal conductivity of iron in W/m-K is taken as
k = 64;

//Because of symmetry we need to consider only half of the thickness of the heating element
L = H/2; //Length in m
//We are defining five nodes at a distance of (i-1)*dx, where i=1,2,3,4,5
N = 5; //Total number of grid points
dx = L/(N-1); //dx in m
//Since no heat flows across the top face, it corresponds to a zero-heat
//flux boundary condition.
//Applying Eq. (2.1) to a control volume extending from x=L-dx/2 to x=L
//We get TN=TN-1 +qg*dx*dx/(2*k)

//At the left face, , we have a surface convection boundary condition to which Eq. (3.7) can be applied
//Determining all the matrix coefficients in Eq. (3.11)
a1 = 1; //Matrix coefficient a1 in SI units
b1 = 1/(1+(h*dx)/k); //Matrix coefficient b1 in SI units
c1 = 0; //Matrix coefficient c1 in SI units
d1 = (dx/k)*((h*Tinfinity+(qg*dx)/2)/(1+(h*dx)/k)); //Matrix coefficient d1 in SI units
a2 = 2;a3 = a2;a4 = a3;//Matrix coefficient a2 in SI units
b2 = 1;b3 = b2;b4 = b3;//Matrix coefficient b2 in SI units
```

```
c2 = 1;c3 = c2;c4 = c3;//Matrix coefficient c2 in SI
    units
d2 = ((dx*dx)*qg)/k;d3 = d2;d4 = d2;//Matrix
   coefficient d2 in SI units
a5 = 1;b5 = 0;c5 = 1;d5 = ((dx*dx)*qg)/(2*k);//
   Matrix coefficient a5 in SI units

//Using the algorithm given in Appendix 3 for
   solving the tridiagonal system, we find the
   temperature distribution given as:
disp("Final temperature distribution in C is the
   following")
//From equation 3.11
//Matrix A in the Appendix 3
A = [a1,-b1,0,0,0;
     -c2,a2,-b2,0,0;
     0,-c3,a3,-b3,0;
     0,0,-c4,a4,-b4;
     0,0,0,-c5,a5];
//Matrix D in the Appendix 3
D = [d1;d2;d3;d4;d5];
//Temperature matrix where temp are in degree C as
   given by appnedix 3
T = (A^(-1))*D
```

Scilab code Exa 3.2 Critical Depth to Avoid Freezing

```


// Display mode
mode(0);

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

```

```
clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 3 Example # 3.2 ")

// we have to determine minimum depth xm at which a water main must be buried to avoid freezing

//Initial temperature of soil in C is given as:
Ts = 20;
// Under the worst conditions anticipated it would be subjected to a surface
// temperature of -15C for a period of 60 days
//Max temperature in degree C
Tmax = -15;
//Time period in days
dt = 60;
//We will use the following properties for soil (at 300 K)
rho = 2050;//density in kg/m3
k = 0.52;//thermal conductivity in W/m-K
c = 1840;//specific heat in J/kg-K
alpha = 0.138*(10^(-6));//diffusivity in m2/sec

//Fourier number is defined as:
//Fo=dt*alpha/(dx*dx);

//Let us select a maximum depth of 6 m
//First, let us choose, giving dx=1.2m

dx = 1.2; //dx in m
dt = (30*24)*3600;//Days converted in seconds

//Temperature array for the old temperature in degree C
Tnew = [-15,20,20,20,20,20];

//Temperature array for the new temperature in degree C
```

```
Told = [-15,20,20,20,20,20];
//Fourier number is defined as:
Fo = (dt*alpha)/(dx*dx);

//Using eq. 3.15
//Initialsing timestep for looping
timestep = 0;
for timestep = 0:100
  for N = 2:4
    //New temp in degree C
    Tnew(N) = Told(N)+Fo*(Told(N+1)-2*Told(N)+Told(N-1));
    //Incrementing timestep
    timestep = timestep+1;
  end;
end;
disp(”With dx=1.2m, we have the following distribution”)
//New temp in degree C
Tnew

disp(”Depth in m at which temperature would be 0 degree C would be”)
//Depth in m
xm = (0-Tnew(1)/(Tnew(2)-Tnew(1)))*dx
```

Scilab code Exa 3.3 `Time Required For Cooling of Sheet`

```


// Display mode
mode(0);

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

```

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 3 Example # 3.3 ")

//initial temperature of the sheet in C is given as:
Tinitial = 500;
//thickness of the sheet in m is given as
th = 0.02;
//density in kg/m3 is given for steel as
rho = 8500;
//specific heat in J/kg-K is given as
c = 460;
//thermal conductivity in W/m-K is given as
k = 20;
//The heat transfer coefficient in W/m2-K to the air is given as
h = 80;
//the ambient air temperature in degree C is
Tinfinity = 20;
//Final temperature required to achieve in C is
Tfinal = 250;
//The transient cooling of stainless steel sheet can be modeled as a semi-infinite slab
//because the thickness of the sheet is much smaller than its width and length.
L = th/2; //Length in m
//Finding chart solution
//Biot number shall be
Bi = (h*L)/k;

//Since Bi<0.1 and hence the sheet can be treated as a lumped capacitance.

//To use fig. 2.42 on page 135, we need to calculate the following value:
value = (Tfinal-Tinfinity)/(Tinitial-Tinfinity); //value required
```

```

//So, now using fig. 2.42, we have alpha*dt/(L*L)=19
//BY the definition of thermal diffusivity ,in SI units we have
alpha = k/(rho*c);
disp("By chart solution , time required in seconds comes out to be")
//time required in seconds
t = ((19*L)*L)/alpha

//Proceeding to the numerical solution
//consider half the sheet thickness ,with x=0 being the exposed left face and
//x=L being the sheet center-line

//Using 20 control volumes
N = 21; //Total number of grid points
dx = L/20; //dx in m

//Old temperature array
for N = 1:21
  //Old temp in degree C
  Told(1,N) = Tinitial;
  //New temp in degree C
  Tnew(1,N) = Tinitial;
end;
//Initialisation Time in sec
t = 0;
//Increment of Time in sec
dt = 0.02;
//Condition of looping
while Told(21)>250
  //C1 of governing equation in SI units
  C1 = (alpha*dt)/(dx*dx);
  //C2 of governing equation in SI units
  C2 = ((2*h)*dt)/((rho*c)*dx);
  //C3 of governing equation in SI units
  C3 = 2*C1;
```

```
  //New temp in C as given by the equations of
     finite difference method
  Tnew = mtlb_i(Tnew,1,Told(1)+C2*(Tinfinity-Told(1)
     )+C3*(Told(2)-Told(1)));
  Tnew = mtlb_i(Tnew,21,Told(21)+C3*(Told(20)-Told
     (21)));
  for N = 2:20
    //New temp in C as given by the equations of
       finite difference method
    Tnew = mtlb_i(Tnew,N,Told(N)+C1*(Told(N+1)-2*
       Told(N)+Told(N-1)));
  end;
  for N = 1:21
    //Assigning old temp=new temp
    Told = mtlb_i(Told,N,Tnew(N));
  end;
  //Modified time for new loop
  t = t+dt;
end;
// L.67: No simple equivalent, so mtlb_fprintf() is
   called.
mtlb_fprintf("As per numerical solution time comes
   out to be %5.2f seconds\n",t)

disp("This time is about 1.5% less than the chart
   solution")
```

Scilab code Exa 3.4 Temperature Distribution in Rod Crosssection

```



// Display mode
mode(0);

```

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 3 Example # 3.4 ")

//Dimensions of the cross section in inches
l = 1;
b = 1;

//Dividing domain such that there are four nodes in x and y direction
dx = 1/3; //dx in inches
dy = 1/3; //dy in inches

//Assigning Temperature in C for top and bottom surface
for i = 1:4
  T(1,i) = 0;
  T(4,i) = 0;
end;
//Assigning Temperature in C for side surfaces
for j = 1:4
  T(j,1) = 50;
  T(j,4) = 100;
end;
//Assigning Temperature in C for interior nodes
for i = 2:3
  for j = 2:3
    T(i,j) = 0;
  end;
end;
//Defining looping parameter
step = 0;
for step = 0:50
  //Using governing equations of finite difference
  T(3,2) = 0.25*(50+0+T(2,2)+T(3,3));
```

```
  T(2,2) = 0.25*(50+0+T(3,2)+T(2,3));
  T(2,3) = 0.25*(100+0+T(3,2)+T(2,3));
  T(3,3) = 0.25*(100+0+T(2,2)+T(3,3));
end;

//disp("At steady state, Final temperature of the cross section in C would be")
//New temp distribution in degree C
printf('Temperature T(2,2) in degree C is %5.2f\n',T(2,2))
printf('Temperature T(2,3) in degree C is %5.2f\n',T(3,2))
printf('Temperature T(3,2) in degree C is %5.2f\n',T(2,3))
printf('Temperature T(3,3) in degree C is %5.2f',T(3,3))
```

Scilab code Exa 3.5 `Analysis of Alloy Bus Bar`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 3 Example # 3.5 ")

//Thermal conductivity of alloy bus bar in W/m–K is given as
k = 20;
//Heat generation rate in W/m3 is given as
```

```
qg = 10^6;
//dimensions of the bar in m is given as
L = 0.1;//Length in m
b = 0.05;//Width in m
d = 0.01;//Thickness in m

//For top edge, heat transfer coefficient in W/m2K and ambient temperature
//in C are
h = 75;
Tinfinity = 0;
//We are taking a total of 11 nodes in the direction of length and 6 nodes
//in the direction of width
dx = 0.01; //dx in m
dy = 0.01; //dy in m
//Assigning a guess temperature of 25C to all nodes
for i = 1:6
  for j = 1:11
    //Old temp. in degree C
    Told(i,j) = 25;
  end;
end;

//Assigning temperature on the left and right hand side
for i = 1:6
  //Old temp. in degree C
  Told(i,1) = 40;
  Told(i,11) = 10;
  //New temp. in degree C
  Tnew(i,1) = 40;
  Tnew(i,11) = 10;
end;
//Intitalisation of looping parameter
p = 0;
//Iteration to find temperature distribution
while p<500
```

```
  //Equation for all interior nodes
  for i = 2:5
    for j = 2:10
      //New temp. in degree C
      Tnew(i,j) = 0.25*(Told(i-1,j)+Told(i+1,j)+Told(i,j-1)+Told(i,j+1)+((qg*dx)*dx)/k);
    end;
  end;

  //Equation for top wall
  for j = 2:10
    //New temp. in degree C
    Tnew(1,j) = (h*Tinfinity+(qg*dx)/2+(k*(0.5*(Told(1,j-1)+Told(1,j+1))+Told(2,j)))/dx)/(h+(2*k)/dx);
  end;

  //Equation for bottom wall
  for j = 2:10
    //New temp. in degree C
    Tnew(6,j) = 0.25*(Told(6,j-1)+Told(6,j+1))+0.5*Told(5,j)+((qg*dx)*dx)/(4*k);
  end;
  for i = 1:6
    for j = 1:11
      //Assigning Old Temp=New Temp
      Told(i,j) = Tnew(i,j);
    end;
  end;
  //New looping parameter incremented
  p = p+1;
end;
disp(”The temperature distribution in the bar in C is the following”)
//Old temp. in degree C
Told

//Finding maximum temperature
```

```
Tmax = Told(1,1);
for i = 1:6
  for j = 1:11
    if Told(i,j)>Tmax then
      Tmax = Told(i,j);
    else
      Tmax = Tmax;
    end;
  end;
end;
disp("The maximum temperature in C in the alloy bus bar is")
//maximum temperature in C
Tmax

//Finding heat transfer rate
dz = 0.01; //dz in m
//Defining areas
for i = 2:10
  A(1,i) = dx*dz; //Area in m2
end;
A = mtlb_i(A,1,(dx*dz)/2);
A = mtlb_i(A,11,A(1));
for i = 1:11
  //heat transfer rate in W
  q(1,i) = (h*A(i))*(Tnew(1,i)-Tinfinity);
end;
disp("The heat transfer rate from the top edge in W is given by")
//heat transfer rate in W
q
```

Scilab code Exa 3.6 `Transient Behavior of Alloy Bar`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 3 Example # 3.6 ")

//Thermal diffusivity in m2/s
alpha = 0.000008;
//%Thermal conductivity of alloy bus bar in W/m-K is given as
k = 20;
//density*specific heat product in SI units
pc = k/alpha;

//dimensions of the bar in m is given as
L = 0.1;//Length in m
b = 0.05;//Width in m
d = 0.01;//Thickness in m

//Heat generation rate in W/m3 is given as
qg = 10^6;

//Assigning temperature on the left and right hand side
for i = 1:6 //i is the looping parameter
  //Old temp. in degree C
  Told(i,1) = 40;
  Told(i,11) = 10;
  //New temp. in degree C
  Tnew(i,1) = 40;
  Tnew(i,11) = 10;
end;

```

```
//Assigning a guess temperature of 20C to all nodes
for i = 1:6//i is the looping parameter
  for j = 1:11//j is the looping parameter
    //Guess temp. in degree C
    Told(i,j) = 20;
    Tnew(i,j) = 20;
  end;
end;

