Scilab Textbook Companion for Fundamentals Of Engineering Heat And Mass Transfer
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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Basic Concepts

Scilab code Exa 1.1 `Rate of heat transfer`

```
//Chapter-1, Example 1.1, Page 9
//=============================================================================

clc
clear

//INPUT DATA
L=0.02;//Thicness of stainless steel plate in m
T=[550,50];//Temperatures at both the faces in degree C
k=19.1;//Thermal Conductivity of stainless steel at 300 degree C in W/m.K

//CALC9ULATIONS
q=((k*(T(1)-T(2)))/(L*1000));//Heat transfered per uni area in kW/m^2

//OUTPUT
mprintf('The heat transfered through the material per unit area is %3.1f kW/m^2',q)
```

```

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 1.2 `Rate of heat transfer`

```
//Chapter-1, Example 1.2, Page 11
//====================================================================================================

clc
clear

//INPUT DATA
L=1;//Length of the flat plate in m
w=0.5;//Width of the flat plate in m
T=30;//Air stream temperature in degree C
h=30;//Convective heat transfer coefficient in W/m^2.K
Ts=300;//Temperature of the plate in degree C

//CALCULATIONS
A=(L*w);//Area of the plate in m^2
Q=(h*A*(Ts-T)/(1000));//Heat transfer in kW

//OUTPUT
mprintf('Heat transfer rate is %3.2f kW',Q)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 1.3 `Rate of radiant heat`

```
//Chapter-1, Example 1.3, Page 11
//
  ==============================================================================

clc
clear

//INPUT DATA
T=55;//Surface temperature in degree C

//CALCULATIONS
q=(5.6697*10^-8*(273+T)^4)/1000;//The rate at which
   the radiator emits radiant heat per unit area if
   it behaves as a black body in kW/m^2

//OUTPUT
mprintf('The rate at which the radiator emits
   radiant heat per unit area is %3.2f kW/m^2',q)

//======================================END OF PROGRAM
  ====================================
```

Scilab code Exa 1.5 Overall heat transfer coefficient

```
//Chapter-1, Example 1.5, Page 20
//
  ==============================================================================

clc
clear

//INPUT DATA
k=0.145;//Thermal conductivity of Firebrick in W/m.K
e=0.85;//Emissivity
L=0.145;//Thickness of the wall in m
```

```
Tg=800;//Gas temperature in degree C
Twg=798;//Wall temperature ion gas side in degree C
hg=40;//Film conductance on gas side in W/m^2.K
hc=10;//Film conductance on coolant side in W/m^2.K
F=1;//Radiation Shape factor between wall and gas

//CALCULATIONS
R1=(((e*5.67*10^-8*F*((Tg+273)^4-(Twg+273)^4))/(Tg-Twg))+(1/hg));//Thermal resistance inverse
R2=(L/k);//Thermal resistance
R3=(1/hc);//Thermal resistance
U=1/((1/R1)+R2+R3);//Overall heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Overall heat transfer coefficient is %3.3f W/m^2.K',U)
```

Scilab code Exa 1.6 `Heat loss per unit length`

```
//Chapter-1, Example 1.6, Page 21
//

clc
clear

//INPUT DATA
D=0.05;//Outside diameter of the pipe in m
e=0.8;//Emmissivity
T=30;//Room Temperature in degree C
Ts=250;//Surface temperature in degree C
h=10;//Convective heat transfer coefficient in W/m^2.K

```

```
//CALCULATIONS
q=((h*3.14*D*(Ts-T))+(e*3.14*D*5.67*10^-8*((Ts+473)^4-(T+273)^4)));//Heat loss per unit length of pipe in W/m

//OUTPUT
mprintf('Heat loss per unit length of pipe is %3.1f W/m',q)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 1.7 `Surface temperature`

```
//Chapter-1, Example 1.7, Page 21
//=============================================================================

clc
clear

//INPUT DATA
A=0.1;//Surface area of water heater in m^2
Q=1000;//Heat transfer rate in W
Twater=40;//Temperature of water in degree C
h1=300;//Heat transfer coefficient in W/m^2.K
Tair=40;//Temperature of air in degree C
h2=9;//Heat transfer coefficient in W/m^2.K

//CALCULATIONS
Tsw=(Q/(h1*A))+Twater;//Temperature when used in water in degree C
Tsa=(Q/(h2*A))+Tair;//Temperature when used in air in degree C

```

```
//OUTPUT
mprintf('Temperature when used in water is %3.1f degree C \n Temperature when used in air is %i degree C',Tsw,Tsa)

//================================================END OF PROGRAM==============================================
```

Chapter 3

OneDimensional Steady State Heat Conduction

Scilab code Exa 3.1 `Rate of heat loss and interior temperature`

```
//Chapter-3, Example 3.1, Page 45
//

clc
clear

//INPUT DATA
l=5;//Length of the wall in m
h=4;//Height of the wall in m
L=0.25;//Thickness of the wall in m
T=[110,40];//Temperature on the inner and outer surface in degree C
k=0.7;//Thermal conductivity in W/m.K
x=0.20;//Distance from the inner wall in m

//CALCULATIONS
A=l*h;//Arear of the wall in m^2
Q=(k*A*(T(1)-T(2)))/L;//Heat transfer rate in W
```

```
T=(((T(2)-T(1))*x)/L)+T(1);//Temperature at interior point of the wall, 20 cm distant from the inner wall in degree C

//OUTPUT
mprintf('a)Heat transfer rate is %i W \n b) Temperature at interior point of the wall, 20 cm distant from the inner wall is %i degree C',Q,T)

//==========================================END OF PROGRAM======================================
```

Scilab code Exa 3.2 `Tempertaure and heat flow`

```
//Chapter-3, Example 3.2, Page 48
//=====================================================================================

clc
clear

Di=0.05;//Inner diameter of hollow cylinder in m
Do=0.1;//Outer diameter of hollow cylinder in m
T=[200,100];//Inner and outer surface temperature in degree C
k=70;//Thermal conductivity in W/m.K

//CALCULATIONS
ro=(Do/2);//Outer radius of hollow cylinder in m
ri=(Di/2);//Inner radius of hollow cylinder in m
Q=((2*3.14*k*(T(1)-T(2)))/(log(ro/ri)));//Heat transfer rate in W
r1=(ro+ri)/2;//Radius at halfway between ro and ri in m
T1=T(1)-((T(1)-T(2))*(log(r1/ri)/(log(ro/ri))));//
```

```
Temperature of the point halfway between the inner and outer surface in degree C

//OUTPUT
mprintf('Heat transfer rate is %3.1f W /m\n Temperature of the point halfway between the inner and outer surface is %3.1f degree C',Q,T1)

//========================================================END OF PROGRAM ================================================
```

Scilab code Exa 3.3 `Heat flow and teperature`

```
//Chapter-3, Example 3.3, Page 51
//==========================================================================================================

clc
clear

Di=0.1;//Inner diameter of hollow sphere in m
Do=0.3;//Outer diameter of hollow sphere in m
k=50;//Thermal conductivity in W/m.K
T=[300,100];//Inner and outer surface temperature in degree C

//CALCULATIONS
ro=(Do/2);//Outer radius of hollow sphere in m
ri=(Di/2);//Inner radius of hollow sphere in m
Q=((4*3.14*ro*ri*k*(T(1)-T(2)))/(ro-ri))/1000;//Heat transfer rate in W
r=ri+(0.25*(ro-ri));//The value at one-fourth way of te inner and outer surfaces in m
T=((ro*(r-ri)*(T(2)-T(1)))/(r*(ro-ri)))+T(1);//Temperature at a point a quarter of the way
```

```
between the inner and outer surfaces in degree C

//OUTPUT
mprintf('Heat flow rate through the sphere is %3.2f kW \nTemperature at a point a quarter of the way between the inner and outer surfaces is %i degree C',Q,T)

//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 3.4 `Heat loss per square meter surface area`

```
//Chapter-3, Example 3.4, Page 55
//==========================================================================================

clc
clear

//INPUT DATA
L=0.4;//Thickness of the furnace in m
T=[300,50];//Surface temperatures in degree C
//k=0.005T-5*10^-6T^2

//CALCULATIONS
q=((1/L)*(((0.005/2)*(T(1)^2-T(2)^2))-((5*10^-6*(T(1)^3-T(2)^3))/3)));//Heat loss per square meter surface area in W/m^2

//OUTPUT
mprintf('Heat loss per square meter surface area is %3.0f W/m^2',q)

//==============================================END OF PROGRAM
```

```
================================================
```

Scilab code Exa 3.5 `Rate of heat flow`

```
//Chapter-3, Example 3.5, Page 55
//==========================================================================================================

clc
clear

//INPUT DATA
L=0.2;//Thickness of the wall in m
T=[1000,200];//Surface temperatures in degree C
ko=0.813;//Value of thermal conductivity at T=0 in W/m.K
b=0.0007158;//Temperature coefficient of thermal conductivity in 1/K

//CALCULATIONS
km=ko*(1+((b*(T(1)+T(2)))/2));//Constant thermal conductivity in W/m.K
q=((km*(T(1)-T(2)))/L);//Rate of heat flow in W/m^2

//OUTPUT
mprintf('Rate of heat flow is %3.0f W/m^2',q)

//=====================================================END OF PROGRAM================================================
```

Scilab code Exa 3.6 `Heat loss per unit length`

```
//Chapter-3, Example 3.6, Page 58
```

```
//==================================================================

clc
clear

//INPUT DATA
r=[0.01,0.02];//Inner and outer radius of a copper cylinder in m
T=[310,290];//Inner and Outer surface temperature in degree C
ko=371.9;//Value of thermal conductivity at T=0 in W/m.K
b=(9.25*10^-5);//Temperature coefficient of thermal conductivity in 1/K

//CALCULATIONS
Tm=((T(1)-150)+(T(2)-150))/2;//Mean temperature in degree C
km=ko*(1-(b*Tm));//Constant thermal conductivity in W/m.K
q=((2*3.14*km*(T(1)-T(2)))/log(r(2)/r(1)))/1000;//Heat loss per unit length in kW/m

//OUTPUT
mprintf('Heat loss per unit length is %3.2f kW/m',q)
```

Scilab code Exa 3.8 `Thickness of insulation`

```
//Chapter-3, Example 3.8, Page 63
//==================================================================

clc
clear
```

```

//INPUT DATA
L1=0.5;//Thickness of the wall in m
k1=1.4;//Thermal conductivity in W/m.K
k2=0.35;//Thermal conductivity of insulating material in W/m.K
q=1450;//Heat loss per square metre in W
T=[1200,15];//Inner and outer surface temperatures in degree C

//CALCULATIONS
L2=(((T(1)-T(2))/q)-(L1/k1))*k2;;//Thickness of the insulation required in m

//OUTPUT
mprintf('Thickness of the insulation required is %3.3f m',L2)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 3.9 `Rate of heat leaking`

```
//Chapter-3, Example 3.9, Page 64
//====================================================================================================

clc
clear

L1=0.006;//Thickness of each glass sheet in m
L2=0.002;//Thickness of air gap in m
Tb=-20;//Temperature of the air inside the room in degree C
Ta=30;//Ambient temperature of air in degree C
```

```
ha=23.26;//Heat transfer coefficient between glass and air in W/m^2.K
kglass=0.75;//Thermal conductivity of glass in W/m.K
kair=0.02;//Thermal conductivity of air in W/m.K

//CALCULATIONS
q=((Ta-Tb)/((1/ha)+(L1/kglass)+(L2/kair)+(L1/kglass)+(1/ha)));//Rate of heat leaking into the room per unit area of the door in W/m^2

//OUTPUT
mprintf('Rate of heat leaking into the room per unit area of the door is %3.1f W/m^2',q)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 3.10 `Heat transfer through the composite wall`

```
//Chapter-3, Example 3.10, Page 65
//==========================================================================================

clc
clear

//INPUT DATA
LA=0.05;//Length of section A in m
LB=0.1;//Length of section A in m
LC=0.1;//Length of section A in m
LD=0.05;//Length of section A in m
LE=0.05;//Length of section A in m
kA=50;//Thermal conductivity of section A in W/m.K
kB=10;//Thermal conductivity of section B in W/m.K
kC=6.67;//Thermal conductivity of section C in W/m.K
```

```
kD=20;//Thermal conductivity of section D in W/m.K
kE=30;//Thermal conductivity of section E in W/m.K
Aa=1;//Area of section A in m^2
Ab=0.5;//Area of section B in m^2
Ac=0.5;//Area of section C in m^2
Ad=1;//Area of section D in m^2
Ae=1;//Area of section E in m^2
T=[800,100];//Temperature at inlet and outlet temperatures in degree C

//CALCULATIONS
Ra=(LA/(kA*Aa));//Thermal Resistance of section A in K/W
Rb=(LB/(kB*Ab));//Thermal Resistance of section B in K/W
Rc=(LC/(kC*Ac));//Thermal Resistance of section C in K/W
Rd=(LD/(kD*Ad));//Thermal Resistance of section D in K/W
Re=(LE/(kE*Ae));//Thermal Resistance of section E in K/W
Rf=((Rb*Rc)/(Rb+Rc));//Equivalent resistance of section B and section C in K/W
R=Ra+Rf+Rd+Re;//Equivalent resistance of all sections in K/W
Q=((T(1)-T(2))/R)/1000;//Heat transfer through the composite wall in kW

//OUTPUT
mprintf('Heat transfer through the composite wall is %3.1f kW',Q)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 3.11 Surface temperature and convective conductance

```
//Chapter-3, Example 3.11, Page 66
//==================================================================================

clc
clear

//INPUT DATA
T1=2000;//Temperature of hot gas in degree C
Ta=45;//Room air temperature in degree C
Qr1=23.260;//Heat flow by radiation from gases to inside surface of the wall in kW/m^2
h=11.63;//Convective heat transfer coefficient in W/m^2.
C=58;//Thermal conductance of the wall in W/m^2.K
Q=9.3;//Heat flow by radiation from external surface to the surrounding in kW.m^2
T2=1000;//Interior wall temperature in degree C

//CALCULATIONS
qr1=Qr1;//Haet by radiation in kW/m^2
qc1=h*((T1-T2)/1000);//Heat by conduction in kW/m^2
q=qc1+qr1;//Total heat entering the wall in kW/m^2
R=(1/C);//Thermal resistance in m^2.K/W
T3=T2-(q*R*1000);//External wall temperature in degree C
Ql=q-Q;//Heat loss due to convection kW/m^2
h4=(Ql*1000)/(T3-Ta);//Convective conductance in W/m^2.K

mprintf('The surface temperature is %i degree C \nThe convective conductance is %3.1f W/m^2.K',T3,h4)

//=====================================END OF PROGRAM=====================================
```

Scilab code Exa 3.12 Heat loss and thickness of insulation

```
//Chapter-3, Example 3.12, Page 67
//
clc
clear

//INPUT DATA
L1=0.125;//Thickness of fireclay layer in m
L2=0.5;//Thickness of red brick layer in m
T=[1100,50];//Temperatures at inside and outside the furnaces in degree C
k1=0.533;//Thermal conductivity of fireclay in W/m.K
k2=0.7;//Thermal conductivity of red brick in W/m.K

//CALCULATIONS
R1=(L1/k1);//Resistance of fireclay per unit area in K/W
R2=(L2/k2);//Resistance of red brick per unit area in K/W
R=R1+R2;//Total resistance in K/W
q=(T(1)-T(2))/R;//Heat transfer in W/m^2
T2= T(1)-(q*R1);//Temperature in degree C
T3=T(2)+(q*R2*0.5);//Temperature at the interface between the two layers in degree C
km=0.113+(0.00023*((T2+T3)/2));//Mean thermal conductivity in W/m.K
x=((T2-T3)/q)*km;//Thickness of diatomite in m

//OUTPUT
mprintf('Amount of heat loss is %3.1f W/m^2 \n Thickness of diatomite is %3.4f m',q,x )
```

```

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 3.13 `Heat loss from the pipe`

```
//Chapter-3, Example 3.13, Page 70
//=============================================================================

clc
clear

//INPUT DATA
Di=0.1;//I.D of the pipe in m
L=0.01;//Thickness of the wall in m
L1=0.03;//Thickness of insulation in m
Ta=85;//Temperature of hot liquid in degree C
Tb=25;//Temperature of surroundings in degree C
k1=58;//Thermal conductivity of steel in W/m.K
k2=0.2;//Thermal conductivity of insulating material in W/m.K
ha=720;//Inside heat transfer coefficient in W/m^2.K
hb=9;//Outside heat transfer coefficient in W/m^2.K
D2=0.12;//Inner diameter in m
r3=0.09;//Radius in m

//CALCULATIONS
q=((2*3.14*(Ta-Tb))/((1/(ha*(Di/2)))+(1/(hb*r3))+(log(D2/Di)/k1)+(log(r3/(D2/2))/k2)));//Heat loss fro an insulated pipe in W/m

//OUTPUT
mprintf('Heat loss fro an insulated pipe is %3.2f W/m',q)
```

```

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 3.14 `Heat loss per meter length of pipe`

```
//Chapter-3, Example 3.14, Page 71
//=============================================================================================================
clc
clear

//INPUT DATA
Di=0.1;//I.D of the pipe in m
Do=0.11;//O.D of the pipe in m
L=0.005;//Thickness of the wall in m
k1=50;//Thermal conductivity of steel pipe line in W/m.K
k2=0.06;//Thermal conductivity of first insulating material in W/m.K
k3=0.12;//Thermal conductivity of second insulating material in W/m.K
T=[250,50];//Temperature at inside tube surface and outside surface of insulation in degree C
r3=0.105;//Radius of r3 in m as shown in fig.3.14 on page no.71
r4=0.155;//Radius of r4 in m as shown in fig.3.14 on page no.71

//CALCULATIONS
r1=(Di/2);//Radius of the pipe in m
r2=(Do/2);//Radius of the pipe in m
q=((2*3.14*(T(1)-T(2)))/(((log(r2/r1))/k1)+((log(r3/r2))/k2)+((log(r4/r3))/k3)));//Loss of heat per
```

```
metre length of pipe in W/m
T3=((q*log(r4/r3))/(2*3.14*k3))+T(2);//Interface temperature in degree C

//OUTPUT
mprintf('Loss of heat per metre length of pipe is %3.1f W/m \n Interface temperature is %3.1f degree C',q,T3)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 3.15 `Change in heat loss`

```
//Chapter-3, Example 3.15, Page 72
//====================================================================================================

clc
clear

//INPUT DATA
Di=0.1;//I.D of the pipe in m
Do=0.11;//O.D of the pipe in m
L=0.005;//Thickness of the wall in m
k1=50;//Thermal conductivity of steel pipe line in W/m.K
k3=0.06;//Thermal conductivity of first insulating material in W/m.K
k2=0.12;//Thermal conductivity of second insulating material in W/m.K
T=[250,50];//Temperature at inside tube surface and outside surface of insulation in degree C
r3=0.105;//Radius of r3 in m as shown in fig.3.14 on page no.71
```

```
r4=0.155;//Radius of r4 in m as shown in fig.3.14 on page no.71

//CALCULATIONS
r1=(Di/2);//Radius of the pipe in m
r2=(Do/2);//Radius of the pipe in m
q=((2*3.14*(T(1)-T(2)))/(((log(r2/r1))/k1)+((log(r3/r2))/k2)+((log(r4/r3))/k3)));//Loss of heat per metre length of pipe in W/m

//OUTPUT
mprintf('Loss of heat per metre length of pipe is %3.2f W/m',q)
//Comparing the result with the previous example Ex.3.14, it is seen that the loss of heat is increased by about 18.11%. Since the purpose of insulation is to reduce the loss of heat, it is always better to provide the insulating material with low thermal conductivity on the surface of the tube first

//==================================END OF PROGRAM===============================
```

Scilab code Exa 3.16 Mass of steam condensed

```
//Chapter-3, Example 3.16, Page 73
//==================================================================

clc
clear

//INPUT DATA
D1=0.1;//O.D of the pipe in m
```

```
P=1373;//Pressure of saturated steam in kPa
D2=0.2;//Diameter of magnesia in m
k1=0.07;//Thermal conductivity of magnesia in W/m.K
k2=0.08;//Thermal conductivity of asbestos in W/m.K
D3=0.25;//Diameter of asbestos in m
T3=20;//Temerature under the canvas in degree C
t=12;//Time for condensation in hours
l=150;//Lemgth of pipe in m
T1=194.14;//Saturation temperature of steam in degree C from Table A.6 (Appendix A) at 1373 kPa on page no. 643
hfg=1963.15;//Latent heat of steam in kJ/kg from Table A.6 (Appendix A) at 1373 kPa on page no. 643

//CALCULATIONS
r1=(D1/2);//Radius of the pipe in m
r2=(D2/2);//Radius of magnesia in m
r3=(D3/2);//Radius of asbestos in m
Q=(((2*3.14*l*(T1-T3))/((log(r2/r1)/k1)+(log(r3/r2)/k2)))*(3600/1000));//Heat transfer rate in kJ/h
m=(Q/hfg);//Mass of steam condensed per hour
m1=(m*t);//Mass of steam condensed in 12 hours

//OUTPUT
mprintf('Mass of steam condensed in 12 hours is %3.2f kg',m1)

//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 3.17 Rate of heat flow

```
//Chapter-3, Example 3.17, Page 74
//
```

```
==================================================
clc
clear

//INPUT DATA
D1=0.1;//I.D of the first pipe in m
D2=0.3;//O.D of the first pipe in m
k1=70;//Thermal conductivity of first material in W/m.K
D3=0.4;//O.D of the second pipe in m
k2=15;//Thermal conductivity of second material in W/m.K
T=[300,30];//Inside and outside temperatures in degree C

//CALCULATIONS
r1=(D1/2);//Inner Radius of first pipe in m
r2=(D2/2);//Outer Radius of first pipe in m
r3=(D3/2);//Radius of second pipe in m
Q=((4*3.14*(T(1)-T(2)))/(((r2-r1)/(k1*r1*r2))+((r3-r2)/(k2*r2*r3))))/1000;//Rate of heat flow through the sphere in kW

//OUTPUT
mprintf('Rate of heat flow through the sphere is %3.2f kW',Q)

//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 3.18 `Heat loss and surface temperature`

```
//Chapter-3, Example 3.18, Page 77
//
```

```
clc
clear

//INPUT DATA
Di=0.1;//I.D of a steam pipe in m
Do=0.25;//I.D of a steam pipe in m
k=1;//Thermal conductivity of insulating material in
    W/m.K
T=[200,20];//Steam temperature and ambient
    temperatures in degree C
h=8;//Convective heat transfer coefficient between
    the insulation surface and air in W/m^2.K

//CALCULATIONS
ri=(Di/2);//Inner Radius of steam pipe in m
ro=(Do/2);//Outer Radius of steam pipe in m
rc=(k/h)*100;//Critical radius of insulation in cm
q=((T(1)-T(2))/((log(ro/ri)/(2*3.14*k))+(1/(2*3.14*
    ro*h))));//Heat loss per metre of pipe at
    critical radius in W/m
Ro=(q/(2*3.14*ro*h))+T(2);//Outer surface
    temperature in degree C

//OUTPUT
mprintf('Heat loss per metre of pipe at critical
    radius is %i W/m \n Outer surface temperature is
    %3.2f degree C',q,Ro)

//=============================================END OF PROGRAM
    ==============================================
```

Scilab code Exa 3.19 Effect of insulation on the current carrying conductor

```
//Chapter-3, Example 3.19, Page 78
//

clc
clear

//INPUT DATA
Di=0.001;//Diameter of copper wire in m
t=0.001;//Thickness of insulation in m;
To=20;//Temperature of surrondings in degree C
Ti=80;//Maximum temperature of the plastic in degree C
kcopper=400;//Thermal conductivity of copper in W/m.K
kplastic=0.5;//Thermal conductivity of plastic in W/m.K
h=8;//Heat transfer coefficient in W/m^2.K
p=(3*10^-8);//Specific electric resistance of copper in Ohm.m

//CAlCULATIONS
r=(Di/2);//Radius of copper tube in m
ro=(r+t);//Radius in m
R=(p/(3.14*r*r*0.01));//Electrical resistance per meter length in ohm/m
Rth=((1/(2*3.14*ro*h))+(log(ro/r)/(2*3.14*kplastic)));//Thermal resistance of convection film insulation per metre length
Q=((Ti-To)/Rth);//Heat transfer in W
I=sqrt(Q/R);//Maximum safe current limit in A
rc=((kplastic*100)/h);//Critical radius in cm

//OUTPUT
mprintf('The maximum safe current limit is %3.3f A \n As the critical radius of insulation is much greater than that provided in the problem, the current carrying capacity of the conductor can be
```

```
raised considerably in increasing the radius of plastic covering upto %3.1f cm.\n This may however lead to the problem of having too high a temperature at the cable centre if the temperature inside the plastic coating has to be kept within the given limits',I,rc)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 3.20 `Surface temperature and maximum temperature in the wall`

```
//Chapter-3, Example 3.20, Page 83
//=============================================================================================================

clc
clear

//INPUT DATA
L=0.1;//Thickness of the wall in m
Q=(4*10^4);//Heat tansfer rate in W/m^3
h=50;//Convective heat transfer coefficient in W/m^2.K
T=20;//Ambient air temperature in degree C
k=15;//Thermal conductivity of the material in W/m.K

//CALCULATIONS
Tw=(T+((Q*L)/(2*h)));//Surface temperature in degree C
Tmax=(Tw+((Q*L*L)/(8*k)));//Maximum temperature in the wall in degree C

//OUTPUT
mprintf('Surface temperature is %i degree C \n
```

```
Maximum temperature in the wall is %3.3f degree C',Tw,Tmax)

//========================================================END OF PROGRAM====================================================
```

Scilab code Exa 3.21 Surface temperature

```
//Chapter-3, Example 3.21, Page 85
//=============================================================================================================

clc
clear

//INPUT DATA
Do=0.006;//Outer diameter of hallow cylinder in m
Di=0.004;//Inner diameter of hallow cylinder in m
I=1000;//Current in A
T=30;//Temperature of water in degree C
h=35000;//Heat transfer coefficient in W/m^2.K
k=18;//Thermal conductivity of the material in W/m.K
R=0.1;//Electrical reisitivity of the material in ohm.mm^2/m

