Scilab Textbook Companion for Elements Of Heat Transfer by M. Jacob And G. A. Hawkins[1]

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Book Description

Title: Elements Of Heat Transfer

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 3

Conduction of heat in the steady state

Scilab code Exa 3.1 Conduction through homogenous plane wall

```
clear;
clc();

// To find heat loss per square feet of wall surface
    per hour

deltax=9/12;                    // thickness of wall in
    ft
k=0.18;                 // thermal conductivity of
   wall in B/hr-ft-degF
t1=1500;                        // inside temperature
   of oven wall in degF
t2=400;                         // outside temperature
   of oven wall in degF

q=k*(t1-t2)/deltax;             // heat loss in Btu/hr
printf("\n The heat loss for each square foot of
   wall surface is %d Btu/hr-ft^2",q);
```

Scilab code Exa 3.2 Conduction through a composite plane wall

```
clear;
clc();

// To compute tempertures at the contact surfaces inside the furnaces

x1=9/12;                // thickness of firebrick in ft
k1=0.72;                // thermal conductivity of firebrick in Btu/hr-ft-degF
x2=5/12;                // thickness of insulating brick in ft
k2=0.08;                // thermal conductivity of insulating brick in Btu/hr-ft-degF
x3=7.5/12;              // thickness of redbrick in ft
k3=0.5;                 // thermal conductivity of firebrick in Btu/hr-ft-degF
t1=1500;                // inner temperature of wall in degF
t2=150;                 // outer temperature of wall in degF

// resistances of mortar joints are neglected
q=(t1-t2)/(x1/k1+x2/k2+x3/k3);    // heat flow per square ft in Btu/hr
t2=t1-(q*x1/k1);                  // first contact temperature in degF
printf("\n The temperature at the contact of firebrick and insulating brick is %d degF",t2);

t3=t2-(q*x2/k2);                  // second contact temperature in degF
printf("\n The temperature at the contact of
```

```
insulating brick and red brick is %d degF",t3);
```

Scilab code Exa 3.3 Conduction through a homogenous cylinder wall

```
clear;
clc();

// to calculate the heat loss from pipe

d1=2.375/12;                          // internal diameter of pipe in ft
t=1/12;                               // thickness of insulating material in ft
d2=d1+2*t;                            // external (insulation)diameter of pipe in ft
k=0.0375;                             // thermal conductivity of insulating material in Btu/hr-ft-F
l=30;                                 // length of pipe in ft
t1=380;                               // inner surface temperature of insulation
t2=80;                                // outer surface temperature of insulation

q=2*%pi*k*(t1-t2)/log(d2/d1);   // heat loss per unit length
printf("\n Heat loss per linear foot is %.d Btu/hr",q)

qtot=round(q)*l;                      // heat loss for 30 ft pipe
printf("\n Total heat loss through 30 ft of pipe is %d Btu/hr",qtot)
```

Scilab code Exa 3.4 Conduction through a composite cylinder wall

```
clear;
clc();

// To calculate heat loss from pipe

d1=10.75/12;                // outer diameter of pipe in
    ft
x1=1.5/12;                  // thickness of insulation 1
    in ft
x2=2/12;                    // thickness of insulation 2
    in ft
d2= d1+2*x1;                // diameter of insulation 1
   in ft
d3=d2+2*x2;                 // diameter of insulation 1
   in ft
t1=700;                     // inner surface temperature
    of composite insulation in degF
t2=110;                     // outer surface temperature
    of composite insulation in degF
k1=0.05;                    //thermal conductivity of
   material 1 in Btu/hr-ft-degF
k2=0.039;                   // thermal conductivity of
   material 2 in Btu/hr-ft-degF

q=2*%pi*(t1-t2)/(log(d2/d1)/k1+log(d3/d2)/k2);
                                              // heat loss
   per linear foot in Btu/hr
printf("\n The heat loss is found to be %d Btu/hr-ft
   ", q);
```

Scilab code Exa 3.5 Influence of variable conductivity

```
clear;
clc();

// To find out heat loss through 1 sq. ft of flat slab of 85%magnesia and 15% asbestos

km=0.0377;                     // Mean thermal conductivity at 220degF
t1=260;                        // Inner surface temperature of slab in degF
t2=180;                        // Outer surface temperature of slab in degF
A=1;                           // Area of slab in ft
x=2/12;                        // Thickness of insulation in ft

q=km*A*(t1-t2)/x;              // Heat loss through slab in Btu/hr
printf("\n Heat loss through flat slab is %.1f Btu/hr",q);
```

Scilab code Exa 3.6 Conduction through edge and corner sections

```
clear all
clc()

// To find out heat loss through conduction through a furnace
k=0.8                           // Avg. thermal conductivity in Btu/hr-ft-degF
T1=400                          // Inner surface temperature of furnace in degF
T2=100                          // Outer surface
```

```
temperature of furnace in degF
a=3                        // Length of furnace in ft
b=4                        // Breadth of furnace in ft
c=2.5                      // Height of furnace in ft
Aa=2*a*b                   // Area of surface A in ft^2
Ab=2*b*c                   // Area of surface A in ft^2
Ac=2*a*c                   // Area of surface A in ft^2
x=4.5/12                   // Thickness of insulation in ft
t=24                       // Time elapsed in hr
M=4                        // Number of edges
N=8                        // Number of corners

S=Aa/x+Ab/x+Ac/x+0.54*(a+b+c)*M+0.15*x*N        // Shape factor
qo=S*k*(T1-T2)                                   // Heat flow per hour
q=qo*t                                           // Heat loss in 24 hr

printf("The heat loss in 24 hr is %d Btu",q)
```

Scilab code Exa 3.7 Conduction through sections of complicated range

```
clear;
clc();

// To compute shape factor  for the special section in figure

// Ratio of diameter of circle to the side of square
```

```
    is 0.5. Hence required lines have been
    estabilished by trial and error method.

M=8*9;                      // number of flow channels
    for the entire section
N=8.37;                     // number of equal channel
    intervals
// the fractional part arises due to the fractional
    part of temperature close to border EG

k = M/N;                    // Ratio of shape factor to
    wall length
printf("\n Shape factor for the special section (
    where the ratio of radius of circle to half side
    length is 0.5),S is %.2fL", k );
```

Scilab code Exa 3.8 Relaxation method

```
clear;
clc();

// To find the temperature of planes indicated by
    grid points using relaxation method
t1=800;                 // inner surface temperature of
    wall in degF
t4=200;                 //  outer surface temperature of
    wall in degF

//Grids are square in shape so delx =dely where delx
    ,y sre dimensions of square grid

t2=[700 550 550 587.5 587.5 596.9 596.9 599.3 599.3
    599.8];                 // Assumed temperature of
    grid point 1
t3=[300 300 375 375 393.8 393.8 398.5 398.5 399.6
```

```
    399.6];                    // Assumed temperature of
    grid point 2

for i=1:9
    th2(i)=t1+t3(i)-2*t2(i);; // th1= q/kz at grid
        pt1
    th3(i)=t2(i)+t4-2*t3(i);// th2= q/kz at grid
        pt2
    printf("\n Assuming t2=%.1f  degF and t2=%.1f
        degF \n th1[%d]=%.1f degF and th2[%d]=%.1f
        degF \n",t2(i),t3(i),i,th2(i),i,th3(i));
    printf(" Since th2[%d] is not equal to th3[%d],
         hence other values of t2 and t3 are to be
        assumed\n",i,i);
end

printf("\nAssuming t2=600 degF and t3=400 degF, th2=
    th3.");
printf("\nHence Steady state condition is satisfied
    at grid temperatures of 400 degF and 600 degF");
```

Scilab code Exa 3.10 realaxation

```
clear;
clc();

// To find the total heat flow per foot of depth
    through the sction and the shape factor

k=0.9;                              // thermal
    conductivity of section material in Btu/hr-ft-
    degF

// Heat is considered to flow through fictitious
    rods and only half of the heat flows through
```

```
symmetry axes

Ta=300;Tb=441;Tc=600;Td=300;Te=432;Tf=600;Tg=600;Th=600;Ti=300;Tj=384;Tk=461;Tl=485;Tm=490;Tn=300;To=340;Tp=372;Tq=387;Tr=391;Ts=300;Tt=300;Tu=300;Tv=300;Tw=300;
// Above grid point temperatures are given in the question for the quarter section considered in degF(a,b,c...w are grid points)

q1=4*k*((Tc-Tb)/2+(Tf-Te)+(Tf-Tk)+(Tg-Tl)+(Th-Tm)/2);                 // Amount of heat coming from inside in Btu/hr
q2=4*k*((Tb-Ta)/2+(Te-Td)+(Tj-Ti)+(To-Tn)+(To-Tt)+(Tp-Tu)+(Tq-Tu)+(Tr-Tw)/2);    // Amount of heat going outside in Btu/hr
q=(q1+q2)/2;                              // average of heat going in and heat coming out
printf("\n Total heat flow per unit depth is %.1fBtu/hr",q);

S=q/(k*(Tc-Ta));                          // shape factor in ft
printf("\n Shape factor is %.2fft",S)
```