//Initialising time
m = 0;

//For top edge, heat transfer coefficient in W/m2K and ambient temperature
//in C are
h = 75;
Tinfinity = 0;

//We are taking a total of 11 nodes in the direction of length and 6 nodes
//in the direction of width
dx = 0.01; //dx in m
dy = 0.01; //dy in m

//Largest permissible time step in sec is
tmax = 1/((2*alpha)*(1/(dx*dx)+1/(dy*dy)));
//Rounding it off to nearest integer
t = 3; //timestep in seconds

//Condition for convergence
while abs(Tnew(5,6)-Told(5,6))<0.0001

  //Equation for all interior nodes
  for i = 2:5
    for j = 2:10
      //New temp. in degree C
      Tnew(i,j) = (Told(i,j)+(alpha*t)*((Tnew(i+1,j)+Tnew(i-1,j))/(dx*dx)+(Tnew(i,j+1)+Tnew(i,j
```

```
            -1))/(dy*dy)+qg/k))/(1+((2*alpha)*t)*(1/(dx
            *dx)+1/(dy*dy)));
    end;
  end;

  //Equation for top wall
  for j = 2:10
    //New temp. in degree C
    Tnew(1,j) = (Told(1,j)+((2*t)/((dx*dx)*pc))*(k
        *((Tnew(1,j+1)+Tnew(1,j-1))/2+Tnew(2,j)))+((
        qg*dx)*dx)/2+(h*dx)*Tinfinity)/(1+((2*t)/((dx
        *dx)*pc))*(2*k+h*dx));
  end;

  //Equation for bottom wall
  for j = 2:10
    //New temp. in degree C
    Tnew(6,j) = (Told(6,j)+((2*t)/((dx*dx)*pc))*(k
        *((Tnew(6,j+1)+Tnew(6,j-1))/2+Tnew(5,j)))+((
        qg*dx)*dx)/2)/(1+((2*t)/((dx*dx)*pc))*(2*k));
  end;
  //New time in sec
  m = m+t;
end;


disp(”Time required to reach steady state using
    deltaT=0.3sec is 1140 seconds”)
```

Scilab code Exa 3.7 `Cooling of Long Cylinder`

```


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

```

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

clc;
disp(”Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter − 3 Example # 3.7 ”)

// Heat Transfer coefficient is given in W/m2−K as:
h = 200;
// Radius of cylinder in m is given as:
R0 = 0.05;
// Thermal conductivity in W/m−K is given as:
k = 20;
// Thermal diffusivityt in m2/sec is given as:
alpha = 10^(-5);
// Therefore the biot number is given as:
Bi = (h∗R0)/k;

// Ambient water bath temperature in C is given as:
Tinfinity = 0;
// Initial temperature of centre line is given as:
T0 = 500;
// Final Temperature of centre line is given as:
Tr = 100;

// Therefore the value of (Tr−Tinfinity)/(T0−
   Tinfinity) is:
value = (Tr-Tinfinity)/(T0-Tinfinity); //Required
   value

// Using above value and biot number, from Figure
   2.43 (a) on page 137, we have
// alpha∗t/(R0∗R0)=1.8

disp(”Therefore from chart solution, time taken in
   seconds shall be”)
//Time taken in seconds
```

```
t = ((1.8*R0)*R0)/alpha

// Proceeding to the numerical solution
//Because of symmetry we need to consider only one quarter of the circular cross section
//The vertical and horizontal radii are then adiabatic surfaces.

//We will have a total of nine types of control volume
//Each of the control volume energy balance equations can be solved

//The coefficient on Tfor control volume type 7 is:
//(dx*dx/(alpha*dt)) -2 -2*h*dx/5
//and for it to be positive

// value of t we use in the numerical solution must be smaller than this
// maximum value. The calculation is continued until the temperature for the control vol-ume nearest the cylinder axis is less than 100 C

disp("And using numerical solution the time in seconds comes out to be")
//Time taken in seconds
tfinal = 431
disp("which is about 4% less than the chart solution of 450 s.")
```

Chapter 4

Analysis of Convection Heat Transfer

Scilab code Exa 4.1 `Computation of Heat Transfer Coefficient`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 4 Example # 4.1 ")

// Temperature of air in C is given as:
Tinfinity = 20;
// Temperature of surface in C is given as:
Ts = 100;
// Therefore avaerage temperature in degree C would
   be:
Ta = (Ts+Tinfinity)/2;
```

```
// From fig. 4.2 on page 232, it can be easily seen that (deltaT/deltaY) at
// y=0 is −66.7 K/mm
// From Table 28 in Appendix 2, at average temperature of air, thermal
// conductivity in W/m−K is
k = 0.028;

//Therefore from eq. 4.1
disp(”The heat transfer coefficient is given by, as per Eq. 4.1, in W/m2K”)
// 1000 is added to convert from mm to m
//heat transfer coefficient in W/m2K
hc = ((-k*(-66.7))/(Ts-Tinfinity))*1000
```

Scilab code Exa 4.2 `Theoretical Problem`

```


// Display mode
mode(0);

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

clc;
disp(”Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter − 4 Example # 4.2 ”)

disp(”The given example is theoretical and does not involve any numerical computation”)

// Local shear stress is given as:
// tau=0.3∗((rho∗mu/x)ˆ0.5)∗(Uinfinityˆ1.5)

```

```
// Using Local friction coefficient = local shear stress /
// (0.5*rho*Uinfinity*Uinfinity), we get local friction coefficient as:

//disp("Cfx = 0.6/((ReL*xstar))^0.5")

//Integrating the local value of shear stress over length L and dividing by
//area i.e. A=L*1, we get average friction coefficient as:

//disp("Cfbar = 1.2/(ReL^0.5)")
```

Scilab code Exa 4.3 `Flat Plate Solar Collector`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 4 Example # 4.3 ")

// Width of the collector plate in ft is given:
b = 1;
// Surface temperature in F is given:
Ts = 140;
// Air temperature in F is given:
Tinfinity = 60;
// Air velocity in ft/sec is given as:
```

```
Uinfinity = 10;
// Average temperature in degree F is given as:
T = (Ts+Tinfinity)/2;
// Properties of air at average temperature are as follows

Pr = 0.72; //Prandtl number
k = 0.0154; // Thermal conductivity in Btu/h ft  F
mu = 1.285*10-5;  //Viscosity in lbm/ft s
cp = 0.24; //Specific heat in Btu/lbm  F
rho = 0.071; //Density in lbm/ft3

// Reynold''s number at x=1ft is
Re1 = ((Uinfinity*rho)*1)/mu;
// Reynold''s number at x=9ft is
Re9 = ((Uinfinity*rho)*1)/mu;
// Assuming that the critical Reynolds number is 5*10^5, the critical distance is
//Critical Reynolds number
Rec = 5*(10^5);
//Critical distance in ft
xc = (Rec*mu)/(Uinfinity*rho);

// From Eq. 4.28, and using the data obtained, we get for part a:
disp(”Delta at x=1ft to be 0.0213ft and at x=9ft to be 0.0638ft”)

// From Eq. 4.30, and using the data obtained, we get for part b:
disp(”Cfx at x=1ft to be 0.00283 and at x=9ft to be 0.000942”)

// From Eq. 4.31, and using the data obtained, we get for part c:
disp(”Cfbar at x=1ft to be 0.00566 and at x=9ft to be 0.00189”)

```

```
// From Eq. 4.29, and using the data obtained, we get for part d:
disp("Tau at x=1ft to be 3.12*10^-4 lb/ft^2 and at x=9ft to be 1.04*10^-4 lb/ft^2")

// From Eq. 4.32, and using the data obtained, we get for part e:
disp("DeltaTH at x=1ft to be 0.0237ft and at x=9ft to be 0.0712ft")

// From Eq. 4.36, and using the data obtained, we get for part f:
disp("hcx at x=1ft to be 1.08Btu/hft^2 F  and at x=9ft to be 0.359Btu/hft^2 F ")

// From Eq. 4.39, and using the data obtained, we get for part g:
disp("hcbar at x=1ft to be 2.18Btu/hft^2 F  and at x=9ft to be 0.718Btu/hft^2 F ")

// From Eq. 4.35, and using the data obtained, we get for part h:
disp("q at x=1ft to be 172 Btu/h and at x=9ft to be 517 Btu/h")
```

Scilab code Exa 4.4 `Heat Flow From Crankcase`

```


// Display mode
mode(0);

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

```

```
clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 4 Example # 4.4 ")

// Length of the crankcase in m is given as
L = 0.6;
// Width of the crankcase in m is given as
b = 0.2;
// Depth of the crankcase in m is given as
d = 0.1;
// Surface temperature in K is given as
Ts = 350;
// Air temperature in K is given as
Tinfinity = 276;
// Air velocity in m/sec is given as
Uinfinity = 30;
// It is stated that  boundary layer is turbulent over the entire surface

//Average air temperature in degree K is
T = (Ts+Tinfinity)/2;
// At this average temperature, we get the following for air
rho = 1.092;//density in kg/m^3
mu = 0.000019123;//viscosity in SI units
Pr = 0.71;//Prandtl number
k = 0.0265;//Thermal conductivity in W/m-K

// Reynold''s number is therefore given as
ReL = ((rho*Uinfinity)*L)/mu;

//From eq. 4.82, average nusselt number could be given as
Nu = (0.036*(Pr^(1/3)))*(ReL^0.8);

//We can write from the basic expression, Nu=hc*L/k, that
//Heat transfer coefficient in W/m^2-K
```

```
hc = (Nu*k)/L;

// The surface area that dissipates heat is 0.28 m2
disp("Total heat loss from the surface in W is therefore")
//Heat loss from the surface in W
q = (hc*0.28)*(Ts-Tinfinity)
```

Chapter 5

Natural Convection

Scilab code Exa 5.1 `Convection Heat Loss From Room Heater`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 5 Example # 5.1 ");

// ''Body temp in degree C''
Tb = 127;
//''Body temp in degree K''
TbK = Tb+273;
//''Ambient temp in degree C''
Ta = 27;
//''Ambient temp in degree K''
TaK = Ta+273;
//''Film temperature = (Body Temperature + Ambient
```

```
Temperature)/2''
//''Film temp in degree K''
TfK = (TbK+TaK)/2;
//''Value of coefficient of expansion at this film temp in degree K inverse''
B = 1/TfK;
//''Value of Prandtl number at this film temp''
Pr = 0.71;
//''Value of kinematic viscosity at this film temp in m2/s''
v = 0.0000212;
//''Value of thermal conductivity at this film temp in W/m-K''
k = 0.0291;
//''acceleration due to gravity in m/s2''
g = 9.81;
//''temperature diff. between body and ambient in degree K''
deltaT = TbK-TaK;
//''diameter of heater wire in m''
d = 0.001;
//''Therefore using Rayleigh number = ((Pr*g*B*deltaT*d^3)/v^2)''
Ra = ((((Pr*g)*B)*deltaT)*(d^3))/(v^2);

//''From Fig. 5.3 on Page 303, we get''
//''log(Nu) = 0.12, where Nu is nusselt number, therefore''
Nu = 1.32;
//''Using Nu = hc*d/k, we get heat transfer coefficient in W/m2-K''
hc = (Nu*k)/d;
disp("The rate of heat loss per meter length in air in W/m is given by hc*(A/l)*deltaT")
//heat loss per meter length in air in W/m
q = ((hc*deltaT)*%pi)*d

//''For Co2, we evaluate the properties at film
```

```
temperature''
//''Following are the values of dimensionless numbers so obtained''
//''Rayleigh number, Ra=16.90''
//''Nusselt number, Nu=1.62''
//''Using Nu = hc*d/k, we get''
//''hc = 33.2 W/m2-K''
disp("The rate of heat loss per meter length in CO2 is given by hc*(A/l)*deltaT")
disp("q = 10.4 W/m")

disp(" Discussion - For same area and temperature difference: ")
disp(" Heat transfer by convection will be more, if heat transfer coeff. is high")
```

Scilab code Exa 5.2 `Power Requirement of Heater`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 5 Example # 5.2 ");

//''Surface temp in degree C''
TsC = 130;
//''Body temp in degree K''
Ts = TsC+273;
//''Ambient temp in degree C''
```

```
TinfinityC = 20;
//''Ambient temp in degree K''
Tinfinity = TinfinityC+273;
//''Film temperature = (Surface Temperature + Ambient Temperature)/2''
//''Film temp in degree K''
Tf = (Ts+Tinfinity)/2;
//''Height of plate in cms''
L = 15;
//''Width of plate in cms''
b = 10;
//''Value of Grashof number at this film temp is given by
//65(L^3)(Ts-Tinfinity)''
//Grashof number
Gr = (65*(L^3))*(Ts-Tinfinity);
//''Since the grashof number is less than 10^9, therefore flow is laminar''
//''For air at film temp = 75C (348K), Prandtl number is''
Pr = 0.71;
//''And the product Gr*Pr is''
//Prodect of Gr and Pr
GrPr = Gr*Pr;
//''From Fig 5.5 on page 305, at this value of GrPr, Nusselt number is''
Nu = 35.7;
//''Value of thermal conductivity at this film temp in W/m-K''
k = 0.029;

//''Using Nu = hc*L/k, we get ''
//Heat transfer coefficient for convection in W/m2-K
hc = (Nu*k)/(L/100);

//''Heat transfer coefficient for radiation, hr in W/m2-K''
hr = 8.5;
```

```

//''Total area in m2 is given by 2*(b/100)*(L/100)''
A = (2*(b/100))*(L/100);


disp("Therefore total heat transfer in W is given by A*(hc+hr)*(Ts-Tinfinity)")
//total heat transfer in W
q = (A*(hc+hr))*(Ts-Tinfinity)

//''For plate to be 450cm in height, Rayleigh number becomes 4.62*10^11''
//''which implies that the flow is turbulent''
//''From Fig 5.5 on page 305, at this value of GrPr, Nusselt number is  973''
//''Using Nu = hc*d/k, we get in W/m2-K, hc_bar =6.3''
//''New Total area in m2, A_bar=2*(0.1)*(4.5)''

disp("Therefore in new case, total heat transfer in W is given by A_bar*(hc_bar+hr)*(Ts-Tinfinity)")
disp("we get q=1465W')


disp(" Discussion - For same temperature difference: ")
disp(" Heat transfer will be more, if area exposed for convection and radiation is more")
```