//CALCULATIONS
ro=(Do/2);//Outer radius of hallow cylinder in m
ri=(Di/2);//Inner radius of hallow cylinder in m
V=((3.14*(ro^2-ri^2)));//Vol. of wire in m^2
Rth=(R/(3.14*(ro^2-ri^2)*10^6));//Resistivity in ohm/mm^2
q=((I*I*Rth)/V);//Heat transfer rate in W/m^3
To=T+(((q*ri*ri)/(4*k))*((((2*k)/(h*ri))-1)*((ro/ri)^2-1)+(2*(ro/ri)^2*log(ro/ri))));//Temperature at the outer surface in degree C
```

```

//OUTPUT
mprintf('Temperature at the outer surface is %3.2f degree C',To)

//==================================================END OF PROGRAM================================================
```

Scilab code Exa 3.22 `Heat transfer coefficient and maximum temperature`

```
//Chapter-3, Example 3.22, Page 88
//==============================================================================================================================

clc
clear

//INPUT DATA
D=0.025;//Diameter of annealed copper wire in m
I=200;//Current in A
R=(0.4*10^-4);//Resistance in ohm/cm
T=[200,10];//Surface temperature and ambient temperature in degree C
k=160;//Thermal conductivity in W/m.K

//CALCULATIONS
r=(D/2);//Radius of annealed copper wire in m
Q=(I*I*R*100);//Heat transfer rate in W/m
V=(3.14*r*r);//Vol. of wire in m^2
q=(Q/V);//Heat loss in conductor in W/m^2
Tc=T(1)+((q*r*r)/(4*k));//Maximum temperature in the wire in degree C
h=((r*q)/(2*(T(1)-T(2))));//Heat transfer coefficient in W/m^2.K

```

```
//OUTPUT
mprintf('Maximum temperature in the wire is %3.2f degree C \n Heat transfer coefficient is %3.2f W/m^2.K',Tc,h)

//=========================================END OF PROGRAM=======================================
```

Scilab code Exa 3.23 Diameter of wire and rate of current flow

```
//Chapter-3, Example 3.23, Page 89
//=============================================================================================================

clc
clear

//INPUT DATA
p=100;//Resistivity of nichrome in    ohm-cm
Q=10000;//Heat input of a heater in W
T=1220;//Surface temperature of nichrome in degree C
Ta=20;//Temperature of surrounding air in degree C
h=1150;//Outside surface coeffient in W/m^2.K
k=17;//Thermal conductivity of nichrome in W/m.K
L=1;//Length of heater in m

//CALCULATIONS
d=(Q/((T-Ta)*3.14*h))*1000;//Diameter of nichrome wire in mm
A=(3.14*d*d)/4;//Area of the wire in m^2
R=((p*10^-8*L)/A);//Resistance of the wire in ohm
I=sqrt(Q/R)/1000;//Rate of current flow in A

//OUTPUT
mprintf('Diameter of nichrome wire is %3.4f mm \n
```

```
Rate of current flow is %i A',d,I)

//==================================END OF PROGRAM================================
```

Scilab code Exa 3.24 Temperature drop

```
//Chapter-3, Example 3.24, Page 93
//====================================================================================

clc
clear

//INPUT DATA
Do=0.025;//O.D of the rod in m
k=20;//Thermal conductivity in W/m.K
Q=(2.5*10^6);//Rate of heat removal in W/m^2

//CALCULATIONS
ro=(Do/2);//Outer radius of the rod in m
q=((4*Q)/(ro));//Heat transfer rate in W/m^3
T=((-3*q*ro^2)/(16*k));//Temperature drop from the centre line to the surface in degree C

//OUTPUT
mprintf('Temperature drop from the centre line to the surface is %3.3f degree C',T)

//==================================END OF PROGRAM================================
```

Scilab code Exa 3.25 Temperature at the centre of orange

```
//Chapter-3, Example 3.25, Page 95
//=============================================================================

clc
clear

//INPUT DATA
Q=300;//Heat produced by the oranges in W/m^2
s=0.08;//Size of the orange in m
k=0.15;//Thermal conductivity of the sphere in W/m.K

//CALCULATIONS
q=(3*Q)/(s/2);//Heat flux in W/m^2
Tc=10+((q*(s/2)^2)/(6*k));//Temperature at the centre of the sphere in degree C

//OUTPUT
mprintf('Temperature at the centre of the orange is %i degree C',Tc)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 3.26 `Total heat dissipated`

```
//Chapter-3, Example 3.26, Page 102
//=============================================================================

clc
clear

//INPUT DATA
To=140;//Temperature at the junction in degree C
```

```
Ti=15;//Temperature of air in the room in degree C
D=0.003;//Diameter of the rod in m
h=300;//Heat transfer coefficient in W/m^2.K
k=150;//Thermal conductivity in W/m.K

//CALCULATIONS
P=(3.14*D);//Perimeter of the rod in m
A=(3.14*D^2)/4;//Area of the rod in m^2
Q=sqrt(h*P*k*A)*(To-Ti);//Total heat dissipated by the rod in W

//OUTPUT
mprintf('Total heat dissipated by the rod is %3.3f W',Q)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 3.27 `Thermal conductivity`

```
//Chapter-3, Example 3.27, Page 103
//=====================================================================================================

clc
clear

//INPUT DATA
D=0.025//Diameter of the rod in m
Ti=22;//Temperature of air in the room in degree C
x=0.1;//Distance between the points in m
T=[110,85];//Temperatures at two points in degree C
h=28.4;//Heat transfer coefficient in W/m^2.K

//CALCULATIONS
```

```
m=-log((T(2)-Ti)/(T(1)-Ti))/x;//Calculation of m for obtaining k
P=(3.14*D);//Perimeter of the rod in m
A=(3.14*D^2)/4;//Area of the rod in m^2
k=((h*P)/((m)^2*A));//Thermal conductivity of the rod material in W/m.K

//OUTPUT
mprintf('Thermal conductivity of the rod material is %3.1f W/m.K',k)

//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 3.28 `Temperature distribution and rate of heat flow`

```
//Chapter-3, Example 3.28, Page 103
//==========================================================================================

clc
clear

//INPUT DATA
L=0.06;//Length of the turbine blade in m
A=(4.65*10^-4);//Cross sectional area in m^2
P=0.12;//Perimeter in m
k=23.3;//Thermal conductivity of stainless steel in W/m.K
To=500;//Temperature at the root in degree C
Ti=870;//Temperature of the hot gas in degree C
h=442;//Heat transfer coefficient in W/m^2.K

//CALCULATIONS
m=sqrt((h*P)/(k*A));//Calculation of m for
```

```
    calculating heat transfer rate
X=(To-Ti)/cosh(m*L);//X for calculating tempetarure distribution
Q=sqrt(h*P*k*A)*(To-Ti)*tanh(m*L);//Heat transfer rate in W

//OUTPUT
mprintf('Temperature distribution is given by : T-Ti = %i cosh[%3.2f(%3.2f-x)] \n

---------------------\n

cosh[%3.2f(%3.2f)] \n Heat transfer rate is %3.1f W',(To-Ti),m,L,m,L,Q)

//=======================================END OF PROGRAM=====================================
```

Scilab code Exa 3.29 Rate of heat transfer and temperature

```
//Chapter-3, Example 3.29, Page 104
//==========================================================================================

clc
clear

//INPUT DATA
W=1;//Length of the cylinder in m
D=0.05;//Diameter of the cylinder in m
Ta=45;//Ambient temperature in degree C
n=10;//Number of fins
k=120;//Thermal conductivity of the fin material in W/m.K
t=0.00076;//Thickness of fin in m
```

```
L=0.0127;//Height of fin in m
h=17;//Heat transfer coefficient in W/m^2.K
Ts=150;//Surface temperature of cylinder in m

//CALCULATIONS
P=(2*W);//Perimeter of cylinder in m
A=(W*t);//Surface area of cyinder in m^2
m=sqrt((h*P)/(k*A));//Calculation of m for determining heat transfer rate
Qfin=(sqrt(h*P*k*A)*(Ts-Ta)*((tanh(m*L)+(h/(m*k)))/(1+((h/(m*k))*tanh(m*L)))));//Heat transfer through the fin in kW
Qb=h*((3.14*D)-(n*t))*W*(Ts-Ta);//Heat from unfinned (base) surface in W
Q=((Qfin*10)+Qb);//Total heat transfer in W
Ti=((Ts-Ta)/(cosh(m*L)+((h*sinh(m*L))/(m*k))));//Ti to calculate temperature at the end of the fin in degree C
T=(Ti+Ta);//Temperature at the end of the fin in degree C

//OUTPUT
mprintf('Rate of heat transfer is %3.2f W\nTemperature at the end of the fin is %3.2f degree C',Q,T )

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 3.31 Rate of heat flow

```
//Chapter-3, Example 3.31, Page 109
//==========================================================================================
```

```
clc
clear

//INPUT DATA
t=0.025;//Thickness of fin in m
L=0.1;//Length of fin in m
k=17.7;//Thermal conductivity of the fin material in W/m.K
p=7850;//Density in kg/m^3
Tw=600;//Temperature of the wall in degree C
Ta=40;//Temperature of the air in degree C
h=20;//Heat transfer coefficient in W/m^2.K
I0(1.9)=2.1782;//Io value taken from table 3.2 on page no.108
I1(1.9)=1.48871;//I1 value taken from table 3.2 on page no. 108

//CALCULATIONS
B=sqrt((2*L*h)/(k*t));//Calculation of B for determining temperature distribution
X=((Tw-Ta)/I0(2*B*sqrt(0.1)));//Calculation of X for determining temperature distribution
Y=(2*B);//Calculation of Y for determining temperature distribution
Q=(sqrt(2*h*k*t)*(Tw-Ta)*((I1(2*B*sqrt(0.1)))/(I0(2*B*sqrt(0.1)))));
m=((p*t*L)/2);//Mass of the fin per meter of width in kg/m
q=(Q/m);//Rate of heat flow per unit mass in W/kg

//OUTPUT
mprintf('Temperature distribution is T=%i+%3.1f(%3.4f x )\nRate of heat flow per unit mass of the fin is %3.2f W/kg',Ta,X,Y,q)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 3.32 `Efficiency of the plate`

```
//Chapter-3, Example 3.32, Page 116
//==========================================================================

clc
clear

//INPUT DATA
t=0.002;//Thickness of fin in m
L=0.015;//Length of fin in m
k1=210;//Thermal conductivity of aluminium in W/m.K
h1=285;//Heat transfer coefficient of aluminium in W/m^2.K
k2=40;//Thermal conductivity of steel in W/m.K
h2=510;//Heat transfer coefficient of steel in W/m^2.K

//CALCULATIONS
Lc=(L+(t/2));//Corrected length of fin in m
mLc1=Lc*sqrt((2*h1)/(k1*t));//Calculation of mLc for efficiency
n1=tanh(mLc1)/mLc1;//Efficiency of fin when aluminium is used
mLc2=Lc*sqrt((2*h2)/(k2*t));//Calculation of mLc for efficiency
n2=tanh(mLc2)/mLc2;//Efficiency of fin when steel is used

//OUTPUT
mprintf('Efficiency of fin when aluminium is used is %3.4f\nEfficiency of fin when steel is used is %3.3f',n1,n2)
```

```

//==========================================END OF PROGRAM======================================
```

Scilab code Exa 3.33 Heat transfer coefficient

```
//Chapter-3, Example 3.33, Page 117
//=============================================================================
clc
clear

//INPUT DATA
k=200;//Thermal conductivity of aluminium in W/m.K
t=0.001;//Thickness of fin in m
L=0.015;//Width of fin in m
D=0.025;//Diameter of the tube in m
Tb=170;//Fin base temperature in degree C
Ta=25;//Ambient fluid temperature in degree C
h=130;//Heat transfer coefficient in W/m^2.K

//CALCULATIONS
Lc=(L+(t/2));//Corrected length of fin in m
r1=(D/2);//Radius of tube in m
r2c=(r1+Lc);//Corrected radius in m
Am=t*(r2c-r1);//Corrected area in m^2
x=Lc^(3/2)*sqrt(h/(k*Am));//x for calculating efficiency
n=0.82;//From fig. 3.18 on page no. 112 efficiency is 0.82
qmax=(2*3.14*(r2c^2-r1^2)*h*(Tb-Ta));//Maximum heat transfer in W
qactual=(n*qmax);//Actual heat transfer in W

```

```
//OUTPUT
mprintf('Heat loss per fin is %3.2f W',qactual)

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 3.34 `Insulation of fin`

```
//Chapter-3, Example 3.34, Page 117
//=============================================================================

clc
clear

//INPUT DATA
k=16;//Thermal conductivity of fin in W/m.K
L=0.1;//Length of fin in m
D=0.01;//Diameter of fin in m
h=5000;//Heat transfer coefficient in W/m^2.K

//CALCULATIONS
P=(3.14*D);//Perimeter of fin in m
A=(3.14*D^2)/4;//Area of fin in m^2
m=sqrt((h*P)/(k*A));//Calculation of m for determining heat transfer rate
n=tanh(m*L)/sqrt((h*A)/(k*P));//Calculation of n for checking whether installation of fin is desirable or not
x=(n-1)*100;//Conversion into percentage

//OUTPUT
mprintf('This large fin only produces an increase of %i percent in heat dissipation, so naturally this configuration is undesirable',x)
```

```

//=================================================END OF PROGRAM
    ==============================================
```

Scilab code Exa 3.35 `Measurement error in temperature`

```
//Chapter-3, Example 3.35, Page 119
//
    ==================================================================================================

clc
clear

//INPUT DATA
k=55.8;//Thermal conductivity of steel in W/m.K
t=0.0015;//Thickness of steel tube in m
L=0.12;//Length of steel tube in m
h=23.3;//Heat transfer coefficient in W/m^2.K
Tl=84;//Temperature recorded by the thermometer in
    degree C
Tb=40;//Temperature at the base of the well in
    degree C

//CALCULATIONS
m=sqrt(h/(k*t));//Calculation of m for determining
    the temperature distribution
x=1/cosh(m*L);//Calculation of x for determining the
     temperature distribution
Ti=((Tl-(x*Tb))/(1-x));//Temperature distribution in
     degree C
T=(Ti-Tl);//Measurement error in degree C

//OUTPUT
mprintf('Measurement error is %3.0f degree C',T)

```

```
//========================================================END OF PROGRAM
    ====================================================
```

Chapter 5

Transient Heat Conduction

Scilab code Exa 5.1 `Heat transfer and temperature`

```
//Chapter-5, Example 5.1, Page 159
//
    ================================================================================

clc
clear

//INPUT DATA
t=0.5;//Thickness of slab in m
A=5;//Area of slab in m^2
k=1.2;//Thermal conductivity in W/m.K
a=0.00177;//Thermal diffusivity in m^2/h
//Remperarure distribution as T=60-50x+12x^2+20x
    ^3-15x^4

//CALCULATIONS
//Partial derivative of T w.r.t x is T'=-50+24x+60x
    ^2-60x^3
//Partial derivative of T' w.r.t x is T''=24+120x
    +180x^2
//Partial derivative of T' w.r.t x is T'''=120-360x
```

```
x=0;
y=-50+(24*x)+(60*x^2)-(60*x^3);//Temperature when x=0
Qo=(-k*A*y);//Heat entering the slab in W
x=0.5;
y=-50+(24*x)+(60*x^2)-(60*x^3);//Temperature when x=0.5
QL=(-k*A*y);//Heat leaving the slab in W
R=(Qo-QL);//Rate of heat storage in W
x=0;
z1=24+(120*x)-(180*x^2);//T' when x=0
p1=(a*z1);//Rate of temperature change at one side of slab in degree C/h
x=0.5;
z2=24+(120*x)-(180*x^2);//T' when x=0.5
p2=(a*z2);//Rate of temperature change at one side of slab in degree C/h
//For the rate of heating or cooling to be maximum, T'''=0
x=(120/360);

//OUTPUT
mprintf('a)i)Heat entering the slab is %i W\n ii)Heat leaving the slab is %i W\nb)Rate of heat storage is %i W\nc)i)Rate of temperature change at one side of slab is %3.4f degree C/h\n ii)Rate of temperature change at other side of slab is %3.4f degree C/h\nd)For the rate of heating or cooling to be maximum x= %3.2f',Qo,QL,R,p1,p2,x)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 5.2 `Time taken`

```
//Chapter-5, Example 5.2, Page 164
//==========================================================================

clc
clear


//INPUT DATA
A=(0.4*0.4);//Area of copper slab in m^2
t=0.005;//Thickness of copper slab in m
T=250;//Uniform teperature  in degree c
Ts=30;//Surface temperature in degree C
Tsl=90;//Slab temperature in degree C
p=9000;//Density in kg/m^3
c=380;//Specific heat in J/kg.K
k=370;//Thermal conductivity in W/m.K
h=90;//Heat transfer coefficient in W/m^2.K

//CALCULATIONS
A1=(2*A);//Area of two sides in m^2
V=(A*t);//Volume of the slab in m^3
Lc=(V/A1);//Corrected length in m
Bi=((h*Lc)/k);//Biot number
t=-log((Tsl-Ts)/(T-Ts))/((h*A1)/(p*c*V));//Time at which slab temperature becomes 90 degree C in s
y=(h*A1)/(p*c*V);

//OUTPUT
mprintf('Time at which slab temperature becomes 90 degree C is %3.2f s',t)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 5.3 `Time taken`

```
//Chapter-5, Example 5.3, Page 164
//==========================================================================================

clc
clear

//INPUT DATA
D=0.01;//Outer diameter of the rod in m
T=320;//Original temperature in degree C
Tl=120;//Temperature of liquid in degree C
h=100;//Heat transfer coefficient in W/m^2.K
Tf=200;//Final temperature of rod in degree C
k=40;//Thermal conductivity in W/m.K
c=460;//Specific heat in J/kg.K
p=7800;//Density in kg/m^3

//CALCULATIONS
V=(3.14*D^2*1)/4;//Volume of rod in m^3 taking 1m length
A=(3.14*D*1);//Surface area of rod in m^2 taking 1m length
Lc=(D/4);//Corrected length in m
Bi=((h*Lc)/k);//Biot number
t=-log((Tf-Tl)/(T-Tl))/((h*4)/(p*c*D));//Time at which rod temperature becomes 200 degree C in s

//OUTPUT
mprintf('Time at which rod temperature becomes 200 degree C is %3.2f s',t)

//=========================================END OF PROGRAM========================================
```

Scilab code Exa 5.4 `Time required to cool aluminium`

```
//Chapter-5, Example 5.4, Page 165
//=============================================================================

clc
clear


//INPUT DATA
w=5.5;//Weight of the sphere in kg
Ti=290;//Initial temperature in degree C
Tl=15;//Temperature of liquid in degree C
h=58;//Heat transfer coefficient in W/m^2.K
Tf=95;//Final temperature in degree C
k=205;//Thermal conductivity in W/m.K
c=900;//Specific heat in J/kg.K
p=2700;//Density in kg/m^3

//CALCULATIONS
V=(w/p);//Volume of the sphere in m^3
R=((3*V)/(4*3.14))^(1/3);//Radius of sphere in m
Lc=(R/3);//Corrected length in m
t=-log((Tf-Tl)/(Ti-Tl))/((h*3)/(p*c*R));//Time at which rod temperature becomes 95 degree C in s

//OUTPUT
mprintf('Time at which rod temperature becomes 95 degree C is %3.0f s',t)

//======================================END OF PROGRAM======================================
```

Scilab code Exa 5.5 `Heat transfer coefficient`

```
//Chapter-5, Example 5.5, Page 166
//===================================================================
clc
clear


//INPUT DATA
Ti=100;//Temperature of air in degree C
t=0.03;//Thickness of slab in m
To=210;//Initial temperature of the plate in degree C
t=300;//Time for attaining temperature in s
T=170;//Temperature decreased in degree C
c=380;//Specific heat in J/kg.K
p=9000;//Density in kg/m^3

//CALCULATIONS
Lc=(t/2);//Corrected length in m
h=-log((T-Ti)/(To-Ti))/((t*10^4)/(p*c*Lc));//Heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient is %3.2f W/m^2.K',h)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 5.6 `Time constant and time period`

```
//Chapter-5, Example 5.6, Page 167
//=============================================================================
clc
clear


//INPUT DATA
D=0.00071;//Diameter of thermocouple in m
h=600;//Heat transfer coefficient in W/m^2.K
c=420;//Specific heat in J/kg.K
p=8600;//Density in kg/m^3

//CALCULATIONS
t=(p*c*D)/(4*h);//Time period in s
T=exp(-1);//Temperture distribution ratio
t1=(4*t);//Total time in s

//OUTPUT
mprintf('Thus at the end of time period t*=%3.3f s the temperature difference between the body and the source would be %3.3f of the initial temperature differnce. For getting a true reading of gas temperature, it should be recorded after 4t* = %i seconds after the thermocouple has been introduced into the stream',t,T,t1)

//==============================END OF PROGRAM=================================
```

Scilab code Exa 5.8 `Temperature and total heat`

```
//Chapter-5, Example 5.8, Page 177
//==============================================================================================================

clc
clear

//INPUT DATA
x=0.2;//Diatance of plane from the wall in m
t=10;//Time for heat flow in h
T=[25,800];//Initial and final tempertaure in degree C
k=0.8;//Thermal conductivity in W/m.K
a=0.003;//Thermal diffusivity in m^2/h

//CALCULATIONS
X=(x*(2*sqrt(a*k)));//Calculation of X for erf function
Y=0.585;//Taking ref(0.577)=0.585 from table 5.1 on page no. 175
Ti=T(2)-((T(2)-T(1)))*Y;//Temperarture of the plane in degree C
Qi=((-k*(T(1)-T(2))*exp(-x^2/(4*a*t)))/(sqrt(3.14*a*t)));//Instanteneous heat flow rate per unit area in W/m^2
Q=((2*k*(T(2)-T(1))*3600)/(sqrt((3.14*a)/t)))/10^8;//Total heat energy taken up by the wall in 10 hours in J/m^2

//OUTPUT
mprintf('Temperarture of the plane is %3.2f degree C\nInstanteneous heat flow rate per unit area is %i W/m^2\nTotal heat energy taken up by the wall in 10 hours is %3.3f*10^8 J/m^2',Ti,Qi,Q)

//=====================================================END OF PROGRAM================================================
```

Scilab code Exa 5.9 `Time taken to cool`

```
//Chapter-5, Example 5.9, Page 177
//====================================================================

clc
clear


//INPUT DATA
Tc=55;//Tempertaure of the concrete in degree C
Ts=35;//Temperature lowered in degree C
Tf=45;//Final temperature in degree C
x=0.05;//Depth of the slab in m
k=1.279;//Thermal conductivity in W/m.K
a=0.00177;//Thermal diffusivity in m^2/h

//CALCULATIONS
T=(Tf-Ts)/(Tc-Ts);//Temperature distribution
X=0.485;//Taking 0.5=erf(0.482) from table 5.1 on page no. 175
t=(x^2)/(4*X^2*a);//Time taken to cool the concrete to 45 degree C in h

//OUTPUT
mprintf('Time taken to cool the concrete to 45 degree C is %3.2f h',t)

//=====================================END OF PROGRAM==================================
```

Scilab code Exa 5.10 `Temperature`

```
//Chapter-5, Example 5.10, Page 178
//==========================================================================

clc
clear


//INPUT DATA
q=(0.3*10^6);//Heat flux in W/m^2
t=(10/60);//Time taken for heat transfer in s
Ti=30;//Initial temperature of the slab in degree C
x=0.2;//Distance of the plane from the surface in m
k=386;//Thermal conductivity in W/m.K
a=0.404;//Thermal diffusivity in m^2/h

//CALCULATIONS
Ts=((q*sqrt(3.14*a*t))/k)+Ti;//Surface temperature in degree C
X=(x/(2*sqrt(a*t)));//X for calculating erf function
Y=0.4134;//Taking ref(0.385)=0.4134 from table 5.1 on page no. 175
T=Ts-(Y*(Ts-Ti));//Tempertaure at a distance of 20 cm from the surface after 10 min in degree C

//OUTPUT
mprintf('Tempertaure at a distance of 20 cm from the surface after 10 min is %3.2f degree C',T)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 5.11 `Time required and depth`

```
//Chapter-5, Example 5.11, Page 178
//=============================================================================
clc
clear


//INPUT DATA
a=0.405;//Thermal diffusivity in m^2/h
Ti=100;//Initial temperture in degree C
Tf=0;//Final tempertaure in degree C
Tg=(4*100);//Temperature gradient in degree C/m
t1=1;//Time taken in m

//CALCULATIONS
t=(Ti-Tf)^2/(Tg^2*3.14*a);//Time required for the temperature gradient at the surface to reach 4 degree/cm in h
x=sqrt(2*a*(t1/60));//The depth at which the rate of cooling is maximum after 1 minute in m

//OUTPUT
mprintf('Time required for the temperature gradient at the surface to reach 4 degree/cm is %3.3f h \n The depth at which the rate of cooling is maximum after 1 minute is %3.4f m',t,x)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 5.12 `Temperature and total thermal energy`

```
//Chapter-5, Example 5.12, Page 185
//
```

```
clc
clear


//INPUT DATA
x=0.1;//Thickness of the slab in m
Ti=500;//Initial temperature in degree C
Tl=100;//Liquid temperature in degree C
h=1200;//Heat transfer coefficient in W/m^2.K
t=(1*60);//Time for immersion in s
k=215;//Thermal conductivity in W/m.K
a=(8.4*10^-5);//Thermal diffusivity in m^2/h
c=900;//Specific heat in J/kg/K
p=2700;//Density in kg/m^3

//CALCULATIONS
X=(a*t)/(x/2)^2;//Calculation for input in Heisler charts
B=(k/(h*(x/2)));//Calculation for input in Heisler charts
T1=0.68;//T value taken from Fig. 5.7 on page no. 183
Tc1=(T1*(Ti-Tl));//Temperature in degree C
To=Tc1+Tl;//Temperature in degree C
T2=0.880;//From Fig 5.8 on page no. 184 at x/L=1.0 and for k/hL=3.583, tempertaure in degree C
Tc2=(T2*(To-Tl))+Tl;//Temperature in degree C
Y=(h^2*a*t)/(k^2);//Y to calculate the energy losses
Bi=(h*(x/2))/k;//Biot number
U=0.32;//U/Uo value from Fig. 5.9 on page no.185
Uo=(p*c*x*(Ti-Tl));//For unit area in J/m^2
U1=(U*Uo)/(10^6);//Heat removed per unit surface area in MJ/m^2

//OUTPUT
mprintf('Temperature at the centreline and the
```

```
surface 1 minute after the immersion is %3.2f degree C \n Heat removed per unit surface area is %3.1f*10^6 J/m^2',Tc2,U1)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 5.13 `Temperature`