Chapter 4

Conduction of heat in the unsteady state

Scilab code Exa 4.1 Unsteady state

```
clc();
clear;

// To find heat changes and temperature change on
   heating of a concrete wall

b=9;                                    // Thickness
   of the wall in ft
A=5;                                    // Area of
   wall
k=0.44;                                 // Thermal
   conductivity in Btu/hr-ft-degF
Cp=.202;                                // Specific
   heat in Btu/lbm-degF
rho=136;                                // Density in
    lb/ft^3

function[t]=templength(x);              //
   Temperature function in terms of length
```

```
    t = 90 - 80*x +16*x^2 +32*x^3 -25.6*x^4;
    funcprot(0);
endfunction
tgo = derivative(templength,0);         // Temperature gradient at x=0ft
tgl = derivative(templength,9/12);      // Temperature gradient at x=9/12ft

qo = -k*A*tgo;                          // Heat entering per unit time in Btu/hr
printf("Heat entering per unit time is %.2f Btu/hr \n",qo);
ql = -k*A*tgl;                          // Heat coming out per unit time in Btu/hr
printf(" Heat coming per unit time is %.2f Btu/hr \n",ql);
q3 = qo-ql;                             //Heat energy stored in Btu/hr
printf(" Heat energy stored in wall is %.2f Btu/hr \n",q3);

a=k/(rho*Cp);                                //Thermal diffusivity
function[t2]=doublederivative(y);            //Derivative of tempearture with respect to length in degF/ft
  t2= -80+32*y+96*y^2-102.4*y^3;
  funcprot(0);
endfunction
timeder0=a*derivative(doublederivative,0);   //derivative of temperature  wrt time at x=0 in degF
printf(" Time derivative of temperature wrt time at x=0ft is %.2f degF/hr\n",timeder0);
timeder1=a*derivative(doublederivative,9/12);// derivative of temperature wrt time at x=9/12 in degF
printf(" Time derivative of temperature wrt time at
```

```
x=9/12ft is %.2f degF/hr\n",timeder1);
```

Scilab code Exa 4.2 Unsteady State

```
clc();
clear;
// To find heat changes and temperature change on heating of a concrete wall
b=9;                                    // thickness of the wall in ft
A=5;                                    // area of wall in ft^2
k=0.44;                                 // Thermal conductivity in Btu/hr-ft-degF
Cp=.202;                                // Specific heat in Btu/lbm-degF
rho=136;                                // density in lb/ft^3

function[t]=templength(x);
    t = 90 - 8*x-80*x^2;
    funcprot(0);
endfunction
tgo = derivative(templength,0);         // temperature gradient at x=0ft
tgl = derivative(templength,9/12);      // temperature gradient at x=9/12ft

qo = -k*A*tgo;                          // Heat entering per unit time in Btu/hr
printf("Heat entering per unit time is %.2f Btu/hr \n",qo);
ql = -k*A*tgl;                          // Heat coming out per unit time in Btu/hr
printf(" Heat coming per unit time is %.2f Btu/hr \n
```

```
    ",ql);
q3 = qo-ql;                              //Heat energy
    stored in Btu/hr
printf(" Heat energy stored in wall is %.2f Btu/hr \
    n",q3);

a=k/(rho*Cp);                            // Thermal
    diffusivity in ft^2/hr
function[t2]=doublederivative(y);        // derivative
    of tempearture with respect to length in degF/ft
  t2= -8-160*x;
  funcprot(0);
endfunction;
timeder0=a*derivative(doublederivative,0);
    // derivative of temperature  wrt time at x=0 in
    degF
printf(" Time derivative of temperature wrt time at
    x=0ft is %.2f degF/hr\n",timeder0);
timeder1=a*derivative(doublederivative,9/12);
    // derivative of temperature wrt time at x=9/12
    in degF
printf(" Time derivative of temperature wrt time at
    x=9/12ft is %.2f degF/hr\n",timeder1);
printf(" Teperature at each part of wall decreases
    equally");
```

Scilab code Exa 4.3 Sudden change of surface temperature

```
clc();
clear;

// To find the tempearure and heat low in case of
    sudden heat change

t = 10;                  // time elapsed in hr
```

```
Ti= 70;                     // tempearature of wall initially in degF
Ts = 1500;                  // temperature of surface when suddenly changed in degF
a = 0.03;                   // thermal diffusivity in ft^2/hr
k = 0.5;                    // thermal conductivity in Btu/hr-ft-degF
A = 10;                     // area of wall in sq ft
x = 7/12;                   // distance from surface where tempearture is to be found in ft
f = x/(2*sqrt(a*t));
// From gaussian error function table erf can be found
errorf = 0.55;              // Referred from table

T = Ts+(Ti-Ts)*errorf;
printf("Temperaure at a distance of 7/12ft from surface is %.1f degF \n",T);
q = -k*A*(Ti-Ts)*exp(-x^2/(4*a*t))/sqrt(t*%pi*a);   // heat flow rate at a distance
qtot = -k*A*(Ti-Ts)*2*sqrt(t/(%pi*a));   // total heat flowing after 10 hrs in Btu
printf(" Heat flowing at a distance of 7/12 ft from surface is %d Btu/hr\n",q);
printf(" Total heat flow after 10hrs is %f Btu",%pi);
```

Scilab code Exa 4.4 Sudden change of temperature

```
clc();
clear;
// To find the temperature at center of sphere on sudden temperature change
d = 16/12;                       // Diameter of sphere in
```

```
    ft
t = 20/60;                    // Time elapsed in hr
a = 0.31;                     // thermal diffusivity of
    steel in ft^2/hr
Ti = 80;                      // Temperature of steel
    sphere initially in degF
Ts = 1200;                     // Temperature of surface
     suddenly changed in degF
s = 4*a*t/d^2;                // A parameter
// From table the value of F(s) can be known
Fs=0.20;
Tc = Ts+(Ti-Ts)*Fs;           // Tempearture at the
    center of sphere in degF
printf("The tempearture at the center of steel
    sphere after 20 mins is %d degF",Tc);
```

Scilab code Exa 4.5 Periodic temperature change

```
clc();
clear;
// To estimate the time lag of temperature (sine)
    wave
t = 24;                            // Time period of
    tempearture wave in hr
k = 0.6;                           // Thermal
    conductivity of wall in Btu/hr-ft-degF
Cp = 0.2;                          // Specific heat
    capacity of wall in Btu/lb-degF
y = 110;                           // specific gravity
    in lb/ft^3
x = 8/12;                          // Distance from
    surface in ft
a = k/(y*Cp);                       // Thermal
    diffusivity in ft^2/hr
n=1/t;                             // frequency in /hr
```

```
delr = x/(2*sqrt(a*%pi*n);       // Time lag in hr
printf("Time lag of the temperature at a point 8 in
   from surface is %.1f hr", delr;
```

Scilab code Exa 4.6 Periodic change of surface temperature

```
clc();
clear;

// To calculate the range in temperatures at
   different depths
T1=-15;                                          // Min
   temperature at surface in degF
T2=25;                                           // Max
   temperature at surface in degF
t=24;                                            // time gap
   in hrs
k=1.3;                                           // thermal
   conductivity in Btu/hr-ft-degF
Cp=0.4;                                          // heat
   capacity in lb/ft-degF
y=126.1;                                         // specific
   gravity in lb/ft^3
n=1/t;                                           // frequency
    in /hr
Tm=(T1+T2)/2;
a=k/(y*Cp);                                      // thermal
   diffusivity in ft^2

x1=2;
x2=6;
th0=(T1-T2)/2;
th1=th0*-exp(-x1*sqrt(%pi*n/a));                 //
   temperature range at 2 ft depth
th2=th0*-exp(-x2*sqrt(%pi*n/a));                 //
```

```
temperature range at 6 ft depth
printf("Amplitude of tempearture at 2ft deep is %.2f degF\n",th1);
printf(" Amplitude of tempearture at 6ft deep is %.2f degF\n",th2);
printf(" At a depth of 2ft , temperature varies from 4.78 degF to 5.22 degF and at a depth of 6 ft , temperature remains constant at 5 degF");
delr1=x1/2*sqrt(1/(a*%pi*n));          // time lag at 2 ft depth
delr2=x2/2*sqrt(1/(a*%pi*n));          // time lag at 6 ft depth
printf(" Lag of temperature wave at a depth 2 ft is %.1f hr \n",delr1);
printf(" Lag of temperature wave at a depth 6 ft is %.1f hr \n",delr2);
```