Scilab code Exa 5.3 `Heat Loss From Grill`

```


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

```

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 5 Example # 5.3 ")

//''Surface temp in degree C''
TsC = 227;
//''Body temp in degree K'')
Ts = TsC+273;
//''Ambient temp in degree C''
TinfinityC = 27;
//''Ambient temp in degree K''
Tinfinity = TinfinityC+273;
//''Film temperature = (Surface Temperature + Ambient Temperature)/2''
//''Film temp in degree K'')
Tf = (Ts+Tinfinity)/2;
//''For a square plate, Height and width of plate in m''
L = 1;
b = 1;
//''For a square plate, characteristic length = surface area/parameter in m''
L_bar = (L*L)/(4*L);
//''Value of coefficient of expansion at this film temp in degree K inverse''
B = 1/Tf;
//''Value of Prandtl number at this film temp''
Pr = 0.71;
//''Value of thermal conductivity at this film temp in W/m-K''
k = 0.032;
//''Value of kinematic viscosity at this film temp in m2/s''
v = 0.000027;
```

```
//''acceleration due to gravity in m/s2''
g = 9.81;
//''temperature diff. between body and ambient in degree K''
deltaT = Ts-Tinfinity;
//''Therefore using Rayleigh number = ((Pr*g*B*deltaT*(L_bar)^3)/v^2)''
//Rayleigh number
Ra = ((((Pr*g)*B)*deltaT)*(L_bar^3))/(v^2);


//''From eq. 5.17 on page 311, we have nusselt number for bottom plate as 0.27*Pr^0.25''
NuBottom = 25.2;
//''From eq. 5.16 on page 311, we have nusselt number for top plate as 0.27*Pr^0.25''
NuTop = 63.4;
//''And therefore corresponding heat transfer coeeficients are in W/m2-K''
hcBottom = (NuBottom*k)/L_bar; //heat transfer coeeficients are in W/m2-K at bottom
hcTop = (NuTop*k)/L_bar; //heat transfer coeeficients are in W/m2-K at top


disp("Therefore total heat transfer in W is given by A*(hcTop+hcBottom)*(deltaT)")
//heat transfer in W
q = ((L*b)*(hcTop+hcBottom))*deltaT
```

Scilab code Exa 5.4 `Transition to Turbulent Flow in Pipe`

```


// Display mode
```

```
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 5 Example # 5.4 ");

//''Ambient temp in degree C''
TinfinityC = 27;
//''Ambient temp in degree K''
Tinfinity = TinfinityC+273;
//''The criterion for transition is rayleigh number to be 10^9''


//''Value of coefficient of expansion at this temp in degree K inverse''
B = 1/Tinfinity;
//''Value of Prandtl number at this ambient temp''
Pr = 0.71;
//''Diameter of pipe in m''
D = 1;
//''Value of kinematic viscosity at this temp in m2/s''
v = 0.0000164;
//''acceleration due to gravity in m/s2''
g = 9.81;

//''Therefore using Rayleigh number = ((Pr*g*B*deltaT*(D)^3)/v^2) = 10^9''
//''we get the temperature difference in centrigrade to be''
deltaT = 12;
disp("therefore the temperature of pipe in C is")
// temperature of pipe in C
Tpipe = TinfinityC+deltaT
```

```


//''From table 13 in Appendix 2, for the case of
   water and using the same procedure we get''
// temperature difference in C
deltaTw = 0.05;
disp("therefore the temperature of pipe in C is")
// temperature of pipe in C
Tpipew = TinfinityC+deltaTw

disp(" Discussion - For air and water: ")
disp(" Temperature required to induce turbulence is
   higher in air")
```

Scilab code Exa 5.5 Rate of Heat Transfer From Burner

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 5 Example # 5.5 ");

//''Top surface temp in degree C''
Tt = 20;
//''Body temp in degree K''
TtK = Tt+273;
//''Bottom temp in degree C''
Tb = 100;
//''Ambient temp in degree K''
```

```
TbK = Tb+273;
//''Average temp = (Bottom Temperature + top Temperature)/2''
//''average temp in degree K''
T = (TbK+TtK)/2;
//''Value of coefficient of expansion at this temp in degree K inverse''
B = 0.000518;
//''Value of Prandtl number at this temp''
Pr = 3.02;
//''Value of kinematic viscosity at this temp in m2/s''
v = 0.000000478;
//''acceleration due to gravity in m/s2''
g = 9.8;
//''temperature diff. between body and ambient in degree K''
deltaT = TbK-TtK;
//''depth of water in m''
h = 0.08;
//''Therefore using Rayleigh number = ((Pr*g*B*deltaT*h^3)/v^2)''
Ra = ((((Pr*g)*B)*deltaT)*(h^3))/(v^2);

//''From Eq. (5.30b) on page 318, we find''
//Nusselt number
Nu = 79.3;
//''Value of thermal conductivity at this film temp in W/m–K''
k = 0.657;
//''Using Nu = hc*d/k, we get heat transfer coefficient in W/m2–K''
hc = (Nu*k)/h;
//''diameter of pan in m''
d = 0.15;
//''area = pi*d*d/4''
a = ((%pi*d)*d)/4;
disp("The rate of heat loss in W is given by hc*(A)*
```

```
deltaT")
//heat loss in W
q = (hc*deltaT)*a
```

Scilab code Exa 5.6 `Convection Heat Transfer From Shaft`

```



// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 5 Example # 5.6 ");

//''RPM of shaft''
N = 3;
//''Angular velocity, omega=2*pi*N/60 in rad/s''
omega = 0.31;
//''Ambient temp in degree C''
Ta = 20;
//''Ambient temp in degree K''
TaK = Ta+273;
//''Shaft temp in degree C''
Ts = 100;
//''Shaft temp in degree K''
TsK = Ts+273;
//''Film temperature = (Shaft Temperature + Ambient Temperature)/2''
//''Film temp in degree K''
TfK = (TsK+TaK)/2;
```

```
//''diameter of shaft in m''
d = 0.2;
//''Value of kinematic viscosity at this film temp in m2/s''
v = 0.0000194;
//''Value of reynolds number''
Re = (((%pi*d)*d)*omega)/v;


//''acceleration due to gravity in m/s2''
g = 9.81;
//''temperature diff. between body and ambient in degree K''
deltaT = TsK-TaK;
//''Value of Prandtl number at this film temp''
Pr = 0.71;
//''Value of coefficient of expansion at this film temp in degree K inverse''
B = 1/TfK;
//''Therefore using Rayleigh number = ((Pr*g*B*deltaT*d^3)/v^2)''
//Rayleigh number
Ra = ((((Pr*g)*B)*deltaT)*(d^3))/(v^2);

//''From Eq. 5.35 on Page 322, we get''
//Nusselt number
Nu = 49.2;
//''Value of thermal conductivity at this film temp in W/m-K''
k = 0.0279;
//''Using Nu = hc*d/k, we get in W/m2-K''
hc = (Nu*k)/d;
//''let the length exposed to heat transfer is l=1m''
//''then area in m2 = pi*d*l''
a = %pi*d;
disp("The rate of heat loss in air in W is given by hc*(a)*deltaT")
```

```
//heat loss in air in W
q = (hc*deltaT)*a
```

Chapter 6

Forced Convection Inside Tubes and Ducts

Scilab code Exa 6.1 `Heating of Water in Tube`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 6 Example # 6.1 ")

//Inlet temperature in degree C
Tin = 10;
//Outlet temperature in degree C
Tout = 40;
//Diameter in m
D = 0.02;
//Massflow rate in kg/s
```

```
m = 0.01;
//Heat flux in W/m2
q = 15000;

//From Table 13 in Appendix 2, the appropriate properties of water at an
//average temperature between inlet and outlet of 25 C  are

//Density in kg/m3
rho = 997;
//Specific heat in J/kgK
c = 4180;
//Thermal conductivity in W/mK
k = 0.608;
//Dynamic viscosity in Ns/m2
mu = 0.00091;

disp(”Reynolds Number is”)
//Reynolds number
Re = (4*m)/((%pi*D)*mu)
disp(”Flow is Laminar”)

//Since the thermal-boundary condition is one of uniform heat flux, Nu= 4.36 from Eq. (6.31)
//Nusselt number
Nu = 4.36;
disp(”Heat transfer coefficient in W/m2K”)
//Heat transfer coefficient in W/m2K
hc = (Nu*k)/D

//The length of pipe needed for a 30 C  temperature rise is obtained from a heat balance
disp(”Length of pipe in m”)
//Length of pipe in m
L = ((m*c)*(Tout-Tin))/((%pi*D)*q)

disp(”Inner surface temperature at outlet in degree
```

```
   C")
//Inner surface temperature at outlet in degree C
Ts = q/hc+Tout

//The friction factor is found from Eq. (6.18)
disp("Friction factor is")
//Friction factor is
f = 64/Re

//Average velocity in m/s
U = (4*m)/(((rho*%pi)*D)*D);
disp("The pressure drop in the pipe in N/m2")
//The pressure drop in the pipe in N/m2
deltaP = ((((f*L)*rho)*U)*U)/(D*2)

//Efficiency
n = 0.5;
//The pumping power P is obtained from Eq. 6.19
disp("Pumping power in W is")
//Pumping power in W
P = (m*deltaP)/(rho*n)
```

Scilab code Exa 6.2 `Recycling of Engine Oil`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 6 Example # 6.2 ")
```

```

//Diameter in m
D = 0.01;
//Wall thickness in m
t = 0.02/100;
//Massflow rate in kg/s
m = 0.05;
//Inlet temperature in degree C
Tin = 35;
//Outlet temperature in degree C
Tout = 45;
//Assuming a constant tube temp. in degree C
T = 100;

//From Table 16 in Appendix 2, we get the following
    properties for oil at
//40 C

//Density in kg/m3
rho = 876;
//Specific heat in J/kgK
c = 1964;
//Thermal conductivity in W/mK
k = 0.144;
//Dynamic viscosity in Ns/m2
mu = 0.21;
//Prandtl number
Pr = 2870;

//Reynolds Number is
Re = (4*m)/((%pi*D)*mu);

//For laminar flow and constant temperature
    assumption
//Nusselt number
Nu = 3.66;
//Heat transfer coefficient in W/m2K
hc = (Nu*k)/D;
```

```
//Heat transfer rate in W
q = (m*c)*(Tout-Tin);
//LMTD in degree K
LMTD = (T-Tout-(T-Tin))/log((T-Tout)/(T-Tin));

disp("Length of pipe in m is")
//Length of pipe in m
L = q/(((%pi*D)*hc)*LMTD)
```

Scilab code Exa 6.3 `Flow of n Butyl Alcohol`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 6 Example # 6.3 ")

//Bulk temperature in degree K
T = 293;
//Side of square duct in m
b = 0.1;
//Length of square duct in m
L = 5;
//Wall temperature in degree K
Tw = 300;
//Velocity in m/s
U = 0.03;

//Hydraulic diameter in m
```

```
D = 4*((b*b)/(4*b));

//Physical properties at 293 K from Table 19 in
   Appendix 2 are

//Density in kg/m3
rho = 810;
//Specific heat in J/kgK
c = 2366;
//Thermal conductivity in W/mK
k = 0.167;
//Dynamic viscosity in Ns/m2
mu = 0.00295;
//Prandtl number
Pr = 50.8;

//Reynolds Number is
Re = ((U*D)*rho)/mu;

//Hence, the flow is laminar. Assuming fully
   developed flow, we get the
//Nusselt number for a uniform wall temperature from
    Table 6.1

Nu = 2.98;
//Heat transfer coefficient in W/m2K
hc = (Nu*k)/D;

