Scilab Textbook Companion for Heat And Mass Transfer by V. K. Dwivedi[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes 4

1 Introduction To Heat Transfer 5

2 General Heat Conduction Equation 16

3 Fins Heat transfer from Extended Surfaces 26

4 Transient Heat Conduction 39

5 Forced Convection Heat Transfer 55

6 Free Convection 70

7 Radiation Heat Transfer 81

8 Heat Exchangers 93

9 Condensation and Boiling 111

10 Mass Transfer 117

List of Scilab Codes

Exa 1.1 Rate of heat transfer 5
Exa 1.2 Area of wall perpendicular to heat flow . . . 5
Exa 1.3 Rate of heat loss 6
Exa 1.4 Electric power supplied to coil 7
Exa 1.5 Inside Plate temperature 7
Exa 1.6 Total heat loss by the pipe 8
Exa 1.7 Rate of heat transfer 9
Exa 1.9 Steady state heat transfer 9
Exa 1.10 Rate of heat transfer 10
Exa 1.11 Temperature drop across the contact joint . 11
Exa 1.12 Heat transfer rate 12
Exa 1.13 Rate of heat transfer 12
Exa 1.14 Heat transfer rate 13
Exa 1.15 Central temperature 14
Exa 1.16 Equilibrium temperature 14
Exa 2.5 Heat transfer rate and interface temperature 16
Exa 2.6 Percentage increase in heat transfer rate . . 17
Exa 2.7 Heat transfer coefficient water to air heat transfer and temperature drom 18
Exa 2.8 Percentage increase in heat dissipation . . . 19
Exa 2.9 Maximum value of thermal conductivity . . 20
Exa 2.10 Current carried by the copper wire 21
Exa 2.11 Critical radius of insulation and heat loss . . 22
Exa 2.12 Temperature of inner surface 23
Exa 2.13 Maximum steady state current 24
Exa 2.16 Maximum possible current that may be passed by the wire 24

Exa 3.1 Temperature distribution equation and heat loss 26
Exa 3.2 Thermal conductivity of the rod material . . 27
Exa 3.3 Fin efficiency 28
Exa 3.4 Heat loss by the fin 29
Exa 3.5 Rate of heat transfer 30
Exa 3.6 Temperature at the centre of the rod and heat transfer by the rod 31
Exa 3.7 Temperature distribution in the rod temp at the free end heat flow out the source and heat flow rate at the free end 32
Exa 3.8 Rate of heat transfer 33
Exa 3.9 Temperature distribution in the rod temp at the free end heat flow out the source and heat flow rate 34
Exa 3.10 Measurement error 35
Exa 3.11 Measurement error percent 35
Exa 3.12 Minimum length of pocket 36
Exa 3.13 Length of shaft 37
Exa 4.1 Rate of change of energy storage in the wall 39
Exa 4.2 Time required to cool the sphere Initial rate of cooling and Instantaneous rate of heat transfer 40
Exa 4.3 Time constant and temp attained by junction 42
Exa 4.4 Time constant and time required to the temp change 43
Exa 4.5 Rate of heat energy stored 44
Exa 4.6 Time constant and time required for the plate to reach the temp of 40 deg C 45
Exa 4.7 Time required to cool plate to 80 deg C and in air 46
Exa 4.8 Maximum speed of ingot passing through the furnace 47
Exa 4.9 Junction diamete and time required for the thermocouple junction 48
Exa 4.10 Heat leaving and entering the slap 49
Exa 4.11 Time required for cooling process 50
Exa 4.12 Time to keep furnace 51
Exa 4.13 Centre temperature 53

Exa 5.1 Boundary layer thickness 55
Exa 5.2 Rate of heat transfer and length of plate . . 57
Exa 5.3 Heat transfer rate 57
Exa 5.4 Length of tube 59
Exa 5.5 Average heat transfer coefficient 59
Exa 5.6 Heat transfer coefficient and friction factor . 61
Exa 5.7 Average heat transfer coefficient and tube length 62
Exa 5.8 Reynold number heat transfer coefficient and pipe length 63
Exa 5.9 Tube length 64
Exa 5.10 Heat transfer rate from the cylinder 65
Exa 5.11 Heat loss by the sphere 66
Exa 5.12 Heat transfer coefficient 66
Exa 5.13 Heat transfer rate 67
Exa 5.14 Heat transfer rate 68
Exa 5.15 Initial rate of heat loss 69
Exa 6.1 Heat transfer rate from the plate in two orientation 70
Exa 6.2 Heat loss from the two surface of the plate . 71
Exa 6.3 Heat loss from the pipe 72
Exa 6.4 Heat transfer coefficient and initial rate of cooling of the plate 73
Exa 6.5 Total rate of heat loss from the pipe 74
Exa 6.6 Heat gained by the duct per meter 76
Exa 6.7 Average heat transfer coefficient and Local heat flux 77
Exa 6.8 Heat transfer by natural convection 78
Exa 6.9 Heat transfer and overall heat transfer coefficient 79
Exa 7.1 Monochromatic emissive power and Maximum emissive power 81
Exa 7.2 Heat transfer by radiation and natural convection 82
Exa 7.3 Heat transfer rate 83
Exa 7.4 Energy emitted by a grey surface 84
Exa 7.5.1 Absorbed Transmitted and emitted energy . 84
Exa 7.5.2 Net heat exchange between the two surface . 85