Scilab code Exa 4.7 Periodic change of surface temperature

```
clc();
clear;

// To calculate the range in temoperatures at different depths
T1=10;                                 // Min temperature at surface in degF
T2=-10;                                // Max temperature at surface in degF
t1=24;
t2=5;                                  // Time gap in hrs
k=0.3;                                 // Thermal conductivity in Btu/hr-ft-degF
Cp=0.47;                               // Heat capacity in lb/ft-degF
```

```
y=100;                                        // Specific gravity in lb/ft^3
n1=1/t1;                                      // Frequency in /hr
Tm=(T1+T2)/2;a=k/(y*Cp);                      // thermal diffusivity in ft^2
n=1/t1;                                       // Frequency in /sec
x1=1;
x2=1;                                         // Depth in ft
th0=(T1-T2)/2;th1=th0*exp(-x1*sqrt(%pi*n/a));          // temperature range at 2 ft depth
th2=th0*exp(-x2*sqrt(%pi*n/a));               // Temperature range at 6 ft depth
printf("Amplitude of tempearture at 2ft deep is %.2f degF\n",th1);
delr1=x1/2*sqrt(1/(a*%pi*n));                 // Time lag at 2 ft depth
printf(" Lag of temperature wave at a depth 2 ft is %.1f hr \n",delr1);
 // To calculate the temperature at a depth of 1 ft, 5 hr after the srface temperature reaches the minimum temperature
 r=3/(4*n);                                   // Time at which minimum surface temperature occurs for the first time in hr
 r1=r+5;                                      // Time ar which temperature is to be found out in degF
 th3=th0*exp(-x1*sqrt(%pi*n/a))*sin(2*%pi*r1/24-4.53);
 Tr=Tm+th3;                                   // Temperature to be found out in degF
 printf(" The temperaure at 1 ft depth is %.2f degF \n",Tr);
```

Scilab code Exa 4.8 Unsteady state conduction

```
clc();
clear;

// to compute the temperatures at different points
a=0.02;                                    // thermal
   diffusivity in ft^2/hr
M=4;                                       // the value of
   4 is selected for M
x=9/12;                                    // thickness of
   wall in ft
delx=1.5/12;
delr=delx^2/(a*M);                            // at time
   interval the heat transfeered will change the
   temperature of sink from tb2 to tb2o
printf("The time interval is to be of %.3f hr \n",
   delr);

t1o=370; t2o=435; t3o=480; t4o=485; t5o=440; t6o
   =360; t7o=250;

// tempetaures at different positions at wall in
   degF initially
// we know qo=Z*delx*dely*rho*Cp(tb2'-tb2)/delr
   So on solving equations we get tb2'=(tb1+tb3+ta2+
   tc2)/4
// using above formula, temperaures at different
   positions as shown below can be calculated in
   degF

ta=[370 430 470 473 431 352 250];
tb=[370 425 461 462 422 346 250];
tc=[370 420 452 452 413 341 250];
```

```
td=[370 415 444 442 404 336 250];
printf(" The temperatures at different positions 0.78 hr after, are as follows \n");
for i=1:7
printf(" The temperature at point %d is %d degF \n",i,td(i));
end
```

Scilab code Exa 4.9 Unsteady state conduction

```
clc();
clear;

// to compute the temperatures at different points

a=0.53;                                    // thermal diffusivity in ft^2/hr
M=4;                                       // the value of 4 is selected for M
x=6/12;                                    // thickness of wall in ft
delx=2/12;
delr=delx^2/(a*M);                         // at time interval the heat transfeered will change the temperature of sink from tb2 to tb2o
printf("the time interval is to be of %.3f hr \n",delr);

// the temperature is constant in the whole wall initiallt 100 degF and afterwards it changes to 1000 degF.
// we know qo=Z*delx*dely*rho*Cp(tb2'-tb2)/delr So on solving equations we get tb2'=(tb1+tb3+ta2+tc2)/4
// Using above formula we can calculate the
```

```
    different temperatures as given below in degF

ta=[100 550 775 888 944];
tb=[100 550 775 888 944];
tc=[100 550 775 888 944];
td=[100 550 775 888 944];
printf(" the temperatures at different positions
    0.052 hr after, are as follows \n");
printf(" the temperature at point a is %d degF \n",
    ta(5));
printf(" the temperature at point a is %d degF \n",
    tb(5));
printf(" the temperature at point a is %d degF \n",
    tc(5));
printf(" the temperature at point a is %d degF \n",
    td(5));
```

Chapter 5

Steady state heat conduction in bodies with heat sources

Scilab code Exa 5.1 Maximum temperature in coil

```
clc();
clear;

// to calculate the maximum temperature inside the
   coil when current was 2.5 amp
// the ratio of radii 12/13.5 is so great that the
   curvature may be neglected

Di= 10/12;                                          //
   inside diameter of the coil in ft
x=7/48;                                             //
   thickness of coil in ft
ts=70.5;                                            //
   Initial temp. of coil in degF
Rm=12.1;                                            //
   Resistance of coil
e=0.0024;                                           //
   Temperature coefficient of coil in degF
i=0.009;                                            //
```

```
Initial current in amp
V=0.1;                                                  //
Initial Voltage in volts
Rs=V/i;                                                 //
Initial resistance in ohms
Thm=(Rm/Rs-1)/e;                                        //
Mean temperature in degF
Th0=1.5*Thm;                                            //
Increase in temperature in degF
to=ts+Th0;                                              //
Maximum temperature in degF
printf("The maximum temperature of the coil was %.1f
    degF",to);
```

Scilab code Exa 5.2 Temperare distribution in solid cylinder

```
 clc();
clear;

// to find tempearture difference between inner and
   outer surface
r=1/4;                                          // radius
   in inches
to=300;                                         // outer
   surface temperature of cylinder in degF
q0=10;                                          // i2r
   heat loss in Btu-in^2/hr
k=10;                                           //
   thermal conductivity of the material in Btu/hr-ft
   -degF
tc=to+(q0*r*r)*12 /(4*k);                       //
   temperature at center
delt=tc-to;
printf("The temperature diference between center and
    outer surface is %.2f degF",delt);
```

```

// to find heat flow from outer surface

// Total energy within the cylinder must be transferred to as heat to outer surface

v=%pi*r^2;                                   // Volume of heatinf element in in^3
q1=q0*v;                                     // heat flow to outer surface in Btu/sec
tr=-q1*r/(2*k);                              // derivative of temperature wrt radius
q=q1*12;                               // Heat flow at the outer surfae in Btu/hr-ft
printf("\n Heat transfer per unit length at the outer surface is %.1f Btu/hr",q);
```

Chapter 6

Introduction to the dimensional analysis of convection

Scilab code Exa 6.1 Reynolds concept of similarity

```
clc();
clear;

// To calculate the reynolds number

u=2.08/32.2;                                          //
   viscosity of water at 80degF in slug/ft-hr
rho=62.4/32.2;                                        // density
   of water in slug/ft^3
d=2/12;                                               // inner
   diameter of tube in ft
v=10;                                                 // average
   water velocity in ft/sec
Nre=d*v*rho*3600/u;                                   // reynolds
    number
// 3600 is multiplies to convert sec into hrs
printf("Reynolds Number is %d",Nre);
```

Scilab code Exa 6.2 Reynolds number

```
clc();
clear;

// To calculate the reynolds number

u=2.08/32.16;                                   // viscosity of water at 80 degF in slug/ft-hr
m=965000/32.16;                                 // mass velocity of water in slug/hr-ft
d=1/12;                                         // inner diameter of tube in ft
Nre=m*d/u;                                      // reynolds number

// 3600 is multiplies to convert sec into hrs
printf("Reynolds Number is %d",Nre);
```

Chapter 7

Heat transfer by free convection

Scilab code Exa 7.1 Heat transfer by vertical and horizontal surfaces

```
clc();
clear;

// To find the film coefficient for free convetion
   for a heated plate

tp=200;                                              //
   Temperature of heated plate in degF
ta=60;                                               //
   Temperature of air in degF
tf=(tp+ta)/2;                                        //
   Temperature of film in degF
delt=tp-ta;                                          //
   Temperature difference in degF
Z=950000;                                            // As
   referred from the chart for corresponding
   temperature
L=18/12;                                             // Height
   of vertical plate in ft
```

```
X=L^3*(delt)*Z;
// This value shows that it is laminar range so formula is as follows

h=0.29*(delt/L)^.25;                              // Heat transfer coeeficient in Btu/hr-ft^2-degF
printf("The film coefficient for free convetion for the heated plate is %.1f Btu/hr-ft^2/degF",h)
```