```
//Chapter-5, Example 5.13, Page 186
//=============================================================================
clc
clear


//INPUT DATA
D=0.12;//Diameter of cylinder in m
Ti=20;//Initial temperature in degree C
Tf=820;//Temperature of furnace in degree C
h=140;//Heat transfer coefficient in W/m^2.K
Ta=800;//Axis temperature in degree C
r=0.054;//Radius in m
k=21;//Thermal conductivity in W/m.K
a=(6.11*10^-6);//Thermal diffusivity in m^2/h

//CALCULATIONS
Bi=(h*(D/2))/(2*k);//Biot number
T=(Ta-Tf)/(Ti-Tf);//Temperature distribution
Fo=5.2;//Using Fig.5.10, on page no.187 for 1/(2Bi)=2.5
t=(Fo*(D/2)^2)/a;//Time required for the axis temperature to reach 800 degree C in s
r1=(r/(D/2));//Ratio at a radius of 5.4 cm
```

```
X=0.85;//From Fig.5.11 on page no. 188 the temperature at r=5.4 i sgiven by X
T1=X*(Ta-Tf)+Tf;//Temperature at a radius of 5.4 cm at that tim ein degree C

//OUTPUT
mprintf('Time required for the axis temperature to reach 800 degree C is %3.0f s \nTemperature at a radius of 5.4 cm at that time is %i degree C',t,T1)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 5.14 `Time required for cooling`

```
//Chapter-5, Example 5.14, Page 189
//=============================================================================

clc
clear


//INPUT DATA
r=0.01;//Radius of the mettalic sphere in m
Ti=400;//Initial temperature in degree C
h1=10;//Heat transfer coefficient in W/m^2.K
Ta=20;//Temperature of air in degree C
Tc=355;//Central temperature in degree C
Tw=20;//Temperature of water bath in degree C
h2=6000;//Heat transfer coefficient in W/m^2.K
Tf=50;//Final temperature of the sphere in degree C
k=20;//Thermal conductivity in W/m.K
a=(6.66*10^-6);//Thermal diffusivity in m^2/h
```

```
c=1000;//Specific heat in J/kg/K
p=3000;//Density in kg/m^3

//CALCULATIONS
Bi1=(h1*r)/(3*k);//Biot number
t=((p*r*c*log((Ti-Ta)/(Tc-Ta)))/(3*h1));//Time required for cooling in air in s
Bi2=(h2*r)/(3*k);//Biot number
X=1/(3*Bi2);//X value for lumped capacity method
T=(Tf-Ta)/(Tc-Ta);//Temperature distribution
Fo=0.5;//Using Fig.5.13, on page no.190
t1=(Fo*r^2)/a;//Time required for cooling in water in s
Z=0.33;//Using Fig.5.14, on page no.191
Tr=Z*(Tf-Ta)+Ta;//Surface temperature at the end of cooling in degree C

//OUTPUT
mprintf('Time required for cooling in air is %3.0f s\nTime required for cooling in water is %3.1f s\nSurface temperature at the end of cooling is %3.0f degree C',t,t1,Tr)

//===================================END OF PROGRAM=================================
```

Scilab code Exa 5.15 Temperature

```
//Chapter-5, Example 5.15, Page 192
//=============================================================================

clc
clear

```

```

//INPUT DATA
Ti=250;//Temperature of aluminium slab in degree C
Tc=50;//Convective environment temperature in degree C
h=500;//Heat transfer coefficient in W/m^2.K
x=0.05;//Depth of the plane in m
t=(1*3600);//Time in s
k=215;//Thermal conductivity in W/m.K
a=(8.4*10^-5);//Thermal diffusivity in m^2/h

//CALCULATIONS
X=(h*sqrt(a*t))/k;//X for calculating Temperature
Y=(x/(2*sqrt(a*t)));//Y for calculating Temperature
Z=0.62;//From Fig. 5.16 on page no.193
T=(Z*(Tc-Ti)+Ti);//Temperature at a depth of 5 cm after 1 hour in degree C

//OUTPUT
mprintf('Temperature at a depth of 5 cm after 1 hour is %3.0f degree C',T)

//========================================END OF PROGRAM====================================
```

Scilab code Exa 5.16 `Centreline temperature`

```
//Chapter-5, Example 5.16, Page 196
//==========================================================================================

clc
clear

//INPUT DATA
```

```
D=0.08;//Diameter of the cylinder in m
L=0.16;//Length of the cylinder in m
Ti=800;//Initial tempertaure in degree C
Tm=30;//Temperature of the medium in degree C
h=120;//Heat transfer coefficient in W/m^2.K
t=(30*60);//Time for cooling in s
k=23.5;//Thermal conductivity in W/m.K
a=0.022;//Thermal diffusivity in m^2/h

//CALCULATIONS
Bi2=(h*(D/2))/k;//2 times the Biot number
X=(a*t)/(D/2)^2;//X for calculating C(R)
CR=0.068;//From Fig.5.10 on page no.187
Bi1=(k/(h*L));//Biot number
Y=(a*t)/L^2;//Y for calculating P(X)
PX=0.54;//From Fig.5.7 on page no.183
T=CR*PX;//Temperature at the centre of the cylinder in degree C
T30=T*(Ti-Tm)+Tm;//Temperature at the centre of cylinder 30 minutes after cooling is initiated in degree C

//OUTPUT
mprintf('Temperature at the centre of cylinder 30 minutes after cooling is initiated is %3.2f degree C',T30)

//========================================END OF PROGRAM========================================
```

Scilab code Exa 5.17 Temperature

```
//Chapter-5, Example 5.17, Page 197
//==========================================================================================
```

```
clc
clear


//INPUT DATA
L=[0.5,0.4,0.2];//Lengths of sides of a rectangular steel billet in m
Ti=30;//Initial temperature in degree C
Tf=1000;//Final temperature in degree C
t=(90*60);//Time for heating in s
h=185;//Heat transfer coefficient in W/m^2.K
k=37;//Thermal conductivity in W/m.K
a=0.025;//Thermal diffusivity in m^2/h

//CALCULATIONS
L1=L/2;//L values of the parallelepiped in m
Bi1=(h*L(1))/k;//Biot number
X1=(a*t)/L(1)^2;//X1 for calculating P(X1)
PX1=0.68;//P(X1) value from From Fig.5.7 on page no.183
Bi2=(h*L(2))/k;//Biot number
X1=(a*t)/L(2)^2;//X1 for calculating P(X2)
PX2=0.57;//P(X2) value from From Fig.5.7 on page no.183
Bi3=(h*L(3))/k;//Biot number
Y=(1/Bi3);//Inverse of Biot number
X1=(a*t)/L(3)^2;//X1 for calculating P(X3)
PX3=0.22;//P(X3) value from From Fig.5.7 on page no.183
T=PX1*PX2*PX3;//Temperature at the centre of billet in degree C
T1=T*(Ti-Tf)+Tf;//Temperature at the centre of cylinder 90 minutes after heating is initiated in degree C

//OUTPUT
mprintf('Temperature at the centre of cylinder 90
```

```
minutes after heating is initiated is %3.2f degree C',T1)

//==========================================END OF PROGRAM=======================================
```

Scilab code Exa 5.18 `Surface temperature`

```
//Chapter-5, Example 5.18, Page 202
//=====================================================================================

clc
clear


//INPUT DATA
Ti=30;//Initial temperature of the slab in degree C
q=(2*10^5);//Constant heat flux in W/m^2
k=400;//Thermal conductivity in W/m.K
a=(117*10^-6);//Thermal diffusivity in m^2/h
n=0.075;//Nodal spacing in m
x=0.15;//Depth in m
t=(4*60);//Time elapsed in s

//CALCULATION
R=(x^2/(a*t));//R value for t1
t1=(n^2/(R*a));//Value of t1 in s
To=121.9;//The surface temperature after 4 min in degree C from the table on page no. 203
T2=64;//Temperature at 0.15 m from the surface after 4 minutes in degree C from the table on page no. 203

//OUTPUT
```

```
mprintf('The surface temperature after 4 min is %3.1f degree C \n Temperature at 0.15 m from the surface after 4 minutes is %i degree C',To,T2)

//==============================================END OF PROGRAM===========================================
```

Scilab code Exa 5.19 `Time elapsed`

```
//Chapter-5, Example 5.19, Page 205
//=============================================================================================

clc
clear


//INPUT DATA
t=0.6;//Thickness of the wall in m
x=0.1;//x value taken from Fig.Ex. 5.19 on page no. 205
Ti=20;//Initial temperature in degree C
T=[150,300];//Temperatures of the sides of the wall in degree C
Tf=150;//Final temperature of the wall in degree C
a=(1.66*10^-3);//Thermal diffusivity in m^2/h

//CALCULATIONS
t=(x^2/(2*a));//Length of one time increment in h
t1=(9*t);//Elapsed time in h

//OUTPUT
mprintf('Elasped time before the centre of the wall attains a temperature of 150 degree C is %3.0f h',t1)
```

```

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 5.20 `Temperature`

```
//Chapter-5, Example 5.20, Page 206
//==========================================================================================================
clc
clear


//INPUT DATA
k=0.175;//Thermal conductivity in W/m.K
a=(0.833*10^-7);//Thermal diffusivity in m^2/h
Th=144;//Heated temeparture in degree C
Tc=15;//Cooled temperature in degree C
x=0.02;//Thickness of the plate in m
h=65;//Heat transfer coefficient in W/m^2.K
t=(4*60);//Tiem elapsed in s

//CALCULATIONS
s=0.002;//Space increment in m from FIg. Ex. 5.20 on page no. 207
t1=(s^2/(2*a));//Time increment for the space increment in s
x1=(k/h);//Convective film thickness in mm
Tn=114;//Temperature at the centre in degree C from Fig. Ex.5.20 on page no. 207
Ts=50;//Surface temperature in degree C from Fig. Ex.5.20 on page no. 207

//OUTPUT
```

```
mprintf('Temperature at the centre is %i degree C \nSurface temperature is %i degree C',Tn,Ts)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 5.21 Amplitude of temperature and time lag

```
//Chapter-5, Example 5.21, Page 213
//==========================================================================================================

clc
clear


//INPUT DATA
t=24;//Time period in h
T=[-10,10];//Range of temperatures in degree C
x=0.1;//Depth in m
c=1970;//Specific heat in J/kg/K
p=1000;//Density in kg/m^3
k=0.349;//Thermal conductivity in W/m.K
ta=5;//Time in h

//CALCULATIONS
w=(2*3.14)/t;//Angular velocity in rad/h
Tm=(T(1)+T(2))/2;//Mean teperature in degree C
Tmax=T(2)-Tm;//Maximum temperature in degree C
a=((k*3600)/(p*c));//Thermal diffusivity in m^2/h
Txmax=Tmax*exp(-sqrt(w/(2*a))*x);//Amplitude of temperature variation in degree C
t1=sqrt(1/(2*a*w))*x;//Time lag of temperature wave at a depth of 0.1 m in h
t2=(3.14/w);//Time for surface temperature is
```

```
minimum in h
t3=t2+ta;//Time in h
Tx=Tmax*exp(-sqrt(w/(2*a))*x)*cos((w*t3)-(x*x*sqrt(w/(2*a))));//Temperature at 0.1m 5 hours after the surface temperature reaches the minimum in degree C

//OUTPUT
mprintf('Amplitude of temperature variation at a depth of 0.1m is %3.2f degree C \n Time lag of temperature wave at a depth of 0.1 m is %3.2f h \n Temperature at 0.1m 5 hours after the surface temperature reaches the minimum is %3.3f degree C',Txmax,t1,Tx)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 5.22 `Time lag and heat flow`

```
//Chapter-5, Example 5.22, Page 214
//=============================================================================

clc
clear

//INPUT DATA
T=[800,200];//Limits in which temperature varies in degree C
t=12;//Cycle time in h
x=0.1;//Depth of penetration in m
k=1.8;//Thermal conductivity in W/m.K
a=0.02;//Thermal diffusivity in m^2/h

```

```
//CALCULATIONS
w=(2*3.14)/t;//Angular velocity in rad/h
t1=sqrt(1/(2*a*w))*x;//Time lag in h
Tmax=(T(1)-T(2))/2;//Range of maximum temperature in degree C
q=((2*k*Tmax)/sqrt(w*a))*(3600/1000);//Heat flow through the surface in kJ/m^2

//OUTPUT
mprintf('(i)Time lag of the temperature wave at a depth of 10 cm from the inner surface is %3.2f h\n(ii)The flow through a surface located at a distance of 10 cm from the surface during the first six hours interval while the temperature is above the mean value is %i kJ/m^2',t1,q)

//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 5.23 `Depth of penetration`

```
//Chapter-5, Example 5.23, Page 215
//==================================================================================================

clc
clear


//INPUT DATA
N=2000;//Speed of the engine
a=0.06;//Thermal diffusivity in m^2/h

//CALCULATIONS
t=1/(60*N);//Period of on oscillation in h
```

```
x=(1.6*sqrt(3.14*a*t))*1000;//Depth of penetration in mm

//OUTPUT
mprintf('Depth of penetration of the temperature oscillation into the cylinder wall of a single acting cylinder two stroke IC engine is%3.0f mm',x)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 5.24 `Instantaneous heat removal rate`

```
//Chapter-5, Example 5.24, Page 218
//=============================================================================


clc
clear


//INPUT DATA
Tc=55;//Tempaerature of concrete hyway in degree C
Tl=35;//Temperature lowered in degree C
Tf=45;//Final temperature in degree C
x=0.05;//Depth in m
k=1.279;//Thermal conductivity in W/m.K
a=(1.77*10^-3);//Thermal diffusivity in m^2/h

//CALCULATIONS
t=1.4;//Time taken from page no. 219 in h
q=2*(k*(Tl-Tf))/(sqrt(3*a*t));//Instantaneous heat removal rate in W/m^2

```

```
//OUTPUT
mprintf('Instantaneous heat removal rate is %3.1f W/m^2',q)

//=====================================END OF PROGRAM=====================================
```

Chapter 6

Fundamentals of convective heat transfer

Scilab code Exa 6.2 `Type of flow`

```
//Chapter-6, Example 6.2, Page 241
//========================================================================

clc
clear

//INPUT DATA
L=1;//Length of the palte in m
W=1;//Width of the plate in m
v=2.5;//Velocity of air in m/s
Re=(5*10^5);//Reynolds number at the transition from laminar to turbulant
p=(0.85*10^-5);//Dynamic viscosity in N.s/m^2
r=1.12;//Density in kg/m^3

//CALCULATIONS
x=(p*Re)/(r*v);//Calculated length in m

```

```
//OUTPUT
mprintf('Since the actual length of the plate is %i m, which is less than %3.2f m, the flow is laminar over the entire length of plate',L,x)

//==========================================END OF PROGRAM======================================
```

Scilab code Exa 6.6 `Maximum temperature rise and heat flux`

```
//Chapter-6, Example 6.6, Page 247
//==========================================================================================

clc
clear

//INPUT DATA
p=0.8;//Dynamic viscosity in N.s/m^2
k=0.15;//Thermal conductivity in W/m.K
Tb=10;//Temperature of bearing in degree C
Ts=30;//Temperature of the shaft in degree C
C=0.002;//Clearance between bearig and shaft in m
U=6;//Velocity in m/s

//CALCULATIONS
qb=(((-p*U^2)/(2*C))-((k/C)*(Ts-Tb)))/1000;//Surface heat flux at the bearing in kW/m^2
qs=(((p*U^2)/(2*C))-((k/C)*(Ts-Tb)))/1000;//Surface heat flux at the shaft in kW/m^2
Tmax=Tb+(((p*U^2)/(2*k))*(0.604-0.604^2))+((Ts-Tb)*0.604);//Maximum temperature in degree C occurs when ymax=0.604L

//OUTPUT
```

```
mprintf('Maximum temperature rise is %3.3f degree C \n Heat fux to the bearing is %3.1f kW/m^2 \n Heat fux to the shaft is %3.1f kW/m^2',Tmax,qb,qs)

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 6.7 `Type of flow and entry length`

```
//Chapter-6, Example 6.7, Page 257
//==============================================================================================================

clc
clear

//INPUT DATA
D=0.02;//I.D of the tube in m
Q=1.5;//Flow rate in litres per minute
k=(1*10^-6);//kinematic viscosity in m^2/s

//CALCULATIONS
um=((Q/60)*10^-3)/(3.14*(D^2/4));//Average velocity in m/s
Re=(um*D)/k;//Reynolds number
x=0.05*D*Re;//Entry length in m

//OUTPUT
mprintf('Since Re which is %3.0f less than 2300, the flow is laminar. \n Entry length is %3.3f m',Re,x)

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 6.8 `Head loss and power required`

```
//Chapter-6, Example 6.8, Page 257
//=============================================================================================================
clc
clear

//INPUT DATA
L=3000;//Diatance transported in m
D=0.02;//I.D of the tube in m
Q=1.5;//Flow rate in litres per minute
k=(1*10^-6);//kinematic viscosity in m^2/s
pw=1000;//Density of water in kg/m^3

//CALCULATIONS
um=((Q/60)*10^-3)/(3.14*(D^2/4));//Average velocity in m/s
Re=(um*D)/k;//Reynolds number
x=0.05*D*Re;//Entry length in m
hL=((64/Re)*L*um^2)/(2*D*9.81)//Head loss in m
P=(pw*9.81*(3.14/4)*D^2*um*hL);//Power required to maintain this flow rate in W

//OUTPUT
mprintf('Head loss is %3.2f m \n Power required to maintain this flow rate is %3.4f W',hL,P)

//===============================================END OF PROGRAM=============================================
```

Scilab code Exa 6.9 Pressure drop

```
//Chapter-6, Example 6.9, Page 258
//=============================================================================

clc
clear

//INPUT DATA
L=100;//Length of rectangular duct in m
A=[0.02,0.025];//Area of duct in m^2
Tw=40;//Temperature of water in degree C
v=0.5;//Velocity of flow in m/s
k=(0.66*10^-6);//kinematic viscosity in m^2/s
p=995;//Density of water in kg/m^3

//CALCULATIONS
P=2*(A(1)+A(2));//Perimeter of the duct in m
Dh=(4*(A(1)*A(2)))/P//Hydraulic diameter of the duct in m
Re=(v*Dh)/k;//Reynolds number
f=0.316*Re^(-0.25);//Friction factor
hL=(f*L*v^2)/(2*Dh*9.81);//Head loss in m
P=(hL*9.81*p)/10^4;//Pressure drop in smooth rectangular duct in 10^4 N/m^2

//OUTPUT
mprintf('Pressure drop in smooth rectangular duct is %3.4f*10^4 N/m^2',P)

//=================================END OF PROGRAM==============================
```

Chapter 7

Forced Convection Systems

Scilab code Exa 7.1 `Thickness of hydrodynamic boundary layer and skin friction coe`

```
//Chapter-7, Example 7.1, Page 275
//=========================================================================

clc
clear

//INPUT DATA
Ta=20;//Temperature of air in degree C
Tp=134;//Temperature of heated plate in degree C
v=3;//Velocity of flow in m/s
L=2;//Length of plate in m
W=1.5;//Width of plate in m
x=0.4;//Distance of plane from the plate in m
k=(15.06*10^-6);//Kinematic viscosity in m^2/s

//CALCULATIONS
Re=(v*x)/k;//Reynold number
q=((5*x)/sqrt(Re))*1000;//Thickness of boundary layer in mm
Cfx=(0.664/sqrt(Re))/10^-3;//Local skin friction
```

```
    coefficient *10^-3

//OUTPUT
mprintf('Thickness of boundary layer is %3.1f mm \
    nLocal skin friction coefficient is %3.2f*10^-3',
    q,Cfx)

//==================================================END OF PROGRAM
    ==============================================
```

Scilab code Exa 7.2 `Local heat transfer coefficient`

```
//Chapter-7, Example 7.2, Page 275
//
    ====================================================================================================

clc
clear

//INPUT DATA
Ta=20;//Temperature of air in degree C
Tp=134;//Temperature of heated plate in degree C
v=3;//Velocity of flow in m/s
L=2;//Length of plate in m
W=1.5;//Width of plate in m
x=0.4;//Distance of plane from the plate in m
k=(15.06*10^-6);//Kinematic viscosity in m^2/s

//CALCULATIONS
Tf=(Ta+Tp)/2;//Film temperature in degree C
pw=0.998;//Density of air at 77 degree C
Cp=1009;//Specific heat of air at 77 degree C
kw=(20.76*10^-6);//Kinematic viscosity of air at 77
    degree C
k=0.03;//Thermal conductivity of air at 77 degree C
```

```
Pr=0.697;//prantl number of air at 77 degree C
Re=(v*x)/kw;//Reynolds number
Nu=(0.332*Re^0.5*Pr^(1/3));//Nusselts number
h=(Nu*k)/x;//Heat transfer coefficient in W/m^2.K
h1=(h*2);//Average value of heat transfer coefficient in W/m^2.K
Q=h1*x*W*(Tp-Ta);//Heat flow in W
Q1=(2*Q);//Heat flow from both sides of the plate in W

//OUTPUT
mprintf('Heat flow from both sides of the plate is %3.0f W',Q1)

//====================================================END OF PROGRAM=============================================
```

Scilab code Exa 7.3 Boundary layer thickness and total drag force

```
//Chapter-7, Example 7.3, Page 282
//==============================================================================================================

clc
clear

//INPUT DATA
Ta=20;//Temperature of air in degree C
v=3;//Velocity of flow in m/s
L=2;//Length of plate in m
W=1;//Width of plate in m
x1=0.3;//Initial point of the boundary layer in m
x2=0.8;//Final point of the boundary layer in m
p=1.17;//Density of air at 20 degree C in kg/m^3
k=(15*10^-6);//Kinematic viscosity in m^2/s
```

```
Re=(5*10^5);//Reynolds number at the transition frm laminar to turbulant

//CALCULATIONS
x=(k*Re)/v;//Critical length in m
Rel=(v*L)/k;//Reynolds number
q=(4.64*L)/sqrt(Rel)*1000;//Boundary layer thickness at the trailing edge of plate in mm
ts=1.292*(0.5*p*v^2)*sqrt(1/Rel);//Average shear stress in N/m^2
F=(2*L*ts);//Drag force on the two sides of the plate in N
q80=(4.64*x2)/sqrt((v*x2)/k);//Boundray layer thickness at x=0.8 m
q30=(4.64*x1)/sqrt((v*x1)/k);//Boundray layer thickness at x=0.3 m
m=((5/8)*p*v*(q80-q30))/10^-3;//Mass flow of air in kg/s

//OUTPUT
mprintf('Boundary layer thickness at the trailing edge of plate is % 3.2f mm \nDrag force on the two sides of the plate is %3.4f N \nMass flow of air is %3.1f*10^-3 kg/s',q,F,m)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 7.4 `Rate of heat to be removed`

```
//Chapter-7, Example 7.4, Page 283
//==========================================================================================================
clc
```

```
clear

//INPUT DATA
P=8;//Pressure of air in kN/m^2
Ta=250;//Temperature of air in degree C
L=1;//Length of the palte in m
W=0.3;//Width of the plate in m
v=8;//Velocity of air in m/s
Tp=78;//Temperature of plate in degree C

//CALCULATIONS
Tf=(Ta+Tp)/2;//Film temperature in degree C
Cp=1018;//Specific heat of air at 164 degree C and 1 atm pressure
kw=(30.8*10^-6);//Kinematic viscosity of air at 164 degree C and 1 atm pressure
k=0.0364;//Thermal conductivity of air at 164 degree C and 1 atm pressure
Pr=0.69;//prant number of air at 164 degree C and 1 atm pressure
k1=kw*(101330/(P*1000));//Kinematic viscosity of air at 164 degree C and 8kN/m^2 pressure
Re=(v*L)/k1;//Reynolds number
h=0.662*(k/L)*sqrt(Re)*Pr^(1/3);//Heat transfer coefficient in W/m.K
Q=2*h*L*W*(Ta-Tp);//Rate of heat removal in W

//OUTPUT
mprintf('Rate of heat removal is %3.1f W',Q)

//==========================================END OF PROGRAM==========================================
```

Scilab code Exa 7.5 Drag force

```
//Chapter-7, Example 7.5, Page 286
//

clc
clear

//INPUT DATA
P=8;//Pressure of air in kN/m^2
Ta=250;//Temperature of air in degree C
L=1;//Length of the palte in m
W=0.3;//Width of the plate in m
v=8;//Velocity of air in m/s
Tp=78;//Temperature of plate in degree C
R=287;//Universal gas constant in J/kg.K

//CALCULATIONS
Tf=(Ta+Tp)/2;//Film temperature in degree C
Cp=1018;//Specific heat of air at 164 degree C and 1 atm pressure
kw=(30.8*10^-6);//Kinematic viscosity of air at 164 degree C and 1 atm pressure
k=0.0364;//Thermal conductivity of air at 164 degree C and 1 atm pressure
Pr=0.69;//prant number of air at 164 degree C and 1 atm pressure
k1=kw*(101330/(P*1000));//Kinematic viscosity of air at 164 degree C and 8kN/m^2 pressure
Re=(v*L)/k1;//Reynolds number
h=0.662*(k/L)*sqrt(Re)*Pr^(1/3);//Heat transfer coefficient in W/m.K
Q=2*h*L*W*(Ta-Tp);//Rate of heat removal in W
p=(P*1000)/(R*(Tf+273));//Density in kg/m^3
St=(h/(p*Cp*v));//Stanton number
Cfx2=(St*Pr^(2/3));//Colburn factor
ts=(Cfx2*p*v^2);//Average shear stress in N/m^2
D=(ts*W*L);//Drag force on one side of plate in N
D2=(2*D)/10^-3;//Total drag force on both sides of
```

```
plate in N

//OUTPUT
mprintf('The drag force exerted on the plate is %3.2f*10^-3 N',D2)

//==========================================END OF PROGRAM======================================
```