Exa 7.6 heat loss and net heat transfer between pipe and duct 86
Exa 7.10 Shape factor of a cylinderical cavity 87
Exa 7.11 Net heat transfer rate and rate of evaporation of liquid oxygen 87
Exa 7.12 Radiation heat transfer 88
Exa 7.13 Steady state temperature 89
Exa 7.14 Rate of absorption and emission 90
Exa 7.15 Radient Heat transfer 91
Exa 8.1 Surface area of heat exchanger 93
Exa 8.2 Length of heat exchanger 94
Exa 8.3 Area of heat exchanger tube 95
Exa 8.4 The overall heat transfer 95
Exa 8.5 Heat transfer rate 96
Exa 8.6 Type of heat exchanger required 97
Exa 8.7 Heat transfer area 98
Exa 8.8 Rate of heat condensation 99
Exa 8.9 Heat transfer area 100
Exa 8.10 Exit temperature of water 102
Exa 8.11 Exit temperature 102
Exa 8.12 Exit temperature 104
Exa 8.13 Outlet temperature 105
Exa 8.14 Total heat transfer and outlet temperature . 106
Exa 8.15 Surface area of heat exchanger 107
Exa 8.16 Heat exchanger area 108
Exa 8.17 Overall heat transfer coefficient 108
Exa 9.1 Rate of heat transfer 111
Exa 9.2 Condensation rate 112
Exa 9.3 Length of tube and total heat transfer rate . 113
Exa 9.4 Film thickness 114
Exa 9.5 Heat transfer rate 115
Exa 10.1 Molar concentration and molar and mass diffusion 117
Exa 10.2 Diffusion coefficient of hydrogen 118
Exa 10.3 Diffusion coefficient of NH3 118
Exa 10.4 Mass flow rate 119
Exa 10.5 Diffusion flux rate 120
Exa 10.6 Loss of H2 by diffusion 121

Exa 10.7 Time taken to evaporate 122
Exa 10.8 Diffusion Flux rate of air 123

Chapter 1

Introduction To Heat Transfer

Scilab code Exa 1.1 `Rate of heat transfer`

```
//Exa 1.1
clc;
clear;
close
// given data
t1=38;// in degree C
t2=21;// in degree C
k=0.19;// unit less
x=4;//in cm
x=x*10^-2;// in meter
// Formula q=k*A*(t1-t2)/x;
q_by_A=k*(t1-t2)/x;
disp("The rate of heat transfer is : "+string(q_by_A
   )+" W/m^2");
```

Scilab code Exa 1.2 `Area of wall perpendicular to heat flow`

```
//Exa 1.2
```

```
clc;
clear;
close
// given data
t_i=120;// in degree C
t_o=40;// in degree C
K=0.04;// unit less
x=0.06;//in m
Q=50;// in W
disp("Assuming steady state heat transfer in the wall.");
// Rate of heat transfer across the wall = Rate of electrical energy dissipation in the furnance
// Formula Q= K*A*(t_i-t_o)/x;
A=Q*x/(K*(t_i-t_o));
disp(A,"Area of wall in square meter is : ")
```

Scilab code Exa 1.3 `Rate of heat loss`

```
//Exa 1.3
clc;
clear;
close
// given data
t_f=30;// in degree C
t_s=400;// in degree C
d=0.04;//in m
h=20;// in W/m^2K
l=1;//in meter
A=%pi*d*l;
q=h*A*(t_s-t_f);// in W

disp(q,"Rate of heat loss in watt is : ")
```

Scilab code Exa 1.4 `Electric power supplied to coil`

```
//Exa 1.4
clc;
clear;
close
// given data
t_s=100;// in degree C
t_w=80;// in degree C
d=2*10^-3;//in m
h=3000;// in W/m^2 degree C
L=100;//in mm
L=L*10^-3;// in meter
A=%pi*d*L;
// Heat loss by convection = Electric power supplied
// Formula h*A*(t_s-t_w) = Q
Q= h*A*(t_s-t_w);
disp(Q,"Electric power supplied in watt is : ")
```

Scilab code Exa 1.5 `Inside Plate temperature`

```
//Exa 1.5
clc;
clear;
close
// given data
A=0.6*0.9;// in square meter
x=.025;// in meter

t_s=310;// in degree C
t_f=15;// in degree C
h=22;// in W/m^2 degree C
```

```
K=45;// in W/m degree C
Q_rad=250;// in W
// Heat transfer through the plate = Convection heat loss + radiation heat loss
// Formula Q_cond = Q_conv + Q_rad
// -K*A*dt/dx = h*A*(t_s-t_f)+ Fg12*sigmaA(Ts^4-Ta64)
t_i=x*(h*A*(t_s-t_f)+Q_rad)/(K*A)+t_s;
disp(t_i," The inside plate temperature in degree C is :");
```