Scilab code Exa 7.2 Heat transfer from horizontal surface

```
clc();
clear;

// To find the film coefficient for natural convetion for a heated square plate

tp=300;                                          // Temperature of heated plate in degF
ta=80;                                           // Temperature of air in degF
tf=(tp+ta)/2;                                    // Temperature of film in degF
delt=tp-ta;                                      // Temperature difference in degF
Z=610000;                                        // As referred from the chart for corresponding temperature
L=7/12;                                          // Height of vertical plate in ft
A=L*L;                                           // Area of square plate in ft^2
X=L^3*(delt)*Z;

```

```
// This value shows that it is turbulent range , so formula for heat transfer coefficient is as follow
h=0.22*delt^(1/3);                          // Temperature coeeficient in Btu/hr-ft^2-degF
q=h*A*delt;                                 // Heat loss in Btu/hr

printf("The film coefficient for free convetion for the heated plate is %.2f Btu/hr-ft^2-degF",h);
printf("\n The heat loss by natural convection from the square plate is %.2f Btu/hr",q);
```

Scilab code Exa 7.3 Heat transfer from horizontal cylinders

```
clc();
clear;
// To calculate heat loss by natural convection in a horizontal nominal steam pipe

D=0.375;                                    // Outer diameter in ft
T1=200;                                     // Pipe surface temperature in degF
T2=70;                                      // Air temperature in degF
Tf=(T1+T2)/2;                               // Film temperature at whih physical properties is to be measured
delT=T1-T2;
rho=0.0667/32.2;                            // Density in slug/ft^3
u=0.0482/32.2;                              // Viscosity in slug/ft-hr
b=1/(460+T2 );
```

```
Cp=0.241*32.2;                          // Heat capacity in Btu/slug-ft
// The value of specific heat is related to 1 lb mass so it must be multiplied to 32.2 to convert it into slugs
k=0.0164;                               // Thermal conductivity in Btu/hr-ft-degF
g=32.2*3600;
// Unit of time used is hour so it must be converted to sec. Hence 3600 is multiplied
Ngr=D^3*rho^2*b*g*delT/(u^3);           // Grasshops number
Npr=u*Cp/k;                             // Prandtls number
A=log(Ngr*Npr);

// Tha value of A is 6.866
// Now seeing the value of nusselt number from the table

Nnu=25.2;                               // Nusselt number
h=Nnu*k/D;                              // Heat transfer coefficient
q=h*delT;                               // Heat loss per unit area in Btu/hr

printf("Heat loss per unit square foot is %d Btu/hr-ft^2",q);
```

Scilab code Exa 7.4 Heat transfer from horizontal cylinders

```
clc();
clear;

```

```
// To find the film coefficient for natural convetion for a heated square plate

tp=200;                                              // Temperature of heated plate in degF
ta=70;                                               // Temperature of air in degF
tf=(tp+ta)/2;                                        // Temperature of film in degF
delt=tp-ta;                                          // Temperature difference in degF
Z=910000;                                            // As referred from the chart for corresponding temperature
D=4.5/12;                                            // Diameter of pipe in ft
X=D^3*(delt)*Z;
// This value lies between X=1000 to X=10^9 , so formula for heat transfer coefficient is as follow

h=0.27*(delt/D)^(1/4);                                // Temperature coeeficient in Btu/hr-ft^2-degF
q=h*delt;                                             // Heat loss in Btu/hr

printf("The film coefficient for free convetion for the heated plate is %.2f Btu/hr-ft^2-degF",h);
printf("\n The heat loss by natural convection from the square plateis %d Btu/hr",q);
```

Chapter 8

Heat transfer by forced convection

Scilab code Exa 8.1 Heating of fluids in turbulent flow

```
clc();
clear;

// To calculate the average film coefficient of heat
    transfer

D=0.0752;                                    // Outer
   diameter in ft
T1=61.4;                                     // Pipe
   surface temperature in degF
T2=69.9;                                     // Air
   temperature in degF
Tf=(T1+T2)/2;                                // Film
   temperature at whih physical properties is to be
   measured
delT=T1-T2;
rho=1.94;                                    // Density
   in slug/ft^3 , 62.3/32.2
u=0.0780;                                    // viscosity
```

```
    in slug/ft-hr , 2.51/32.2
Cp=1*32.2;                                  // heat
    capacity in Btu/slug-ft
k=0.340;                                    // thermal
    conductivity in Btu/hr-ft-degF
v=7*3600;                                   // velocity
    in ft/sec

Nre=D*v*rho/u;                              // Reynolds
    number
Npr=u*Cp/k;                                 // Prandtls
    number
Nnu=0.023*Nre^.8*Npr^.4;
h=Nnu*k/D;                                  // heat
    transfer coefficient
printf("The average film coefficient of heat
    transfer is %.d Btu/hr-ft^2-degF",h);
```

Scilab code Exa 8.3 The heating of fluids flowing normal to tubes

```
clc();
clear;

// To calculate heat transfer coeeficient fir air
    flowing over a pipe

D=1/12;                                       // Inner
    diameter of pipe in ft
k=0.0174;                                     //
    Thermal conductivity in btu/hr-ft-degF
Nre=8000;                                     //
    Reynolds number

// From table we can find out nusselt number
Nnu=0.3*Nre^0.57;                              //
```

```
    Nusselt number
h=round(Nnu)*k/D;                          // Heat transfer coefficient in btu/hr-ft^2-degF

printf("heat transfer coefficient for air flowing is %.1f Btu/hr-ft^2-degF",h);
```

Chapter 9

Heat transfer by the combined effect of conduction and convection

Scilab code Exa 9.1 Heat transfer from a rod

```
clc();
clear;

// To find the temperature at the free end is made
   of copper iron and glass

D = 3/48;                                          // diameter
    in ft
L = 9/12;                                          // Length
   of steam vessel in ft
T1 = 210;                                          // Vessel
   temperature in degF
T2 = 80;                                           // Air
   temperature in degF
th0 = T1-T2;                                       //
   Temperature difference in degF
h = 1.44;                                          // Assumed
```

```
    heat coefficient in Btu/hr-ft^2-degF
C = %pi*D;                                      //
    Circumference of vessel in ft
A = %pi*D*D/4;                                  // Area of
    vessel in ft^2

// For copper
k1 = 219;                                       // Heat
    conductivity of copper in Btu/hr-ft-degF
m1 = sqrt(h*C/(k1*A));                          // in  /ft
th1 = th0*2/(exp(m1*L)+exp(-m1*L));
Tl1 = round(th1+T2);                            // The
    temperaure at the free end in degF
printf("Temperature at free end of the copper rod is
    %d degF \n",Tl1);

// For iron
k2 = 36;                                        // heat
    conductivity of copper in Btu/hr-ft-degF
m2 = sqrt(h*C/(k2*A));                          // in  /ft
th2 = th0*2/(exp(m2*L)+exp(-m2*L));
Tl2 = th2+T2;                                   // The
    temperaure at the free end in degF
printf(" Temperature at free end of the iron rod is
    %.2f degF \n",Tl2);

// For glass
k3 = 0.64;                                       // Heat
    conductivity of copper in Btu/hr-ft-degF
m3 = sqrt(h*C/(k3*A));                           // in  /ft
th3 = th0*2/(exp(m3*L)+exp(-m3*L));
Tl3 = th3+T2;                                    // The
    temperaure at the free end in degF
printf(" Temperature at free end of the glass rod is
    %.2f degF \n",Tl3);
```

Scilab code Exa 9.2 Heat transfer from a rod

```
clc();
clear;

// To find the temperature at the free end is made of copper iron and glass

D = 3/48;                                        // diameter in ft
L = 9/12;                                        // Length of steam vessel in ft
T1 = 210;                                        // Vessel temperature in degF
T2 = 80;                                         // Air temperature in degF
th0 = T1-T2;                                     // Temperature difference in degF
h = 1.44;                                        // Assumed heat coefficient in Btu/hr-ft^2-degF
C = %pi*D;                                       // Circumference of vessel in ft
A = %pi*D*D/4;                                   // Area of vessel in ft^2

k = 36;                                          // heat conductivity of copper in Btu/hr-ft-degF
m = sqrt(h*C/(k*A));                             // in  /ft
q=k*A*m*th0*(exp(m*L)-exp(-m*L))/(exp(m*L)+exp(-m*L));
// Heat loss by iron rod in Btu/hr
printf("The rate of heat loss by iron rod is %.d Btu/hr",q);
```