//Similarly, from Table 6.1, the product Re*f=56.91

disp("Friction factor is")
//Friction factor
f = 56.91/Re
```

Scilab code Exa 6.4 Cooling of Electronic Device

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 6 Example # 6.4 ")

//Temperature of device casing in degree K
Ts = 353;
//Length of holes in m
L = 0.3;
//Diameter of holes in m
D = 0.00254;
//Inlet temperature in degree K
Tin = 333;
//Velocity in m/s
U = 0.2;

//The properties of water at 333 K, from Table 13 in
    Appendix 2, are

//Density in kg/m3
rho = 983;
//Specific heat in J/kgK
c = 4181;
//Thermal conductivity in W/mK
k = 0.658;
//Dynamic viscosity in Ns/m2
mu = 0.000472;
//Prandtl number
Pr = 3;

//Reynolds Number is
```

```
Re = ((U*D)*rho)/mu;

if (((Re*Pr)*D)/L)>10 then
  //Eq. (6.42) can be used to evaluate the heat transfer coefficient.
  //But since the mean bulk temperature is not known, we shall evaluate all the properties first at the inlet bulk temperature Tb1 ,
  //then determine an exit bulk temperature , and then make a second iteration to obtain a more precise value.

  //At the wall temperature of 353 K
  //Viscosity in SI units
  mus = 0.000352;
  //From Eq. (6.42)
  //Nusselt number
  Nu = (1.86*((((Re*Pr)*D)/L)^0.33))*((mu/mus)^0.14);
  //Heat transfer coefficient in W/m2K
  hc = (Nu*k)/D;
  //mass flow rate in kg/s
  m = ((((rho*%pi)*D)*D)*U)/4;

  //Inserting the calculated values for hc and m into Energy balance equation , along with Tb1 and Ts and
  //gives Tb2=345K

  //For the second iteration , we shall evaluate all properties at the new average bulk temperature
  //Bulk temp. in degree C
  Tb = (345+Tin)/2;

  //At this temperature , we get from Table 13 in Appendix 2:
  //Density in kg/m3
  rho = 980;
```

```
  //Specific heat in J/kgK
  c = 4185;
  //Thermal conductivity in W/mK
  k = 0.662;
  //Dynamic viscosity in Ns/m2
  mu = 0.000436;
  //Prandtl number
  Pr = 2.78;

  //New reynolds Number is
  Re = ((U*D)*rho)/mu;

  //With this value of Re, the heat transfer
     coefficient can now be calculated.
  //We obtain the following similarly
  //Nusselt number
  Nu = 5.67;
  //Heat transfer coefficient in W/m2K
  hc = (Nu*k)/D;
  //Similarly putting this value in energy balance
     yields
  //Bulk temperature in degree K
  Tb2 = 345;

  disp("Outlet temperature in degree K")
  //Outlet temperature in degree K
  Tb2
end;
```

Scilab code Exa 6.5 Water Flowing in an Annulus

```



// Display mode
```

```
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 6 Example # 6.5 ")

//Velocity in ft/s
U = 10;
//Outer diameter in inches
D = 1.5;
//Inner diameter in inches
d = 1;
//Temperature of water in degree F
Tw = 180;
//Temperature of wall in degree F
Twall = 100;

//The hydraulic diameter D for this geometry is 0.5 in.
D = 0.5;

//Using properties given in the table provided

//Reynolds number
Re = (((U*D)*3600)*60.8)/(12*0.75);
//Prandtl number
Pr = (1*0.75)/0.39;
//The Nusselt number according to the Dittus-Boelter correlation [Eq. (6.60)]
Nu = (0.023*(125000^0.8))*(Pr^0.3);
printf('The Nusselt number according to the Dittus-Boelter correlation comes out to be %5.2f\n',Nu)

//Using the Sieder-Tate correlation [Eq. (6.61)]
//Nusselt number
```

```
Nu = 358;
printf('The Nusselt number according to the Sieder-Tate correlation comes out to be %5.2f\n',Nu)

//The Petukhov-Popov correlation [Eq. (6.63)] gives
//Friction factor
f = (1.82*log10(125000)-1.64)^(-2);
//K1 of Eq. 6.63
K1 = 1+3.4*f;
//K2 of Eq. 6.63
K2 = 11.7+1.8/(Pr^0.33);
//Nusselt number
Nu = 370;

//The Sleicher-Rouse correlation [Eq. (6.64)] yields
//a of Eq. 6.64
a = 0.852;
//b of Eq. 6.64
b = 1/3+0.5/exp(0.6*4.64);
//Reynolds number
Re = 82237;
//Nusselt number
Nu = 5+(0.015*(Re^a))*(4.64^b);
printf('Nusselt number according to The Sleicher-Rouse correlation comes out to be %5.2f\n',Nu)

disp("Assuming that the correct answer is  Nu=370")
disp("The first two correlations underpredict by about 10% and 3.5%, respectively")
disp("while the Sleicher-Rouse method overpredicts by about 10.5%.")
```

Scilab code Exa 6.6 `Tube Length in Metal Flow`

```

```

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 6 Example # 6.6 ")

//Mass flow rate in kg/s
m = 3;
//Diameter of tube in m
D = 5/100;
//Temperature of fluid in degree K
Tb = 473;
//Temperature of wall in degree K
Ts = 503;

//Density in kg/m3
rho = 7700;
//Specific heat in J/kgK
c = 130;
//Thermal conductivity in W/mK
k = 12;
//Kinematic viscosity in m2/s
nu = 0.00000008;
//Prandtl number
Pr = 0.011;

//The rate of heat transfer per unit temperature
   rise in W is
q = (m*c)*1;

//Reynolds Number is
Re = (D*m)/(((((rho*%pi)*D)*D)*nu)/4);

```

```
//The heat transfer coefficient in W/m2K is obtained
    from Eq. (6.67)
hc = ((k*0.625)*((Re*Pr)^0.4))/D;

//Surface area in m2
A = q/(hc*(Ts-Tb));

disp("Required length of tube in m is")
//Required length of tube in m
L = A/(%pi*D)
```

Scilab code Exa 6.7 `Heat Transfer Coefficient in Circuit`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 6 Example # 6.7 ")

//Temperature of airstream in degree C
Tair = 20;
//Velocity of air in m/s
U = 1.8;
//Side of circuit in m
L = 27/1000;
//Spacing in the circuit in m
H = 17/1000;

//At 20 C , the properties of air from Table 28,
```

```
   Appendix 2, are

//Density in kg/m3
rho = 7700;
//Specific heat in J/kgK
c = 130;
//Thermal conductivity in W/mK
k = 0.0251;
//Kinematic viscosity in m2/s
nu = 0.0000157;
//Prandtl number
Pr = 0.011;

//Reynolds number
Re = (U*H)/nu;

//From Fig. (6.27), we see that the second
   integrated circuit is in the inlet region and
   estimate Nu2 =29.
//Nusselt number in second circuit
Nu2 = 29;
disp("Heat transfer coefficient along 2nd circuit in
    W/m2K")
//Heat transfer coefficient in W/m2K
hc2 = (Nu2*k)/L

//The sixth integrated circuit is in the developed
   region and from Eq. (6.79)
//Nusselt number in sixth circuit
Nu6 = 21.7;
disp("Heat transfer coefficient along 6th circuit in
    W/m2K")
////Heat transfer coefficient in W/m2K
hc6 = (Nu6*k)/L
```

Chapter 7

Forced Convection Over Exterior Surfaces

Scilab code Exa 7.1 `Heat Transfer Coefficient Over Wing`

```



// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 7 Example # 7.1 ")

//Diameter in m
D = 0.3;
//Cruising speed in m/s
Uinfinity = 150;

//At an altitude of 7500 m the standard atmospheric
   air pressure is 38.9 kPa and the density of the
```

```
air is 0.566 kg/m3 (From Table 38 in Appendix 2).
rho = 0.566;
//Dynamic viscosity in kgm/s
mu = 0.0000174;
//Prandtl number
Pr = 0.72;
//Thermal conductivity in W/mK
k = 0.024;

//The heat transfer coefficient at the stagnation point (0) is, according to Eq. (7.2)

disp("Heat transfer coefficient at stagnation point in W/m2K")
//Heat transfer coefficient at stagnation point in W/m2K
h = (((k*1.14)*((((rho*Uinfinity)*D)/mu)^0.5))*(Pr^0.4))/D

disp("Distribution of the convection heat trans-fer coefficient over the forward portion of the wing")
for o = 0:15:75 //o is the parameter used in the loop
    //convection heat trans-fer coefficients in W/m2K
  ho = h*(1-(o/90)^3);
  // L.26: No simple equivalent, so mtlb_fprintf() is called.
  mtlb_fprintf("At an angle of %5.2f degree, heat transfer coeffcient is %5.2f\n",o,ho)
end;
```

Scilab code Exa 7.2 `Current in Hot Wire Anemometer`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 7 Example # 7.2 ")

//Diameter of wire in m
D = 0.000025;
//Length of wire in m
L = 0.006;
//Free stream temperature of air in degeee C
T = 20;
//Wire temperature to be maintain in degree C
Tw = 230;
//Resistivity of platinum in ohm-cm
Re = 0.0000171;

//Since the wire is very thin, conduction along it
    can be neglected; also, the temperature gradient
    in the wire at any cross section can be
    disregarded.

//At freestream temperature, for air:

//Thermal conductivity in W/mC
k = 0.0251;
//Kinematic viscosity in m2/s
nu = 0.0000157;

//Reynolds number at velocity = 2m/s
Rey = (2*D)/nu;
if Re<40 then
```

```
  //Using the correlation equa-tion from Eq. (7.3) and Table 7.1
  //Average convection heat transfer coefficient as a function of velocity
  //is
  //hc=799U^0.4 W/m2C

  //At this point, it is necessary to estimate the heat transfer coefficient for radiant heat flow.
  //According to Eq. (1.21), we have approximately
  //hr=sigma*epsilon*((Ts+Tinfinity)^3)/4

  //The emissivity of polished platinum from Appendix 2, Table 7 is about 0.05, so hr is about 0.05 W/m2C.

  //The rate at which heat is transferred from the wire is therefore
  //0.0790U^4 W.

  //The electrical resistance of the wire in ohm is
  R = ((Re*L)*4)/(((100*%pi)*D)*D);
end;

//A heat balance with the current i gives
disp("Current in ampere as a function of velocity is")
disp("i=0.19*U^0.2")
```

Scilab code Exa 7.3 `Heat Loss From Solar Collector`

```


// Display mode
```

```
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 7 Example # 7.3 ")

//Velocity of air in m/s
Uinfinity = 0.5;
//Length and breadth of square shaped array in m
L = 2.5;
//Surface temperature in degree C
Ts = 70;
//Ambient temperature in degree C
Ta = 20;

//At free stream temperature of air
//Kinematic viscosity in m2/s
nu = 0.0000157;
//Density in kg/m3
rho = 1.16;
//Specific heeat in Ws/kgC
c = 1012;
//Prandtl number
Pr = 0.71;

//Reynolds number
Re = (Uinfinity*L)/nu;

//From equation 7.18
//The average heat transfer coefficient in W/m2C is
//Heat transfer coefficient in W/m2C
h = (((0.0033*(Pr^(-2/3)))*c)*rho)*Uinfinity;
disp("Heat loss from array in W is")
//Heat loss in W
q = ((h*L)*L)*(Ts-Ta)
```

Scilab code Exa 7.4 `Heat Transfer Coefficient in Pipe`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 7 Example # 7.4 ")

//Diameter of pipe in m
D = 7.62/100;
//Diameter and length of cylinder in m
d = 0.93/100;
l = 1.17/100;
//Initial temperature in degree C
Ti = 50;
//Final temperature in degree C
Tf = 350;
//Temperature of pipe surface in degree C
Tp = 400;
//Therefore film temp. at inlet in degree C
Tfi = (Ti+Tp)/2;
//Therefore film temp. at outlet in degree C
Tfo = (Tf+Tp)/2;
//Average film temp. in degree C
Tf = (Tfi+Tfo)/2;

//At this film temperature
//Kinematic viscosity in m2/s
```

```
nu = 0.0000482;
//Thermal conductivity in W/mC
k = 0.042;
//Density in kg/m3
rho = 0.6;
//Specific heat in J/kgC
c = 1081;
//Prandtl number
Pr = 0.71;
//Flow rte of gas in kg/h is
m = 5;

//Superficial velocity in m/h
Us = m/((((rho*%pi)*D)*D)/4);
//Cylinder packaging volume in m3
V = (((%pi*d)*d)*l)/4;
//Surface area in m2
A = (((2*%pi)*d)*d)/4+(%pi*d)*l;
//Equivalent packaging dia in meter
Dp = (6*V)/A;

//REynolds number based on this dia
Re = ((Us*3600)*Dp)/nu;
//From eq. 7.23
disp("Heat transfer coefficient in W/m2C is")
//Heat transfer coefficient in W/m2C
h = (14.3*k)/Dp
```

Scilab code Exa 7.5 Heating of Atmospheric Air

```


// Display mode
mode(0);

```

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 7 Example # 7.5 ")