Scilab code Exa 1.6 `Total heat loss by the pipe`

```
//Exa 1.6
clc;
clear;
close
// given data
T1=50;// in degree C
T1=T1+273;// in K
T2=20;// in degree C
T2=T2+273;// in K
d=5*10^-2;//in m
h=6.5;// in W/m^2K
l=1;//in meter
epsilon=0.8;
sigma=5.67*10^-8;
A=%pi*d*l;// in Square meter
q_conv = h*A*(T1-T2);// in W/m
disp(q_conv,"The heat loss by convection in W/m")
// formula q= sigma*A*F_g12*(T1^4-T2^4) = sigma*A*epsilon*(T1^4-T2^4)     (since A1<<A2, so F_g12=epsilon)
q_rad = sigma*A*epsilon*(T1^4-T2^4);// in W/m
disp(q_rad," Heat loss by radiation in W/m")
```

```
q_total= q_conv+q_rad;
disp(q_total,"Total heat loss in W/m is :")
```

Scilab code Exa 1.7 `Rate of heat transfer`

```
//Exa 1.7
clc;
clear;
close
// given data
T1=1350;// in degree C
T2=50;// in degree C
L=25*10^-2;//in meter
// Formula q= -k*A*dT/dx
// or q/A= -k*dT/dx
// let q/A = q_by_A
q_by_A=(integrate('-0.838*(1+0.0007*T)','T',T1,T2))
    /(integrate('1','x',0,L));
disp(q_by_A,"Heat transfer rate per square meter
    through the cylinder in watt is : ");

// Note : Answer in the book is wrong
```

Scilab code Exa 1.9 `Steady state heat transfer`

```
//Exa 1.9
clc;
clear;
close
// given data
K_A=0.5;// in W/m degree C
K_B=0.8;// in W/m degree C
Ti_A=600;// inside temp. of slab A in degree C
```

```
To_B=100;// outside temp. of slab B in degree C
t_A=4*10^-2;// thickness of slab A
t_B=6*10^-2;// thickness of slab B
// Heat transfer rate per square meter through the slab A
// q/A = +K_A * ( Ti_A - T) / t_A          (1)
// Heat transfer rate through slab B
// q/A = +K_B * ( T - To_B) / t_B         (2)
// Equating Eqns (1) and (2)
// K_A*(Ti_A - T)/t_A  =  K_B*(T - To_B)/t_B
 T=t_A*t_B/(K_A*t_B+K_B*t_A)*(K_A*Ti_A/t_A + K_B*To_B/t_B);
disp("T, intermediate temperature of slab A and B is : "+string(T)+" degree C");
//Putting the value of T in Eq(1), we get
q_by_A= K_A*( Ti_A - T) / t_A;
disp("Steady state heat transfer rate per square meter is : "+string(q_by_A)+" W/m^2")
//Note : Answer in the book is wrong
```

Scilab code Exa 1.10 `Rate of heat transfer`

```
//Exa 1.10
clc;
clear;
close
// given data
La=3*10^-2;// in meter
Aa=1;// in m^2
ka=150;// in W/m-K

Lb=8*10^-2;// in meter
Ab=0.5;// in m^2
kb=30;// in W/m-K

```

```
Lc=8*10^-2;// in meter
Ac=0.5;// in m^2
kc=65;// in W/m-K

Ld=5*10^-2;// in meter
Ad=1;// in m^2
kd=50;// in W/m-K

T1=400;// in degree C
T2=60;// in degree C

Ra=La/(ka*Aa);
Rb=Lb/(kb*Ab);
Rc=Lc/(kc*Ac);
Rd=Ld/(kd*Ad);
//The equivalent resistance for Rb and Rc
Re=Rb*Rc/(Rb+Rc);
//Total Resistance
sigmaR=Ra+Re+Rd;
// heat transfer rate per square meter
q=(T1-T2)/sigmaR;
disp("Heat transfer rate per square meter is : "+
   string(q)+" Watt");
```

Scilab code Exa 1.11 Temperature drop across the contact joint

```
//Exa 1.11
clc;
clear;
close
// given data
k_Al=202;// in W/mK
x_Al=0.005;// in m
del_T=80;// in degree C
R_contact=0.88*10^-4;// in m^2K/W
```

```
sigmaR=x_Al/k_Al+R_contact+x_Al/k_Al;// in m^2K/W
q=del_T/sigmaR;// in W/m^2
//Temperature drop across the rough surface
del_T=q*R_contact;//in degree C
disp(del_T,"Temperature drop across the rough
   surface in degree C is :")
```

Scilab code Exa 1.12 `Heat transfer rate`

```
//Exa 1.12
clc;
clear;
close
// given data
T1=100;// in degree C
T2=10;// in degree C
A=3*5;//in square meter
x=40*10^-2;// thickness in m^2
k=1.6;// in W/mk
h=10;// in W/m^2k
// Total resistance in heat flow path
sigmaR=x/(k*A)+1/(h*A);
// so heat transfer rate
q=(T1-T2)/sigmaR;// in Watt
q=q*10^-3;//in kW
disp(q,"Heat transfer rate in kW is :");//

// Note: Answer in the book is wrong
```