Scilab code Exa 9.3 Heat transmision through a plane wall

```
clc();
clear;

// To calculate the heat transfer coefficient

x = 3/96;                                    // Thickness of plate  in ft
k = 220;                                     // thermal conductivity in Btu/hr-ft-degF
h1 = 480;                                    // Inner film coefficient in Btu/hr-ft^2-degF
h2 = 1250;                                   // Outer film coefficient in Btu/hr-ft^2-degF
U = 1/((1/h1)+(x/k)+(1/h2));                 // Overall heat transer coeeficient in Btu-hr-ft^2-degF
printf("Overall heat transfer coefficient is %d Btu/hr-ft^2-degF",U);
```

Scilab code Exa 9.4 Heat transfer through a cylinder wall

```
clc();
clear;

// To calculate the overall heat transfer coefficient

r2 = 3/96;                                   // Outer radius in ft
x = 0.1/12;                                  // Thickness of plate  in ft
```

```
r1 = r2-x;                                        // Outer radius in ft
k = 200;                                          // thermal conductivity in Btu/hr-ft-degF
h1 = 280;                                         // Inner film coefficient in Btu/hr-ft^2-degF
h2 = 2000;                                        // Outer film coefficient in Btu/hr-ft^2-degF
U = 1/((r2/(h1*r1))+(r2*log(r2/r1)/k)+(1/h2));            // Overall heat transer coeeficient in Btu-hr-ft^2-degF
printf("Overall heat transfer coefficient is %d Btu/hr-ft^2-degF",U);
```

Scilab code Exa 9.5 LMTD

```
clc();
clear;

// To calculate LMTD for heat exchanger

Tc1 = 120;                                              // Inlet cold fluid temperature in degF
Tc2 = 310;                                              // Outlet cold fluid temperature in degF
Th1 = 500;                                              // Inlet hot fluid temperature in degF
Th2 = 400;                                              // Outlet hot fluid temperature in degF
delt1 = Th2-Tc1;                                        // Maximum temperature difference in degF
delt2 = Th1-Tc2;                                        // Minimum temperature difference in degF
LMTD = (delt1-delt2)/log(delt1/delt2);                  // Log mean temperature difference
```

```
printf("The log mean temperature difference is %d
   degF",LMTD)
```

Scilab code Exa 9.6 LMTD through graphs

```
clc();
clear;

// To calculate temperature difference for heat
   exchanger

Tc1 = 120;                                    // Inlet
    cold fluid temperature in degF
Tc2 = 310;                                    //
   Outlet cold fluid temperature in degF
Th1 = 500;                                    // Inlet
    hot fluid temperature in degF
Th2 = 400;                                    //
   Outlet hot fluid temperature in degF
K = (Tc2-Tc1)/(Th2-Tc2);                      //
   Temperature ratio
R = (Th1-Th2)/(Tc2-Tc1);                      //
   Temperature ratio
delt1 = Th2-Tc1;                              //
   Maximum temperature difference in degF
delt2 = Th1-Tc2;                              //
   Minimum temperature difference in degF
LMTD = (delt1-delt2)/log(delt1/delt2);        // Log
   mean temperature difference
f = 0.99;                                     //
   Correction factor as seen from figure
LMTDc = round(LMTD*f);                        //
   Corrected log mean temperature difference
printf("Log mean temperature difference is %d degF",
   LMTDc);
```

Scilab code Exa 9.7 Calculation for heat exchanger design

```
clc();
clear;
// To calculate the outside tube area for a single-
    pass steam condenser

Do=1/12;                                     // Outside
    diameter of the condenser in ft
Di=0.902/12;                                 // Outside
    diameter of the condenser in ft
Ts=81.7;                                     // Steam
    temperature in degF
Tw1=61.4;                                    // Water
    inlet temperature in degF
Tw2=69.9;                                    // Water
    outlet temperature in degF
k=63;                                        // Thermal
    conductivity in Btu/hr-ft-degF
v=7;                                         // average
    velocity in ft/sec
h1=1270;                                     // water side
     film coefficient i Btu/hr-ft^2-degF
h2=1000;                                     // Steam side
     film coefficient in Btu/hr-ft^2-degF

U=1/((Do/(Di*h1))+(Do*log(Do/Di)/(2*k))+(1/h2));
        // Heat transfer coefficient
LMTD=((Ts-Tw1)-(Ts-Tw2))/log((Ts-Tw1)/(Ts-Tw2));
    // Log mean temperature diff.
m=731300;
    // Saturated steam to be handled in lb/hr
L=1097.4-49.7;
    // Change in enthalpy in Btu/lb
```

```
q=m*L;                                          // Heat required in Btu/hr
A=q/(U*LMTD);                                   // Area of condenser in ft^2
printf("The area of steam condenser is %d ft^2",A);
```

Scilab code Exa 9.8 Heat exchanger design

```
clc();
clear;

// To calculate overall heat transfer coefficient for heat exchanger

Tc1 = 139.7;                    // Inlet cold fluid temperature in degF
Tc2 = 59.5;                     // Outlet cold fluid temperature in degF
Th1 = 108.7;                    // Inlet hot fluid temperature in degF
Th2 = 97.2;                     // Outlet hot fluid temperature in degF
delt1 = Tc1-Th2;                // Maximum temperature difference in degF
delt2 = Th1-Tc2;                // Minimum temperature difference in degF
LMTD = round((delt1-delt2)/log(delt1/delt2));
printf(" \n The log mean temperature difference is %d degF",LMTD);

m = 18210;                      // Flow rate through tubes
q = m*(Th2-Tc2);                // Heat loss in Btu/hr
A = 48.1;                       // Area in
```

```
ft^2
U = q/(A*LMTD);                          // Overall heat transfer coefficient
printf(" \n The overall heat transfer coefficient is %d Btu/hr-ft^2-degF \n",U);


// To calcalute using equations estabilished by correlation
Ts = 113;                                // Average tube temperature in degF
Tf = (123.9+Ts)/2;                       // Film temperature in degF
// At this temperature thermal properties are considered
p1 = 61.7/32.2;                               // Density in slug/ft^3
u1 = 1.38/32.2;                               // Viscosity in slug/ft-hr
Cp1 = 1*32.2;                                 // Btu/slug/ft
k1 = 0.366;                                   // Thermal conductivity in Btu/hr-ft-degF
D1 = 0.375/12;                                // Diameter in ft
v1 = 7610;                                    // Velocity in ft/sec
Nre1 = v1*D1*p1/u1;                           // Reynolds number
Npr1 = u1*Cp1/k1;                             // Prandtls number
Nnu1 = 0.33*Nre1^0.6*Npr1^(1/3);              // Nusselt number
h1 = Nnu1*k1/D1;                              // Heat transfer coefficient
printf(" \n The outer heat transfer coefficient is %d Btu/hr-ft^2-degF ",h1);

```

```
// Taking the thermal properties at 78.3 degF
p2 = 62.2/32.2;                                   // Density in slug/ft^3
u2 = 2.13/32.2;                                   // Viscosity in slug/ft-hr
Cp2 = 1*32.2;                                     // Heat capacity in Btu/slug/ft
k2 = 0.348;                                       // Thermal conductivity in Btu/hr-ft-degF
D2 = 0.277/12;                                    // Diameter in ft
v2 = 7140;                                        // Velocity in ft/sec
Nre2 = v2*D2*p2/u2;                               // Reynolds number
Npr2 = u2*Cp2/k2;                                 // Prandtls number
Nnu2 = 0.023*Nre2^0.8*Npr2^(0.4);                 // Nusselt number
h2 = Nnu2*k2/D2;                                  // Heat transfer coefficient
printf(" \n The inner heat transfer coefficient is %d Btu/hr-ft^2-degF",h2);

k3 = 58;
U1 = 1/((D1/(D2*h2))+(D1*log(D1/D2)/(2*k3))+(1/h1));      // Heat transfer coefficient
printf(" \n The overall heat transfer coefficient accordind to estabilished correlation  is %d Btu/hr-ft^2-degF \n",U1);
```

Scilab code Exa 9.9 Heat exchanger effectiveness ratio

```
clc();
clear;
```

```

// To determine the value of product of overall heat transfer and the total area

To1=140;                                    // inlet temperature of oil in degF
To2=90;                                     // Outlet temperature of oil in degf
Cpo=0.5;                                    // Specific heat capacity in Btu/lb-degf
Tw1=60;                                     // Inlet tempeartture of water in degF
Tw2=80;                                     // Outlet temperature of water in degF
mo=2000;                                    // Mass flow rate of oil in lb/hr
q=mo*Cpo*(To1-To2);                         // Heat transferred in Btu/hr
Cpw=1;                                      // Heat capacity of water in Btu/hr
mw=q/(Cpw*(Tw2-Tw1));                       // Mass flow rate in lb/hr
E1=(Tw1-Tw2)/(Tw1-To2);                     // Effective ratio

// Seeing the effective ratio and mass flow rate ratio, from the graph we get UA
UA=1.15*mo*Cpo;
printf("The product of overall heat transfer and total area is %d Btu/hr-degF",UA);
```