//Initial temperature in degree F
Ti = 58;
//Final temperature in degree F
Tf = 86;
//Film temperature of air in degree F
Tair = (Ti+Tf)/2;
//Temperature of condensing steam in degree F
Tsteam = 212;
//Heat transfer coeffcient in Btuh/ft2F
ho = 1000;
//Length of tube in ft
L = 2;
//Diameter of tube in in
d = 0.5;
//Wall thickness in inches
t = 0.049;
//Pitch in inches
p = 3/4;
//Width in ft and height in inches of rectangular shell
H = 15;
W = 2;
//Mass flow rate of air in lb/h
m = 32000;

//Appendix 2, Table 28 then gives for the properties of air at this mean
//bulk temperature

//Density in lb/ft3
rho = 0.072;
```

```
//Thermal conductivity in Btu/h F ft
k = 0.0146;
//Dynamic viscosity in lb/fth
mu = 0.0444;
//Prandtl number for air and steam
Pr = 0.71;

//Calcaulating minimum free area in ft2
A = ((H/p)*W)*((p-d)/12);
//Maximum gas velocity in lb/h.ft2
Gmax = m/A;
//Hence the reynolds number is
Re = (Gmax*d)/(12*mu);

//Assuming that more than 10 rows will be required, the heat transfer coefficient is calculated from Eq. (7.29)

//h value in Btu/h ft2 F
h = ((((k*12)/d)*(Pr^0.36))*0.27)*(Re^0.63);

//The resistance at the steam side per tube in h F/Btu
R1 = 12/(((ho*%pi)*(d-2*t))*L);

//The resistance of the pipe wall in h F/Btu
R2 = 0.049/(((60*%pi)*L)*(d-t));

//The resistance at the outside of the tube in h F/Btu
R3 = 1/((((h*%pi)*d)*L)/12);

//Total resistance in h F/Btu
R = R1+R2+R3;

//Mean temperature difference between air and steam in degree F is
deltaT = Tsteam-Tair;
```

```

//Specific heat of air in Btu/lb F
c = 0.241;

//Equating the rate of heat flow from the steam to
    the air to the rate of enthalpy rise of the air

//Solving for N gives
disp("Total number of transverse tubes needed are")
//Total number of transverse tubes
N = (((m*c)*(Tf-Ti))*R)/(20*deltaT)
disp("Rounding off = 5 tubes")

if N<10 then
  //Correction for h value, again in Btu/h ft2 F
  h = 0.92*h;
end;

//The pressure drop is obtained from Eq. (7.37) and
    Fig. 7.25.

//Velocity in ft/s
Umax = Gmax/(3600*rho);
//Acceleration due to gravity in ft/s2
g = 32.2;
disp("Corresponding pressure drop in lb/ft2")
//Corresponding pressure drop in lb/ft2
P = ((((6*0.75)*rho)*Umax)*Umax)/(2*g)
```

Scilab code Exa 7.6 Pre Heating of Methane

```


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

```

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 7 Example # 7.6 ")

//Temperature of methane in degree C
T = 20;
//Outer dia of tube in m
D = 4/100;
//Longitudinal spacing in m
SL = 6/100;
//Transverse spacing in m
ST = 8/100;
//Wall temperature in degree C
Tw = 50;
//Methane flow velocity in m/s
v = 10;

//For methane at 20 C , Table 36, Appendix 2 gives

//Density in kg/m3
rho = 0.668;
//Thermal conductivity in W/mK
k = 0.0332;
//Kinematic viscosity in m2/s
nu = 0.00001627;
//Prandtl number
Pr = 0.73;

//From the geometry of the tube bundle, we see that the minimum flow
//area is between adjacent tubes in a row and that this area is half
//the frontal area of the tube bundle. Thus,
//Velocity in m/s
```

```
Umax = 2*v;

//Reynolds number
Re = (Umax*D)/nu;

//Since ST/SL<2, we use Eq. (7.30)

//Nusselt number
Nu = ((0.35*((ST/SL)^0.2))*(Re^0.6))*(Pr^0.36);

//Heat transfer coefficient in W/m2K
h = (Nu*k)/D;

//Since there are fewer than 10 rows, the correlation factor in Table 7.3 gives
disp("Heat transfer coefficient in W/m2K")
//Heat transfer coefficient in W/m2K
h = 0.92*h

//Tube-bundle pressure drop is given by Eq. (7.37). The insert in Fig. (7.26) gives the correction factor x.

disp("Corresponding pressure drop in N/m2")
//Corresponding pressure drop in N/m2
P = ((((5*0.25)*rho)*Umax)*Umax)/2
```

Scilab code Exa 7.7 `Analysis in Water Jet Problem`

```



// Display mode
mode(0);

// Display warning for floating point exception
```

```
ieee(1);

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 7 Example # 7.7 ")


//Temperature of jet in degree C
T = 20;
//Thermal conductivity in W/mK
k = 0.597;
//Dynamic viscosity in Ns/m2
mu = 0.000993;
//Prandtl number
Pr = 7;
//Mass flow rate in kg/s
m = 0.008;
//Diameter of jet in m
d = 6/1000;
//Total heat flux in W/m2
q = 70000;

//Reynolds number
Re = (4*m)/((%pi*d)*mu);

disp("For r=3mm")
//From Eq. (7.45)
//Heat transfer coefficient in W/m2K
h = (63*k)/d;
disp("Surface temperature at r=3mm in degree C is")
//Surface temperature in degree C
Ts = T+q/h

disp("For r=12mm")
//From Eq. (7.48)
//Heat transfer coefficient in W/m2K
h = (35.3*k)/d;
disp("Surface temperature at r=12mm in degree C is")
```

```
//Surface temperature in degree C
Ts = T+q/h
```

Scilab code Exa 7.8 `Analysis of Air Jet Problem`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 7 Example # 7.8 ")

//Temperature of plate in degree C
Tplate = 60;
//Temperature of jet in degree C
T = 20;
//Thermal conductivity in W/mK
k = 0.0265;
//Dynamic viscosity in Ns/m2
mu = 0.00001912;
//Prandtl number
Pr = 0.71;
//Density in kg/m3
rho = 1.092;
//Mass flow rate in kg/s
m = 0.008;
//Width of jet in m
w = 3/1000;
//Length of jet in m
l = 20/1000;
```

```
//Velocity of jet in m/s
v = 10;
//Exit distance in m
z = 0.01;
//Width given for plate in m
L = 0.04;
//Reynolds number
Re = ((rho*v)*w)/mu;

//From Eq. (7.68) with x= 0.02 m, z =0.01 m, and w=
    0.003 m
//Nusselt number
Nu = 11.2;
// ! L.33: mtlb(d) can be replaced by d() or d
    whether d is an M-file or not.
//Heat transfer coefficient in W/m2K
h = (Nu*k)/mtlb(w);

disp("Heat transfer rate from the plate in W is")
//Heat transfer rate from the plate in W
q = ((h*L)*l)*(Tplate-T)
```

Chapter 8

Heat Exchangers

Scilab code Exa 8.1 `Heat Transfer Surface Area Calculations`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 8 Example # 8.1 ")

//Outer dia in m
d = 0.0254;
//mass flow rate of hot fluid in kg/s
mh = 6.93;
//Specific heat of hot fluid n J/kgK
ch = 3810;
//Inlet temperature of hot fluid in degree C
Thin = 65.6;
//Outlet temperature of hot fluid in degree C
```

```
Thout = 39.4;
//mass flow rate of cold fluid in kg/s
mc = 6.3;
//Specific heat of cold fluid n J/kgK
cc = 4187;
//Inlet temperature of cold fluid in degree C
Tcin = 10;
//Overall heat transfer coefficient in W/m2K
U = 568;

//Using energy balance, outlet temp. of cold fluid in degree C
Tcout = Tcin+((mh*ch)*(Thin-Thout))/(mc*cc);

//The rate of heat flow in W
q = (mh*ch)*(Thin-Thout);

disp("Parallel-flow tube and shell")
//From Eq. (8.18) the LMTD for parallel flow
//Temperature difference at inlet in degree K
deltaTa = Thin-Tcin;
//Temperature difference at outlet in degree K
deltaTb = Thout-Tcout;
//LMTD in degree K
LMTD = (deltaTa-deltaTb)/log(deltaTa/deltaTb);

//From Eq. (8.16)
disp("Heat transfer surface area in m2 is")
//Heat transfer surface area in m2
A = q/(U*LMTD)

disp("Counterflow tube and shell")
//LMTD in degree K
LMTD = 29.4;

disp("Heat transfer surface area in m2 is")
//Heat transfer surface area in m2
A = q/(U*LMTD)
```

```

A1 = A;//To be used further as a copy of this area

disp("Counterflow exchanger with 2 shell passes and 72 tube passes")

//Correction factor found from Fig. 8.15 to the mean temperature for counterflow
P = (Tcout-Tcin)/(Thin-Tcin);
//Heat capacity ratio
Z = (mh*ch)/(mc*cc);
//From the chart of Fig. 8.15, F= 0.97
F = 0.97; //F-Factor
disp("Heat transfer surface area in m2 is")
//Heat transfer surface area in m2 is
A = A1/F

disp("Cross-flow, with one tube pass and one shell pass, shell-side fluid mixed")
//Using same procedure, we get from charts
F = 0.88; //F-Factor
disp("Heat transfer surface area in m2 is")
//Heat transfer surface area in m2 is
A = A1/F
```

Scilab code Exa 8.2 `Oil Water Heat Exchanger Problem`

```


// Display mode
mode(0);

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

```

```
clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 8 Example # 8.2 ")

//mass flow rate of hot fluid in kg/s
mh = 1;
//Specific heat of hot fluid n J/kgK
ch = 2100;
//Inlet temperature of hot fluid in degree C
Thin = 340;
//Outlet temperature of hot fluid in degree C
Thout = 310;
//Specific heat of cold fluid n J/kgK
cc = 4187;
//Inlet temperature of cold fluid in degree C
Tcin = 290;
//Outlet temperature of cold fluid in degree C
Tcout = 300;

//The heat capacity rate of the water in J/kgK is, from Eq. (8.14)
cc = ch*((Thin-Thout)/(Tcout-Tcin));

//Temperature ratio P and Z is, from Eq. (8.20)
P = (Thin-Thout)/(Thin-Tcin); // P Temperature ratio
Z = (Tcout-Tcin)/(Thin-Thout); // Z Temperature ratio

//From Fig. 8.14, F0.94 and the mean temperature difference in degree K is
//F Value
F = 0.94;
//Temperature difference at inlet in degree K
deltaTa = Thin-Tcout;
//Temperature difference at outlet in degree K
deltaTb = Thout-Tcin;
//LMTD in degree K
LMTD = (deltaTa-deltaTb)/log(deltaTa/deltaTb);
```

```
//Mean temperature difference in degree K
deltaTmean = F*LMTD;

//From Eq. (8.17) the overall conductance in W/K is
UA = ((mh*ch)*(Thin-Thout))/deltaTmean;

//With reference to the new conditions and Eq. 6.62
//Conductance in W/K
UA = UA*((3/4)^0.8);
//Number of transfer units(NTU) value
NTU = UA/(((3/4)*mh)*ch);
//Heat capacity ratio
K = (((3/4)*mh)*ch)/cc;

//From Fig. 8.20 the effectiveness is equal to 0.61
//Effectiveness
E = 0.61;
//New inlet temperaturre of oil in degree K
Toilin = 370;
//From eq. 8.22a
disp("Outlet temperature of oil in degree K")
//Outlet temperature of oil in degree K
Toilout = Toilin-E*(Toilin-Tcin)
```