Scilab code Exa 1.13 `Rate of heat transfer`

```
//Exa 1.13
clc;
```

```
clear;
close
// given data
k='2.0+0.0005*T';// in W/m-k
A=3*5;//in square meter

T1=150;// in degree C
T2=50;// in degree C
L=20*10^-2;// thickness in m^2
// Formula q= -k*A*dt/dx
q=-A*(integrate(k,'T',T1,T2))/(integrate('1','x',0,L));// in Watt
q=q*10^-3;//in kW
disp(q,"Rate of heat transfer in kW is : ");
```

Scilab code Exa 1.14 `Heat transfer rate`

```
//Exa 1.14
clc;
clear;
close
// given data
T1=300;//in degree C
T2=50;//in degree C
x2=2*10^-2;// thickness of boiler wall in m
tc2=58;// thermal conductivity of wall in W/mk
x3=0.5*10^-2;// thickness of outer surface of the wall in m
tc3=116*10^-3;// thermal conductivity of outer surface of the wall in W/mk
R1=2.3*10^-3;// in k/W
R2=x2/tc2;
R3=x3/tc3;
sigmaR=R1+R2+R3;// Total Resistance
q=(T1-T2)/sigmaR;
```

```
disp(q,"Heat transfer rate per unit area in W/m^2 :")
// Note: Answer in the book is wrong
```

Scilab code Exa 1.15 Central temperature

```
//Exa 1.15
clc;
clear;
close
// given data
Tf=80;// in degree C
I=200;// in amp
h=4000;// in W/m^2degree C
rho=70*10^-6;
L=100;// in cm
R=0.1;// in ohm
d=3;// in mm
d=d*10^-3;
As= %pi*d;
//Formula I^2*R= h*As*(Tw-Tf)
Tw= I^2*R/(h*As)+Tf;
disp(Tw,"Central temperature of the wire in  C ")
```

Scilab code Exa 1.16 Equilibrium temperature

```
//Exa 1.16
clc;
clear;
close
// given data
E=500;//Absorb solar energy in W/m^2
epsilon= 0.9;
```

```
T_s= 280;// in K
T_infinite=300;// in K
h_c=20;// in W/m^2degree C
T_sky=280;// in K
sigma=5.67*10^-8;
// Formula E= h_c*(T_p-T_infinite)+epsilon*sigma*(T_P^4-T_s^4)
// On simplication T_P= 340.6-0.255*T-p^4
T_p= 315.5;// in K
disp(T_p,"Equilibrium Temperature of the plate in K")
```

Chapter 2

General Heat Conduction Equation

Scilab code Exa 2.5 `Heat transfer rate and interface temperature`

```
//Exa 2.5
clc;
clear;
close;
//given data
r1=5;// in cm
r2=5+4;// in cm
r3= 9+2.5;// in cm
k1=0.0701;// in W/mK
k2=0.1;// in W/mK
L=20;// in m
disp("Saturation temperature of steam at 171*10^4 N/
   m^2 is 204.36 degree C. So temperature of steam
    passing through the pipe is = 204.36+30 = 234.36
    degree C")
T1=234.36;// in degree C
T3=24;// in degree C
sigmaR= (log(r2/r1)/(2*%pi*k1*L) + log(r3/r2)/(2*%pi
    *k2*L));
```

```


// Part (i)
q=(T1-T3)/sigmaR;// in watt
disp(q,"Heat transfer rate in watt");

// Part(ii)
// Formula q= (T1-T2)/(log(r2/r1)/(2*%pi*k1*L))
T2 =T1- (q*(log(r2/r1)/(2*%pi*k1*L)));
disp(T2,"Interface temperature of insulation in degree ")
```

Scilab code Exa 2.6 Percentage increase in heat transfer rate

```
//Exa 2.6
clc;
clear;
close;
//given data
k_brick=0.93;// in W/mK
k_insulation=0.12;// in W/mK
k_wood=0.175;// in W/mK
k_Al=204;// in W/mK
k1=k_brick;
k2=k_insulation;
k3=k_wood;
T1=200;// in degree C
T4=10;// in degree C
x1=10*10^-2;// in m
x2=25*10^-2;// in m
x3=1*10^-2;// in m
A=0.1;// in m^2
sigmaR= x1/(k1*A)+x2/(k2*A)+x3/(k3*A);
q1=(T1-T4)/sigmaR;
disp(q1,"Heat transfer rate without rivet in Watt");
```

```

// Heat transfer rate with rivet
d=3*10^-2;// in meter
x=x1+x2+x3;
k_rivet=k_Al;
A_rivet=%pi*d^2/4;// in m^2
R_rivet= x/(k_rivet*A_rivet);
A_eff=A-A_rivet;// in m^2
sigmaRw= 1/A_eff*(x1/k1+x2/k2+x3/k3);// in k/W
R_eq= R_rivet*sigmaRw/(R_rivet+sigmaRw);// in k/W
q2=(T1-T4)/R_eq;// in watt
disp(q2,"Heat transfer rate with rivet in Watt");
percentIncrease=(q2-q1)*100/q1;// percent increase in heat flow due to rivet
disp(ceil(percentIncrease),"Percentage increase in heat flow due to rivet in %")
```