Scilab code Exa 9.9b Heat transfer from wall in contact with a medium

```
clc();
clear;
```

```

// To calculate the temperature of surface and centre plane

t=2;                                    // Thickness of wall in ft
To=100;                                 // Initial temperature of wall in degF
Tg=1000;                                // Temperature of hot gases exposed in degF
k=8;                                    // Thermal conductivity in Btu/hr-ft-degF
p=162;                                  // density in lb/ft^-3
Cp=0.3;                                 // Heat capacity in Btu/lb-degF
h=1.6;                                  // Heat transfer coefficient in Btu/hr-ft^-2-degF
a=k/(p*Cp);                             // Thermal diffusivity

// Considering the values of a and 4at/L^2 and hl/2k , the value of Phis, Phic and Si can be obtained
Phis=0.37;
Phic=0.41;
Si=0.62;

Ta=Tg+(To-Tg)*Phis;                     // Temperature of surface in degF
printf("The temperature of surface is %d degF \n ",Ta);
Tc=Tg+(To-Tg)*Phic;                     // Temperature of center plane in degF
printf("The temperature of surface is %d degF \n ",Tc);
A=10;                                    // area of wall through which heat is absorbed
q=p*Cp*t*A*Si*(To-Tg);                   // Heat
```

```
absorbed in Btu/hr
printf("The heat absorbed by wall is %d Btu",q);
```

Scilab code Exa 9.10 Heat exchanger effectiveness ratio

```
clc();
clear;

// To calculate the terminal temperature of oil and water

To1=160;                          // inlet temperature of oil in degF
Cpo=0.5;                          // Specific heat capacity in Btu/lb-degf
Tw1=60;                           // Inlet temperature of water in degF
mo=1000;                          // Mass flow rate of oil in lb/hr
mw=2500;                          // Mass flow rate of water in lb/hr
Cpw=1;                            // Heat capacity of water in Btu/hr
X=mo*Cpo/(mw*Cpw);                // Ratio of flow rates
UA=1.15*mo*Cpo;
B=UA/mo*Cpo;

// from the graph, we can locate the point of A and B And corresponding effectiveness ratio
E=0.86;                           // Effectiveness ratio
To2=To1-E*(To1-Tw1);              // Outlet temperature of oil in degF
printf("The outlet temperature of oil is %d degF \n"
```

```
,To2);

q=mo*Cpo*(To1-To2);                              // Heat transferred in Btu/hr
Tw2=Tw1+(q/(mw*Cpw));                            // Outlet temperature of oil in degF
printf(" The outlet tempearture of water is %.1f degF",Tw2);
```

Scilab code Exa 9.11 Combined conduction and convection

```
clc();
clear;

// To compute the temprature distribution
h=1;                                             // Heat transfer coefficient in Btu/hr-ft^2-degF
x=1;                                             // Assumed thickness in ft
k=1;                                             // Thermal conductivity in Btu/hr-ft-degF
N=h*x/k;
t0=600;
t4=200;
t1=[500 550 550 525 525 512.5 512.5 512.5 506.2 506.2 506.2 506.2 503.1 503.1];
t2=[450 450 450 450 425 425 425 412.5 412.5 412.5 406.3 406.3 406.3 403.1];
t3=[350 350 325 325 325 325 312.5 312.5 312.5 306.3 306.3 303.1 303.1 303.1];

// Assumed temperatures in degF for points 1 2 & 3 respectively
for i=1:14
th1(i)=t0+t2(i)-2*t1(i);
```

```
th2(i)=t1(i)+t3(i)-2*t2(i);
th3(i)=t2(i)+t4-2*t3(i);
printf("Assuming t1=%.1f degF  t2=%.1fdegF  t3=%.1fdegF \n th1=%.1fdegF  th2=%.1fdegF  th3=%.1fdegF \n \n",t1(i),t2(i),t3(i),th1(i),th2(i),th3(i));
end
printf("This way assumption must be continued till all sink strengths are zero");
```

Chapter 10

Heat transfer in condensing and boiling

Scilab code Exa 10.1 Condensation

```
clc();
clear;

// To determne the heat transfer coefficient for steam
y=1.9;                                          // Density in slug/ft^-2
u=0.0354;                                       // Viscosity in slug/ft-hr
k=0.376;                                        // Thermal conductivity in Btu/hr-ft-degF
l=32600;                                        // Heat of condensation in Btu/slug
Tg=142;                                         // Temperature of steam in degF
Tw=138;                                         // Temperature of wall in degF
delT=Tg-Tw;                                     // Temperature driving force in degF
```

```
g=418*10^6;                                    //
   Gravity in ft/sec^2
L=1/12;                                        //
   Outside diameter of horizontal tube in ft
C=0.725;                                       // For
   horizontal tube
h=C*(g*y^2*l*k^3/(L*u*delT))^0.25;             // Heat
   transfer coefficient in Btu/hr-ft^2-degF
printf("The heat transfer coefficient for steam
   condensing on a horizontal tube is %d Btu/hr-ft
   ^2-degF",h);
```

Chapter 11

Heat transfer by radiation

Scilab code Exa 11.1 Heat excahnge between black planes

```
clc();
clear;

// To calculate the net radiant interchange between two parallel black planes

T1=1660/100;                                        // Temperature of first black plane in degR
T2=1260/100;                                        // Temperature of second black plane in degR
s=0.174;                                            // Stephan Boltzman's constant
q=s*(T1^4-T2^4);
printf("The net radiant interchange between two bodies of unit area is %d Btu/hr-ft^2",q);
```

Scilab code Exa 11.2 Heat exchange between floor and roof

```
clc()
// To calculate the net radiant interchange between floor and roof of a furnace


A1=15*15;                                           // Area of floor in ft^2
A2=A1;                                              // Area of roof in ft^2
T1=2460/100;                                        // Temperature of floor in degR
T2=1060/100;                                        // temperature of roof in degR
s=0.174;                                            // Stephan Boltzman's constant
// S/L=1.5, So considering graph F12=0.31

F12=0.31;
q=s*F12*A1*(T1^4-T2^4);
printf("The net radiant interchange between two bodies of unit area is %d Btu/hr-ft^2",q);
```

Scilab code Exa 11.3 Heat exchange between perpendicular surfaces

```
clc()
// To calculate he net radiant interchange between floor of a furnace and the wall

x=6;                                                // length of wall in ft
y=12;                                               // breadth of wall in ft
z=18;                                               // height of wall in ft
A1=x*y;
```

```
s=0.174;                                    // Stephan Boltzman's constant
T1=1000;                                    // Temperature of floor in degF
T2=500;                                     // Temperature of wall in degF
Y=y/x;                                      // Ratios
Z=z/x;

// Seeing the graph, F12 could be found out
F12=0.165;
q12=s*F12*A1*((((T1+460)/100)^4)-((T2+460)/100)^4);   // Radiant interchange
printf("The net radiant interchange between two bodies of unit area is %d Btu/hr-ft^2",q12);
```

Scilab code Exa 11.4 Heat exchange between irradiating surfaces

```
clc();
clear;
// To calculate the radiant interchange between two black discs

D=10/12;                                      // Diameter of black disc
L=5/12;                                       // Distance between two discs
T1=(1500+460)/100;                            // Temperature of disc 1 in degR
T2=(1000+460)/100;                            // Temperature of disc 2 in degR
// From the ratio of S/L, the value of F1r2 can be found out
F1r2=0.669;                                   // Shape factor
```

```
A1=%pi*D*D/4;                                   // Area of disc 1 in ft^2
A2=%pi*D*D/4;                                   // Area of disc 2 in ft^2
s=0.174;                                        // Stephan Boltzman's constant
q12=s*F1r2*A1*((T1^4)-(T2^4));                  // Radiant interchange in Btu/hr
printf("The net radiant interchange between two parallel black discs is %d Btu/hr",q12);
```

Scilab code Exa 11.5 heat excange between large planes of different emissivity

```
clc();
clear;
// To calculate the net radiant interchange between two parallel black discs

T1=(1500+460)/100;                              // Temperature of plane 1 in degR
T2=(1000+460)/100;                              // Temperature of plane 2 in degR
e1=0.8;                                         // Emmisivity for higher temperature
e2=0.6;                                         // Emmisivity for lower temperature
s=0.174;                                        // Stephan Boltzman's constant
D=10/12;                                        // Diameter of disc in ft
A=%pi/4*D^2;                                    // Area of disc in ft^2
F1r2=0.669;
F1r2g=1/((1/F1r2)+(1/e1)+(1/e2)-2);             // Shape
```

```
factor
q12=s*F1r2g*A*((T1^4)-(T2^4));             // Radiant interchange in Btu/hr
printf("The net radiant interchange between two parallel very large planes per square foot is %d Btu/hr",q12);
```