Scilab code Exa 8.3 Heating of Air From Gases

```


// Display mode
mode(0);

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

clc;
```

```
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 8 Example # 8.3 ")

//Airflow rate in kg/s
mair = 0.75;
//Inlet temperature of air in degree K
Tairin = 290;
//Hot gas flow rate in kg/s
mgas = 0.6;
//Inlet temperature of hot gases in degree K
Tgasin = 1150;
//wetted perimeter on air side in m
Pa = 0.703;
//wetted perimeter on gas side in m
Pg = 0.416;
//cross-sectional area of gas passage (per passage) in m2
Ag = 0.0016;
//cross-sectional area of air passage (per passage) in m2
Aa = 0.002275;
//heat transfer surface area in m2
A = 2.52;

//Given that unit is of the cross-flow type, with both fluids unmixed.

//length of air duct in m
La = 0.178;
//hydraulic diameter of air duct in m
Dha = (4*Aa)/Pa;
//length of gas duct in m
Lg = 0.343;
//hydraulic diameter of gas duct in m
Dhg = (4*Ag)/Pg;

//The heat transfer coefficients can be evaluated from Eq. (6.63) for flow
```

```
//in ducts.
//Heat transfer coefficient for air in W/m2K
ha = La/Dha;
//Heat transfer coefficient for gas in W/m2K
hg = Lg/Dhg;

//Assuming the average air-side bulk temperature to
   be 573 K and the average
//gas-side bulk temperature to be 973 K, the
   properties at those temperatures are, from
   Appendix 2, Table 28.

//Specific heat of air in J/kgK
cair = 1047;
//Thermal conductivity of air in W/mK
kair = 0.0429;
//Dynamic viscosity of air in Ns/m2
muair = 0.0000293;
//Prandtl number of air
Prair = 0.71;

//Specific heat of hot gas in J/kgK
cgas = 1101;
//Thermal conductivity of hot gas in W/mK
kgas = 0.0623;
//Dynamic viscosity of hot gas in Ns/m2
mugas = 0.00004085;
//Prandtl number of hot gas
Prgas = 0.73;

//The mass flow rates per unit area in kg/m2s
//mass flow rate of air in kg/m2s
mdotair = mair/(19*Aa);
//mass flow rate of gas in kg/m2s
mdotgas = mgas/(18*Ag);

//The Reynolds numbers are
//Reynolds number for air
```

```
Reair = (mdotair*Dha)/muair;
//Reynolds number for gas
Regas = (mdotgas*Dhg)/mugas;

//Using Eq. (6.63), the average heat transfer coefficients in W/m2K
hair = (((0.023*kair)*(Reair^0.8))*(Prair^0.4))/Dha;

//Since La/DHa=13.8, we must correct this heat transfer coefficient for
//entrance effects, per Eq. (6.68). The correction factor is 1.377.
//Corrected heat transfer coefficient of air in W/m2K
hair = 1.377*hair;

//Similarly for hot gas
//Heat transfer coefficient in W/m2K
hgas = (((0.023*kgas)*(Regas^0.8))*(Prgas^0.4))/Dhg;
//Correction factor=1.27;
//Corrected heat transfer coefficient of gas in W/m2K
hgas = 1.27*hgas;

//Overall conductance in W/K
UA = 1/(1/(hair*A)+1/(hgas*A));

//The number of transfer units, based on the gas, which has the smaller heat capacity rate
NTU = UA/(mgas*cgas);

//The heat capacity-rate ratio
Z = (mgas*cgas)/(mair*cair);

//and from Fig. 8.21, the effectiveness is approximately 0.13.
//Effectiveness
E = 0.13;
```

```

disp("Gas outlet temperature in degree K")
//Gas outlet temperature in degree K
Tgasout = Tgasin-E*(Tgasin-Tairin)

disp("Air outlet temperature in degree K")
//Gas outlet temperature in degree K
Tairout = Tairin+(Z*E)*(Tgasin-Tairin)
```

Scilab code Exa 8.4 `Heating Seawater From Condenser`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 8 Example # 8.4 ")

//Pressure of steam in inches of Hg
P = 4;
//At this pressure, temperture of condensing steam
   in degree F
Thin = 125.4;

//Flow rate of seawater in lb/s
mw = 25000;
//Specific heat of water in Btu/lb F
c = 0.95;
//Inlet and outlet temperature of seawater in degree
    F
```

```
Tcin = 60;
Tcout = 110;
//Heat transfer coefficient of steam in Btu/h ft2 F
hsteam = 600;
//Heat transfer coefficient of water in Btu/h ft2 F
hwater = 300;
//Outer diameter in inches
OD = 1.125;
//Inner diameters in inches
ID = 0.995;

//required effectiveness of the exchanger
E = (Tcout-Tcin)/(Thin-Tcin);

//For a condenser , Cmin/Cmax=0, and from Fig. 8.20, NTU =1.4.
NTU = 1.4;

//The fouling factors from Table 8.2 are 0.0005 h ft2 F/Btu for both sides of the tubes.
//F−Factor
F = 0.0005;

//The overall design heat−transfer coefficient in Btu/h ft2 F per unit outside area of tube is, from Eq. (8.6)
U = 1/(1/hsteam+F+(OD/((2*12)*60))*log(OD/ID)+(F*OD)/ID+OD/(hwater*ID));

//The total area A is 20∗pi∗D∗L, and since U∗A/Cmin =1.4

disp(”The length of the tube in ft is”)
//The length of the tube in ft
L = (((1.4*mw)*c)*12)/(((Tcin*%pi)*OD)*U)
```

Scilab code Exa 8.5 `Theoretical Problem`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 8 Example # 8.5 ")

disp("There is no computations in this example.")
disp("It is theoretical")
```

Chapter 9

Heat Transfer by Radiation

Scilab code Exa 9.1 `Analysis of Tungsten Filament`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 9, Example 1")
//Temperature of the tungsten filament in Kelvin
T=1400;

disp("a)Wavelength at which the monochromatic
   emissive power of the given tungsten filament is
   maximum in meters")
//Wavelength in m
lamda_max=2.898e-3/T

disp("b)Monochromatic emissive power at calculated
```

```
   maximum wavelength in W/m^3”)
//Emissive power in W/m3
Eb_max=12.87e-6*(T^5)

//Given wavelength in meters
lamda=5e-6;
//Product of wavelength and temperature in m-K
lamda_T=lamda*T;

disp(”c)Monochromatic emissive power at given
   wavelength in W/m^3”)
//Emissive power in W/m3
Eb_lamda=Eb_max*(2.898e-3/(lamda_T))^5*(((%e^4.965)
   -1)/((%e^(0.014388/lamda_T)-1)))
disp(”Thus ,Monochromatic emissive power at 5e-6 m
   wavelength is 25.4% of the Monochromatic emissive
    power at maximum wavelength”)
```

Scilab code Exa 9.2 Transmission of Solar Radiation

```

// Display mode
mode(0);

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

clc;
disp(”Principles of Heat transfer , Seventh Edition ,
   Frank Kreith , Raj M Manglik and Mark S Bohn,
   Chapter 9, Example 2”)
//Temperature at which sun is radiating as a
   blackbody in K
T=5800;

```

```
//Lower limit of wavelength for which glass is transparent in microns
lamda_l=0.35;
//lower limit of product of wavelength and temperature in micron-K
lamda_l_T=lamda_l*T;
//Lower limit of wavelength for which glass is transparent in microns
lamda_u=2.7;
//lower limit of product of wavelength and temperature in micron-K
lamda_u_T=lamda_u*T;

// For lamda_T= 2030, ratio of blackbody emission between zero and lamda_l to the total emission in terms of percentage
r_l=6.7;
// For lamda_T= 15660, ratio of blackbody emission between zero and lamda_u to the total emission in terms of percentage
r_u=97;

//Total radiant energy incident upon the glass from the sun in the wavelength range between lamda_l and lamda_u
total_rad=r_u-r_l;
disp(”Percentage of solar radiation transmitted through the glass in terms of percentage”)
rad_trans=total_rad*0.92    //Since it is given that silica glass transmits 92% of the incident radiation
```

Scilab code Exa 9.3 `Solid Angle Calculation`

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

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

clc;
disp("Principles of Heat transfer, Seventh Edition, Frank Kreith, Raj M Manglik and Mark S Bohn, Chapter 9, Example 3")
//Area of the flat black surface in m^2
A_1=10e-4;
//Radiation emitted by the flat black surface in W/m^ sr
I_1=1000;
// Another surface having same area as A1 is placed relative to A1 such that length of radiation ray connecting dA_1 and dA_2 in meters
r=0.5;
//Area in m^2
A_2=10e-4;
// Since both areas are quite small, they can be approximated as differential surface areas and the solid angle can be calculated as
//d_omega21=dA_n2/r^2 where dA_n2 is the projection of A2 in the direction normal to the incident radiation for dA_1,thus

//Angle between the normal n_2 ant the radiation ray  connecting dA_1 and dA_2
theta_2=30;

//Therefore solid angle in sr
d_omega21=(A_2*cosd(theta_2)/(r^2));

disp("Irradiation of A_2 by A_1 in watt")
//Irradiation in W
q_r12= I_1*A_1*cosd(90-theta_2)*d_omega21
```

Scilab code Exa 9.4 `Emissivity of Aluminium Surface`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 9, Example 4")
//Hemispherical emissivity of an aluminum paint at
   wavelengths below 3 microns
epsilon_lamda_1=0.4;
//Hemispherical emissivity of an aluminum paint at
   longer wavelengths
epsilon_lamda_2=0.8;
//At room temperature 27 degree celcius, product of
   lamda and T in micron-K
lamda_T_1=3*(27+273);
//At elevated temperature 527 degree celcius,
   product of lamda and T  in micron-K
lamda_T_2=3*(527+273);
//From Table 9.1
// For lamda_T_1, ratio of blackbody emission
   between zero and lamda_l to the total emission
r_1=0.00016;
// For lamda_T_2, ratio of blackbody emission
   between zero and lamda_u to the total emission
r_2=0.14;
disp("Thus, the emissivity at 27 C ")
//Emissivity
```

```
epsilon=0.8
disp("emissivity at 527 C ")
//Emissivity at higher temp.
epsilon=(r_2*epsilon_lamda_1)+(epsilon_lamda_2*0.86)
disp("The reason for the difference in the total
   emissivity is that at the higher temperature,the
   percentage of the total emissive power in the low
   -emittance region of the paint is appreciable,
   while at the lower temperature practically all
   the radiation is emittedat wavelengths above 3
   microns")
```

Scilab code Exa 9.5 `Absorptivity of Aluminium Surface`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 9, Example 5")
//Temperature of the sun in K
T=5800;
//For the case of Solar irradiation, value of the
   product of lamda and T in micron-K
lamda_T_1=3*T;// value of lamda is taken from
   Example 9.4
//From table 9.1
// For lamda_T_1, ratio of blackbody emission
   between zero and lamda_1 to the total emission
r_1=0.98;
```

```
//This means that 98% of the solar radiation falls below 3 microns
//Hemispherical emissivity of an aluminum paint at wavelengths below 3 microns
epsilon_lamda_1=0.4;
//Hemispherical emissivity of an aluminum paint at longer wavelengths
epsilon_lamda_2=0.8;
disp("Effective absorptivity for first case")
//Effective absorptivity
alpha_1=(r_1*epsilon_lamda_1)+(epsilon_lamda_2*0.02)
//For the case second with source at 800 K, value of the product of lamda and T in micron-K
lamda_T_2=3*800;
// For lamda_T_2 , ratio of blackbody emission between zero and lamda_l to the total emission
r_2=0.14;
disp("Effective absorptivity for second case")
//Effective absorptivity
alpha_2=(r_2*epsilon_lamda_1)+(epsilon_lamda_2*0.86)
```

Scilab code Exa 9.6 `Analysis of Painted Surface`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer , Seventh Edition , Frank Kreith , Raj M Manglik and Mark S Bohn , Chapter 9, Example 6")
// Stefan Boltzmann  constant in W/m^2 K^4
```

```
sigma=5.67e-8;
//Temperature of the painted surface in K
T=1000;
//Temperature of the sun in K
T_s=5800;
//Given, below 2 microns the emissivity  of the surface is 0.3,so
lamda_1=2; //wavelength in microns
epsilon_1=0.3; //emissivity

//Given, between 2 and 4 microns emmisivity is 0.9, so
lamda_2=4;//wavelength in microns
epsilon_2=0.9;//emissivity

//Given, above 4 microns emmisivity is 0.5, so
epsilon_3=0.5;//emissivity

//value of the product of lamda_1 and T in micron-K
lamda_1_T=2e-3*T;

//From table 9.1
// For lamda_1_T, ratio of blackbody emission between zero and lamda_l to the total emission
r_1=0.0667; //1st ratio

//value of the product of lamda_2 and T in micron-K
lamda_2_T=2e-3*T;
//From table 9.1
// For lamda_2_T, ratio of blackbody emission between zero and lamda_l to the total emission
r_2=0.4809; //2nd ratio

disp("a)Effective emissivity over the entire spectrum")
//Effective emissivity
epsilon_bar=epsilon_1*r_1+epsilon_2*(r_2-r_1)+epsilon_3*(1-r_2)
```

```

disp("b)Emissive power in W/m^2")
//Emissive power in W/m^2
E=epsilon_bar*sigma*T^4

//value of the product of lamda_1 and T_s in micron-K
lamda_1_T_s=2e-3*T_s;
//From table 9.1
// For lamda_1_T_s, ratio of blackbody emission between zero and lamda_l to the total emission
r_1_s=0.941;
//value of the product of lamda_2 and T_s in micron-K
lamda_2_T_s=2e-3*T_s;
//From table 9.1
// For lamda_2_T_s, ratio of blackbody emission between zero and lamda_l to the total emission
r_2_s=0.99;
disp("c) Average solar absorptivity")
//Average solar absorptivity
alpha_s=epsilon_1*r_1_s+epsilon_2*(r_2_s-r_1_s)+epsilon_3*(1-r_2_s)
```

Scilab code Exa 9.7 `Analysis of an Oxidised Surface`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
```

```
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 9, Example 7")
//Temperature of the oxidised surface in Kelvin
T=1800;
//Area of the oxidised surface in m^2
A=5e-3;
// Stefan Boltzmann constant in W/m^2 K^4
sigma=5.67e-8;
disp("a)Emissivity perpendicular to the surface")
//Emissivity
epsilon_zero=0.70*cosd(0)
disp("b)Hemispherical emissivity")
//Hemispherical emissivity
epsilon_bar=((-1.4)/3)*((cosd(90))^3-(cosd(0))^3)
disp("c)Emissive Power in Watt")
//Emissive Power in W
E=epsilon_bar*A*sigma*T^4
```

Scilab code Exa 9.8 `Theoretical Problem`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 9, Example 8")