Scilab code Exa 2.7 `Heat transfer coefficient water to air heat transfer and tempe`

```
//Exa 2.7
clc;
clear;
close;
//given data
k_cu=384;// in W/mK
k_s=1.75;// in W/mK
k1=k_cu;
k2=k_s;
hi=221;//  in W/m^2K
ho=3605;//  in W/m^2K
Ti=100;// in degree C
To=125;// in degree C
r1=0.2;// in m
r2=0.02+0.006;// in m
r3=0.026+0.003;// in m
```

```
ri=0.02;// in m
L=1;// in m
// Part(i)
Ao= 2*%pi*r3*L;
Ai= 2*%pi*r1*L;
// Formula Uo= 1/Ao*sigmaR
Uo= 1/[ r3/(ri*hi) + r3/k1*log(r2/r1) + r3/k2*log(r3/r2) + 1/ho ];// in w/m^2K
disp(Uo,"Overall heat transfer coefficient based on outer area in W/m^2K");

//Part(ii)
del_T= To-Ti;
q=Uo*Ao*del_T;
disp(q,"Water to air heat transfer rate in W/m");

//Part (iii)
// Formula q= T/(log(r3/r2)/(2*%pi*k*L)) , where T= T2-T3 and k=k_s
k=k_s;
T= q*log(r3/r2)/(2*%pi*k*L);
disp(T,"Temperature drop across the scale deposited in degree C")

// Note: In Part (i), they put wrong value of r2 and r1 in log(r2/r1) to calculate the value of Uo. So there is some difference in answer of coding and book
```

Scilab code Exa 2.8 Percentage increase in heat dissipation

```
//Exa 2.8
clc;
clear;
close;
```

```
//given data
k=0.175;// in W/mK
h_infinite=9.3;//  in W/m^2K
T_infinite=30;// in degree C
T_s=70;// in degree C
d=10*10^-3;// in m
r=d/2;
L=1;// in m
rc=k/h_infinite;// in m
CriticalThickness = rc-r;// in meter
CriticalThickness=CriticalThickness*10^3;
disp(CriticalThickness,"Critical thickness in mm");

q1=2*%pi*r*L*h_infinite*(T_s-T_infinite);// in W/m
q2= (T_s-T_infinite)/(log(rc/r)/(2*%pi*k*L)+1/(2*%pi*rc*h_infinite));// in W/m
PerIncHeatDiss= (q2-q1)*100/q1;
disp(PerIncHeatDiss,"Percentage increase in heat dissipation rate in %")
//Also q1=I1^2*R with bare cable
//     q2=I2^2*R with insulated cable
I2_by_I1 = sqrt(q2/q1);
// ( I2-I1 ) / I1 = (I2_by_I1 -1) / 1
// Percentage increase in current carrying capacity
PerIncCurrent = (I2_by_I1 -1) / 1 *100;
disp(floor(PerIncCurrent),"Increase in current carrying capacity in %")
```

Scilab code Exa 2.9 `Maximum value of thermal conductivity`

```
//Exa 2.9
clc;
clear;
close;
//given data
```

```
k_in=0.3;// in W/mK
k_gw=0.038;// in W/mK
ro=1.5;// in cm
ho=12;//  in W/m^2 degree C
rc=k_in/ho;// in m
rc=rc*10^2;// in cm
disp(rc,"Critical radius in cm")
if ro<rc then
    disp("Since radius of insulation ("+string(ro)+" cm) is less than critical radius of insulation ("+string(rc)+" cm), so heat transfer rate will increase by adding thsi insulation");
    disp("and hence it is not effective")
end
ro=ro*10^-2;// in meter
// For effective insulation
// ro>=rc
// Kin/ho<= ro
roho=ro*ho;// in W/mK
/// Kin<= ro*ho
disp(roho,"Maximum value of thermal conductivity in W/mK")
```

Scilab code Exa 2.10 `Current carried by the copper wire`

```
//Exa 2.10
clc;
clear;
close;
//given data
format('v',9)
d=1.2*10^-3;// in m
r=d/2;// in m
rc=1.8*10^-3;// in m
```

```
T1=100;// in degree C
T_infinite=30;// in degree C
k=0.3;// in W/mK
h=10;// in W/m^2K
L=1;// in m
ke=5.1*10^7;
q=(T1-T_infinite)/(log(rc/r)/(2*%pi*k)+1/(2*%pi*rc*h
   ));// in W/m
// Volume of wire for one meter length
vol= %pi*r^2*L;// in m^3
disp("in steady state heat transfer process, the
   heat produced by the wire is dissipated to
   surrounding.")
// Heat produced per unit volume of the wire
HeatProduced= q/vol;// in w/m^2
// Formula HeatProduced= I^2*R = I^2/ke
I=sqrt(HeatProduced*ke);// in amp/m^2
// Area of wire
A= %pi*r^2;
// so current carrying capacity of the given wire
Current= I*A;
disp(Current,"The current carried by the copper wire
    in amphere")
```