Scilab code Exa 7.6 Thickness of boundary layer and heat transfer coefficient

```
//Chapter-7, Example 7.6, Page 289
//=============================================================================

clc
clear

//INPUT DATA
L=1;//Length of the palte in m
W=1;//Width of the plate in m
Ts=10;//Temperature of free strem air in degree C
v=80;//Velocity of free stream air in m/s

//CALCULATIONS
k=0.025;//Thermal conductivity of air at 10 degree C
Pr=0.72;//prant number of air at 10 degree C
v1=(14.15*10^-6);//Kinematic viscosity of air at 10 degree C
Re=(v*L)/v1;//Reynolds number
q=0.381*L*Re^(-1/5);//Thickness of the boundary layer at the trailing edge of the plate in m
Nu=(0.037*Re^(4/5)*Pr^(1/3));//Nusselts number
h=(Nu*k)/L;//Mean value of the heat transfer coefficient in W/m^2.K
```

```

//OUTPUT
mprintf('Thickness of the boundary layer at the trailing edge of the plate is %3.4f m \nMean value of the heat transfer coefficient is %3.0f W/m^2.K',q,h)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 7.7 `Friction coefficient and heat transfer coefficient`

```
//Chapter-7, Example 7.7, Page 290
//=============================================================================

clc
clear

//INPUT DATA
Ta=0;//Temperature of air stream in degree C
Tp=90;//Temperature of heated plate in degree C
v=75;//Speed of air in m/s
L=0.45;//Length of the palte in m
W=0.6;//Width of the plate in m
Re=(5*10^5);//Reynolds number at the transition from laminar to turbulant

//CALCULATIONS
Tf=(Ta+Tp)/2;//Film temperature in degree C
k=0.028;//Thermal conductivity of air at 10 degree C
Pr=0.698;//prant number of air at 10 degree C
v1=(17.45*10^-6);//Kinematic viscosity of air at 10 degree C
x=(Re*v1)/v;//Critical length in m
```

```
Rel=(v*L)/v1;//Reynolds number
Cfl=((0.074/Rel^(1/5))-(1740/Rel))/10^-3;//Average value of friction coefficient *10^-3
Nu=((0.037*Rel^(4/5))-870)*Pr^(1/3);//Nussults number
h=(Nu*k)/L;//Heat transfer coefficient in W/m^2.K
Q=(2*h*L*W*(Tp-Ta));//Rate of energy dissipation in W

//OUTPUT
mprintf('Average value of friction coefficient is %3.2f*10^-3 \nHeat transfer coefficient is %3.0f W/m^2.K \nRate of energy dissipation is %i W',Cfl,h,Q)

//==================================END OF PROGRAM================================
```

Scilab code Exa 7.8 `Heat loss`

```
//Chapter-7, Example 7.8, Page 296
//=============================================================================

clc
clear

//INPUT DATA
D=0.3;//Diameter of cylinder in m
L=1.7;//Height of cylinder in m
Ts=30;//Surface temperature in degree C
v=10;//Speed of wind in m/s
Ta=10;//Temperature of air in degree C

//CALCULATIONS
```

```
Tf=(Ta+Ts)/2;//Film temperature in degree C
k=0.0259;//Thermal conductivity of air at 20 degree C
Pr=0.707;//prant number of air at 20 degree C
v1=(15*10^-6);//Kinematic viscosity of air at 20 degree C
Re=(v*D)/v1;//Reynolds number
Nu=0.027*Re^0.805*Pr^(1/3)//Nusselts number
h=(Nu*k)/D;//Heat transfer coefficent in W/m^2.K
Q=(h*3.14*D*L*(Ts-Ta));//Rate of heat loss in W

//OUTPUT
mprintf('Rate of heat loss is %3.1f W',Q)

//==========================================END OF PROGRAM==========================================
```

Scilab code Exa 7.9 Heat transfer rate and percentage of power lost

```
//Chapter-7, Example 7.9, Page 297
//==================================================================================

clc
clear

//INPUT DATA
Ta=27;//Temperature of air stream in degree C
v=0.3;//Velodity of air in m/s
Q=100;//Poer of electric bulb in W
Te=127;//Temperature of electric bulb in degree C
D=0.06;//Diameter of sphere in m

//CALCULATIONS
Tf=(Ta+Te)/2;//Film temperature in degree C
```

```
k=0.03;//Thermal conductivity of air at 77 degree C
Pr=0.697;//prant number of air at 77 degree C
v1=(2.08*10^-5);//Kinematic viscosity of air at 77 degree C
Re=(v*D)/v1;//Reynolds number
h=(k*0.37*Re^0.6)/D;//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*D^2*(Te-Ta));//Heat transfer rate in W
Qp=(Q*100)/100;//Percentage of heat lost by forced convection

//OUTPUT
mprintf("Heat transfer rate is %3.2f W \nPercentage of power lost due to convection is %3.2f percent',Q,Qp)

//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 7.10 `Heat transfer coefficient and current intensity`

```
//Chapter-7, Example 7.10, Page 297
//==================================================================================================

clc
clear

//INPUT DATA
D=0.015;//Diamter of copper bus bar in m
Ta=20;//Temperature of air stream in degree C
v=1;//Velocity of air in m/s
Ts=80;//Surface temperature in degree C
p=0.0175;//Resistivity of copper in ohm mm^2/m

```

```
//CALCULATIONS
Tf=(Ta+Ts)/2;//Film temperature in degree C
k=0.02815;//Thermal conductivity of air at 50 degree C
Pr=0.703;//prant number of air at 50 degree C
v1=(18.9*10^-6);//Kinematic viscosity of air at 50 degree C
Re=(v*D)/v1;//Reynolds number
Nu=0.3+(((0.62*sqrt(Re)*Pr^(1/3))/(1+(0.4/Pr)^(2/3))^(1/4))*(1+(Re/28200)^(5/8))^(4/5));//Nusselts number
h=(Nu*k)/D;//Heat transfer coefficent in W/m^2.K
I=1000*3.14*D*sqrt((h*(Ts-Ta)*D)/(4*p));//Current in A

//OUTPUT
mprintf('Heat transfer coefficient between the bus bar and cooling air is %3.2f W/m^2.K \nMaximum admissible current intensity for the bus bar is %3.0f A',h,I)

//==================================END OF PROGRAM==============================
```

Scilab code Exa 7.11 `Rate of heat transfer`

```
//Chapter-7, Example 7.11, Page 298
//=============================================================================

clc
clear

//INPUT DATA
Ta=30;//Temperature of air stream in degree C
```

```
v=25;//Velocity of stream in m/s
x=0.05;//Side of a square in m
D=0.05;//Diameter of circular cylinder in m
Ts=124;//Surface temperature in degree C

//CALCULATIONS
Tf=(Ta+Ts)/2;//Film temperature in degree C
k=0.03;//Thermal conductivity of air at 77 degree C
Pr=0.7;//prantL number of air at 77 degree C
v1=(20.92*10^-6);//Kinematic viscosity of air at 77 degree C
Re=(v*D)/v1;//Reynolds number
Nu1=0.027*Re^0.805*Pr^(1/3);//Nussults number for circulat tube
h1=(Nu1*k)/D;//Heat tansfer coefficient for circular tube in W/m^2.K
Nu2=0.102*Re^0.675*Pr^(1/3);//Nussults number for square tube
h2=(Nu2*k)/D;//Heat transfer coefficient for square tube in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient for circular tube is %3.1f W/m^2.K \nHeat transfer coefficient for square tube is %3.2f W/m^2.K',h1,h2)

//==================================END OF PROGRAM==============================
```

Scilab code Exa 7.12 `Heat transfer coefficient and pressure drop`

```
//Chapter-7, Example 7.12, Page 302
//==============================================================================
```

```
clc
clear

//INPUT DATA
n=7;//Number of rows of tube
Ta=15;//Temperature of air in degree C
v=6;//Velocity of air in m/s
ST=0.0205;//Transverse  pitch in m
SD=0.0205;//Longitudinal pitch in m
D=0.0164;//Outside diameter of the tube in m
Ts=70;//Surface temperature in degree C

//CALCULATIONS
Tf=(Ta+Ts)/2;//Film temperature in degree C
k=0.0274;//Thermal conductivity of air at 42.5 degree C
Pr=0.705;//prant number of air at 42.5 degree C
v1=(17.4*10^-6);//Kinematic viscosity of air at 42.5 degree C
p=1.217;//Density in kg/m^3
vmax=(v*ST)/(ST-D);//Maximum velocity in m/s
Re=(vmax*D)/v1;//Reynolds number
Nu=(1.13*0.518*Re^0.556*Pr^(1/3))*0.97;//Nusselts number
h=(Nu*k)/D;//Heat transfer coefficent in W/m^2.K
f=0.4;//From Fig. 7.10 on page no 303
g=1.04;//From Fig. 7.10 on page no 303
dp=(n*f*p*vmax^2*g)/2;//Pressure drop in N/m^2

//OUTPUT
mprintf('Heat transfer coefficent is %3.2f W/m^2.K \nPressure drop is %3.0f N/m^2',h,dp)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 7.13 `Convection coefficient`

```
//Chapter-7, Example 7.13, Page 304
//

clc
clear

//INPUT DATA
n=7;//Number of rows of tube
Ta=15;//Temperature of air in degree C
v=6;//Velocity of air in m/s
ST=0.0205;//Transverse  pitch in m
SD=0.0205;//Longitudinal pitch in m
D=0.0164;//Outside diameter of the tube in m
Ts=70;//Surface temperature in degree C

//CALCULATIONS
Tf=(Ta+Ts)/2;//Film temperature in degree C
k=0.0253;//Thermal conductivity of air at 15 degree C
Pr=0.710;//prant number of air at 15 degree C
v1=(14.82*10^-6);//Kinematic viscosity of air at 15 degree C
p=1.217;//Density in kg/m^3
Pr1=0.701;//prant number of air at 70 degree C
vmax=(v*ST)/(ST-D);//Maximum velocity in m/s
Re=(vmax*D)/v1;//Reynolds number
Nu=0.35*Re^0.6*(Pr/Pr1)^0.25;//
h=(Nu*k)/D;//Heat transfer coefficient in W/m^2.K

mprintf(' Heat transfer coefficient is %3.1f W/m^2.K which is 10 percent more than that obtained in
```

```
the previous example',h)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 7.14 Convective heat transfer coefficient

```
//Chapter-7, Example 7.14, Page 305
//==================================================================================================

clc
clear

//INPUT DATA
m=0.314;//Mass flow rate of air in m^3/s
n1=7;//Number of tubes in the direction of flow
n2=8;//Number of tubes perpendicular to the direction of flow
L=1.25;//Length of each tube in m
D=0.019;//Outer diameter in m
ST=0.0286;//Transverse  pitch in m
SD=0.038;//Longitudinal pitch in m
Ta=200;//Temperature of air in degree C
Ts=96;//Surface temperature in degree C

//CALCULATIONS
Tf=(Ta+Ts)/2;//Film temperature in degree C
k=0.039;//Thermal conductivity of air at 15 degree C
Pr=0.688;//prantl number of air at 15 degree C
v1=(3*10^-5);//Kinematic viscosity of air at 15 degree C
vmax=(m/((ST*n2*L)-(D*n2*L)));//Maximum velocity in m/s
Re=(vmax*D)/v1;//Reynolds number
```

```
Nu=(0.299*Re^0.602*Pr^(1/3));//Nusselts number
X=0.96;//From Table 7.5 on page no.302
Nux=(X*Nu);//Average nusselts number
h=(Nux*k)/D;//Convective heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Convective heat transfer coefficient is %3.2f W/m^2.K',h)

//=================================END OF PROGRAM=================================
```

Scilab code Exa 7.15 `Average temperature of the fluid`

```
//Chapter-7, Example 7.15, Page 310
//=================================================================================

clc
clear

//INPUT DATA
D=0.2;//Diameter of pipeline in m
//velocity profile is given by u=96r-190r^2 m/s
//Temperature profile is given by T=100(1-2r) degree C

//CALCULATIONS
vmax=(64*(D/2))-(95*(D/2)^2);//Mean velocity in m/s
T=(2/(vmax*(D/2)^2))*(((9600*(D/2)^3)/3)-((38200*(D/2)^4)/4)+((38000*(D/2)^5)/5));//Average temperature of the fluid in degree C

//OUTPUT
```

```
mprintf('Average temperature of the fluid is %3.2f degree C',T)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 7.16 `Length and heat transfer coefficient`

```
//Chapter-7, Example 7.16, Page 311
//=============================================================================================================

clc
clear

//INPUT DATA
Di=0.025;//I.D of the tube in m
Do=0.04;//O.D of the tube in m
m=5;//Mass flow rate of water in kg/m
T=[20,70];//Temperature at entry and exit of water in degree C
Q=10^7;//Heat in W/m^3
Ts=80;//Surface temperature in degree C
Cp=4179;//Specific heat of water in J/kg.K

//CALCULATIONS
Tb=(T(1)+T(2))/2;//Film temperature in degree C
L=((4*(m/60)*Cp*(T(2)-T(1)))/(3.14*(Do^2-Di^2)*Q));//Length of tube in m
qs=((Q*(Do^2-Di^2))/(4*Di));//Heat flux at the surface in W/m^2
h=(qs/(Ts-T(2)));//Heat transfer coefficient at the outlet in W/m^2.K

//OUTPUT
```

```
mprintf('Length of tube is %3.3f m \nHeat transfer coefficient at the outlet is %3.0f W/m^2.K',L,h)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 7.17 `Heat transfer coefficient and heat transfer rate`

```
//Chapter-7, Example 7.17, Page 312
//=============================================================================

clc
clear

//INPUT DATA
k=0.175;//Thermal conductivity in W/m.K
Di=0.006;//I.D of the tube in m
L=8;//Length of the tube in m
dT=50;//Mean temperature difference in degree C

//CALCULATIONS
h=(3.66*k)/Di;//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*Di*L*dT);//Heat transfer rate in W

//OUTPUT
mprintf('Heat transfer coefficient is %3.2f W/m^2.K \nHeat transfer rate is %3.0f W',h,Q)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 7.18 `Heat transfer coefficient and length of the tube`

```
//Chapter-7, Example 7.18, Page 312
//=============================================================================

clc
clear

//INPUT DATA
Ti=25;//Initial temperature of water in degree C
D=0.05;//Diamter of the tube in m
Re=1600;//Reynolds number
q=800;//Heat flux in W/m
Tf=50;//Final temperature of water in degree C

//CALCULATIONS
k=0.61;//Thermal conductivity of water at 25 degree C in W/m.K
u=(915*10^-6);//Dynamic viscosity in N.s/m^2
m=(Re*3.14*D*u)/4;//Mass flow rate of water in kg/s
h=(4.364*k)/D;//Heat transfer coefficient in W/m^2.K
qs=(q/(3.14*D));//Constant heat flux in W/m^2
Cp=4178;//Specific heat of water in J/kg.K
L=((m*Cp*(Tf-Ti))/q);//Length of the tube in m

//OUTPUT
mprintf('Average heat transfer coefficient is %3.2f W/m^2.K \nLength of the tube is %3.3f m',h,L)

//===================================END OF PROGRAM===================================
```

Scilab code Exa 5.19 `Nusselt number`

```
//Chapter-7, Example 7.19, Page 314
//
```

```
clc
clear

//INPUT DATA
Di=0.015;//I.D of the tube in m
Tb=60;//Temperature of the tube in degree C
m=10;//Flow rate of water in ml/s
Ti=20;//Temperature of water at entry in degree C
x=1;//Distance form the plane in m
Tx=34;//Temperature of water at 1 m distance in degree C

//CALCULATIONS
Tbm=(Ti+Tx)/2;//Mean value of bulk temperature in degree C
pw=997;//Density of air at 27 degree C in kg/m^3
Cp=4180;//Specific heat of air at 27 degree C in J/kg.K
u=(855*10^-6);//Dynamic viscosity of air at 27 degree C in N.s/m^2
k=0.613;//Thermal conductivity of air at 27 degree C in W/m.K
Pr=5.83;//prantl number of air at 27 degree C
us=(464*10^-6);//Dynamic viscosity of air at 60 degree C in Ns/m^2
um=(m*10^-6)/((3.14/4)*Di^2);//Mean speed in m/s
Re=(pw*um*Di)/u;//Reynolds number
Nu=3.66+((0.0668*(Di/x)*Re*Pr)/(1+(0.04*((Di/x)*Re*Pr)^(2/3))));//Nusselts number in Haussen correlation
Nux=(1.86*((Re*Pr)/(x/Di))^(1/3)*(u/us)^0.14);//Nusselsts number in Sieder - Tate correlation

//OUTPUT
mprintf('Nusselts number in Haussen correlation is %3.2f \nNusselsts number in Sieder - Tate
```

```
correlation is %3.3f',Nu,Nux)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 7.20 `Heat transfer coefficient`

```
//Chapter-7, Example 7.20, Page 318
//====================================================================================================

clc
clear

//INPUT DATA
Tw=50;//Temperature of water in degree C
Di=0.005;//Inner diameter of the tube in m
L=0.5;//Length of the tube in m
v=1;//Mean velocity in m/s
Ts=30;//Surface temperature in degree C

//CALCULATIONS
Tf=(Tw+Ts)/2;//Film temperature in degree C
k=0.039;//Thermal conductivity of air at 15 degree C
Pr=0.688;//prant number of air at 15 degree C
p=990;//Density of air at 50 degree C in kg/m^3
Cp=4178;//Specific heat of air at 50 degree C in J/kg.K
v1=(5.67*10^-7);//Kinematic viscosity of air at 50 degree C
v2=(6.57*10^-7);//Kinematic viscosity of air at 40 degree C
Re=(v*Di)/v1;//Reynolds number
h=((0.316/8)*((v*Di*10)/v2)^(-0.25)*p*Cp*v*(4.34)^(-2/3));//Heat transfer coefficient using the
```

```
    Colburn analogy in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient using the Colburn analogy is %3.0f W/m^2.K',h)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 7.21 `Heat transfer coefficient and heat transfer rate`

```
//Chapter-7, Example 7.21, Page 319
//=============================================================================

clc
clear

//INPUT DATA
Ti=50;//Temperature of water at inlet in degree C
D=0.015;//Diameter of tube in m
L=3;//Length of the tube in m
v=1;//Velocity of flow in m/s
Tb=90;//Temperature of tube wall in degree C
Tf=64;//Exit temperature of water in degree C

//CALCULATIONS
Tm=(Ti+Tf)/2;//Bulk mean temperature in degree C
p=990;//Density of air at 57 degree C in kg/m^3
Cp=4184;//Specific heat of air at 57 degree C in J/kg.K
u=(0.517*10^-6);//Kinematic viscosity of air at 57 degree C in m^2/s
k=0.65;//Thermal conductivity of air at 57 degree C in W/m.K
```

```
Pr=3.15;//prantl number of air at 57 degree C
Re=(v*D)/u;//Reynolds number
Nu=(0.023*Re^(4/5)*Pr^0.4);//Nusselts number
h=(Nu*k)/D;//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*D*L*(Tb-Tm))/1000;//Rate of heat transfered in kW

//OUTPUT
mprintf('Heat transfer coefficient is %3.0f W/m^2.K\nRate of heat transfered is %3.2f kW',h,Q)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 7.22 `Heat transfer coefficient`

```
//Chapter-7, Example 7.22, Page 320
//=============================================================================

clc
clear

//INPUT DATA
D=0.022;//Diamter of the tube in m
v=2;//Average velocity in m/s
Tw=95;//Temperature of tube wall in degree C
T=[15,60];//Initial and final temperature of water in degree C

//CALCULATIONS
Tm=(T(1)+T(2))/2;//Bulk mean temperature in degree C
p=990;//Density of air at 37.5 degree C in kg/m^3
Cp=4160;//Specific heat of air at 37.5 degree C in J/kg.K
```

```
u=(0.69*10^-3);//Dynamic viscosity of air at 37.5 degree C in Ns/m^2
k=0.63;//Thermal conductivity of air at 37.5 degree C in W/m.K
us=(0.3*10^-3);//Dynamic viscosity of air at 37.5 degree C in Ns/m^2
Re=(p*v*D)/u;//Reynolds number
Pr=(u*Cp)/k;//Prantl number
Nu=(0.027*Re^(4/5)*Pr^(1/3)*(u/us)^0.14);//Nusselts number
h=(Nu*k)/D;//Heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient is %3.0f W/m^2.K',h)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 7.23 `Heat transfer coefficient`

```
//Chapter-7, Example 7.23, Page 320
//==============================================================================

clc
clear

//INPUT DATA
D=0.05;//Diamter of the tube in m
T=147;//Average temperature in degree C
v=0.8;//Flow vwlocity in m/s
Tw=200;//Wall temperature in degree C
L=2;//Length of the tube in m

```

```
//CALCULATIONS
p=812.1;//Density in kg/m^3 of oil at 147 degree C
Cp=2427;//Specific heat of oil at 147 degree C in J/kg.K
u=(6.94*10^-6);//Kinematic viscosity of oil at 147 degree C in m^2/s
k=0.133;//Thermal conductivity of oil at 147 degree C in W/m.K
Pr=103;//prantl number of oil at 147 degree C
Re=(v*D)/u;//Reynolds number
Nu=(0.036*Re^0.8*Pr^(1/3)*(D/L)^0.055);//Nussults number
h=(Nu*k)/D;//Average heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Average heat transfer coefficient is %3.1f W/m^2.K',h)

//==========================================================END OF PROGRAM==========================================
```

Scilab code Exa 7.24 `Heat leakage`

```
//Chapter-7, Example 7.24, Page 321
//=============================================================================================

clc
clear

//INPUT DATA
D=[0.4,0.8];//Dimensions of the trunk duct in m
Ta=20;//Temperature of air in degree C
v=7;//Velocity of air in m/s
```

```
v1=(15.06*10^-6);//Kinematic viscosity in m^2/s
a=(7.71*10^-2);//Thermal diffusivity in m^2/h
k=0.0259;//Thermal conductivity in W/m.K

//CALCULATIONS
Dh=(4*(D(1)*D(2)))/(2*(D(1)+D(2)));//Value of Dh in m
Re=(v*Dh)/v1;//Reynolds number
Pr=(v1/a)*3600;//Prantl number
Nu=(0.023*Re^(4/5)*Pr^0.4);//Nussults number
h=(Nu*k)/Dh;//Heat transfer coefficient in W/m^2.K
Q=(h*(2*(D(1)+D(2))));//Heat leakage per unit length per unit difference in W

//OUTPUT
mprintf('Heat leakage per unit length per unit difference is %3.2f W',Q)

//==========================================END OF PROGRAM========================================
```

Scilab code Exa 7.25 Heat transfer coefficient

```
//Chapter-7, Example 7.25, Page 322
//==================================================================================

clc
clear

//INPUT DATA
Di=0.03125;//I.D of the annulus in m
Do=0.05;//O.D of the annulus in m
Ts=50;//Outer surface temperature in degree C
Ti=16;//Temeperature at which air enters in degree C
```

```
Tf=32;//Temperature at which air exits in degree C
v=30;//Flow rate in m/s

//CALCULATIONS
Tb=(Ti+Tf)/2;//Mean bulk temperature of air in degree C
p=1.614;//Density in kg/m^3 of air at 24 degree C
Cp=1007;//Specific heat of air at 24 degree C in J/kg.K
u=(15.9*10^-6);//Kinematic viscosity of air at 24 degree C in m^2/s
k=0.0263;//Thermal conductivity of air at 24 degree C in W/m.K
Pr=0.707;//prantl number of air at 24 degree C
Dh=(4*(3.14/4)*(Do^2-Di^2))/(3.14*(Do+Di));//Hydraulic diameter in m
Re=(v*Dh)/u;//Reynolds number
Nu=(0.023*Re^0.8*Pr^0.4);//Nussults number
h=(Nu*k)/Dh;//Heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient is %3.1f W/m^2.K',h)

//=============================================END OF PROGRAM=========================================
```

Scilab code Exa 7.26 `Minimum length of the tube`

```
//Chapter-7, Example 7.26, Page 324
//=========================================================================================

clc
clear
```

```

//INPUT DATA
T=[120,149];//Initail and final temperatures in degree C
m=2.3;//Mass flow rate in kg/s
D=0.025;//Diameter of the tube in m
Ts=200;//Surface temperature in degree C

//CALCULATIONS
Tb=(T(1)+T(2))/2;//Bulk mean temperature in degree C
p=916;//Density in kg/m^3 of air at 134.5 degree C
Cp=1356.6;//Specific heat of air at 134.5 degree C in J/kg.K
u=(0.594*10^-6);//Kinematic viscosity of air at 134.5 degree C in m^2/s
k=84.9;//Thermal conductivity of air at 134.5 degree C in W/m.K
Pr=0.0087;//prantl number of air at 134.5 degree C
Q=(m*Cp*(T(2)-T(1)))/1000;//Total heat transfer in kW
v=(m/(p*(3.14/4)*D^2));//Velocity of flow in m/s
Re=(v*D)/u;//Reynolds number
Pe=(Pr*Re);//Peclet number
Nu=(4.82+(0.0185*Pe^0.827));//Nussults number
h=(Nu*k)/D;//Heat transfer coefficient in W/m^2.K
L=((Q*1000)/(h*3.14*D*(Ts-Tb)));//Minimum length of the tube in m if the wall temperature is not to exceed 200 degree C

//OUTPUT
mprintf('Minimum length of the tube if the wall temperature is not to exceed 200 degree C is %3.3f m',L)

//==================================END OF PROGRAM==================================
```

Chapter 8

Natural Convection

Scilab code Exa 8.1 Boundary layer thickness

```
//Chapter-8, Example 8.1, Page 340
//
  ==========================================================================

clc
clear

//INPUT DATA
L=0.3;//Length of the glass plate in m
Ta=27;//Temperature of air in degree C
Ts=77;//Surface temperature in degree C
v=4;//Velocity of air in m/s

//CALCULATIONS
Tf=(Ta+Ts)/2;//Film temperature in degree C
k=0.02815;//Thermal conductivity in W/m.K
v1=(18.41*10^-6);//Kinematic viscosity in m^2/s
Pr=0.7;//Prantl number
b=(3.07*10^-3);//Coefficient of thermal expansion in
    1/K
Gr=(9.81*b*(Ts-Ta)*L^3)/v1^2;//Grashof number
```

```
q=L*((3.93*(1/sqrt(Pr))*(0.952+Pr)^0.25*Gr^(-0.25)));//Boundary layer thickness at the trailing edge of the plate in free convection in m
Re=(v*L)/v1;//Reynolds number
q1=(5*L)/sqrt(Re);//Boundary layer thickness at the trailing edge of the plate in forced convection in m