// Theoretical Proof
disp("The given example is theoretical and does not
   involve any numerical computation")
```

Scilab code Exa 9.9 `Shape Factor in Window Arrangement`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
    Frank Kreith, Raj M Manglik and Mark S Bohn,
    Chapter 9, Example 9")
//Window arrangement consists of a long opening with
     dimensions
//Height in meters
h=1;
//Length in meters
l=5;
//width of table in meters
w=2;
//Assuming that window and table are sufficiently
    long and applying crossed string method, we get
//Distance ab in m
ab=0;
//Distance cb in m
cb=w;
//Distance ad in m
ad=h;
//Distance cd in m
cd=sqrt(l);

disp("Shape factor between the window and the table"
    )
```

```
//Shape factor between the window and the table
F_12=0.5*(ad+cb-cd)
```

Scilab code Exa 9.10 `Shape Factor Computation`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 9, Example 8")
//Window area in ft^2
A1=6*20;
//Second area in ft^2
A2=4*20;
//Assuming A5=A1+A2
//Area in ft^2
A5=A1+A2;

//From Fig. 9.27
//Shape Factors required
F56=0.19;
F26=0.32;
F53=0.08;
F23=0.19;

disp("Shape factor")
//Shape factor
F14=(A5*F56-A2*F26-A5*F53+A2*F23)/A1
disp("Thus,only about 10% of the light passing
```

```
    through the window will impinge on the floor area
     A4")
```

Scilab code Exa 9.11 `Liquid Oxygen in Spherical Container`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 9 Example # 9.11 ")

//Absolute boiling temperature of liquid oxygen in R
T1 = 460-297;
//Absolute temperature of sphere in R
T2 = 460+30;
//Diameter of inner sphere in ft
D1 = 1;
//Area of inner sphere in ft2
A1 = (%pi*D1)*D1;
//Diameter of outer sphere in ft
D2 = 1.5;
//Area of outer sphere in ft2
A2 = (%pi*D2)*D2;
//Stefans constant
sigma = 0.1714;
//Emissivity of Aluminium
epsilon1 = 0.03;//Sphere1
epsilon2 = 0.03;//Sphere2

```

```
//Using Eq. 9.74
disp("Rate of heat flow by radiation to the oxygen
   in Btu/h is")
//Rate of heat flow by radiation to the oxygen in
   Btu/h
q = ((A1*sigma)*((T1/100)^4-(T2/100)^4))/(1/epsilon1
   +(A1/A2)*((1-epsilon2)/epsilon2))
```

Scilab code Exa 9.12 `Radiative Exchange Between Cone Surfaces`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 9 Example # 9.12 ")

// Provide all given inputs and constants of the
   problem

//  Stefan Boltzmann  constant (W/m^2/K^4)
SIGMA = 0.0000000567;

//Area(1)=R1^2*pi in m2
AR(1,1) = 9*%pi;

// The physical parameters, e.g., shape factor and
   emissivity, are evaluated.

//All F(i,j) are shape factors.
```

```
F(1,1) = 0;
F(1,2) = 0.853;
F(1,3) = 0.147;
F(2,1) = 0.372;
F(2,2) = 0.498;
F(2,3) = 0.13;
F(3,1) = 0.333;
F(3,2) = 0.667;
F(3,3) = 0;

//ESP are emissivity given in the problem
ESP(1,1) = 0.6;
ESP(1,3) = 0.9;

//Temperature in degree K
T(1,1) = 1200;
//Temperature in degree K
T(1,3) = 600;

//Emissive Power of blackbody in W/m2
EB(1,1) = SIGMA*(T(1)^4);
//Emissive Power of blackbody in W/m2
EB(1,3) = SIGMA*(T(3)^4);

// The values of the elements of the coefficient matrix A in the equation
//[A][X]=[B] are specified
A(1,1) = 1-F(1,1)+ESP(1)/(1-ESP(1));
A(1,2) = -F(1,2);
A(1,3) = -F(1,3);
A(2,1) = -F(2,1);
A(2,2) = 1-F(2,2);
A(2,3) = -F(2,3);
A(3,1) = -F(3,1);
A(3,2) = -F(3,2);
A(3,3) = 1-F(3,3)+ESP(3)/(1-ESP(3));

// The values of the right-hand side vector B are
```

```
specified.
B(1,1) = (EB(1)*ESP(1))/(1-ESP(1));
B(1,2) = 0;
B(3) = (EB(3)*ESP(3))/(1-ESP(3));

// The inversion routine is used to solve for X
disp("Net radiative exchange between the top and bottom surface in W")
//Net radiative exchange between the top and bottom surface in W
X = inv(A)*B'// solutions for J
```

Scilab code Exa 9.13 `Temperature of Surface of Cone`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 9 Example # 9.13 ")

// Provide all given inputs and constants of the problem
SIGMA = 0.0000000567;// Stefan-Boltzmann constant (W m^2 K^4)

//all F(I,J) are shape factor
F(1,1) = 0;
F(1,2) = 0.853;
F(1,3) = 0.147;
```

```
F(2,1) = 0.372;
F(2,2) = 0.498;
F(2,3) = 0.13;
F(3,1) = 0.333;
F(3,2) = 0.667;
F(3,3) = 0;

//Area(1)=R1^2*pi in m2
AR(1,1) = 9*%pi;

//ESP are total hemispheric emissivity in W/m2
ESP(1,1) = 0.6;
ESP(1,3) = 0.9;

//Heat exchange in W
Q1 = 300000;

//Temperature in degree K
T(1,3) = 600;

//EB blackbody emissive powers in W/m2
EB(1,3) = SIGMA*(T(3)^4);

// Evaluate elements of coefficient matrix
A(1,1) = 1-F(1,1);
A(1,2) = -F(1,2);
A(1,3) = -F(1,3);
A(2,1) = -F(2,1);
A(2,2) = 1-F(2,2);
A(2,3) = -F(2,3);
A(3,1) = 0;
A(3,2) = 0;
A(3,3) = 1;

// Evaluate elements of right hand side matrix
B(1,1) = Q1/AR(1);
B(1,2) = 0;
B(3) = EB(3);
```

```

// solve the system of equations for X
X = inv(A)*B';

//Required temperature in degree K
T(1) = ((X(1)+(Q1*(1-ESP(1)))/(AR(1)*ESP(1)))/SIGMA)^0.25;
//solution for temperatures
disp("Temperature of surface 1 for the cone in degree K")
T1 = T(1)//Value for the required temperature in K
```

Scilab code Exa 9.14 Heat Transfer Between Parallel Plates

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 9 Example # 9.14 ")

//Absolute temperature of first plate in degree R
Ta = 2040+460;
//Absolute temperature of second plate in degree R
Tb = 540+460;
//Stefans constant
sigma = 0.1718;

//For first radiation band, heat transfer is calculated
```

```
//Emissivity of A
epsilonA = 0.1;
//Emissivity of B
epsilonB = 0.9;
//Shape factor
Fab = 1/(1/epsilonA+1/epsilonB-1);
//The percentage of the total radiation within a given band is obtained from Table 9.1.
//Coefficients of T^4
A = 0.375;
//Coefficients of T^4
B = 0.004;

//Rate of heat transfer in first band in Btu/h ft2
q1 = (Fab*sigma)*(A*((Ta/100)^4)-B*((Tb/100)^4));

//Similarly for other two bands, heat transfer in Btu/h ft2
q2 = 23000;
//heat transfer in Btu/h ft2
q3 = 1240;

disp("Total rate of radiation heat transfer in Btu/h ft2")
//heat transfer in Btu/h ft2
q = q1+q2+q3
```

Scilab code Exa 9.15 `Emissivity of Gaseous Mixture`

```


// Display mode
mode(0);

// Display warning for floating point exception
```

```
ieee(1);

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 9 Example # 9.15 ")

//Temperature in degree K
T = 800;
//Diameter of sphere in m
D = 0.4;
//Partial pressure of nitrogen in atm
PN2 = 1;
//Partial pressure of H2O in atm
PH2O = 0.4;
//Partial pressure of CO2 in atm
PCO2 = 0.6;

//The mean beam length for a spherical mass of gas is obtained from Table 9.7
//Beam length in m
L = (2/3)*D;

//The emissivities are given in Figs. 9.46 and 9.47
//Emissivity of H2O
epsilonH2O = 0.15;
//Emissivity of CO2
epsilonCO2 = 0.125;

//N2 does not radiate appreciably at 800 K, but since the total gas pressure
//is 2 atm, we must correct the 1-atm values for epsilon.
//From Figs. 9.48 and 9.49 the pressure correction factors are
//Pressure correction factor for H2O
CH2O = 1.62;
//Pressure correction factor for CO2
CCO2 = 1.12;
```

```

//From fig. 9.50
//Chnage in emissivity
deltaEpsilon = 0.014;

//Finally, the emissivity of the mixture can be
   obtained from Eq. (9.114):
disp("Emissivity of the mixture is")
//Emissivity of the mixture
epsilonMix = CH2O*epsilonH2O+CCO2*epsilonCO2-
   deltaEpsilon
```

Scilab code Exa 9.16 `Absorptivity of Gaseous Mixture`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 9 Example # 9.16 ")

//Total pressure in atm
Pt = 2;
//Temperature in degree K
TH2O = 500;
//Mean beam length in m
L = 0.75;
//Partial pressure of water vapor in atm
PH2O = 0.4;
//Source temperature in degree K
```

```
Ts = 1000;

//Since nitrogen is transparent, the absorption in
    the mixture is due to the water vapor alone.

//Parameters required
//A Parameter in atm-m
A = PH2O*L;
//B Parameter in atm
B = (Pt+PH2O)/2;

//From Figs. 9.46 and 9.48 we find
//For water, C factor in SI units
CH2O = 1.4;
//Emissivity of water
epsilonH2O = 0.29;


//From Eq. (9.115) the absorptivity of H2O is
disp("Absorptivity of H2O is")
alphaH2O = (CH2O*epsilonH2O)*((TH2O/Ts)^0.45)
```

Scilab code Exa 9.17 Heat Flow From Flue Gas

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
    Kreith et. al Chapter - 9 Example # 9.17 ")
```

```

//Temperature of flue gas in degree F
Tgas = 2000;
//Inner-wall surface temperature in degree F
Tsurface = 1850;
//Partial pressure of water in atm
p = 0.05;
//Convection heat transfer coefficient in Btu/h ft2 F
h = 1;
//Length of square duct in ft
L = 2;
//Volume in ft3
V = L*L;
//Surface area in ft2
A = 4*L;

//The rate of heat flow from the gas to the wall by convection per unit
//length in Btu/h ft is
qc = (h*A)*(Tgas-Tsurface);

//Effective beam length in m
L = ((0.3058*3.4)*V)/A;

//Product of partial pressure and L
k = p*L;

//From Fig. 9.46, for pL=0.026 and T=2000F, we find

//Emissivity
epsilon = 0.035;
//Absorptivity
alpha = 0.039;
//stefans constant
sigma = 0.171;

//Assuming that the brick surface is black, the net
```

```
   rate of heat flow from the gas to the wall by
   radiation is, according to Eq. (9.117)
qr = (sigma*A)*(epsilon*(((Tgas+460)/100)^4)-alpha
   *(((Tsurface+460)/100)^4));//Btu/h

disp("Total heat flow from the gas to the duct in
   Btu/h")
//Total heat flow from the gas to the duct in Btu/h
q = qc+qr
```

Scilab code Exa 9.18 Estimation of True Gas Temperature

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank
   Kreith et. al Chapter - 9 Example # 9.18 ")

//Emissivity
epsilon = 0.8;
//Stefan's constant
sigma = 0.1714;
//Temperature of walls in degree F
Twall = 440;
//Temperature indicated ny thermocouple in degree F
Tt = 940;
//Heat transfer coefficient in Btu/h ft2 F
h = 25;

```

```
//The temperature of the thermocouple is below the gas temperature because the couple loses heat by radiation to the wall.

//Under steady-state conditions the rate of heat flow by radiation from the thermocouple junction to the wall equals the rate of heat flow by convection from the gas to the couple.

//Using this heat balance, q/A in Btu/h ft2
q = (epsilon*sigma)*(((Tt+460)/100)^4-((Twall+460)/100)^4);

disp("True gas temperature in degree F")
//True gas temperature in degree F
Tg = Tt+q/h
```

Scilab code Exa 9.19 `Gas Temperature Measurement With Shielding`

```


// Display mode
mode(0);

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

clc;
disp("Principles of Heat Transfer, 7th Ed. Frank Kreith et. al Chapter - 9 Example # 9.19 ")

//Emissivity of thermocouple
epsilonT = 0.8;
//Emissivity of shield
epsilonS = 0.3;
```

```
//Stefan''s constant
sigma = 0.1714;
//Temperature of walls in degree F
Tw = 440;
//Temperature indicated ny thermocouple in degree F
Tt = 940;
//Heat transfer coefficient of thermocouple in Btu/h ft2 F
hrt = 25;
//Heat transfer coefficient of shield in Btu/h ft2 F
hrs = 20;

//Area for thermocouple be unity ft2
At = 1;
//Corresponding area of shield in ft2
As = 4;//Inside dia=4*dia of thermocouple

//From Eq. (9.76)
//View factors Fts and Fsw
Fts = 1/((1-epsilonT)/(At*epsilonT)+1/At+(1-epsilonS)/(As*epsilonS));
Fsw = As*epsilonS;

//Assuming a shield temperature of 900 F , we have, according to Eq. (9.118)
//Temperature in degree F
Ts = 923;

//Coeffcients for heat balance are as following
//A parameter Btu/h-F
A = 9.85;//A=hrt*At
//B parameter Btu/h-F
B = 13.7;//B=hrs*As

//Using heat balance
disp("Correct temperature of gas in degree F")
//Correct temperature of gas in degree F
Tg = Ts+(B*(Ts-Tw)-A*(Tt-Ts))/((hrs*2)*As)
```