Scilab code Exa 2.11 `Critical radius of insulation and heat loss`

```
//Exa 2.11
clc;
clear;
close;
//given data
d_i=.1;// inner dia in m
r_i=d_i/2;// in m
Ti=473;// in K
T_infinite=293;// in K
```

```
k=1;// in W/mK
h=8;// in W/m^2K
rc=k/h;// in m
disp(rc,"Critical radius in meter");
//when
ro=rc;
q_by_L= (Ti-T_infinite)/(log(rc/r_i)/(2*%pi*k)+1/(2*%pi*rc*h));// in W/m
disp(q_by_L,"Heat loss per meter length of pipe in W/m")

// Note: To calculate the value of q_by_L the calculation is wrong in the book so answer in the book is wrong
```

Scilab code Exa 2.12 `Temperature of inner surface`

```
//Exa 2.12
clc;
clear;
close;
//given data
r1=100*10^-3;// in m
r2=200*10^-3;// in m
q1=1.16*10^5;// in W/m^2
t2=30;// in degree C
k=50;// in W/mK
L=1;// in m
// Total heat passing through the cylinder q
//q=q1*2*%pi*r1*L                       (1)
// and heat conducted through the cylinder
// q= 2*%pi*k*L(t1-t2)/log(r2/r1)       (2)
// From (1) and (2)
t1= t2+ q1*2*%pi*r1*L*log(r2/r1)/(2*%pi*k*L);// in degree C
```

```
disp(t1,"Temperature of inner surface in degree C");
```

Scilab code Exa 2.13 `Maximum steady state current`

```
//Exa 2.13
clc;
clear;
close;
//given data
d1=1*10^-3;// in m
d2=3*10^-3;// in m
r1=d1/2;
r2=d2/2;
kp=384;// in W/mK
kw=0.35;// in W/mK
rho=1.96*10^-8;// in Wm
t_s=95;// in degree C
t_infinite=40;// in degree C
h=8.75;// in W/m^2K
q_by_L= (t_s-t_infinite)/(log(r2/r1)/(2*%pi*kp)
    +1/(2*%pi*r2*h));
// Also q_by_L = I^2*R/L = I^2*rho/(%pi/4*d^2)
I= sqrt(q_by_L*(%pi/4*d1^2)/rho);// in amp
disp(I,"The maximum steady state current in amphere"
    )
```

Scilab code Exa 2.16 `Maximum possible current that may be passed by the wire`

```
//Exa 2.16
clc;
clear;
close;
//given data
```

```
d1=10*10^-3;// in mm
r1=d1/2;
K=0.2;// in W/mK
T_max=177;// in degree C
T_infinite=27;// in degree C
ho=10;// in W/m^2K
R=10; // in W/m
rc=K/ho;// in m
x=rc-r1;// in m
q_by_L= (T_max-T_infinite)/(log(rc/r1)/(2*%pi*K)
   +1/(2*%pi*ho*rc));
// Also q_by_L = I^2*R
I= sqrt(q_by_L/R);// in amp
disp(I,"The maximum possible current in amphere")

// Note: Answer in the book is wrong
```

Chapter 3

Fins Heat transfer from Extended Surfaces

Scilab code Exa 3.1 `Temperature distribution equation and heat loss`

```
//Exa 3.1
clc;
clear;
close
// given data
format('v',5);
d=20;// in mm
d=d*10^-3;//in m
h=5;// in W/m^2K
T_0=100;// in degree C
T_infinite=20;// in degree C
K=15;// in W/m-K
//(i)Temperature distribution equation
disp("(i) Temperature distribution equation");
disp("theta/theta_0= (T-T_infinite)/(T_0-T_infinite) = %e^-m*x ")
rho=%pi*d;// in m
A=%pi*d^2/4;//in square meter
m=sqrt(h*rho/(K*A));
```

```
disp("m = "+string(m));
disp("Temperature distribution equation is ")
disp("theta/theta_0= (T-T_infinite)/(T_0-T_infinite) = %e^-"+string(m)+"*x");

//(ii)Heat loss from the rod
t_0=100;// in degree C
t_infinite=20;// in degree C
q=sqrt(K*A*h*rho)*(t_0-t_infinite);
disp("(ii) Heat loss from the road is : "+string(q)+" watt");
```

Scilab code Exa 3.2 `Thermal conductivity of the rod material`

```
//Exa 3.2
clc;
clear;
close
// given data
format('v',13);
d=3;// in cm
d=d*10^-2;//in m
h=20;// in W/m^2K
T1=140;// in degree C
T2=100;// in degree C
L=15*10^-2;// in meter
T_infinite=30;// in degree C
// Let at
x=0;T_0=T1;
x=15;//in cm
x=x*10^-2;// in m
T=100;// in degree C
rho=%pi*d;
A=%pi*d^2/4;
// Formula (T-T_infinite)/(T_0-T_infinite) = %e^-m*x
```

```
m=log((T_0-T_infinite)/(T-T_infinite))/x;
// Formula m=sqrt(h*rho/(k*A))
k=h*rho/(m^2*A);
disp(k,"Thermal conductivity of the rod material in
   W/m-k is ")
```