//OUTPUT
mprintf('Boundary layer thickness at the trailing edge of the plate in free convection is % 3.4f m\nBoundary layer thickness at the trailing edge of the plate in forced convection is %3.4f m',q,q1)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 8.2 Heat transfer coefficient

```
//Chapter-8, Example 8.2, Page 341
//=============================================================================================================

clc
clear

//INPUT DATA
L=0.3;//Length of the glass plate in m
Ta=27;//Temperature of air in degree C
Ts=77;//Surface temperature in degree C
v=4;//Velocity of air in m/s

//CALCULATIONS
Tf=(Ta+Ts)/2;//Film temperature in degree C
```

```
k=0.02815;//Thermal conductivity in W/m.K
v1=(18.41*10^-6);//Kinematic viscosity in m^2/s
Pr=0.7;//Prantl number
b=(3.07*10^-3);//Coefficient of thermal expansion in 1/K
Gr=(9.81*b*(Ts-Ta)*L^3)/v1^2;//Grashof number
Re=(v*L)/v1;//Reynolds number
Nu=(0.677*sqrt(Pr)*(0.952+Pr)^(-0.25)*Gr^0.25);//Nusselts number
h=(Nu*k)/L;//Heat transfer coefficient for natural convection in W/m^2.K
Nux=(0.664*sqrt(Re)*Pr^(1/3));//Nusselts number
hx=(Nux*k)/L;//Heat transfer coefficient for forced convection in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient for natural convection is %3.1f W/m^2.K \nHeat transfer coefficient for forced convection is %3.2f W/m^2.K',h,hx)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 8.3 `Heat transfer coefficient and rate of heat transfer`

```
//Chapter-8, Example 8.3, Page 343
//=============================================================================

clc
clear

//INPUT DATA
L=0.609;//Height of the metal plate in m
```

```
Ts=161;//Temperature of the wall in degree C
Ta=93;//Temperature of air in degree C

//CALCULATIONS
Tf=(Ts+Ta)/2;//Film temperature in degree C
k=0.0338;//Thermal conductivity in W/m.K
v1=(26.4*10^-6);//Kinematic viscosity in m^2/s
Pr=0.69;//Prantl number
b=0.0025;//Coefficient of thermal expansion in 1/K
a=(38.3*10^-6);//Thermal diffusivity in m^2/s
Ra=((9.81*b*L^3*(Ts-Ta))/(v1*a));//Rayleigh number
Nu=(0.68+((0.67*Ra^0.25)/(1+(0.492/Pr)^(9/16))^(4/9)));//Nussults number
h=(Nu*k)/L;//Heat transfer coefficient in W/m^2.K
Q=(h*L*(Ts-Ta));//Rate of heat transfer in W

//OUTPUT
mprintf('Heat transfer coefficient is %3.3f W/m^2.K\nRate of heat transfer is %3.2f W',h,Q)

//==========================================END OF PROGRAM======================================
```

Scilab code Exa 8.4 Convective heat loss

```
//Chapter-8, Example 8.4, Page 344
//==========================================================================

clc
clear

//INPUT DATA
W=0.5;//Width of the radiator in m
L=1;//Height of the radiator in m
```

```
Ts=84;//Surface temperature in degree C
Ta=20;//Room temperature in degree C

//CALCULATIONS
Tf=(Ts+Ta)/2;//Film temperature in degree C
k=0.02815;//Thermal conductivity in W/m.K
v1=(18.41*10^-6);//Kinematic viscosity in m^2/s
Pr=0.7;//Prantl number
b=0.003077;//Coefficient of thermal expansion in 1/K
Ra=((9.81*b*L^3*(Ts-Ta)*Pr)/(v1^2));//Rayleigh number
Nu=(0.825+((0.387*Ra^(1/6))/(1+(0.492/Pr)^(9/16))^(8/27)))^2;//Nussults number
h=(Nu*k)/L;//Heat transfer coefficient in W/m^2.K
Q=(h*W*L*(Ts-Ta));//Convective heat loss in W

//OUTPUT
mprintf('Convective heat loss from the radiator is %3.2f W',Q)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 8.5 `Rate of heat input`

```
//Chapter-8, Example 8.5, Page 345
//==============================================================================

clc
clear

//INPUT DATA
L=0.8;//Height of the plate in m
W=0.08;//Width of the plate in m
```

```
Ts=170;//Surafce temperature in degree C
Tw=70;//Temperature of water in degree C
Tf=130;//Final temperature in degree C

//CALCULATIONS
Tb=(Ts+Tw)/2;//Film temperature in degree C
p=960.63;//Density in kg/m^3
k=0.68;//Thermal conductivity in W/m.K
v1=(0.294*10^-6);//Kinematic viscosity in m^2/s
b=0.00075;//Coefficient of thermal expansion in 1/K
Cp=4216;//Specific heat in J/kg.K
a=(1.68*10^-7);//Thermal diffusivity in m^2/s
Lc=(W/2);//Characteristic length in m
Ra=((9.81*b*Lc^3*(Tf-Tw))/(v1*a));//Rayleigh number
Nu1=(0.15*Ra^(1/3));//Nussults number
h1=(Nu1*k)/Lc;//Heat transfer coefficient at top surface in W/m^2.K
Nu2=0.27*(Ra)^(0.25);//Nusselts number
h2=(Nu2*k)/Lc;//Heat transfer coefficient at bottom surface in W/m^2.K
Q=((h1+h2)*W*L*(Tf-Tw))/1000;//Rate of heat input to the plate in kW

//OUTPUT
mprintf('Rate of heat input to the plate necessary to maintain the temperature at %3.0f degree C is %3.2f kW',Tf,Q)

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 8.6 Heat gained by the duct

```
//Chapter-8, Example 8.6, Page 346
//
```

```
clc
clear

//INPUT DATA
L=0.3;//Height of the duct in m
W=0.6;//Width of the duct in m
Ts=15;//Surface temperature in degree C
Ta=25;//Temeprature of air in degree C

//CALCULATIONS
Tb=(Ts+Ta)/2;//Film temperature in degree C
p=1.205;//Density in kg/m^3
k=0.02593;//Thermal conductivity in W/m.K
v1=(15.06*10^-6);//Kinematic viscosity in m^2/s
b=0.00341;//Coefficient of thermal expansion in 1/K
Cp=1005;//Specific heat in J/kg.K
Pr=0.705;//Prantl number
Ra=((9.81*b*L^3*(Ta-Ts)*Pr)/(v1^2));//Rayleigh number
Nux=(0.59*Ra^(0.25));//Nusselts number
hx=(Nux*k)/L;//Heat transfer coefficient in W/m^2.K
Lc=(W/2);//Characteristic length in m
Nu1=(0.15*Ra^(1/3));//Nussults number
h1=(Nu1*k)/Lc;//Heat transfer coefficient at top surface in W/m^2.K
Nu2=0.27*(Ra)^(0.25);//Nusselts number
h2=(Nu2*k)/Lc;//Heat transfer coefficient at bottom surface in W/m^2.K
Q=((2*hx*L)+(W*(h1+h2)))*(Ta-Ts);//Rate of heat gained per unit length in W/m

//OUTPUT
mprintf('Rate of heat gained per unit length is %3.2f W/m',Q)

//==================================END OF PROGRAM
```

```
==========================================================
```

Scilab code Exa 8.7 `Coefficient of heat transfer`

```
//Chapter-8, Example 8.7, Page 348
//
==========================================================================================================================

clc
clear

//INPUT DATA
LH=0.08;//Horizantal length in m
LV=0.12;//Vertical length in m
Ts=50;//Surface temperature in degree C
Ta=0;//Temeprature of air in degree C

//CALCULATIONS
L=(LH*LV)/(LH+LV);//Characteristic length in m
Tb=(Ts+Ta)/2;//Film temperature in degree C
p=0.707;//Density in kg/m^3
k=0.0263;//Thermal conductivity in W/m.K
v1=(15.89*10^-6);//Kinematic viscosity in m^2/s
b=(1/300);//Coefficient of thermal expansion in 1/K
Pr=0.707;//Prantl number
Gr=((9.81*b*L^3*(Ts-Ta))/(v1^2));//Grashof number
Nu=0.55*Gr^(0.25);//Nussults number
h=(Nu*k)/L;//Heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient is %3.2f W/m^2.K'
   ,h)

//==============================================================END OF PROGRAM
==========================================================
```

Scilab code Exa 8.8 `Rate of heat loss`

```
//Chapter-8, Example 8.8, Page 349
//
    ===========================================================================

clc
clear

//INPUT DATA
D=0.2;//Outer diameter of the pipe in m
Ts=100;//Surface temperature in degree C
Ta=20;//Temperature of air in degree C
L=3;//Length of pipe in m

//CALCULATIONS
Tf=(Ts+Ta)/2;//Film temperature in degree C
k=0.02896;//Thermal conductivity in W/m.K
v1=(18.97*10^-6);//Kinematic viscosity in m^2/s
b=(1/333);//Coefficient of thermal expansion in 1/K
Pr=0.696;//Prantl number
Gr=((9.81*b*L^3*(Ts-Ta))/(v1^2));//Grashof number
Ra=(Gr*Pr);//Rayleigh number
Nu=(0.1*Ra^(1/3));//Nussults number
h=(Nu*k)/L;//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*D*(Ts-Ta));//Rate of heat loss per meter
    length of pipe in W/m

//OUTPUT
mprintf('Rate of heat loss per meter length of pipe
    is %3.2f W/m',Q)

//=====================================END OF PROGRAM
    ===================================
```

Scilab code Exa 8.9 `Rate of heat loss`

```
//Chapter-8, Example 8.9, Page 350
//=============================================================================

clc
clear

//INPUT DATA
D=0.1;//Outer diamter of the pipe in m
Ta=30;//Ambient temperature of air degree C
Ts=170;//Surface temperature in degree C
e=0.9;//Emissivity

//CALCULATIONS
Tb=(Ts+Ta)/2;//Film temperature in degree C
k=0.0321;//Thermal conductivity in W/m.K
v1=(23.13*10^-6);//Kinematic viscosity in m^2/s
b=0.00268;//Coefficient of thermal expansion in 1/K
Pr=0.688;//Prantl number
Ra=((9.81*b*D^3*(Ts-Ta)*Pr)/(v1^2));//Rayleigh number
Nu=(0.6+((0.387*Ra^(1/6))/(1+(0.559/Pr)^(9/16))^(8/27)))^2;//Nussults number
h=(Nu*k)/D;//Heat transfer coefficient in W/m^2.K
Q=(h*3.1415*D*(Ts-Ta))+(e*3.1415*D*5.67*10^-8*((Ts+273)^4-(Ta+273)^4));//Total heat loss per meter length of pipe in m

//OUTPUT
mprintf('Total heat loss per meter length of pipe is %3.2f W/m',Q)

```

```
//========================================================END OF PROGRAM========================================================
```

Scilab code Exa 8.10 `Coefficient of heat transfer and current intensity`

```
//Chapter-8, Example 8.10, Page 351
//==============================================================================

clc
clear

//INPUT DATA
Ta=25;//Temperature of air in degree C
Ts=95;//Surface temperature of wire in degree C
D=0.0025;//Diameter of wire in m
R=6;//Resistivity in ohm/m

//CALCULATIONS
Tf=(Ts+Ta)/2;//Film temperature in degree C
k=0.02896;//Thermal conductivity in W/m.K
v1=(18.97*10^-6);//Kinematic viscosity in m^2/s
b=(1/333);//Coefficient of thermal expansion in 1/K
Pr=0.696;//Prantl number
Gr=((9.81*b*D^3*(Ts-Ta))/(v1^2));//Grashof number
Ra=(Gr*Pr);//Rayleigh number
Nu=(1.18*Ra^(1/8));//Nussults number
h=(Nu*k)/D;//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*D*(Ts-Ta));//Rate of heat loss per unit length of wire in W/m
I=sqrt(Q/R);//Maximum current intensity in A

//OUTPUT
mprintf('Heat transfer coefficient is %3.2f W/m^2.K\nMaximum current intensity is %3.2f A',h,I)
```

```

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 8.11 `Rate of convective heat loss`

```
//Chapter-8, Example 8.11, Page 352
//=============================================================================================================

clc
clear

//INPUT DATA
D=0.01;//Diameter of spherical steel ball in m
Ts=260;//Surface temperature in degree C
Ta=20;//Temperature of air in degree C

//CALCULATIONS
Tf=(Ts+Ta)/2;//Film temperature in degree C
k=0.0349;//Thermal conductivity in W/m.K
v1=(27.8*10^-6);//Kinematic viscosity in m^2/s
b=(1/413);//Coefficient of thermal expansion in 1/K
Pr=0.684;//Prantl number
Ra=((9.81*b*D^3*(Ts-20)*Pr)/(v1^2));//Rayleigh number
Nu=(2+(0.43*Ra^0.25));//Nusuults number
h=(k*Nu)/D;//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*D^2*(Ts-Ta));//Rate of heat loss in W

//OUTPUT
mprintf('Rate of convective heat loss is %3.2f W',Q)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 8.12 `Rate of heat loss`

```
//Chapter-8, Example 8.12, Page 353
//==============================================================================

clc
clear

//INPUT DATA
D=0.1;//Outer diamter of the pipe in m
Ta=30;//Ambient temperature of air degree C
Ts=170;//Surface temperature in degree C
e=0.9;//Emissivity

//CALCULATIONS
h=(1.32*((Ts-Ta)/D)^0.25);//Heat transfer coefficient in W/m^2.K
q=(h*3.1415*D*(Ts-Ta));//Heat transfer in W/m

//OUTPUT
mprintf('Heat loss due to free convection is %3.2f W/m',q)

//====================================END OF PROGRAM====================================
```

Scilab code Exa 8.13 `Thermal conductivity and heat flow`

```
//Chapter-8, Example 8.13, Page 355
```

```
//==========================================================================
clc
clear

//INPUT DATA
L=0.015;//Thickness of the slot in m
D=2;//Dimension of square plate in m
T1=120;//Temperature of plate 1
T2=20;//Temperature of plate 2

//CALCULATIONS
Tf=(T1+T2)/2;//Film temperature in degree C
k=0.0295;//Thermal conductivity in W/m.K
v1=(2*10^-5);//Kinematic viscosity in m^2/s
b=(1/343);//Coefficient of thermal expansion in 1/K
Gr=((9.81*b*L^3*(T1-T2))/(v1^2));//Grashof number
ke=(0.064*k*Gr^(1/3)*(D/L)^(-1/9));//Effective thermal conductivity in W/m.K
Q=(ke*D^2*(T1-T2))/L;//Rate of heat transfer in W

//OUTPUT
mprintf('Effective thermal conductivity is %3.4f W/m.K \nRate of heat transfer is %3.1f W',ke,Q)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 8.14 `Free convection heat transfer`

```
//Chapter-8, Example 8.14, Page 356
//==========================================================================
```

```
clc
clear

//INPUT DATA
d=0.0254;//Diatance between the plates in m
Tl=60;//Temperature of the lower panel n degree C
Tu=15.6;//Temperature of the upper panel in degree C

//CALCULATIONS
Tf=(Tl+Tu)/2;//Film temperature in degree C
p=1.121;//Density in kg/m^3
k=0.0292;//Thermal conductivity in W/m.K
v1=(0.171*10^-4);//Kinematic viscosity in m^2/s
b=(3.22*10^-3);//Coefficient of thermal expansion in 1/K
Pr=0.7;//Prantl number
Gr=((9.81*b*d^3*(Tl-Tu))/(v1^2));//Grashof number
Nu=(0.195*Gr^0.25);//Nussults number
q=(Nu*k*(Tl-Tu))/d;//Heat flux across the gap in W/m^2

//OUTPUT
mprintf('Free convection heat transfer is %3.1f W/m^2',q)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 8.15 `Convective heat transfer coefficient`

```
//Chapter-8, Example 8.15, Page 359
//=============================================================================
clc
```

```
clear

//INPUT DATA
p=3;//Pressure of air in atm
r1=0.075;//Radius of first sphere in m
r2=0.1;//Radius of second sphere in m
L=0.025;//Distance in m
T1=325;//Temperature of first sphere in K
T2=275;//Temperature of second sphere in K
R=287;//Universal gas constant in J/

//CALCULATIONS
Tf=(T1+T2)/2;//Film temperature in degree C
d=(p/(R*Tf));//Desnsity in kg/m^3
k=0.0263;//Thermal conductivity in W/m.K
v1=(5.23*10^-6);//Kinematic viscosity in m^2/s
b=(1/300);//Coefficient of thermal expansion in 1/K
Pr=0.707;//Prantl numbe
Gr=((9.81*b*L^3*(T1-T2))/(v1^2));//Grashof number
Ra=(Gr*Pr);//Rayleigh number
Ra1=((L/((4*r1*r2)^4))*(Ra/((2*r1)^(-7/5)+(2*r2)^(-7/5))^5))^0.25;//Equivalent Rayleigh's number
ke=(k*0.74*((Pr*Ra1)/(0.861+Pr))^0.25);//Effective thermal conductivity in W/m.K
Q=(ke*3.14*4*r1*r2*(T1-T2))/L;//Rate of heat loss in W

//OUTPUT
mprintf('Convection heat transfer rate is %3.2f W',Q)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 8.16 `Heat transfer`

```
//Chapter-8, Example 8.16, Page 362
//==========================================================================

clc
clear

//INPUT DATA
p=1;//Pressure of air in atm
Ta=27;//Temperature of air in degree C
D=0.02;//Diamter of the tube in m
v=0.3;//Velocity of air in m/s
Ts=127;//Surface temperature in degree C
L=1;//Length of the tube in m

//CALCULATIONS
k=0.0262;//Thermal conductivity in W/m.K
v1=(1.568*10^-5);//Kinematic viscosity in m^2/s
Pr=0.708;//Prantl number
b=(1/300);//Coefficient of thermal expansion in 1/K
ub=(1.847*10^-5);//Dynamic viscosity in Ns/m^2
us=(2.286*10^-5);//Viscosity of wall in Ns/m^2
Re=(v*D)/v1;//Reynolds number
Gr=((9.81*b*D^3*(Ts-Ta))/(v1^2));//Grashof number
Gz=(Re*Pr*(D/L));//Graetz number
Nu=(1.75*(ub/us)^0.14*(Gz+(0.012*(Gz*Gr^(1/3))^(4/3)))^(1/3));//Nussults number
h=(k*Nu)/D;//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*D*L*(Ts-Ta));//Heat transfer in W

//OUTPUT
mprintf('Heat transfer in the tube is %3.2f W',Q)

//=================================END OF PROGRAM==============================
```

Chapter 9

Thermal radiation basic relations

Scilab code Exa 9.1 `Rate of solar radiation`

```
//Chapter-9, Example 9.1, Page 378
//

clc
clear

//INPUT DATA
T=5527;//Temperature of black body in degree C
D=(1.39*10^6);//Diameter of the sun in km
L=(1.5*10^8);//Distance between the earth and sun in km

//CALCULATIONS
q=(5.67*10^-8*(T+273)^4*D^2)/(4*L^2);//Rate of solar radiation in W/m^2

//OUTPUT
mprintf('Rate of solar radiation on a plane normal
```

```
    to sun rays is %3.0f W/m^2',q)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 9.2 `Fraction of thermal radiation emmitted by the surafce`

```
//Chapter-9, Example 9.2, Page 383
//=============================================================================================================

clc
clear

//INPUT DATA
T=(727+273);//Temperature of black body in K
l1=1;//Wavelength in micro meter
l2=5;//Wavelength in micro meter
F1=0.0003;//From Table 9.2 on page no. 385
F2=0.6337;//From Table 9.2 on page no. 385

//CALCULATIONS
a=(5.67*10^-8*T^4)/1000;//Heat transfer in kW/m^2
F=(F2-F1)*a;//Fraction of thermal radiation emitted by the surface in kW/m^2

//OUTPUT
mprintf('Fraction of thermal radiation emitted by the surface is %3.1f kW/m^2',F)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 9.3 Hemispherical transmittivity

```
//Chapter-9, Example 9.3, Page 384
//==============================================================================

clc
clear

//INPUT DATA
t=0.8;//Transmittivity of glass in the region except in the wave length region [0.4,3]
T=5555;//Temperature of black body in K

//CALCULATIONS
ao=0;//a0 in micro K
a1=(0.4*T);//a1 for the wavelength 0.4 micro meter in micro K
a2=(3*T);//a1 for the wavelength 3 micro meter in micro K
F0=0;//From Table 9.2 on page no.385
F1=0.10503;//From Table 9.2 on page no.385
F2=0.97644;//From Table 9.2 on page no.385
t1=t*(F2-F1);//Average hemispherical transmittivity of glass

//OUTPUT
mprintf('Average hemispherical transmittivity of glass is %3.2f',t1)

//================================END OF PROGRAM==============================
```

Scilab code Exa 9.4 Surface temperature and emmisive power

```
//Chapter-9, Example 9.4, Page 386
//=============================================================================

clc
clear

//INPUT DATA
l=0.5;//Wavelength at maximum intensity of radiation in micro meter

//CALCULATIONS
T=(0.289*10^-2)/(l*10^-6);//Temperature according to Wien's displacement law in degree C
E=(5.67*10^-8*T^4)/10^6;//Emissive power using Stefan-Boltzmann law in MW/m^2

//OUTPUT
mprintf('Surface temperature is %3.0f K \nEmissive power is %3.1f MW/m^2',T,E)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 9.5 `Emmissivity and wave length`

```
//Chapter-9, Example 9.5, Page 389
//=============================================================================

clc
clear

//INPUT DATA
Ts=(827+273);//Surface temperature in degree C
```

```
E=(1.37*10^10);//Emmisive power in W/m^3

//CALCULATIONS
Eblmax=(1.307*10^-5*Ts^5);//Maximum emissive power in W/m^3
e=(E/Eblmax);//Emissivity of the body
lmax=((0.289*10^-2)/Ts)/10^-6;//Wavelength correspoing to the maximum spectral intensity of radiation in micro meter

//OUTPUT
mprintf('Wavelength corresponding to the maximum spectral intensity of radiation is %3.2f micro meter',lmax)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 9.6 `True temperature of the body`

```
//Chapter-9, Example 9.6, Page 389
//================================================================================================

clc
clear

//INPUT DATA
T=(1400+273);//Temperature of the body in K
l=0.65;//Wavelength in micro meter
e=0.6;//Emissivity

//CALCULATIONS
T=(1/((1/T)-((l*10^-6*log(1/e))/(1.439*10^-2))));//Temperature of the body in K
```

```
Tb=(T-273);//Temperature of the body in degree C

//OUTPUT
mprintf('Temperature of the body is %3.0f degree C',Tb)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 9.7 `Rate of absorbption and emmission`

```
//Chapter-9, Example 9.7, Page 391
//=====================================================================================================

clc
clear

//INPUT DATA
Ts=(37+273);//Temperature of metallic bar in K
T=1100;//Interior temperature in K
a=0.52;//Absorptivity at 1100 K
e=0.8;//Emissivity at 310 K
//CALCULATIONS
Q=(a*5.67*10^-8*T^4)/1000;//Rate of absorption in kW/m^2
E=(e*5.67*10^-8*Ts^4)/1000;//Rate of emissin in kW/m^2

//OUTPUT
mprintf('Rate of absorption is %3.2f kW/m^2 \nRate of emissin is %3.2f kW/m^2',Q,E)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 9.8 `Energy absorbed and transmitted`

```
//Chapter-9, Example 9.8, Page 391
//
    ==================================================================

clc
clear

//INPUT DATA
e1=0.3//Emissivity of glass upto 3 micro meter
e2=0.9;//Emissivity of glass above 3 micro meter
t=0.8;//Transmittivity of glass in the region except
    in the wave length region [0.4,3]

//CALCULATIONS
E=(5.67*10^-8*5780^4)/10^6;//Emissive power in MW/m
   ^2
F1=0.10503;//From Table 9.2 on page no.385
F2=0.97644;//From Table 9.2 on page no.385
I=(E*10^6*(F2-F1))/10^6;//Total incident radiation
   in MW/m^2
T=(t*I);//Total radiation transmitted in MW/m^2
t1=(e1*I);//Absorbed radiation in MW/m^2 in
   wavelength  [0.4,3] micro meter
t2=(e1*E*F1);//Absorbed radiation in MW/m^2 in
   wavelength not in the range [0.4,3] micro meter
t3=(e2*(1-F2)*E);//Absorbed radiation in MW/m^2 in
   wavelength greater than 3 micro meter
R=(t1+t2+t3);//Total radiation absorbed in MW/m^2

//OUTPUT
mprintf('Total radiation transmitted is %3.2f MW/m^2
    \nTotal radiation absorbed is %3.2f MW/m^2',T,R)
```

```

//==================================================END OF PROGRAM
    ==============================================
```

Chapter 10

Radiative Heat exchange between surfaces

Scilab code Exa 10.1 `Surface temperature`

```
//Chapter-10, Example 10.1, Page 403
//=============================================================================

clc
clear

//INPUT DATA
I=1350;//Solar Irradiation in W/m^2
L=(1.5*10^8);//Approximate distance in km
D=(1.39*10^6);//Approximate diameter in km


//CALCULATIONS
E=(I*(L*1000)^2*3.14)/((3.14/4)*(D*1000)^2);//
    Emissive power of Earth
Ts=(E/(5.67*10^-8))^0.25;//Surface temperature of
    sun in K

```

```
//OUTPUT
mprintf('Surface temperature of sun is %3.0f K',Ts)

//==========================================END OF PROGRAM==========================================
```

Scilab code Exa 10.4 Net exchange of energy

```
//Chapter-10, Example 10.4, Page 409
//=====================================================================================================

clc
clear

//INPUT DATA
S=1;//Side of a square in m
L=0.4;//Diatance between the plates in m
T1=900;//Temperature of one plate in degree C
T2=400;//Temperature of the other plate in degree C

//CALCULATIONS
R=(S/L);//Ratio of the side of the square to the distance between plates
F12=0.415;//From Fig.10.4 on page no.409
Q=(5.67*10^-8*S*S*F12*((T1+273)^4-(T2+273)^4))/1000;//The net heat transfer in kW

//OUTPUT
mprintf('The net exchange of energy due to radiation between the plates is %3.1f kW',Q)

//==========================================END OF PROGRAM==========================================
```

Scilab code Exa 10.5 `Shape factor`

```
//Chapter-10, Example 10.5, Page 411
//=============================================================================

clc
clear

//INPUT DATA
A51=2;//Ratio of areas A5 and A1
A21=1;//Ratio of areas A2 and A1
F56=0.15;//Shape factor
F53=0.11;//Shape factor
F26=0.24;//Shape Factor
F23=0.2;//Shape Factor

//CALCULATIONS
F14=(A51*(F56-F53))-(A21*(F26-F23));//Shape factor

//OUTPUT
mprintf('Shape factor F14 is %3.2f',F14)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 10.8 `Net heat exchange`