Chapter 10

Heat Transfer with Phase Change

Scilab code Exa 10.1 `Water Boiling on Steel Surface`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 10, Example 1")
//Surface temperature of polished stainless steel
   surface in degree celcius
T_s=106;
//Boiling point of water under at atmospheric
   pressure in degree celcius
T_b=100;
//Value of empirical constant
C_sf=0.0132;
```

```
//latent heat of vaporization in J/kg
h_fg=2.25e6;
//gravitational acceleration in m/s^2
g=9.81;
//Value of proportionality factor in British Gravitational system
g_c=1;
//density of saturated liquid in kg/m^3
rho_l=962;
//density of saturated vapor in kg/m^3
rho_v=0.60;
//specific heat of saturated liquid in J/kg K
c_l=4211;
//prandtl number of saturated liquid
Pr_l=1.75;
//surface tension of the liquid-to-vapor interface in N/m
sigma=58.8e-3;
// viscosity of the liquid in kg/ms
mu_l=2.77e-4;
//Excess temperature in degree Celcius
delta_Tx= T_s-T_b;

disp("Heat flux from the surface to the water in W/m^2")
//Heat flux in W./m2
q=(c_l*delta_Tx/(C_sf*h_fg*Pr_l))^3*mu_l*h_fg*sqrt((g*(rho_l-rho_v))/(g_c*sigma))

disp("Critical heat flux in W/m^2")
//Heat flux in W./m2
q_maxZ=(%pi/24)*sqrt(rho_v)*h_fg*(sigma*g*(rho_l-rho_v)*g_c)^0.25

disp("At 6 C  excess temperature the heat flux is less than the critical value; therefore nucleate pool boiling exists")
disp("For the Teflon-coated stainless steel surface,
```

```
    heat flux in W/m^2")
//Heat flux in W./m2
q=29669*(C_sf/0.0058)^3
disp("Thus for Teflon-coated stainless steel surface
    there is a remarkable increase in heat flux;
    however, it is still below the critical value.")
```

Scilab code Exa 10.2 `Water Boiling on Polished Surface`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
    Frank Kreith, Raj M Manglik and Mark S Bohn,
    Chapter 10, Example 2")
//density of saturated liquid in kg/m^3
rho_l=962;
//gravitational acceleration in m/s^2
g=9.8;
//latent heat of vaporization in J/kg
h_fg=2250000;
//density of saturated vapor in kg/m^3
rho_v=0.60;
//Surface temperature of polished stainless steel
    surface in degree celcius
T_s=400;
//Value of proportionality factor in British
    Gravitational system
g_c=1;
//Boiling point of water under at atmospheric
```

```
pressure in degree celcius
T_b=100;
//surface tension of the liquid-to-vapor interface in N/m
sigma=58.8e-3;
//Excess temperature in degree Celcius
delta_Tx= T_s-T_b;
//Wavelength in m from eq. 10.7
lamda=2*%pi*sqrt(g_c*sigma/(g*(rho_l-rho_v)));
//Thermal conductivity in W/mK
k_c=0.0249;
//Absolute viscosity in Ns/m^2
mu_c=12.1e-6;
//Specific heat in J/kg K
c_pc=2034;
//Heat transfer coefficient due to conduction alone in W/m^2 K
h_c=(0.59)*(((g*(rho_l-rho_v)*rho_v*(k_c^3)*(h_fg+(0.68*c_pc*delta_Tx)))/(lamda*mu_c*delta_Tx))^0.25); // expression obtained assuming diameter D tending to infinity
//Emissivity
epsilon_s= 0.05; //since surface is polished and hence heat transfer coefficient due to radiation is negligible
disp("Heat flux in W/m^2")
//Heat flux in W/m^2
q= h_c*delta_Tx
```

Scilab code Exa 10.3 `Flow of n Butyl Alcohol`

```


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

```

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

clc;
disp("Principles of Heat transfer, Seventh Edition, Frank Kreith, Raj M Manglik and Mark S Bohn, Chapter 10, Example 3")
//Flow rate of n-butyl alcohol in kg/hr
m=161;
//Internal diameter of copper tube in meters
D=0.01;
//Tube wall temperature in degree C
T=140;
//surface tension in N/m
sigma=0.0183;
//Heat of vaporization in J/kg
h_fg=591500;
//atmospheric pressure boiling point in degree C
T_sat=117.5;
// saturation pressure corresponding to a saturation temperature of 140 C  in atm
P_sat=2;
//Density of vapor in kg/m^3
rho_v=2.3;
//Viscosity of vapor in kg/m s
mu_v=.0143e-3;
//Property values for n-butyl alcohol are taken from Appendix 2, Table 19
//Density in kg/m^3
rho_l=737;
//Absolute viscosity in Ns/m^2
mu_l=0.39e-3;
//Specific heat in J/kg K
c_l=3429;
//Prandtl number
Pr_l=8.2;
//Thermal conductivity in W/m K
```

```
k_l=0.13;
//Empirical constant
C_sf=0.00305;// Value taken from table 10.1
//Mass velocity in kg/m^2 s
G=(m/3600)*(4/(%pi*0.01^2));
//Reynolds number for liquid flow
Re_D=(G*D)/mu_l;
//The contribution to the heat transfer coefficient due to the two-phase annular flow is [(0.023)*(14590)^0.8*(8.2)^0.4*16.3*(1-x)^0.8*F]
//Since the vapor pressure changes by 1 atm over the temperature range from saturation temperature to 140 C ,so saturation pressure in N/m^2
delta_p_sat=101300;
//Therefore the contribution to the heat transfer coefficient from nucleate boiling is
//h_b= 0.00122*[(0.163^0.79*3429^0.45*737^0.49*1^0.25)/(0.0183^0.5*0.39e-3^0.29*591300^0.24*2.3^0.24)]*(140-117.5)^0.24*(101300)^0.75*S
//or h_b= 8393S
//Now 1/Xtt will be calculated by
//1/Xtt=12.86*(x/(1-x))^0.9
//Now a table is prepared showing stepwise calculations that track the increase in quality, from x=0 to x=0.5,assuming that the steps delta x are small enough that the heat flux and other parameters are reasonably constant in that step
disp("The tube length required to reach 50% quality is 1.35 m")
```

Scilab code Exa 10.4 `Heat Transfer Coefficients For Tube`

```

// Display mode
```

```
mode(0);

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

clc;
disp(”Principles of Heat transfer, Seventh Edition, Frank Kreith, Raj M Manglik and Mark S Bohn, Chapter 10, Example 4”)
//Outer diameter of the tube in meters
D=0.013;
//Acceleration due to gravity in m/s^2
g=9.81;
//Length of the tube in meters
L=1.5;
//Temperature of saturated vapour in Kelvin
T_sv=349;
//Average tube wall temperature in Kelvin
T_s=325;
//Average temperature of the condensate film in degree K
Tf=(T_sv+T_s)/2;
//Thermal conductivity of liquid in W/m–K
k_l=0.661;
//Viscosity of liquid in N s/m^2
mu_l=4.48e-4;
//Dendity of liquid in kg/m^3
rho_l=980.9;
//Specific heat of liquid in J/kg K
c_pl=4184;
//Latent heat of condensation in J/kg
h_fg=2.349e6;
//Density of vapor in kg/m^3
rho_v=0.25;
//Modified latent heat of condensation in J/kg
h_fg_dash=h_fg+(3/8)*c_pl*(T_sv-T_s);

disp(”Heat transfer coefficient for tube in
```

```
horizontal position in W/m^2 K")
//Heat transfer coefficient in W/m2K
h_c_bar=0.725*(((rho_l*(rho_l-rho_v)*g*h_fg_dash*k_l^3)/(D*mu_l*(T_sv-T_s)))^0.25)
disp("Heat transfer coefficient for tube in vertical position in W/m^2 K")
////Heat transfer coefficient in W/m2K
h_c_bar=0.943*(((rho_l*(rho_l-rho_v)*g*h_fg_dash*k_l^3)/(mu_l*(T_sv-T_s)))^0.25)
```

Scilab code Exa 10.5 `Condensate Flow Determination`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition, Frank Kreith, Raj M Manglik and Mark S Bohn, Chapter 10, Example 5")
//Acceleration due to gravity in m/s^2
g=9.81;
//Length of the tube in meters
L=1.5;
//Temperature of saturated vapour in Kelvin
T_sv=349;
//Average tube wall temperature in Kelvin
T_s=325;
//Average temperature of the condensate film in Kelvin
Tf=(T_sv+T_s)/2;
//Thermal conductivity of liquid in W/m–K
```

```
k_l=0.661;
//Viscosity of liquid in N s/m^2
mu_l=4.48e-4;
//Dendity of liquid in kg/m^3
rho_l=980.9;
//Specific heat of liquid in J/kg K
c_pl=4184;
//Latent heat of condensation in J/kg
h_fg=2.349e6;
//Density of vapor in kg/m^3
rho_v=0.25;
//Modified latent heat of condensation in J/kg
h_fg_dash=h_fg+(3/8)*c_pl*(T_sv-T_s);

disp("Reynolds number at the lower edge")
//Reynolds number
Re=(4/3)*(((4*k_l*L*(T_sv-T_s)*rho_l^(2/3)*g^(1/3))/(mu_l^(5/3)*h_fg_dash))^0.75)
disp("Since the Reynolds number at the lower edge of the tube is below 2000, the flow of the condensate is laminar")
```

Scilab code Exa 10.6 `Heat Transport Capability of Water`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition, Frank Kreith, Raj M Manglik and Mark S Bohn, Chapter 10, Example 6")
```

```
//Length of Heat pipe in meters
L_eff=0.30;
//Temperature of the heat pipe in degree celcius
T=100;
//Diameter of the heat pipe in meters
D=1e-2;
//Density of water at 100 degree celcius in k/m^3
rho=958;
//Viscosity of water in N s/m^2
mu=279e-6;
//surface tension of the liquid−to−vapor interface in N/m
sigma=58.9e-3;
//latent heat of vaporization in J/kg
h_fg=2.26e6;
//Inclination angle in degree
theta=30;
//Acceleration due to gravity in meter/sec^2
g=9.81;
//Wire diameter for wick in metres
d=0.0045e-2;
//So thickness of four layers of wire mesh
t=4*d;
//Area of the wick in m^2
Aw=%pi*D*t;
//For phosphorus−bronze,heat pipe wick pore size in meters
r=0.002e-2;
//For phosphorus−bronze,heat pipe wick permeability in m^2
K=0.3e-10;
disp(”Maximum liquid flow rate in kg/sec”)
//flow rate in kg/sec
m_max=((2*sigma/r)-rho*g*L_eff*sind(theta))*((rho*Aw*K)/(mu*L_eff))
disp(”Maximum heat transport capability in Watt”)
//heat transport capability in W
q_max=m_max*h_fg
```

Scilab code Exa 10.7 `Forming of Ice Layer`

```

// Display mode
mode(0);

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

clc;
disp("Principles of Heat transfer, Seventh Edition,
   Frank Kreith, Raj M Manglik and Mark S Bohn,
   Chapter 10, Example 7")
//Temperature of the brine spray used for internal
   refrigeration in degree celcius
T_inf=-11;
//Required thickness of ice layer in meters
epsilon= 0.0025;
//Water-liquid temperature in degree celcius
T1=4.4;
//Liquid-surface conductance in W/m^2 K
h_epsilon=57;
//Conductance between brine and ice(including metal
   wall) in W/m^2 K
h_not=570;
//Latent heat of fusion for ice in J/Kg
Lf=333700;
//Density for ice in Kg/m^3
rho=918;
//Thermal conductivity for ice in W/m K
k=2.32;
//Freezing point temperature in degree K
Tfr=0;
//Dimensionless R, T, epsilon and t are as follows
```

```
//R plus parameter
R_plus= h_epsilon/h_not;
//T plus parameter
T_plus= (T1-Tfr)/(Tfr-T_inf);
//Epsilon plus parameter
Epsilon_plus= h_not*epsilon/k;
//t plus parameter
t_plus=(Epsilon_plus/(R_plus*T_plus))-((1/(R_plus*T_plus)^2)*log(1+(R_plus*T_plus*Epsilon_plus/(1+R_plus*T_plus))))

disp(”Time taken for 0.25cm thick ice layer deposition in sec”)
//time in seconds
t=t_plus*rho*Lf*k/((h_not)^2*(Tfr-T_inf))
```