Scilab code Exa 3.3 `Fin efficiency`

```
//Exa 3.3
clc;
clear;
close;
//given data
format('v',9);
t=1;// in mm
t=t*10^-3;// in meter
L= 10;// in mm
L= L*10^-3;// in meter
k= 380;// W/mK
To= 230;// in  C
T_inf= 30;// in  C
h= 40;// in W/m^2K
B= 1;// in meter
Ac= B*t;// in m^2
rho= 2*(B+t);
m= sqrt(h*rho/(k*Ac));
// Part(a)
nita= tanh(m*L)/(m*L)*100;// fin efficiency in %
disp(nita,"Fin efficiency in %");

// Part(b)
N=1000/9+1;// number of fin
Af= N*rho*L;// in square meter
A1= 1;// plate area in m^2
A2= N*1*1*10^-3;// Area where fins are attached in
```

```
square meter
Au= A1-A2;// in square meter
q_T= N*sqrt(h*rho*k*Ac)*(To-T_inf)*tanh(m*L)+Au*h*(To-T_inf);// in W/m^2
disp(q_T*10^-3,"Total heat transfer per square meter of plane wall surface in kW/m^2")

// Part(c)
A=1*1;// in m^2
q= h*A*(To-T_inf);// in W/m^2
disp(q*10^-3,"Heat transfer if there were no fins attached in kW/m^2")

// Note : Answer of part(b) in the book is wrong
```

Scilab code Exa 3.4 `Heat loss by the fin`

```
//Exa 3.4
clc;
clear;
close;
//given data
format('v',9);
w=5*10^-2;// in meter
L=1;// in meter
t=2.5*10^-2;// in meter
h=47;// in W/m^2K
k=16.3;// in W/mK (for 18.8 steel)
T_0=100;// in degree C
T_infinite=20;// in degree C
Ac=w*t;// in square meter
rho=2*(w+t);
m=sqrt(h*rho/(k*Ac));
q_fin=k*Ac*m*(T_0-T_infinite)*[(tanh(m*L)+h/(k*m)  )/(1+h/(m*k)*tanh(m*L))];
```

```
disp("The heat lost by the fin of one meter length is : "+string(q_fin)+" W");
```

Scilab code Exa 3.5 `Rate of heat transfer`

```
//Exa 3.5
clc;
clear;
close;
//given data
format('v',13)
w=1;// in meter
L=2.5*10^-2;// in meter
t=0.8*10^-3;// in meter
l=1;// in meter
T_0=150;// in degree C
T_infinite=40;// in degree C
h=20;// in W/m^2K
k=65;// in W/mK (for 18.8 steel)
Ac=w*t;
d=5*10^-2;// Cylinder dia in meter
rho=2*(w+t);
rho=floor(rho);

m=sqrt(h*rho/(k*Ac));
mL=m*L;
// heat transfer rate from 12 fins
q_fin=12*k*Ac*m*(T_0-T_infinite)*[(tanh(m*L)+h/(k*m))/(1+h/(m*k)*tanh(m*L))];
disp("Heat transfer rate from 12 fins si : "+string(q_fin)+" watt");
Au=%pi*d*l-12*w*t;
qu=h*Au*(T_0-T_infinite);
disp("Now heat transfer from unfinned surface area is : "+string(qu)+" watt");
```

```
q=q_fin+qu;
disp("Total head transfer rate from the cylinder is : "+string(q)+" watt");
```

Scilab code Exa 3.6 Temperature at the centre of the rod and heat transfer by the

```
//Exa 3.6
clc;
clear;
close;
//given data
format('v',5)
T_0=100;// in degree C
T_infinite=30;// in degree C
T_L=100;// in degree C
d=6*10^-3;// copper rod dia in meter
L=50*10^-2;// developed length in meter
Ac=%pi*d^2/4;// in square meter
rho=%pi*d;// in meter
h=30;// in W/m^2K
k=330;// in W/mK
m=sqrt(h*rho/(k*Ac));
//(i) Temperature distribution equation for the fin
// (T-T_infinite)/(T_0-T_infinite)=([(T_L-T_infinite)/(T_0-T_infinite)]*sinh(m*x)+sinh(m*(L-x)))/sinh(m*L)
//Temperature at
x=0.25;// in m
T= ([(T_L-T_infinite)/(T_0-T_infinite)]*sinh(m*x)+sinh(m*(L-x)))/sinh(m*L)*(T_0-T_infinite)+T_infinite;
disp("(i) Temperature at the centre of the rod is : "+string(T)+" degree C");
disp("(ii) Heat transfer rate from the fin- This is equivalent to two fins of length 25 cm long with
```

```
insulated tip")
L=25*10^-2;// in meter
q=2*sqrt(h*rho*k*Ac)*(T_0-T_infinite)*tanh(m*L);
disp("Heat transfer by the rod is : "+string(q)+" watt");
```