```
//Chapter-10, Example 10.8, Page 415
//=============================================================================
```

```
clc
clear

//INPUT DATA
Th=40;//Radiating heating panel in degree C
Tb=5;//Temperature of black plane in degree C
Tc=31;//Temperature of ceiling in degree C
A=(10*12);//Area in m^2

//CALCULATIONS
F56=0.075;//Using Fig.10.2 on page no. 408
F63=0.04;//Using Fig.10.2 on page no. 408
F12=0.052;//Shape factor
F1w=(1-F12);//Shape factor between the floor and all the walls but the window
Q12=(A*F12*5.67*10^-8*((Th+273)^4-(Tb+273)^4));//Heat exchange between the floor and window in W
Q1=(5.67*10^-8*A*((Th+273.15)^4-((F12*(Th+273.15)^4)-(F1w*(Tb+273.15)^4))))/1000;//Net heat given up by the floor in kW

//OUTPUT
mprintf('Heat exchange between the floor and window is %3.0f W \nNet heat given up by the floor is %3.1f kW',Q12,Q1)

//==========================================================END OF PROGRAM===================================
```

Scilab code Exa 10.14 Net heat exchange and equilibrium temperature

```
//Chapter-10, Example 10.14, Page 424
//=============================================================================
```

```
clc
clear

//INPUT DATA
A2=(6*2);//Area of windows in m^2
A1=(10*12);//Area of floor in m^2
Th=40;//Radiating heating panel in degree C
Tb=5;//Temperature of black plane in degree C
F12=0.052;//Shape factor

//CALCULATIONS
F12a=((A2-(A1*F12^2))/(A1+A2-(2*A1*F12)));//Shape factor
Q12=(A1*F12a*5.67*10^-8*((Th+273)^4-(Tb+273)^4));//Net heat exchange in W
X=(((A2/A1)-F12)/(1-F12));//X value for equilibrium temperature
T=(((Th+273)^4+(X*(Tb+273)^4))/(X+1))^0.25;//Equilibrium temperature in K

//OUTPUT
mprintf('Net heat exchange is %3.0f W \nEquilibrium temperature is %3.2f K',Q12,T)

//==========================================END OF PROGRAM==============================
```

Scilab code Exa 10.15 `Radiant heat exchange`

```
//Chapter-10, Example 10.15, Page 430
//==================================================================================

clc
clear
```

```

//INPUT DATA
D=0.2;//Diameter of each disc in m
L=2;//Distance between the plates in m
T=[800+273,300+273];//Temperatures of the plates in K
e=[0.3,0.5];//Emissivities of plates

//CALCULATIONS
e1=(e(1)*e(2));//Equivalent emissivity
R=(D/L);//Ratio between diameter and distance between the plates
F=0.014;//F value from Fig.10.4 from page no. 409
Q=(e1*(3.14/4)*D^2*F*5.67*10^-8*((T(1)^4-(T(2)^4))));//Radiant heat exchange for the plates in W

//OUTPUT
mprintf('Radiant heat exchange for the plates is %3.2f W',Q)

//==================================END OF PROGRAM==============================
```

Scilab code Exa 10.16 Radiant heat exchange

```
//Chapter-10, Example 10.16, Page 430
//=============================================================================
clc
clear

//INPUT DATA
e=0.8;//Emissivity of brick wall
D1=[6,4];//Width and Height in m
```

```
L=0.04;//Distance from the wall in m
D2=[0.2,0.2];//Dimensions of the furnace wall in m
D3=[1,1];//Dimensions at lower and left of the centre of the wall in m
T=[1523+273,37+273];//Furnace temperature and wall temperature in degree C

//CALCULATIONS
F12=0.033;//Shape factor from Fig.10.3 on page no. 409
F13=0.05;//Shape factor from Fig.10.3 on page no. 409
F14=0.12;//Shape factor from Fig.10.3 on page no. 409
F15=0.08;//Shape factor from Fig.10.3 on page no. 409
Fow=(F12+F13+F14+F15);//Shape factor between opening and wall
Q=(e*L*Fow*5.67*10^-8*(T(1)^4-T(2)^4))/1000;//Net radiation exchange in kW

//OUTPUT
mprintf('Net radiation exchange between the opening and the wall is %3.1f kW',Q)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 10.17 Reduction in heat loss

```
//Chapter-10, Example 10.17, Page 431
//==========================================================================================
clc
```

```
clear

//INPUT DATA
D=[2,1,1];//Dimensions of the tank in m
A=8;//Area of the tank in m^2
e=0.9;//Surface emissivity
Ts=25+273;//Surface temperature in K
Ta=2+273;//Ambient temperature in K
e1=0.5;//Emissivity of aluminium

//CALCULATIONS
Q=(e*A*5.67*10^-8*(Ts^4-Ta^4))/1000;//Heat lost by radiation in kW
r=((e-e1)/e)*Q;//Reduction in heat loss if the tank is coated with an aluminium paint in kW

//OUTPUT
mprintf('Heat lost by radiation is %3.2f kW \nReduction in heat loss if the tank is coated with an aluminium paint is %3.3f kW',Q,r)

//==============================================END OF PROGRAM==============================================
```

Scilab code Exa 10.18 Loss of heat

```
//Chapter-10, Example 10.18, Page 432
//==============================================================================================================

clc
clear

//INPUT DATA
D=0.2;//Outer diameter of the pipe in m
```

```
Ta=30+273;//Temperature of the air in K
Ts=400+273;//Surface temperature in K
e=0.8;//Emissivity of the pipe surface
D1=0.4;//Diamter of brick in m
e1=0.91;//Emissivity of brick

//CALCULATIONS
Q=(e*3.14*D*5.67*10^-8*(Ts^4-Ta^4))/1000;//Loss of heat by thermal radiation in kW/m
e2=(1/((1/e)+((D/D1)*((1/e1)-1))));//Equivalent emissivity
Q1=(e2*3.14*D*5.67*10^-8*(Ts^4-Ta^4))/1000;//Heat loss when brick is used in kW/m
r=(Q-Q1)*1000;//Reduction in heat loss in W/m

//OUTPUT
mprintf('Loss of heat by thermal radiation is %3.1f*10^3 W/m \nReduction in heat loss is %3.0f W/m',Q,r)

//==========================================END OF PROGRAM ======================================
```

Scilab code Exa 10.19 `Radiation heat transfer`

```
//Chapter-10, Example 10.19, Page 433
//=============================================================================

clc
clear

//INPUT DATA
e=0.03;//Emissivity of silver
T2=-153+273;//Temperature of the outer surface of
```

```
the inner wall in K
T1=27+273;//Temperature of the inner surface of the outer wall in K
D1=0.42;//Diamter of first sphere in m
D2=0.6;//Diamter of the second sphere in m
V=220;//Rate of vapourization in kJ/kg

//CALCULATIONS
e1=(1/((1/e)+((D1/D2)^2*((1/e)-1))));//Equivalent emissivity
A=(4*3.14*(D1/2)^2);//Area in m^2
Q=(e1*A*5.67*10^-8*(T1^4-T2^4))/(1000/3600);//Radiation heat transfer through walls into the vessel in kJ/h
R=(Q/V);//Rate of evaporation in kg/h

//OUTPUT
mprintf('Radiation heat transfer through walls into the vessel is %3.3f kJ/h \nRate of evaporation of liqiud oxygen is %3.4f kg/h',Q,R)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 10.20 `Net radiant heat exchange`

```
//Chapter-10, Example 10.20, Page 433
//=============================================================================

clc
clear

//INPUT DATA
T=[800+273,300+273];//Temperatures of the plates in
```

```
K
e=[0.3,0.5];//Emissivities of the plates

//CALCULATIONS
Q=((5.67*10^-8*(T(1)^4-T(2)^4))/((1/e(1))+((1/e(2)))-1))/1000;//Net radiant heat exchange in kW/m^2

//OUTPUT
mprintf('Net radiant heat exchange is %3.2f kW/m^2',Q)

//==================================END OF PROGRAM===============================
```

Scilab code Exa 10.21 `Loss of heat`

```
//Chapter-10, Example 10.21, Page 434
//=============================================================================

clc
clear

//INPUT DATA
T1=127+273;//Temperature of the outer side of the brick setting in K
T2=50+273;//Temperature of the inside of the steel plate in K
e1=0.6;//Emissivity of steel
e2=0.8;//Emissivity of fireclay

//CALCULATIONS
Q=((5.67*10^-8*(T1^4-T2^4))/((1/e1)+((1/e2))-1));//Net radiant heat exchange in W/m^2

```

```
//OUTPUT
mprintf('Net radiant heat exchange is %3.0f W/m^2',Q)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 10.22 Net heat transfer

```
//Chapter-10, Example 10.22, Page 445
//=============================================================================

clc
clear

//INPUT DATA
D=1;//Dimension of the plate in m
L=0.5;//Distance between the plates in m
Ts=27+273;//Surface temperature of the walls in K
T=[900+273,400+273];//Temperature of the plates in K
e=[0.2,0.5];//Emissivities of the plates

//CALCULATIONS
F12=0.415;//From Fig.10.4 on page no.409
F13=(1-F12);//Shape factor
F23=(1-F12);//Shape factor
R1=(1-e(1))/(e(1)*D*D);//Resistance for 1
R2=(1-e(2))/(e(2)*D*D);//Resistance for 2
R3=0;//Resistance for 3
A1F12I=(1/(D*D*F12));//Inverse of the product of area and Shape factor
A1F13I=(1/(D*D*F13));//Inverse of the product of area and Shape factor
A2F23I=(1/(D*D*F23));//Inverse of the product of
```

```
area and Shape factor
Eb1=(5.67*10^-8*T(1)^4)/1000;//Emissive power of 1 in kW/m^2
Eb2=(5.67*10^-8*T(2)^4)/1000;//Emissive power of 2 in kW/m^2
Eb3=(5.67*10^-8*Ts^4);//Emissive power of 3 in W/m^2
J1=25;//Radiosity at node 1 in kW/m^2
J2=11.53;//Radiosity at node 2 in kW/m^2
J3=0.46;//Radiosity at node 3 in kW/m^2
Q1=((Eb1-J1)/R1);//Total heat loss by plate 1 in kW
Q2=((Eb2-J2)/R2);//Total heat loss by plate 2 in kW
Q3=((J1-J3)/(A1F13I))+((J2-J3)/(A2F23I));//Total heat received by the room in kW

//OUTPUT
mprintf('Total heat loss by plate 1 is %3.1f kW \nTotal heat loss by plate 2 is %3.1f kW \nTotal heat received by the room is %3.2f kW',Q1,Q2,Q3)

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 10.23 Percentage reduction in heat transfer and temperature of the

```
//Chapter-10, Example 10.23, Page 447
//==========================================================================================

clc
clear

//INPUT DATA
T=[800+273,300+273];//Temperatures of the plates in K
e=[0.3,0.5];//Emissivities of the plates
```

```
e3=0.05;//Emissivity of aluminium

//CALCULATIONS
q=((5.67*10^-8*(T(1)^4-T(2)^4))/((1/e(1))+(1/e(2))-1))/1000;//Heat transfer without the shield in kW/m^2
R1=(1-e(1))/e(1);//Resistance in 1
R2=(1-e(2))/e(2);//Resistance in 2
R3=(1-e3)/e3;//Resistance in 3
R=(R1+(2*R2)+(2*R3));//Total resistance
q1=((5.67*10^-8*(T(1)^4-T(2)^4))/R)/1000;//Heat transfer with shield in kW/m^2
r=((q-q1)*100)/q;//Reduction in heat transfer
X1=((1/e3)+(1/e(2))-1);//X1 for tempearture T3
X2=((1/e(1))+(1/e3)-1);//X1 for tempearture T3
T3=(((X1*T(1)^4)+(X2*T(2)^4))/(X2+X1))^0.25;//Temperature of the sheild in K
T3c=T3-273;//Temperature of the sheild in degree C

//OUTPUT
mprintf('Percentage reduction in heat transfer is %3.0f percent \nTemperature of the sheild is %3.2f degree C',r,T3c)

//========================================END OF PROGRAM========================================
```

Scilab code Exa 10.24 Number of screens

```
//Chapter-10, Example 10.24, Page 448
//=============================================================================
clc
clear
```

```

//INPUT DATA
Q=79;//Reduction in net radiation from the surfaces
e1=0.05;//Emissivity of the screen
e2=0.8;//Emissivity of the surface

//CALCULATIONS
n=(((Q*((2/e2)-1))-((2/e2)+1))/((2/e1)-1));//Number of screens to be placed between the two surfaces to achieve the reduction in heat exchange

//OUTPUT
mprintf('Number of screens to be placed between the two surfaces to achieve the reduction in heat exchange is%3.0f',n)

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 10.25 Loss of heat and reduction in heat

```
//Chapter-10, Example 10.25, Page 449
//==========================================================================================

clc
clear

//INPUT DATA
e=0.8;//Emissivity of the pipe
D=0.275;//Diameter of the pipe in m
Ts=500+273;//Surface temperature in K
Te=30+273;//Temperature of enclosure in K
D1=0.325;//Diamter of the steel screen in m
e1=0.7;//Emissivity of steel screen
```

```
Tsc=240+273;//Temperature of screen in K

//CALCUATIONS
Q=(e*5.67*10^-8*3.14*D*(Ts^4-Te^4))/1000;//Loss of heat per unit length by radiation in kW/m
e2=(1/((1/e)+((D/D1)*((1/e1)-1))));//Equivalent emissivity
Q1=(e2*5.67*10^-8*3.14*D*(Ts^4-Tsc^4))/1000;//Radiant heat exchange per unit length of header with screen in kW/m
R=(Q-Q1);//Reduction in heat by radiation due to the provision of the screen in kW/m

//OUTPUT
mprintf('Loss of heat per unit length by radiation is %3.1f kW/m \nReduction in heat by radiation due to the provision of the screen is %3.2f kW/m',Q,R)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 10.26 Error in temperature

```
//Chapter-10, Example 10.26, Page 451
//=============================================================================

clc
clear

//INPUT DATA
e=0.6;//Emissivity of thermocouple
Ta=20+273;//Ambient temperature in K
Tt=500+273;//Temperature from the thermocouple in K
```

```
e=0.3;//Emissivity of radiation shield
h=200;//Convective heat transfer coefficient in W/m^2.K
Ts=833;//Temperature in K

//CALCULATIONS
T=((5.67*10^-8*e*(Tt^4-Ta^4))/(h*1000))+Tt;//Temperature of the shield in K
T1=(Ts-T);//Error between the thermocouple temperature and gas temperature in K
Ts=825;//Surface temperature with radiation shield in K
Tc=829;//Thermocouple temperature with radiation shield in K
e=(Tc-Ts);//Error between the thermocouple temperature and gas temperature with the shielded thermocouple arrangement in K

//OUTPUT
mprintf('Error between the thermocouple temperature and gas temperature is%3.0f K \nError between the thermocouple temperature and gas temperature with the shielded thermocouple arrangement is%3.0f K',T1,e)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 10.27 `Rate of heat loss`

```
//Chapter-10, Example 10.27, Page 452
//=============================================================================

clc
```

```
clear

//INPUT DATA
D=0.2;//Diameter of pipe in m
Ta=30+273;//Temperature of air in K
Ts=200+273;//Temperature of surface in K
e=0.8;//Emissivity of the pipe

//CALCULATIONS
Q=(e*5.67*10^-8*3.14*D*(Ts^4-Ta^4));//Heat lost by
    thermal radiation in W/m
T=(Ta+Ts)/2;//Film temperature in degree C
k=0.03306;//Thermal conductivity in W/m.K
v1=(24.93*10^-6);//Kinematic viscosity in m^2/s
b=(1/388);//Coefficient of thermal expansion in 1/K
Pr=0.687;//Prantl number
Ra=((9.81*b*D^3*(Ts-Ta)*Pr)/(v1^2));//Rayleigh
    number
Nu=(0.53*(Ra)^0.25);//Nussults number
h=(k*Nu)/D;//Heat transfer coefficient in W/m^2.K
Q1=(h*3.14*D*(Ts-Ta));//Heat lost by convection in W
    /m
Q2=(Q+Q1);//Total heat lost per meter length in W/m

//OUTPUT
mprintf('Heat lost by thermal radiation is %3.0f W/m
    \nHeat lost by convection is %3.1f W/m',Q,Q1)

//=================================END OF PROGRAM
    ==============================
```

Scilab code Exa 10.28 Heat transfer coefficient

```
//Chapter-10, Example 10.28, Page 453
//
```

```
==========================================================
clc
clear

//INPUT DATA
Ts=200+273;//Temperature of stream main in K
Ta=30+273;//Rooom temperature in K
h=17.98;//Heat transfer coefficient in W/m^2.K
e=0.8;//Emissivity of the pipe surface

//CALCULATIONS
q=(5.67*10^-8*e*(Ts^4-Ta^4));//Heat transfer by radiation in W/m^2
hr=(q/(Ts-Ta));//Heat transfer coefficient due to radiation in W/m^2.K
hc=(h-hr);//Heat transfer coefficient due to convection in W/m^2.K

//OUTPUT
mprintf('Heat transfer coefficient due to radiation is %3.1f W/m^2.K \nHeat transfer coefficient due to convection is %3.2f W/m^2.K',hr,hc)

//==================================END OF PROGRAM==============================
```

Scilab code Exa 10.29 `Extinction coefficient for radiation`

```
//Chapter-10, Example 10.29, Page 461
//==========================================================
clc
clear
```

```

//INPUT DATA
t=0.05;//Thickness of the gas layer in m
r=0.1;//Remaining radiation  intensity

//CALCULATIONS
a=(-1/t)*2.3*(log(r)/log(10));//Extinction coefficient per m

//OUTPUT
mprintf('Extinction coefficient is %3.2f/m',a)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 10.30 Emmissivity of the mixture

```
//Chapter-10, Example 10.30, Page 462
//==================================================================================================
clc
clear

//INPUT DATA
A=30;//Total surface area in m^2
V=10;//Volume in m^3
Ts=1000;//Temperature of the furnace in degree C
p=2;//Total pressure in atm
ph2o=0.1;//Partial pressure of water vapour in atm
pco2=0.3;//Partial pressure of CO2

//CALCULATIONS
lms=(3.6*V)/A;//Mean beam length in m
pco2lms=(pco2*lms);//pco2lms in m.atm
```

```
eco2=0.16;//From Fig.10.23 on page no. 458
cco2=1.11;//From Fig.10.23 on page no. 458
cco2eco2=(cco2*eco2);//cco2eco2 value
ph2olms=(ph2o*lms);//ph2olms in m.atm
eh2o=0.12;//From Fig.10.24 on page no. 459
P=(p+ph2o)/2;//P value in atm
ch2o=1.43;//From Fig.10.26 on page no. 460
ch2oeh2o=(ch2o*eh2o);//ch2oeh2o value
P1=(ph2o/(ph2o+pco2));//Ratio of pressures
X=(pco2lms+ph2olms);//X value in m.atm
e=0.035;//Error value from Fig. 10.27 on page no.461
et=(cco2eco2+ch2oeh2o-e);//Total emissivity of the gaseous mixture

//OUTPUT
mprintf('Emissivity of the gaseous mixture is %3.4f',et)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 10.31 `Net radiation exchange and coefficient of heat transfer`

```
//Chapter-10, Example 10.31, Page 463
//==========================================================================

clc
clear

//INPUT DATA
Tg=950+273;//Flue gas temperature in K
p=1;//Total pressure in atm
pco2=0.1;//Percent of co2
ph2o=0.04;//Percent of h2o
```

```
D=0.044;//Diameter of the tube in m
e=0.8;//Emissivity of grey surface
Tw=500+273;//Uniform temperature in K

//CALCULATIONS
lms=(3*0.044);//lms value from Table 10.2 on page no. 457
pco2lms=(pco2*lms);//pco2lms in m.atm
ph2olms=(ph2o*lms);//ph2olms in m.atm
eco2=0.05;//From Fig.10.23 on page no. 458
eh2o=0.005;//From Fig.10.24 on page no. 459
b=1.05;//Correction factor from Fig. 10.28 on page no. 461
eg=0.061;//Total emissivity of gaseous mixture
ag=((0.056*(Tg/Tw)^0.65)+(b*0.021));//Absorbtivity of the gases
q=(0.5*(e+1)*5.67*10^-8*((eg*Tg^4)-(ag*Tw^4)));//Heat transfer rate by radiation in W/m^2
hr=(q/(Tg-Tw));//Radiation heat transfer coefficient in W/m^2.degree C

//OUTPUT
mprintf('Net radiation exchange between the gas and the tube walls is %3.0f W/m^2 \nRadiation heat transfer coefficient is %3.2f W/m^2.degree C',q,hr)

//===================================END OF PROGRAM==================================
```

Chapter 11

Boiling and Condensation

Scilab code Exa 11.1 `Temperature of the surface`

```
//Chapter-11, Example 11.1, Page 480
//==========================================================================

clc
clear

//INPUT DATA
Tsat=100;//Saturation temperature of water in degree C
p1=957.9;//Density of liquid in kg/m^3
Cpl=4217;//Specific heat in J/kg.K
u=(279*10^-6);//Dynamic viscosity in N.s/m^2
Pr=1.76;//Prantl number
hjg=2257;//Enthalpy in kJ/kg
s=(58.9*10^-3);//Surface tension in N/m
pv=0.5955;//Density of vapour in kg/m^3
m=30;//Rate of water in kg/h
D=0.3;//Diameter in m

//CALCULATIONS
```

```
q=(m*hjg*1000)/(3600*3.14*(D^2/4));//Heat transfer in W/m^2
Ts=Tsat+(((q/(u*hjg*1000))*sqrt(s/(9.81*(p1-pv))))^0.33

//OUTPUT
mprintf('Temperature of the bottom surface of the pan is %3.2f degree C',Ts)

//==========================================END OF PROGRAM========================================
```

Scilab code Exa 11.2 `Burnout heat flux`

```
//Chapter-11, Example 11.2, Page 481
//==================================================================================================

clc
clear

//INPUT DATA
Tsat=100;//Saturation temperature of water in degree C
p1=957.9;//Density of liquid in kg/m^3
Cpl=4217;//Specific heat in J/kg.K
u=(279*10^-6);//Dynamic viscosity in N.s/m^2
Pr=1.76;//Prantl number
hjg=2257;//Enthalpy in kJ/kg
s=(58.9*10^-3);//Surface tension in N/m
pv=0.5955;//Density of vapour in kg/m^3
m=30;//Rate of water in kg/h
D=0.3;//Diameter in m

//CALCULATIONS
```

```
q=(0.18*hjg*1000*pv*((s*9.81*(p1-pv))/pv^2)^0.25)
   /10^6;//Burnout heat flux in MW/m^2

//OUTPUT
mprintf('Burnout heat flux is %3.3f MW/m^2',q)

//==================================END OF PROGRAM
   ==============================
```

Scilab code Exa 11.3 Heat transfer coefficient and power dissipation

```
//Chapter-11, Example 11.3, Page 481
//
   ==================================================================

clc
clear

//INPUT DATA
D=0.0016;//Diameter of the wire in m
T=255;//Temperature difference in degree C
p1=957.9;//Density of liquid in kg/m^3
Cpl=4640;//Specific heat in J/kg.K
u=(18.6*10^-6);//Dynamic viscosity in N.s/m^2
hjg=2257;//Enthalpy in kJ/kg
k=(58.3*10^-3);//Thermal conductivity in W/m.K
pv=31.54;//Density of vapour in kg/m^3
Ts=628;//Surface temperature in K
Tsat=373;//Saturation temperature in K

//CALCULATIONS
hc=(0.62*((k^3*pv*(p1-pv)*9.81*((hjg*1000)+(0.4*Cpl*
   T)))/(u*D*T))^0.25);//Convective heat transfer
   coefficient in W/m^2.K
hr=((5.67*10^-8)*(Ts^4-Tsat^4))/(Ts-Tsat);//
```

```
Radiative heat transfer coefficient in W/m^2.K
hm=(hc+(0.75*hr));//Mean heat transfer coefficient in W/m^2.K
Q=(hm*3.14*D*T)/1000;//Power dissipation rate per unit length of the heater in kW/m

//OUTPUT
mprintf('Mean heat transfer coefficient is %3.1f W/m^2.K \nPower dissipation rate per unit length of the heater is %3.3f kW/m',hm,Q)

//==================================================END OF PROGRAM=============================================
```

Scilab code Exa 11.4 `Heat transfer coefficient`

```
//Chapter-11, Example 11.4, Page 485
//=================================================================================================================

clc
clear

//INPUT DATA
Ts=10;//Surface temperature in degree C
p1=10;//Pressure of water in atm

//CALCULATIONS
hp=(5.56*Ts^0.4);//Heat transfer coefficient in kW/m^2.K
hp1=(5.56*(2*Ts)^3*p1^0.4);//Heat transfer coefficient in kW/m^2.K
hp2=(5.56*Ts^3*(2*p1)^0.4);//Heat transfer coefficient in kW/m^2.K
x1=(hp1/hp)/1000;//Ratio of heat transfer
```

```
coefficients
x2=(hp2/hp)*100;//Ratio of heat transfer coefficients

//OUTPUT
mprintf('Heat transfer coefficient becomes%3.0f times the original value in the first case \nHeat transfer coefficient is increased only by 32 percent in the second case',x1)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 11.5 `Heat transfer`

```
//Chapter-11, Example 11.5, Page 485
//=============================================================================

clc
clear

//INPUT DATA
p=6;//Pressure of water in atm
D=0.02;//Diameter of the tube in m
Ts=10;//Wall temperature in degree C
L=1;//Length of the tube in m

//CALCULATIONS
p1=(p*1.0132*10^5)/10^6;//Pressure in MN/m^2
h=(2.54*Ts^3*exp(p1/1.551));//Heat transfer coefficient in W/m^2.K
Q=(h*3.14*D*L*Ts);//Heat transfer rate in W/m