Scilab code Exa 11.6 Heat exchange between two non black bodies

```
clc();
clear;

// To calculate the net radiant interchange between two parallel planes

T1=1460/100;                               // Temperature of first black plane in degK
T2=1060/100;                               // temperature of second black plane in degK
s=0.174;                                   // Stephan Boltzman's constant
e1=0.9;                                    // Emmisivity for higher temperature
e2=0.7;                                    // Emmisivity for higher temperature
F1r2=1/((1/e1)+(1/e2)-1);                  // Shape factor

q=s*F1r2*(T1^4-T2^4);
printf("The net radiant interchange between two bodies of unit area is %d Btu/hr-ft^2",q);
```

Scilab code Exa 11.7 Heat exchange in an enclosure

```
clc();
clear;

// To calculate the net radiant interchange per foot
    length of pipe of 2 in. standard diameter

e=0.8;                                          //
   emmisivity of pipe metal
D=2.375/12;                                     // Diameter
    of pipe in ft
s=0.174;                                        // Stephans
    Boltzman's constant
T1=(300+460)/100;                               //
   Temperature of disc 1 in degF
T2=(80+460)/100;                                //
   Temperature of disc 2 in degF
A1=%pi*D;                                       // Area of
   one foot of pipe in ft^2
q12=s*e*A1*((T1^4)-(T2^4));                     // Radiant
   interchange in Btu/hr
printf("The net radiant interchange per foot length
   of pipe is %.1f Btu/hr-ft",q12);
```

Chapter 12

Heat transfer by the combined effect of conduction convection and radiation

Scilab code Exa 12.1 Heat losses from insulated horizontal table

```
clc();
clear;

// To calculate the heat loss per linear foot from a 4-in. (out-side diameter=4.5 in.) nominal horizontal steel pipe covered with 1 in.of insulation

D=4.5/12;                                    // Outer diameter of pipe in ft
D2=6.5/12;                                   // Outer diameter of insulation in ft
k=0.035;                                     // Thermal conductivity in Btu/hr-ft-degF
T1=400;                                      // Temperature of pipe in degF
T3=70;                                       //
```

```
    Temperature of air in degF
T2=120;                                        //
    Assumed temperature in degF
h=2*k*(T1-T2)/(D2*(T2-T3)*log(D2/D));          // Sum
     of coefficient of convection and radiation
delT=T2-T3;                                    //
    Temperature differnce in degF
T2=120;                                        //
    Assumed temperature in degF
printf("The assumption of T2=120 comes out to be
    satisfactory and hc+hr=%.1f \n ",h);
q=h*%pi*D2*delT;                               //
    Heat loss in Btu/hr
printf("The heat loss per unit foot of pipe is %d
    Btu/hr-ft",q);
```

Scilab code Exa 12.2 Heat loss from bare tubes

```
clc();
clear;

// To calculate the heat loss per square foot from
    an uninsulated 2 inch sch. pipe

D=2.375/12;                                      //
    Outer diameter of pipe in ft
k=0.035;                                       //
    Thermal conductivity in Btu/hr-ft-degF
T1=400;                                        //
    Temperature of pipe in degF
T2=70;                                         //
    Temperature of air in degF
delT=T1-T2;                                    //
    Temperature differnce in degF
T2=120;                                        //
```

```
                                                    //
    Assumed temperature in degF
h=3.67;
// As seen from the table , for delT=330. the value
    of hc+hr=3.67
q=h*delT;                                           //
    Heat loss in Btu/hr
printf("The heat loss per square foot of pipe is %d
    Btu/hr-ft",q);
```

Chapter 14

Heat transfer in temperature measurements

Scilab code Exa 14.1 Influence of convection and radiation

```
clc();
clear;

// To calculate the true gas temperature

D1=36/12;                                   // diameter of circular duct in ft
D2=5/96;                                    // diameter of tube in ft
T1=800;                                     // Temperature of tube in degF
To=500;                                     // Temperature of duct in degF
k=0.02;                                     // Thermal conductivity in lb/ft^-2-hr
u=0.18*(10^-9)*(3600^2);                    // Viscosity in slug/ft-hr
p=0.04/32.2;                                // Density in slug/ft^3
```

```
n=u/p;                                          // Kinematic viscosity in ft^2/hr
v=15*3600;                                      // Velocity in ft/hr
e=0.8;                                          // Emmisivity
Nre=v*D2/n;                                     // Reynolds number
Nnu=0.3*(Nre^0.57);                             // Nusselt number
h=Nnu*k/D2;                                     // Heat transfer coefficient
Tg=Tl+0.174*e*((((Tl+460)/100)^4)-((To+460)/100)^4)/h;    // Gas temperature in degF
printf("The temperature of gas is %d degF",Tg);
```

Chapter 15

Heat transfer and fluid friction

Scilab code Exa 15.1 Reynolds Analogy

```
clc();
clear;

// To calculate the pressure drop , heat loss per
   hour and fil coefficient of heat transfer

Tm=70;                                          // Average
    air temperature in degF
Tw=60;                                          // Pipe
   wall temperature in degF
thm=Tm-Tw;                                      // Mean
   temperature difference in degF
// Thm is so small that the fluid properties may be
   based on 70 degF

v=30;                                           //
   Velocity in ft/sec
L=1000;                                         // Length
   of pipe
D=3/12;                                         //
   Diameter in ft
```

```
y=0.15;                                    // Specific weight in  lb/ft^3
p=0.15/32.2;                               // Density in slug/ft^3
u=0.00137;                                 // Viscosity in slug/ft/hr
Nre=v*3600*D*p/u;                              // Reynolds number
f=0.08/(Nre)^.25;                          // Nusselt number
delp=2*f*L*p*(v^2)/D;                      // Pressure drop in lb/sq.in
printf("The pressure drop is %d lb/sq.ft \n ",delp);


cp=0.24*32.2;                              // Specific heat capacity in slug/degF
Cp=0.24*0.15;                              // Heat capacity in Btu/ft^3-degF
k=0.0148;                                  // Thermal conductivity in Btu/ft-hr-degF
Npr=u*cp/k;                                // Prandtls number
phi=sqrt(Npr)/(1+(750*sqrt(Npr)/Nre)+7.5*(Npr^0.25)/sqrt(Nre));
A=%pi*L*D;                                 // Area in ft^2
q=phi*f*Cp*A*v*thm*3600/(2*Npr);           // Heat loss in Btu/hr
printf("Heat loss per hour of air is %f Btu/hr \n ",phi);
h=q/(A*thm);                              // Film coefficient
printf("The film coefficient of heat transfer on the inner pipe wall is %.1f Btu/hr-ft^2-degF",h);
```

Chapter 16

Mass transfer

Scilab code Exa 16.1 Diffusion coefficient

```
clc();
clear;

// To compute the diffusion coeffiient for water
   vapour in air

T=25+273;                            // Temperature in
   degK
p=1;                                 // Pressure in atm
Va=18.9;                             // Molecular volume
    of water vapour in cm^3/gm-mol
Vb=29.9;                             // Molecular volume
    of air in cm^3/gm-mol
Ma=18;                               // Molecular weight
    of water vapour in gm/mol
Mb=29;                               // Molecular weight
    of air in gm/mol
Dab=0.0043*(T^1.5)*sqrt((1/Ma)+(1/Mb))/(p*(Va^(1/3)+
   Vb^(1/3))^2);
printf("The diffusion coefficient is %.3f cm^3/sec "
   ,Dab);
```

Scilab code Exa 16.2 Diffusion coefficient

```
clc();
clear;

// To compute the diffusion coeffiient for benzene in air

T=25+273;                                // Temperature in degK
p=1;                                     // Pressure in atm
Va=96;                                   // Molecular volume of benzene in cm^3/gm-mol
Vb=29.9;                                 // Molecular volume of air in cm^3/gm-mol
Ma=78;                                   // Molecular weight of benzene in gm/mol
Mb=29;                                   // Molecular weight of air in gm/mol
Dab=0.0043*(T^1.5)*sqrt((1/Ma)+(1/Mb))/(p*(Va^(1/3)+Vb^(1/3))^2);
printf("The diffusion coefficient is %.3f cm^3/sec ",Dab);
```