//OUTPUT
```

```
mprintf('Heat transfer rate is %3.1f W/m',Q)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 11.6 `Thickness of condensate film`

```
//Chapter-11, Example 11.6, Page 489
//==========================================================================================

clc
clear

//INPUT DATA
p=2.45;//Pressure of dry saturated steam in bar
h=1;//Height of vertical tube in m
Ts=117;//Tube surface temperature in degree C
d=0.2;//Distance from upper end of the tube in m

//CALCULATIONS
Tsat=127;//Saturation temperature of water in degree C
p1=941.6;//Density of liquid in kg/m^3
k1=0.687;//Thermal conductivity in W/m.K
u=(227*10^-6);//Dynamic viscosity in N.s/m^2
hfg=2183;//Enthalpy in kJ/kg
pv=1.368;//Density of vapour in kg/m^3
q=(((4*k1*u*10*d)/(9.81*p1*(p1-pv)*hfg*1000))^0.25)*1000;//Thickness of condensate film in mm
h=(k1/(q/1000));//Local heat transfer coefficient at x=0.2 in W/m^2.K

//OUTPUT
mprintf('Thickness of condensate film is %3.2f mm\
```

```
nLocal heat transfer coefficient at x=0.2 is %3.0f W/m^2.K',q,h)

//========================================END OF PROGRAM========================================
```

Scilab code Exa 11.7 Rate of heat transfer and condensate mass flow rate

```
//Chapter-11, Example 11.7, Page 491
//=============================================================================

clc
clear

//INPUT DATA
D=0.05;//Diameter of the tube in m
L=2;//Length of the tube in m
Ts=84;//Outer surface temperature in degree C
Tsat=100;//Saturation temperature of water in degree C
Tf=(Tsat+Ts)/2;//Film temperature in degree C
p1=963.4;//Density of liquid in kg/m^3
u=(306*10^-6);//Dynamic viscosity in N.s/m^2
hfg=2257;//Enthalpy in kJ/kg
pv=0.596;//Density of vapour in kg/m^3
k1=0.677;//Thermal conductivity in W/m.K

//CALCULATIONS
hL=(1.13*((9.81*p1*(p1-pv)*k1^3*hfg*1000)/(u*16*L))^0.25);//Heat transfer coefficient in W/m^2.K
Ref=((4*hL*L*2)/(hfg*1000*u));//Reynolds nmber
Q=(hL*3.14*D*L*10);//Heat transfer rate in W
m=(Q/(hfg*1000))*3600;//Condensate mass flow rate in kg/h
```

```

//OUTPUT
mprintf('Heat transfer rate is %3.0f W \n Condensate mass flow rate is %3.1f kg/h',Q,m)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 11.8 `Heat transfer rate`

```
//Chapter-11, Example 11.8, Page 492
//=============================================================================
clc
clear

//INPUT DATA
h=2.8;//Height of the plate in m
T=54;//Temperature of the plate in degree C
Tsat=100;//Saturation temperature of water in degree C
Tf=(Tsat+T)/2;//Film temperature in degree C
p1=937.7;//Density of liquid in kg/m^3
u=(365*10^-6);//Dynamic viscosity in N.s/m^2
hfg=2257;//Enthalpy in kJ/kg
pv=0.596;//Density of vapour in kg/m^3
k1=0.668;//Thermal conductivity in W/m.K

//CALCULATIONS
Re=(0.00296*((p1*9.81*(p1-pv)*k1^3*(Tsat-T)^3*h^3)/(u^5*(hfg*1000)^3))^(5/9));//Reynolds number
hL=(0.0077*((9.81*p1*(p1-pv)*k1^3)/u^2)^(1/3)*Re^0.4);//Heat transfer coefficient in W/m^2.K
Q=(hL*h*(Tsat-T))/1000;//Heat transfer rate per unit
```

```
 width in kW/m

//OUTPUT
mprintf('Heat transfer rate per unit width is %3.2f kW/m',Q)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 11.9 `Rate of formation of condensate`

```
//Chapter-11, Example 11.9, Page 494
//==================================================================================================

clc
clear

//INPUT DATA
T=100;//Temperature of dry steam in degree C
Do=0.025;//Outer diameter of the pipe in m
Ts=84;//Surface temmperature of pipe in degree C
Tf=(T+Ts)/2;//Film temperature in degree C
p1=963.4;//Density of liquid in kg/m^3
u=(306*10^-6);//Dynamic viscosity in N.s/m^2
hfg=2257;//Enthalpy in kJ/kg
pv=0.596;//Density of vapour in kg/m^3
k1=0.677;//Thermal conductivity in W/m.K

//CALCULATIONS
h=(0.725*((9.81*p1*(p1-pv)*k1^3*hfg*1000)/(u*(T-Ts)*Do))^0.25);//Heat transfer coefficient in W/m^2.K
q=(h*3.14*Do*(T-Ts))/1000;//Heat transfer per unit length in kW/m
m=(q/hfg)*3600;//Total mass flow of condensate per
```

```
unit length in kg/h

//OUTPUT
mprintf('Rate of formation of condensate per unit length is %3.2f kg/h',m)

//====================================END OF PROGRAM==================================
```

Scilab code Exa 11.10 `Condensation rate`

```
//Chapter-11, Example 11.10, Page 494
//===========================================================================================

clc
clear

//INPUT DATA
m=50;//Mass of vapour per hour
n=100;//Number of tubes
D=0.01;//Diameter of the tube in m
L=1;//Length of the tube in m
n1=10;//Array of 10*10

//CALCULATIONS
mr=((0.725/1.13)*(L/(n1*D))^0.25);//Ratio of horizontal and vertical position
mv=(m/mr);//Mass flow rate in the vertical position in kg/h

//OUTPUT
mprintf('Mass flow rate in the vertical position is %3.2f kg/h',mv)

```

```
//========================================END OF PROGRAM
    ====================================
```

Chapter 12

Heat Exchangers

Scilab code Exa 12.1 `Overall heat transfer coefficient`

```
//Chapter-12, Example 12.1, Page 503
//=============================================================================
clc
clear

//INPUT
T=80;//Bulk Temperature of water in degrees C
Di=0.0254;//Inner diameter of steel pipe in m
Do=0.0288;//Outer diameter of steel pipe in m
k=50;//Thermal conductivity of steel in W/m.K
ho=30800;//Average convection coefficient in W/m^2.K
v=0.50;//Velocity of water in m/s

//INPUT DATA FROM HEAT AND MASS TRANSFER DATA BOOK FOR WATER AT BULK TEMPERATURE OF 80 degree C
d=974;//Density in kg/m^3
v1=0.000000364;//Kinematic viscosity in m^2/s
k1=0.6687;//Thermal conductivity in W/m.K
Pr=2.2;//Prantl Number
```

```

//CALCULATIONS
Re=(v*Di)/v1;//Reynold's number
Nu=(0.023*Re^0.8*Pr^0.4);//Nusselts number
hi=Nu*(k1/Di);//Heat transfer coefficient in W/m^2.K
ri=(Di/2);//Inner radius of steel pipe in m
ro=(Do/2);//Outer radius of steel pipe in m
U=(1/((1/ho)+((ro/k)*log(ro/ri))+(ro/(ri*hi))));//Overall heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Overall heat transfer coefficient is %3.1f W/m^2.K',U)

//==================================================================END OF PROGRAM===========================================================
```

Scilab code Exa 12.2 Overall heat transfer coefficient

```
//Chapter-12, Example 12.2, Page 504
//=============================================================================================================================

clc
clear

//INPUT DATA
Do=0.0254;//Outer Diameter of heat exchanger tube in m
Di=0.02286;//Inner Diameter of heat exchanger tube in m
k=102;//Thermal conductivity of the tube in W/m.K
hi=5500;//Heat transfer coefficients at the inner side of tube in W/m^2.K
ho=3800;//Heat transfer coefficients at the outer
```

```
side of tube in W/m^2.K
Rfi=0.0002;//Fouling factor in m^2.W.K
Rfo=0.0002;//Fouling factor in m^2.W.K

//CALCULATIONS
ro=(Do/2);//Outer radius of heat exchanger tube in m
ri=(Di/2);//Inner radius of heat exchanger tube in m
U=(1/((1/ho)+Rfo+((ro/k)*log(ro/ri))+((ro*Rfi)/ri)+(ro/(ri*hi))));//Overall heat transfer coefficient in W/m^2.K

//OUTPUT
mprintf('Overall heat transfer coefficient is %i W/m^2.K',U)

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 12.3 Heat exchanger area

```
//Chapter-12, Example 12.3, Page 509
//==========================================================================================

clc
clear

//INPUT DATA
mh=10000;//Mass flow rate of oil in kg/h
ch=2095;//Specific heat of oil J/kg.K
Thi=80;//Inlet temperature of oil in degree C
Tho=50;//Outlet temperature of oil in degree C
mc=8000;//Mass flow rate of water in kg/h
Tci=25;//Inlet temperature of water in degree C
U=300;//Overall heat ransfer coefficient in W/m^2.K
```

```
cc=4180;//Specific heat of water in J/kg.K

//CALCULATIONS
Q=(mh*ch*(Thi-Tho));//Heat transfer rate in W
Tco=((Q/(mc*cc))+Tci);//Outlet temperature of water in degree C
T=(Thi-Tco);//Temperature difference between oil inlet temperature and water outlet temperature in degree C
t=(Tho-Tci);//Temperature difference between oil outlet temperature and water inlet temperature in degree C
A=(((Q/U)*log(t/T))/(3600*(t-T)));//Area of heat exchanger in m^2

//OUTPUT
mprintf('Area of heat exchanger is %3.2f m^2',A)

//==================================END OF PROGRAM==============================
```

Scilab code Exa 12.4 `Heat exchanger area`

```
//Chapter-12, Example 12.4, Page 510
//==================================================================================

clc
clear

//INPUT DATA
Ch=2500;//Capacity rate of hot oil in W/K
Thi=360;//Temperature of hot fluid at the entrance of heat exchanger in degree C
Tho=300;//Temperature of hot fluid at the exit of
```

```
heat exchanger in degree C
Tci=30;//Temperature of cold fluid at the entrance of heat exchanger in degree C
Tco=200;//Temperature of hot fluid at the exit of heat exchanger in degree C
U=800;//Overall heat transfer coefficient in W/m^2.K

//CALCULATIONS
Q=(Ch*(Thi-Tho));//Heat transfer from the oil in W
//Parallel flow
T1=Thi-Tci;//Temperature difference between hot fluid inlet temperature and cold fluid inlet temperature in degree C
T2=Tho-Tco;//Temperature difference between hot fluid outlet temperature and cold fluid outlet temperature in degree C
Tlm1=((T1-T2)/log(T1/T2));//LMTD for parallel flow arrangement in degree C
A1=(Q/(U*Tlm1));//Area of heat exchanger in m^2
//Counter flow
t1=Thi-Tco;//Temperature difference between hot fluid inlet temperature and cold fluid outlet temperature in degree C
t2=Tho-Tci;//Temperature difference between hot fluid outlet temperature and cold fluid inlet temperature in degree C
Tlm2=((t1-t2)/log(t1/t2));//LMTD for counter flow arrangement in degree C
A2=(Q/(U*Tlm2));//Area of heat exchanger in m^2

//OUTPUT
mprintf('Area of heat exchanger in parallel flow arrangement is %3.3f m^2 \n Area of heat exchanger in counter flow arrangement is %3.3f m^2',A1,A2)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 12.5 `Length of heat exchanger`

```
//Chapter-12, Example 12.5, Page 511
//==========================================================================

clc
clear

//INPUT DATA
ch=2130;//Specific heat of oil in J/kg.K
T1=160;//Temperature of hot fluid (oil) at the entrance of heat exchanger in degree C
T2=60;//Temperature of hot fluid (oil) at the exit of heat exchanger in degree C
t1=25;//Temperature of cold fluid (water) at the entrance of heat exchanger in degree C
d=0.5;//Inner diameter of the tube in m
mc=2;//Mass flow rate of cooling water in kg/s
D=0.7;//outer annulus outer diameter in m
mh=2;//Mass flow rate of hot oil in kg/s
U=250;//Overall heat transfer coefficient in W/m^2.K
cc=4186;//Specific heat of water in J/kg.K

//CALCULATIONS
Q=(mh*ch*(T1-T2));// Required heat transfer rate in W
t2=((Q/(mc*cc))+t1);//Outer water temperature in degree C
T=T1-t2;//Change in temperature between inlet tmperature of hot fluid and outlet temperature of cold fluid in degree C
t=T2-t1;//Change in temperature between outlet tmperature of hot fluid and inlet temperature of
```

```
cold fluid in degree C
Tlm=((T-t)/(log(T/t)));//Value of LMTD in degree C
L=(Q/(U*3.14*d*Tlm));//Length of the heat exchanger in m

//OUTPUT
mprintf('Length of the heat exchanger is %3.2f m',L)

//==================================END OF PROGRAM===============================
```

Scilab code Exa 12.6 Surface area and rate of condensation of steam

```
//Chapter-12, Example 12.6, Page 512
//=================================================================================

clc
clear

//INPUT DATA
T=120;//Saturated steam temperature in degree C
U=1800;//Heat transfer coefficient in W/m^2.K
m=1000;//mass flow rate of water in kg/h
t1=20;//Inlet temperature of water in degree C
t2=90;//Outlet tmperature of water in degree C
hfg=2200;//Enthalpy of steam in kJ/kg
c=4186;//Specific het of water in J/kg.K

//CALCULATIONS
Tlm=(((T-t1)-(T-t2))/(log((T-t1)/(T-t2))));//LMTD in a condenser in degree C
Q=((m/3600)*c*(t2-t1));//Rate of heat transfer in W
A=(Q/(U*Tlm));//Surface area of heat exchanger in m^2
```

```
ms=((Q*3600)/(hfg*1000));//Rate of condensation of steam in kg/h

//OUTPUT
mprintf('Surface area of heat exchanger is %3.2f m^2 \n Rate of condensation of steam is %3.1f kg/h',A,ms)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 12.7 `Effective log mean temperature difference`

```
//Chapter-12, Example 12.7, Page 516
//=============================================================================

clc
clear

//INPUT DATA
T=100;//Temperature of saturated steam in degree C
t1=30;//Inlet temperature of water in degree C
t2=70;//Exit temperature of water in degree C

//CALCULATIONS
//COUNTER FLOW
Tc=(T-t2);//Temperature difference between saturated steam and exit water temperature in degree C
tc=(T-t1);//Temperature difference between saturated steam and inlet water temperature in degree C
Tlmc=((Tc-tc)/log(Tc/tc));//LMTD for counter flow in degree C
//PARALLEL FLOW
Tp=(T-t1);//Temperature difference between saturated
```

```
steam and inlet water temperature in degree C
tp=(T-t2);//Temperature difference between saturated steam and exit water temperature in degree C
Tlmp=((Tp-tp)/log(Tp/tp));//LMTD for counter flow in degree C
//CROSS FLOW
R=((T-T)/(t2-t1));//R value for Correction factor F
P=((t2-t1)/(T-t1));//P value for Correction Factor F
F=1;//Referring to Fig.12.12 in page no 515
Tlmx=(F*Tlmc);//LMTD for cross flow in degree C

//OUTPUT
mprintf('The effective log mean temperature difference for: \n i)COUNTER FLOW is %3.1f degree C \n ii)PARALLEL FLOW is %3.1f degree C \n iii)CROSS FLOW is %3.1f degree C',Tlmc,Tlmp,Tlmx)

//==================================END OF PROGRAM==============================
```

Scilab code Exa 12.8 `Area of heat exchanger`

```
//Chapter-12, Example 12.8, Page 516
//==========================================================================

clc
clear

//INPUT DATA
Ti=18;//Inlet temperature of Shell fluid in degree C
To=6.5;//Outlet temperature of Shell fluid in degree C
ti=-1.1;//Inlet temperature of Tube fluid in degree C
```

```
to=2.9;//Outlet temperature of Tube fluid in degree C
U=850;//Overall heat transfer coefficient in W/m^2.K
Q=6000;//Design heat load in W

//CALCULATIONS
T=(Ti-to);//Temperature difference between shell side inlet fluid and tube side outlet fluid in degree C
t=(To-ti);//Temperature difference between shell side outlet fluid and tube side inlet fluid in degree C
Tlm=((T-t)/log(T/t));//LMTD for a counterflow arrangement in degree C
P=((to-ti)/(Ti-ti));//P value to calculate correction factor
R=((Ti-To)/(to-ti));//R value to calculate correction factor
F=0.97//Taking correction factor from fig. 12.9 on page no.514
A=(Q/(U*F*Tlm));//Area of shell aand tube heat exchanger in m^2

//OUTPUT
mprintf('Area of shell-and-tube heat exchanger is %3.2f m^2',A)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 12.9 Area of heat exchanger

```
//Chapter-12, Example 12.9, Page 517
//==================================================================================================================
```

```
clc
clear

//INPUT DATA
Q=6000;//Taking design heat load value in W from Example no. 12.8 on page no.516
U=850;//Taking overall heat transfer coefficient value in W/m^2.K from Example no. 12.8 on page no.516
Tlm=10.92//Taking LMTD for a counterflow arrangement in degree C from Example no. 12.8 on page no.517
R=2.875;//Taking R value from Example no. 12.8 on page no.517
P=0.209;//Taking P value from Example no. 12.8 on page no.517
F=0.985;//Taking correction factor from Fig. 12.10 on page no.514

//CALCULATIONS
A=(Q/(U*F*Tlm));//Area of shell-and-tube heat exchanger in m^2

//OUTPUT
mprintf('Area of shell aand tube heat exchanger is %3.3f m^2',A)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 12.10 Surface area

```
//Chapter-12, Example 12.10, Page 517
//=================================================================================
```

```
clc
clear

//INPUT DATA
Ti=360;//Inlet temperature of hot fluid in degree C taken from Example no. 12.4 on page no. 510
To=300;//Outlet temperature of hot fluid in degree C taken from Example no. 12.4 on page no. 510
ti=30;//Inlet temperature of cold fluid in degree C taken from Example no. 12.4 on page no. 510
to=200;//Outlet temperature of cold fluid in degree C taken from Example no. 12.4 on page no. 510
U=800;//Overall heat transfer coefficient in W/m^2.K taken from Example no. 12.4 on page no. 510
Q=150000;//Calculated heat transfer rate in W from Example no. 12.4 on page no. 510
Tlm=210.22//Calculated LMTD for counterflow arrangement in degree C taken from Example no. 12.4 on page no. 511

//CALCULATIONS
P=((to-ti)/(Ti-ti));//P value for calculation of correction factor
R=((Ti-To)/(to-ti));//R value for calculation of correction factor
F=0.98;//Correction Factor value taken from Fig.12.11 on page no.515
A=(Q/(U*F*Tlm));//Required surface area in a cross flow heat exchanger in m^2

//OUTPUT
mprintf('The required surface area in a cross flow heat exchanger is %3.2f m^2',A)

//==============================================END OF PROGRAM============================================
```

Scilab code Exa 12.11 Number of tube passes and number of tubes per pass

```
//Chapter-12, Example 12.11, Page 518
//==========================================================================

clc
clear

//INPUT DATA
mc=4;//Mass flow rate of cold water in kg/s
Tci=38;//Inlet Temperature of cold water in degree C
Tco=55;//Outlet Temperature of cold water in degree C
D=0.02;//Diameter of the tube in m
v=0.35;//Velocity of water in m/s
Thi=95;//Inlet Temperature of hot water in degree C
mh=2;//Mass flow rate of hot water in kg/s
L=2;//Length of the tube in m
U=1500;//Overall heat transfer coefficient in W/m^2.K
c=4186;//Specific heat of water in J/kg.K
d=1000;//Density of water in kg/m^3

//CALCULATIONS
Q=(mc*c*(Tco-Tci));//Heat transfer rate for cold fluid in W
Tho=(Thi-(Q/(mh*c)));//Outlet temperature of hot fluid in degree C
T=Thi-Tco;//Difference of temperature between hot water inlet and cold water outlet in degree C
t=Tho-Tci;//Difference of temperature between hot water outlet and cold water inlet in degree C
Tlm=((T-t)/log(T/t));//LMTD for counterflow heat
```

```
exchanger
A=(Q/(U*Tlm));//Area of heat exchanger in m^2
A1=(mc/(d*v));//Total flow area in m^2
n=((A1*4)/(3.14*D^2));//Number of tubes
L=(A/(36*3.14*D));//Length of each tube taking n=36 in m
N=2;//Since this length is greater than the permitted length of 2m, we must use more than one tube pass. Let us try 2 tube passes
P=((Tco-Tci)/(Thi-Tci));//P value for calculation of correction factor
R=((Thi-Tho)/(Tco-Tci));//R value for calculation of correction factor
F=0.9;//Corrction Factor from Fig.12.9 on page no. 514
A2=(Q/(U*F*Tlm));//Total area required for one shall pass,2 tube pass exchanger in m^2
L1=(A2/(2*36*3.14*D));//Length of tube per pass taking n=36 in m

//OUTPUT
mprintf('Number of tubes per pass is %i \n Number of passes is %i \n Length of tube per pass is %3.3f m',n,N,L1)

//========================================END OF PROGRAM========================================
```

Scilab code Exa 12.12 `Surface area and temperature`

```
//Chapter-12, Example 12.12, Page 524
//==========================================================================================

clc
```

```
clear

//INPUT DATA
mh=250;//Mass flow rate of hot liquid in kg/h
ch=3350;//Specific heat of hot liquid in J/kg.K
Thi=120;//Inlet temperature of hot liquid in degree C
mc=1000;//Mass flow rate of cold liquid in kg/h
Tci=10;//Inlet temperature of cold liquid in degree C
U=1160;//Overall heat transfer coefficient in W/m^2.K
A=0.25;//Surface area of heat exchanger in m^2
cc=4186;//Specific heat of cold liquid in J/kg.K

//CALCULATIONS
Cc=((mc*cc)/3600);//Heat capacity rate for cold liquid in W/K
Ch=((mh*ch)/3600);//Heat capacity rate for hot liquid in W/K
Cmin=min(Cc,Ch);//Minimum heat capacity rate in W/K
Cmax=max(Cc,Ch);//Maximum heat capacity rate in W/K
r=(Cmin/Cmax);//Ratio of min amd max heat capacity rates
NTU=((U*A)/Cmin);//Number of transfer units
e=((1-exp(-NTU*(1+r)))/(1+r));//Effectiveness for a parallel flow heat exchanger
Qmax=(Cmin*(Thi-Tci));//Maximum possible heat transfer rate in W
Q=(e*Qmax);//Actual rate of heat transfer in W
Tco=((Q/Cc)+Tci);//Outlet temperature of cold liquid in degree C
Tho=(Thi-(Q/Ch));//Outlet temperature of hot liquid in degree C


//OUTPUT
mprintf('Effectiveness for a parallel flow heat
```

```
exchanger is %3.3f \n Outlet temperature of water is %3.2f degree C \n Outlet temperature of cooled liquid is %3.2f degree C',e,Tco,Tho)

//==========================================END OF PROGRAM ==========================================
```

Scilab code Exa 12.13 `Total heat transfer and surface temperature`

```
//Chapter-12, Example 12.13, Page 527
//=============================================================================

clc
clear

//INPUT DATA
Tci=15;//Inlet temperature of water in degree C
mc=1300;//Mass flow rate of water in kg/h
ch=2000;//Specific heat of oil in J/kg.K
mh=550;//Mass flow rate of oil in kg/h
Thi=94;//Inlet temperature of oil in degree C
A=1;//Area of heat exchanger in m^2
U=1075;//Overall heat transfer coefficient in W/m^2.K
cc=4186;//Specific heat of water in J/kg.K

//CALCULATIONS
Cc=((mc*cc)/3600);//Heat capacity of water in W/K
Ch=((mh*ch)/3600);//Heat capacity of oil in W/K
Cmin=min(Cc,Ch);//Minimum heat capacity in W/K
Cmax=max(Cc,Ch);//Maximum heat capacity in W/K
r=(Cmin/Cmax);//Ratio of min and max heat capacity
NTU=((U*A)/Cmin);//Number of transfer Units
e=0.94//Effectiveness of heat exchanger from Fig.
```

```
12.15 on page no.524
Qmax=(Cmin*(Thi-Tci));//Maximum possible heat transfer rate in W
Q=(e*Qmax);//Actual heat transfer rate in W
Tco=((Q/Cc)+Tci);//Outlet Temperature of water in degree C
Tho=(Thi-(Q/Ch));//Outlet Temperature of oil in degree C

//OUTPUT
mprintf('The total heat transfer is %3.1f W \n Outlet Temperature of water is %i degree C \n Outlet Temperature of oil is %3.2f degree C',Q,Tco,Tho)

//==========================================END OF PROGRAM======================================
```

Scilab code Exa 12.14 `Parameters of heat exchanger`

```
//Chapter-12, Example 12.14, Page 528
//=============================================================================

clc
clear

//INPUT DATA
N=3000;//Number of brass tubes
D=0.02;//Diameter of brass tube in m
Tci=20;//Inlet temperature of cooling water in degree C
mc=3000;//Mass flow rate of cooling water in kg/s
ho=15500;//Heat transfer coefficient for condensation in W/m^2.K
```

```
Q=(2.3*10^8);//Heat load of the condenser in W
Thi=50;//Temperature at which steam condenses in
    degree C
hfg=2380//Enthalpy of liquid vapour mixture in kJ/kg
m=1;//Flow rate of each tube in kg/s
Cc=4180;//Specific heat of water in J/kg.K

//Properties of water at 300K from data book
Cc=4186;//Specific heat in J/kg.K
mu=(855*10^-6);//Dynamic viscosity in Ns/m^2
k=0.613;//Thermal Conductivity in W/mK
Pr=5.83//Prantl number

//CALCULATIONS
Tco=((Q/(mc*Cc))+Tci);//Outlet temperature of
    cooling water in degree C
Re=((4*m)/(3.1415*D*mu));//Reynold's number
Nu=(0.023*Re^(4/5)*Pr^(2/5));//Nusselts number
hi=(Nu*(k/D));//Heat transfer coefficient in W/m^2.K
U=(1/((1/ho)+(1/hi)));//Overall heat transfer
    coefficient in W/m^2.K
Cmin=(mc*Cc);//Minimum heat capacity in W/K
Qmax=(Cmin*(Thi-Tci));//Maximum heat transfer rate
    in W
e=(Q/Qmax);//Effectiveness of heat transfer
NTU=0.8;//Number of transfer units from Fig. 12.16
    on page no.525
A=((NTU*Cmin)/U);//Area of heat exchanger in m^2
L=(A/(2*N*3.1415*D));//Length of tube per pass in m
ms=(Q/(hfg*1000));//Amount of steam condensed in kg/
    s