Scilab code Exa 12.3 Diffusion of one gas into another stagnant gas

```
clc();
clear;

// To compute the ammonia diffusing through the stagnant air
```

```

x=0.1/12;                                   // thickness of still air layer in ft
T=77+460;                                   // temperature in degR
p=1;                                        // Atmospheric pressure in atm
pa1=0.3;                                    // Pressure of ammonia in still air in atm
pb1=p-pa1;                                  // pressure of air in atm
pa2=0;                                      // pressure of ammonia in the absorption plane
pb2=p-pa2;                                  // pressure of air in absorption plane
pbm=(pb2-pb1)/(log(pb2/pb1));               // Logarithmic mean pressure
D=0.914;                                    // Diffusion coefficient for ammonia
R=0.729;                                    // Gas constant in ft^3-atm/lb-mole-degR
N=D*p*(pa1-pa2)/(R*T*x*pbm);
printf("The amount of ammonia diffusing through the stagnant air is %.1f lb-mol/hr-ft^2",N);
```

Scilab code Exa 16.4 Mass transfer coefficient

```
clc();
clear;

// To compute the hydrogen loss per unit pipe by diffusion

ri=3/96;                                   // Inner radius of pipe in ft
```

```
ro=1/24;                              // Outer radius of pipe in ft
Ca1=0.0003;                           // Concentration at the inner hose of pipe in lb-mol/ft^2
Ca2=0;                                // Concentration at the outer surface
D=0.7*10^-5;                          // Diffusion coefficient of hydrogen in rubber in ft^2/hr
N=2*%pi*D*(Ca1-Ca2)/log(ro/ri);       // Rate of diffusion in lb-mol/hr
printf("The rate of diffusion iof hydrogen in rubber is %.2f*10^-8 lb-mole/hr",N*10^8);
```

Scilab code Exa 16.5 Air over water surface

```
clc();
clear;

// To calculate the amount of water evaporated per hour per square foot of surface area

u=0.0437;                                 // Viscosity in lb/hr-ft
rho=0.077;                                // Density in lb-ft^2
D=0.992;                                  // Diameter of pipe in ft
v=4*3600;                                 // Velocity in ft/sec
L=6/12;                                   // Length of pipe parallel to direction of air flow in ft
p=14.7;                                   // Atmospheric pressure in psi
T=460+65;                                 // Temperature in degR
```

```

// Heat transfer equation for laminar flow of a flat surface
Nre=L*v*rho/u;                              // Reynolds number
Ns=u/(rho*D);                               // Schimdt mumber
Nnu=0.662*(Ns)^(1/3)*sqrt(Nre);             // Nusselt number
hmc=Nnu*D/L;                                // Heat transfer coefficient
pv1=0.144;                                  // Vapour pressure at 40% humidity
pv2=0.252;                                  // Vapour pressure at saturation
pa1=p-pv1;                                  // Absolute pressure of air at 40% rel. humidity in psi
pa2=p-pv2;                                  // Absolute pressure of saturated air in psi
pbm=(pa1+pa2)/2;                            // Log mean pressure in psi
R=1544;                                     // Universal gas constant in ft^3-psi/lbmol-degR
N=hmc*p*(pa1-pa2)*144/(R*T*pbm);
printf("The amount of water evaporated per hour is %.4f lb mol/hr-ft^2",N);
```

Scilab code Exa 16.6 Air flowing over water surface

```
clc();
clear;

// To estimate the amount of water transferred

u=0.047;                                    // Viscosity
```

```
in lb/hr-ft
rho=0.069;                                   // Density in lb-ft^2
D=0.992;                                     // Diameter of pipe in ft
v=7.5*3600;                                  // Velocity in ft/sec
L=2;                                         // Length of pipe parallel to direction of air flow in ft
M=0.992;                                     // Molecular weight
p=14.696;                                    // Atmospheric pressure in psi
T=460+65;                                    // Temperature in degR
M=29;                                        // molecular weight of air
M2=18;                                       // Molecular weight of water vapour
A=4;                                         // Area of water surface in ft^2
// Heat transfer equation for laminar flow of a flat surface
Nre=L*v*rho/u;                               // Reynolds number

// Assuming the case that of a fluid flowing parallel to a flat plate , jm=0.0039
jm=0.0039;
Ns=u/(rho*D);                                // Schimdt mumber
Gm=v*rho/M;                                  // Mole flow rate
pv1=0.672;                                   // Vapour pressure at 40% humidity
pv2=0.600;                                   // Vapour pressure at saturation
pa1=p-pv1;                                   // Absolute
```

```
pressure of air at 40% rel. humidity in psi
pa2=p-pv2;                                  // Absolute pressure of saturated air in psi
pbm=(pa1+pa2)/2;                            // Log mean pressure in psi
hmp=jm*Gm/(pbm*144*Ns^(2/3));               // Heat transfer coefficient in lbmol/ft^2-hr-psi
N=hmp*(pv1-pv2)*144;                        // Mass transfer rate in lb mol/hr-ft^2
W=N*A*M2;
printf("The amount of water evaporated per hour is %.3f lb mol/hr-ft^2",W);
```

Scilab code Exa 16.7 Heat and mass transfer in free convection

```
clc();
clear;

// To calculate the amount of water evaporated in per hour for a square foot of water surface

u=3.82*10^-7;                               // Viscosity in lb-sec/ft^2
rho=2.3*10^-3;                              // Density in lbsec^2/ft^4
A=1;                                        // Area in ft^2
Cp=0.24;                                    // Specific heat capacity in abtu/lbm-degF
v=4*3600;                                   // Velocity in ft/sec
k=0.015;                                    // Thermal conductivity in Btu/hr-ft-degF
p=14.7;                                     // Atmospheric pressure in psi
```

```
M=29;                                    // Avg. molecular weight of air
T1=70+460;                               // Temperature of still air in degF
T2=90+460;                               // temperature of surface of water in degF
L=1;                                     // For characteristic of 1 ft
D=0.992;                                 // Diffusivity in ft^2/sec

// Heat transfer equation for laminar flow of a flat surface
Ngr=32.2*L^3*((T2/T1)-1)/(u/rho)^2;      // Grasshops number
Npr=u*3600*Cp*32.2/k;                    //  Prandtls number
Nnu=0.75*(Ngr*Npr)^.25;                  // Nusselt number
h=Nnu*k/L;                               // Heat transfer coefficient
Ns=u*3600/(rho*D);                       // Schimdt mumber
hmc=h*D*(Ns/Npr)^0.25/k;                 // Heat transfer coe
pv1=0.18;                                // Vapour pressure at 40% humidity
pv2=0.69;                                // Vapour pressure at saturation
pa1=p-pv1;                               // Absolute pressure of air at 40% rel. humidity in psi
pa2=p-pv2;                               // Absolute pressure of saturated air in psi
pbm=(pa1+pa2)/2;                         // Log mean pressure in psi
R=1544;                                  // Universal gas constant in ft^3-psi/lbmol-degR
T=(T1+T2)/2;                             // Average
```

```
temperature in degR
N=hmc*p*(pv2-pv1)*144/(R*T*pbm)*18;     // mass transfer rate in lbmol/hr-ft^2
printf("The amount of water evaporated per hour is %.4f lb mol/hr-ft^2",N);
```

Scilab code Exa 16.8 Humidification

```
clc();
clear;

// To know the moisture content of air

Td=70+460;                                   // Dry bulb temperature in degR
Tw=60+460;                                   // Wet bulb temperature in degR
a=0.26;                                      // Ratio of coefficients ie. h/hmw from table
L=1059.9;                                    // Latent heat Btu/lbmol
p=14.7;                                      // Atmospheric pressure in psi
pa=0.259;                                    // Partial pressure of water in psi
Ma=18;                                       // Molecular weight of water vapour
Mb=29;                                       // Molecular weight of air

Wwb=pa*Ma/(Mb*(p-pa));                       // Absolte dry bulb humidity of air
Wdb=Wwb-(a*(Td-Tw)/L);                       // Absolte dry bulb humidity of air
printf("The humidity of air at dry conditions is %.5
```

```
f lbm/lbm of dry air",Wdb);
```

Scilab code Exa 16.9 Absortion over wetted surface

```
clc();
clear;

// To estimate the mass transfer coefficient

v=20;                                  // Velocity of
     air ammonia mixture in ft/sec
Npr=0.72;                              // Prandtls
   number
Ns=0.60;                               // Schimdt
   number
pbm=14.7;                              // log mean
   pressure in psi
Mm=29;                                 // Molecular
   weight of mixture
Mv=17;                                 // Molecular
   weight of ammonia
Ma=29;                                 // Molecular
   weight of air
Cp=0.24;                               // specific
   heat capacity in Btu/lbm-degF
h=8;                                   // Heat
   transfer coefficient
p=1;                                   // Atospheric
   pressure in atm

hmp=h*Mv*(Npr/Ns)^(2/3)/(Cp*p*Ma);    // Mass
   transfer coefficient based on pressure
printf("The mass transfer coefficient based on
   pressure is %.1f lbm/hr-ft^2-atm",hmp);
```