//OUTPUT
mprintf('The outlet temperature of the cooling water
     is %3.2f degree C \n The overall heat transfer
    coefficient is %3.1f W/m^2.K \n Tube length per
    pass using NTU method is %3.2f m \n The rate of
    condensation of steam is %3.0f kg/s',Tco,U,L,ms)
```

```

//==================================================END OF PROGRAM==================================================
```

Scilab code Exa 12.15 Exit temperature

```
//Chapter-12, Example 12.15, Page 530
//=============================================================================

clc
clear

//INPUT DATA
Tci=5;//Inlet temperature of water in degree C
mc=4600;//Mass flow rate of water in kg/h
mh=4000;//Mass flow rate of air in kg/h
Thi=40;//Inlet temperature of air in degree C
U=150;//Overall heat transfer coefficient in W/m^2.K
A=25;//Area of heat exchanger in m^2
Cc=4180;//Specific heat of water in J/kg.K
Ch=1010;//Specific heat of air in J/kg.K

//CALCULATIONS
C1=((mh*Ch)/3600);//Heat capacity of air in W/K
C2=((mc*Cc)/3600);//Heat capacity of water in W/K
Cmin=min(C1,C2);//Minimum value of heat capacity in W/K
Cmax=max(C1,C2);//Maximum value of heat capacity in W/K
r=(Cmin/Cmax);//Ratio of min and max heat capacity in W/K
NTU=((U*A)/Cmin);//Number of heat transfer units
e=0.92;//Effectiveness of heat exchanger from Fig.12.18 on page no.526
```

```
Q=(e*Cmin*(Thi-Tci));//Heat transfer rate in W
Tco=((Q/C2)+Tci);//Outlet temperature of water in degree C
Tho=(Thi-(Q/C1));//Outlet temperature of air in degree C

//OUTPUT
mprintf('The exit temperature of water is %3.1f degree C \n The exit temperature of air is %3.1f degree C',Tco,Tho)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 12.16 `Outlet temperature`

```
//Chapter-12, Example 12.16, Page 532
//=============================================================================

clc
clear

//INPUT DATA
A=15.82;//Total outside area of heat exchanger in m^2
Thi=110;//Inlet temperature of oil in degree C
Ch=1900;//Specific heat of oil in J/kg.K
mh=170.9;//Mass flow rate of oil in kg/min
mc=68;//Mass flow rate of water in kg/min
Tci=35;//Inlet temperature of water in degree C
U=320;//Overall heat transfer coefficient in W/m^2.K
Cc=4186;//Specific heat of water in J/kg.K

//CALCULATIONS
```

```
C1=((mh*Ch)/60);//Heat capacity of oil in W/K
C2=((mc*Cc)/60);//Heat capacity of water in W/K
D=(U*A*((1/C1)-(1/C2)));//Constant
r=(C1/C2);//Ratio of heat capacity of oil and water
Tho=Thi-(((Thi-Tci)*(1-exp(D)))/(r-exp(D)));//Outlet temperature of oil in degree C
Tco=Tci+(r*(Thi-Tho));//Outlet temperature of water in degree C

//OUTPUT
mprintf('The exit temperature of oil is %3.2f degree C \n The exit temperature of water is %3.1f degree C',Tho,Tco)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 12.17 `Outlet temperature`

```
//Chapter-12, Example 12.17, Page 533
//==========================================================================================

clc
clear

//INPUT DATA
Tci=20;//Inlet temperature of water in degree C
Tco=50;//Outlet temperature of water in degree C
Th=120;//Temperature at which steam condenses in degree C
newTci=15;//New Inlet temperature of water in degree C

//CALCULATIONS
```

```
13 newTco=(((Tco-Tci)*(Th-newTci))/(Th-Tci))+newTci;// New outlet temperature of water in degree C
14 
15 //OUTPUT
16 mprintf('New outlet temperature of water is %3.1f degree C',newTco)
17 
18 //==============================END OF PROGRAM==============================
```

Scilab code Exa 12.18 `Diameter and length of heat exchanger`

```
1 //Chapter-12, Example 12.18, Page 534
2 //=============================================================================
3 clc
4 clear
5 
6 //INPUT DATA
7 T=100;//Total length of tubes in m
8 //ct=10000 Rs - Cost of the tubes in Rs
9 //cs=(15000*D^3*L) Cost of the shell in Rs
10 //cf=(2000*D*L) Cost of the floor space occupied by the exchanger in Rs
11 
12 //CALCULATIONS
13 //Cost=(ct+cs+cf) Total first cost in Rs
14 //Cost=(10000+(15000*D^3*L)+(2000*D*L))
15 //The constraint requires the heat exchanger to include 100m tubes such that (((3.1414*D^2)/4)*L*200)=100
16 //L=(2/(3.1415*D^2))
17 //Substitute L in the equation in line 8
18 //Cost=(10000+(15000*D^3*(2/(3.1415*D^2)))+(2000*D
```

```
*(2/(3.1415*D^2))))
//Cost=(10000+((30000*D)/3.1415)+(4000/(3.1415*D)))
//For optimizaation partial derivative of Cost w.r.t D should be zero
//((30000/3.1415)-(4000/(3.1415*D^2)))=0
D=((3.1415*4000)/(3.1415*30000))^0.5;//Diameter of the exchanger in m
L=(2/(3.1415*D^2));//Length of the exchanger in m
Cost=(10000+(15000*D^3*L)+(2000*D*L));//Optimal cost in Rs

//Output
mprintf('The diameter of the exchanger is %3.3f m \n The Length of the exchanger is %3.2f m \n Optimal cost is %3.0f Rs',D,L,Cost)

//==================================END OF PROGRAM==================================
```

Chapter 13

Diffusion Mass Transfer

Scilab code Exa 13.1 `Average molecular weight`

```
//Chapter-13, Example 13.1, Page 544
//=============================================================================

clc
clear

//INPUT DATA
ro2=0.21;//Ratio of O2 in the mixture
rn2=0.79;//Ratio of N2 in the mixture
T=(25+273);//Temperature of container in degree C
p=1;//Total pressure in atm

//CALCULATIONS
Co2=(ro2*10^5)/(8314*T);//Molar concentration of O2 in K.mol/m^3
Cn2=(rn2*10^5)/(8314*T);//Molar concentration of N2 in K.mol/m^3
po2=(32*Co2);//Mass density in kg/m^3
pn2=(28*Cn2);//Mass density in kg/m^3
p=(po2+pn2);//Overall mass density in kg/m^3
```

```
mo2=(po2/p);//Mass fraction of O2
mn2=(pn2/p);//Mass fraction of N2
M=(ro2*32)+(rn2*28);//Average molecular weight

//OUTPUT
mprintf('Molar concentration of O2 is %3.4f K.mol/m^3 \n Molar concentration of N2 is %3.3f K.mol/m^3 \n Mass density of O2 is %3.3f kg/m^3 \n Mass density of N2 is %3.3f kg/m^3 \n Mole fraction of O2 is %3.2f \n Mole fraction of N2 is %3.2f \n Mass fraction of O2 is %3.3f \n Mass fraction of N2 is %3.3f \n Average molecular weight is %3.2f',Co2,Cn2,po2,pn2,ro2,rn2,mo2,mn2,M)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 13.2 `Mass and molar average velocities and flux`

```
//Chapter-13, Example 13.2, Page 545
//=============================================================================================

clc
clear

//INPUT DATA
yh2=0.4;//Mole fraction og H2
yo2=0.6;//Mole fraction of O2
vh2=1;//velocity of H2 in m/s
vo2=0;//velocity of O2 in m/s

//CALCULATIONS
V=(yh2*vh2)+(yo2*vo2);//Molar average velocity in m/s
```

```
M=(yh2*2)+(yo2*32);//Molecular weight of the mixture
mh2=(yh2*2)/M;//Mass fraction of H2
mo2=(yo2*32)/M;//Mass fraction of O2
v=(mh2*vh2)+(mo2*vo2);//Mass average velocity in m/s
x1=(mh2*vh2);//Mass flux
x2=(mo2*vo2);//Mass flux
y1=(v*vh2);//Molar flux
y2=(yo2*vo2);//Molar flux
jh2=(mh2*(vh2-v));//Mass diffusion flux
jo2=(mo2*(vo2-v));//Mass diffusion flux
Jh2=(yh2*(vh2-V));//Molar diffusion flux
Jo2=(yo2*(vo2-V));//Molar diffusion flux

//OUTPUT
mprintf('Molar average velocity is %3.1f m/s \nMass average velocity is %3.2f m/s \n Mass flux of H2 when it is stationary is %3.2fp kg/m2.s3 \nMass flux of O2 when it is stationary is %3.0f kg/m^2.s \nMolar flux of H2 when it is stationary is %3.2fC k.mol/m^2.s \nMolar flux of O2 when it is stationary is %3.0f k.mol/m^2.s \nMass diffusion flux of H2 across a surface moving with mass average velocity is %3.4fp kg/m^2.s \nMass diffusion flux of O2 across a surface moving with mass average velocity is %3.4fp kg/m^2.s  \nMolar diffusion flux across a surface moving with molar average velociy for H2 is %3.2fC k.mol/m^2.s \nMolar diffusion flux across a surface moving with molar average velociy for O2 is %3.2fC k.mol/m^2.s',V,v,x1,x2,y1,y2,jh2,jo2,Jh2,Jo2)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 13.3 `Diffusion flux`

```
//Chapter-13, Example 13.3, Page 557
//=============================================================================

clc
clear

//INPUT DATA
t=0.001;//Thickness of the membrane in m
CA1=0.02;//Concentration of helium in the membrane at inner surface in k.mol/m^3
CA2=0.005;//Concentration of helium in the membrane at outer surface in k.mol/m^3
DAB=10^-9;//Binary diffusion coefficient in m^2/s

//CALCULATIONS
NAx=((DAB*(CA1-CA2))/t)/10^-9;//Diffusion flux of helium through the plastic in k.mol/sm^2 *10^-9

//OUTPUT
mprintf('Diffusion flux of helium through the plastic is %3.0f*10^-9 k.mol/sm^2',NAx)

//==============================END OF PROGRAM==============================
```

Scilab code Exa 13.4 `Initial rate of leakage`

```
//Chapter-13, Example 13.4, Page 557
//=============================================================================

clc
clear

```

```
//INPUT DATA
T=273+25;//Temperature of Helium gas in K
p=4;//Pressure of helium gas in bar
Di=0.1;//Inner diamter of wall in m
Do=0.003;//Outer diamter of wall in m
DAB=(0.4*10^-13);//Binary diffusion coefficient in m^2/s
S=(0.45*10^-3);//S value for differentiation

//CALCULATIONS
A=(3.14*Di^2);//Area in m^2
V=(3.14*Di^3)/6;//Volume in m^3
R=0.08316//Gas constant in m^3 bar/kmol.K
d=((-6*R*T*DAB*S*p)/(Do*Di))/10^-11;//Decrease of pressure with time in bar/s*10^-11

//OUTPUT
mprintf('Initial rate of leakage for the system is provided by the decrease of pressure with time which is %3.2f*10^-11 bar/s',d)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 13.5 Loss of oxygen by diffusion

```
//Chapter-13, Example 13.5, Page 558
//===================================================================================

clc
clear

//INPUT DATA
po2=2;//Pressure of O2 in bar
```

```
Di=0.025;//inside diamter of the pipe in m
L=0.0025;//Wall thickness in m
a=(0.21*10^-2);//Diffusivity of O2 in m^2/s
S=(3.12*10^-3);//Solubility of O2 in k.mol/m^3.bar
DAB=(0.21*10^-9);//Binary diffusion coefficient in m^2/s

//CALCULATIONS
CAi=(S*po2);//Concentration of O2 on inside surface in kmol/m^3
RmA=((log((Di+(2*L))/Di))/(2*3.14*DAB));//Diffusion resistance in sm^2
Loss=(CAi/RmA)/10^-11;//Loss of O2 by diffusion per meter length of pipe *10^-11

//OUTPUT
mprintf('Loss of O2 by diffusion per meter length of pipe is %3.2f*10^-11 kmol/s',Loss)

//==========================================END OF PROGRAM==========================================
```

Scilab code Exa 13.6 Mass transfer rate

```
//Chapter-13, Example 13.6, Page 560
//================================================================================

clc
clear

//INPUT DATA
p=1;//Pressure of system in atm
T=25+273;//Temperature of system in K
pco2=(190/760);//Partial pressure of CO2 at one end
```

```
in atm
pco2o=(95/760);//Partial pressure of CO2 at other end in atm
DAB=(0.16*10^-4);//Binary diffusion coefficient in m^2/s from Table 13.3
R=0.08205//Gas constant in m^3 atm/kmol.K

//CALCULATIONS
NAx=(DAB*(pco2-pco2o))/(R*T*p);//Equimolar counter diffusion in kmol/m^2s
M=(NAx*3.14*(0.05^2/4)*3600);//Mass transfer rate in kmol/h
MCO2=(M*44)/10^-5;//Mass flow rate of CO2 in kg/h *10^-5
Mair=(29*-M)/10^-5;//Mass flow rate of air in kg/h *10^-5

//OUTPUT
mprintf('Mass transfer rate of CO2 is %3.2f*10^-5 kg/h \nMass transfer rate of air is %3.2f*10^-5 kg/h',MCO2,Mair)

//==============================================END OF PROGRAM==========================================
```

Scilab code Exa 13.7 `Diffusion rate`

```
//Chapter-13, Example 13.7, Page 563
//==========================================================================================================

clc
clear

//INPUT DATA
```

```
T=27+273;//Temperature of water in K
D=0.02;//Diameter of the tube in m
L=0.4;//Length of the tube in m
DAB=(0.26*10^-4);//Diffusion coefficient in m^2/s

//CALCULATIONS
p=1.0132;//Atmospheric pressure in bar
pA1=0.03531;//Vapour pressure in bar
m=((p*10^5*3.14*(D/2)^2*18*DAB)/(8316*T*L))*(1000*3600)*log(p/(p-pA1));//Diffusion rate of water in gram per hour

//OUTPUT
mprintf('Diffusion rate of water is %3.4f gram per hour',m)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 13.8 `Diffusion coefficient`

```
//Chapter-13, Example 13.8, Page 564
//====================================================================================

clc
clear

//INPUT DATA
T=25+273;//Temperature of water in K
D=0.02;//Diameter of the tube in m
L=0.08;//Length of the tube in m
m=(8.54*10^-4);//Diffusion coefficient in kg/h

//CALCULATIONS
```

```
p=1.0132;//Atmospheric pressure in bar
pA1=0.03165;//Vapour pressure in bar
DAB=(((m/3600)*8316*T*L)/(p*10^5*3.14*(D/2)^2*18*log(p/(p-pA1))*10^2))/10^-4;//Diffusion coefficient of water in m^2/s *10^-4

//CALCULATIONS
mprintf('Diffusion coefficient of water is %3.3f *10^-4 m^2/s',DAB)

//===================================END OF PROGRAM===================================
```

Scilab code Exa 13.9 `Time required`

```
//Chapter-13, Example 13.9, Page 569
//==========================================================================

clc
clear

//INPUT DATA
CAs=0.02;//Carbon mole fraction
CAo=0.004;//Content of steel
CA=0.012;//Percet of depth
d=0.001;//Depth in m
H=(6*10^-10);//Diffusivity of carbon in m^2/s

//CALCULATIONS
X=(CA-CAs)/(CAo-CAs);//Calculation for erf function
n=0.48;//erf(n)=0.5; n=0.48
t=((d/(n*2))^2/(3600*H))*3600;//Time required to elevate the carbon content of steel in s

```

```
//OUTPUT
mprintf('Time required to elevate the carbon content of steel is %3.2f s',t)

//==================================================END OF PROGRAM==============================================
```

Chapter 14

Convective Mass Transfer

Scilab code Exa 14.1 `Convection mass transfer coefficient`

```
//Chapter-14, Example 14.1, Page 574
//============================================================================

clc
clear

//INPUT DATA
D=0.025;//Diameter of the cylinder in m
R=(2*10^-6);//Rate of sublime in kg/s
C=(6*10^-6);//Saturated vapour concentration in kmol/m^3
W=128;//Molecular weight in kg/kmol

//CALCULATIONS
q=(R/W);//Molar transfer rate in k.mol/sm
h=(q/(%pi*D*C));//Convective mass transfer coefficient in m/s

//OUTPUT
mprintf('Convective mass transfer coefficient is %3
```

```
.3f m/s',h)

//==========================================END OF PROGRAM==========================================
```

Scilab code Exa 14.2 Local Mass transfer coefficient

```
//Chapter-14, Example 14.2, Page 576
//==============================================================================

clc
clear

//INPUT DATA
pA=-0.9;//Partial pressure of water vapour in atm
t=0.0025;//Boundary layer thickness in m

//CALCULATIONS
//pA=(exp(-33.35y)-0.9)
y=0;
pAs1=exp(-33.35*y)-0.9;//Partial pressure in atm
y=t;
pAs2=exp(-33.35*y)-0.9;//Partial pressure in atm
//partial derivative of pA wrt y is -33.35exp(y)-0.9
x=0;
X=(-33.35*exp(x))-pA;//Partial derivative value at x=0
DAB=(0.26*10^-4)//DAB value in m^2/s
h=(DAB*X)/(pAs2-pAs1);//Local mass transfer coefficient in m/s

//OUTPUT
mprintf('Local mass transfer coefficient is %3.4f m/s',h)
```

```

//==========================================================END OF PROGRAM==================================================
```

Scilab code Exa 14.3 `Mass Transfer coefficient`

```
//Chapter-14, Example 14.3, Page 583
//=============================================================================================================================

clc
clear

//INPUT DATA
T=27;//Temperature of dry air in degree C
p=1;//Pressure of dry air in atm
L=0.5;//Length of the plate in m
v=50;//Velocity in m/s

//CALCULATIONS
DAB=(0.26*10^-4)//DAB value in m^2/s
p=1.16;//Density in kg/m^3
u=(184.6*10^-7);//Dynamic viscosity in N.s/m^2
Pr=0.707;//Prantl number
Sc=(u/(p*DAB));//Schmidt number
Re=(p*v*L)/u;//Reynolds number
jm=(0.0296*(Re^(-1/5)));//jm value
h=(jm*v)/Sc^(2/3);//Mass transfer coefficient of water vapour in m/s

//OUTPUT
mprintf('Mass transfer coefficient of water vapour is %3.3f m/s',h)

//==========================================================END OF PROGRAM
```

Scilab code Exa 14.4 `Mass transfer coefficient`

```
//Chapter-14, Example 14.4, Page 583
//==========================================================================

clc
clear

//INPUT DATA
T=27;//Temperature of swimming pool in degree C
h=0.4;//Relative humidity
v=2;//Speed of wind in m/s
v1=(15.89*10^-6);//Kinematic viscosity in m^2/s
p=0.0436;//Density in kg/m^3
DAB=(0.26*10^-4)//DAB value in m^2/s
L=15;//Length in m


//CALCULATIONS
Sc=(v1/DAB);//Schmidt number
Re=(v*L)/v1;//Reynolds number
ShL=(((0.037*Re^(4/5))-870)*Sc^(1/3));//Equivalent Schmidt number
h1=(ShL*(DAB/L))/10^-3;//Mass transfer coefficient for evaporation in mm/s

//OUTPUT
mprintf('Mass transfer coefficient for evaporation is %3.1f*10^-3 m/s',h1)

//=================================END OF PROGRAM==============================
```

Scilab code Exa 14.5 `Average mass transfer coefficient`

```
//Chapter-14, Example 14.5, Page 585
//====================================================================================
clc
clear

//INPUT DATA
T=25;//Temperature of air in degree C
v=3;//Velocity im m/s
D=0.01;//Diameter of tube in m
L=1;//Length of tube in m

//CALCULATIONS
v1=(15.7*10^-6);//Kinematic viscosity in m^2/s
DAB=(0.62*10^-5)//DAB value in m^2/s
Re=(v*D)/v1;//Reynolds number
Sh=3.66;//Schmidt number
h=(Sh*DAB)/D;//Average mass transfer coefficient in m/s

//OUTPUT
mprintf('Average mass transfer coefficient is %3.5f m/s',h)

//=================================================END OF PROGRAM=============================================
```

Scilab code Exa 14.6 `Mass transfer coefficient`

```
//Chapter-14, Example 14.6, Page 586
//==============================================================================

clc
clear

//INPUT DATA
T=25;//Temperature of air in degree C
v=5;//Velocity in m/s
D=0.03;//Diameter of tube in m
DAB=(0.82*10^-5)//DAB value in m^2/s

//CALCULATIONS
v1=(15.7*10^-6);//Kinematic viscosity in m^2/s
Sc=(v1/DAB);//Schnidt number
Re=(v*D)/v1;//Reynolds number
h=(0.023*Re^(4/5)*Sc^(1/3)*DAB)/D;//Mass transfer coefficient in m/s

//OUTPUT
mprintf('Mass transfer coefficient is %3.4f m/s',h)

//===================================END OF PROGRAM==================================
```

Scilab code Exa 14.7 Steady state temperature

```
//Chapter-14, Example 14.7, Page 589
//==============================================================================

clc
clear

```

```
//INPUT DATA
Ta=40+273;//Temperature of air in K
w=100;//Molecular weight in kg/k.mol
H=120;//Latent heat of vapourisation of volatile liquid in kJ/kg
p=3530;//Saturated vapour pressure in N/m^2
DAB=(0.2*10^-4);//DAB value in m^2/s

//CALCULATIONS
p1=1.16;//Density in kg/m^2
Cp=1.007;//Specific heat in J/kg.K
a=(22.5*10^-6);//Diffusivity in m^2/s
X=((H*100*p*10^-3)/(8.315*p1*Cp*(a/DAB)^(2/3)));//X value for temperature
T=(Ta+sqrt((Ta^2-(4*X))))*0.5;//Temperature in K

//OUTPUT
mprintf('Steady state temperature of cold water inside the pot is %3.1f K',T)

//=========================================END OF PROGRAM=====================================
```

Scilab code Exa 14.8 `True air temperature`

```
//Chapter-14, Example 14.8, Page 590
//==========================================================================================

clc
clear

//INPUT DATA
T=22+273;//Thermometer reading in K

```

```
//CALCULATIONS
p=2617;//Pressure in N/m^2
hfg=2449;//Enthalpy in kJ/kg
p1=(p*18)/(8315*T);//Density in kg/m^3
p2=(1.0132*10^5)/(287*T);//Density in kg/m^3
Cp=1.008;//Specific heat in kJ/kg.K
a=(26.2*10^-6);//Diffusivity in m^2/s
DAB=(0.26*10^-4);//DAB value in m^2/s
Ts=((T-273)+((hfg*1000*p1)/(p2*Cp*1000)));//True air temperature in degree C

//OUTPUT
mprintf('True air temperature is %3.2f degree C',Ts)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 14.9 `Relative humidity`

```
//Chapter-14, Example 14.9, Page 591
//====================================================================================================

clc
clear

//INPUT DATA
T=50;//Temperature of air stream in degree C
Tb=22;//Bulb temperature in degree C

//CALCULATIONS
Tf=(T+Tb)/2;//Film temperature in degree C
p=1.14;//Density in kg/m^3
Cp=1.006;//Specific heat in J/kg.K
Pr=0.7;//Prantl number
```

```
u=(2*10^-5);//Dynamic viscosity in Ns/m^2
DAB=(0.26*10^-4);//DAB value in m^2/s
Sc=(u/(p*DAB));//Schmidt nuber
Le=(Sc/Pr);//Lewis number
p1=0.01920;//Density in kg/m^3
hfg=2449;//Enthalpy in kJ/kg
pA=0.0064;//Density in kg/m^3
psat=(1/12.23);//Saturation density in kg/m^3
RH=(pA/0.0817)*100;//Relative humidity

//OUTPUT
mprintf('Relative humidity of the airstream is %3.2f percent',RH)

//==================================END OF PROGRAM==================================
```

Scilab code Exa 14.10 `Specific humidity`

```
//Chapter-14, Example 14.10, Page 592
//==============================================================================

clc
clear

//INPUT DATA
Td=27;//Dry bulb teperature in degree C
Tw=17;//Wet bulb temperature in degree C
Pr=0.74;//Prantl number
Sc=0.6;//Schmidt number
Mv=18;//Molecular weight of vapour
Ma=29;//Molecular weight of air
Cp=1004;//Specific heat in J/kg.K
p=(1.0132*10^5);//Pressure in N/m^2
```

```

//CALCULATIONS
pv2=1917;//Saturation presusre of air at 17 degree C in N/m^2
hfg=2461;//Enthalpy in kJ/kg
w2=(Mv*pv2)/(Ma*(p-pv2));//Weight in kg/kg of dry air
w1=w2-((Cp*(Pr/Sc)^(2/3)*(Td-Tw))/(hfg*1000));//Specific humidity of air in kg/kg of dry air

//OUTPUT
mprintf('Specific humidity of air is %3.5f kg/kg of dry air',w1)

//==================================================END OF PROGRAM==============================================
```

Scilab code Exa 14.11 Rate of evaporation

```
//Chapter-14, Example 14.11, Page 592
//==============================================================================

clc
clear

//INPUT DATA
T=27;//Temperature of swimming pool in degree C
Ts=37;//Surface temperature in degree C
h=0.4;//Relative humidity
D1=5;//Dimension of swimming pool in m
D2=15;//Dimension of swimming pool in m
v=2;//Speed of wind in m/s
v1=(15.89*10^-6);//Kinematic viscosity in m^2/s
p=0.0436;//Density in kg/m^3
```

```
DAB=(0.26*10^-4)//DAB value in m^2/s
Sc=(v1/DAB);//Schmidt number
Re=(v*D2)/v1;//Reynolds number
ShL=(((0.037*Re^(4/5))-870)*Sc^(1/3));//Equivalent Schmidt number
h1=(ShL*(DAB/D2));//Mass transfer coefficient for evaporation in m/s

//CALCULATIONS
Psat=3531;//Partial pressure of water vapour in N/m^2
pi=(0.4*6221);//Saturation pressure of water vapour in N/m^2
pt=101325;//Total pressure of air in N/m^2
pAs=(18*Psat)/(8361*(T+273));//Density at the water surface in kg/m
pAi=(18*pi)/(8316*(T+273));//Density at the water surface in kg/m
n=(h1*(pAs-pAi)*3600*24);//Rate of evaporation of water in kg/m^2 day
L=(n*D1*D2);//Total water loss from the swimming pool in kg/day

//OUTPUT
mprintf('Rate of evaporation of water is %3.1f kg/day',L)

//==================================================END OF PROGRAM==============================================
```