Scilab code Exa 3.7 `Temperature distribution in the rod temp at the free end heat`

```
//Exa 3.7
clc;
clear;
close;
//given data
T_0=100;// in degree C
T_infinite=25;// in degree C
d=5*10^-2;// in meter
L=15*10^-2;// in meter
h=8;// in W/m^2K
k=20;// in W/mK
rho=%pi*d;// in meter
Ac=%pi*d^2/4;// in square meter
m=sqrt(h*rho/(k*Ac));

//(i) Temperature distribution in the rod
 disp("(i) Temperature distribution in the rod")
 disp(" (T-T_infinite)/(T_0-T_infinite)= (cosh(m*(L-x))+ h/(k*m)*sinh(m(L-x)))/(cosh(m*L)+h/(k*m)*sinh(m*L))")

//(ii) Temperature at free end i.e. at
x=L;
// Formula  (T_L-T_infinite)/(T_0-T_infinite)= 1/(cosh(m*L)+h/(k*m)*sinh(m*L)  )
T_L=(1/(cosh(m*L)+h/(k*m)*sinh(m*L) ))*(T_0-T_infinite)+T_infinite;
```

```
disp("(ii) Temperature at free end is : "+string(T_L)+" degree C");

//(iii) Heat flow out the source means heat transfer from the fin
q_f=sqrt(h*rho*k*Ac)*(T_0-T_infinite)*[(h/(k*m)+tanh(m*L))/(1+h*tanh(m*L)/(k*m))];
disp("(iii) Heat flow out the source : "+string(q_f)+" watt");

// (iv) Heat flow rate at free end
q_L=h*Ac*(T_L-T_infinite);
disp("(iv) Heat flow rate at free end is : "+string(q_L)+" watt");
```

Scilab code Exa 3.8 `Rate of heat transfer`

```
//Exa 3.8
clc;
clear;
close;
//given data
T_0=150;// in degree C
T_infinite=40;// in degree C
w=1;// in m
t=0.75*10^-3;// in m
d=5*10^-2;// in meter
L=25*10^-3;// in meter
k=75;// in W/mK
h=23.3;// in W/m^2K
N=12;// numbers of fins
Ac=w*t;//in square meter
rho=2*(w+t);// in meter
delta=Ac/rho;
L_c=L+delta;
```

```
ML_c=L_c*sqrt(h*rho/(k*Ac))
q_fin= N*sqrt(h*rho*k*Ac)*(T_0-T_infinite)*tanh(ML_c);
q_fin=floor(q_fin);
A_0=%pi*d*w-12*Ac
q_unfin= h*A_0*(T_0-T_infinite);
q_total=q_fin+q_unfin;
disp("Rate of heat transfer is : "+string(q_total)+" watt");
```

Scilab code Exa 3.9 Temperature distribution in the rod temp at the free end heat

```
//Exa 3.9
clc;
clear;
close;
disp("Temperature distribution equation for fin with insulated end is ");
disp("(T-T_infinite)/(T_0-T_infinite)= cosh(m*(L-x))/cosh(m*L)");

//given data
L=0.06;// in meter
A=4.64*10^-4;// in m^2
rho=0.12;// in m
h=442;// in W/m^2
T_0=773;// in K
T_infinite=1143;// in K
K=23.2;// in W/mK
m=sqrt(h*rho/(K*A));
q=sqrt(h*rho*K*A)*(T_0-T_infinite)*tanh(m*L);
disp("Heat transfer rate is : "+string(q)+" watt");

// Note: Answer in the book is wrong
```

Scilab code Exa 3.10 `Measurement error`

```
//Exa 3.10
clc;
clear;
close;
//given data
L=0.12;// in meter
t=.15*10^-2;// thickness in m
K=55.5;// in W/mK
h=23.5;// in W/mK
T_L=357;// in K
T_0=313;// in K

// Formula m=sqrt(h*rho/(K*A)) and rho=%pi*d and A=
   %pi*d*t, putting value of rho and A
m=sqrt(h/(K*t));
mL=m*L;
mL=floor(mL);
// Formula (T_L-T_infinite)/(T_0-T_infinite)= 1/cosh
   (m*L)
T_infinite=(T_L-T_0/cosh(mL))/(1-1/cosh(mL));
T_infinite=ceil(T_infinite);
measurement_error=T_infinite-T_L;
disp("Measurement Error is : "+string(
   measurement_error)+" K")

// Note: In the book, Unit of answer is wrong
```

Scilab code Exa 3.11 `Measurement error percent`

```
//Exa 3.11
```

```
clc;
clear;
close;
//given data
k=20;// in W/mK
T_L=150;// in degree C
T_0=70;// in degree C
L=12*10^-2;// in meter
h=80;// in W/m^2K
t=3*10^-3;// in m
// Formula m=sqrt(h*rho/(K*A)) and rho=%pi*d and A=%pi*d*t, putting value of rho and A
m=sqrt(h/(k*t));
// Formula (T_L-T_infinite)/(T_0-T_infinite)= 1/cosh(m*L)
T_infinite=(T_L-T_0/cosh(m*L))/(1-1/cosh(m*L));
PercentageError=(T_infinite-T_L)*100/T_infinite;
disp("Percentage Error is : "+string(PercentageError)+" %");
```

Scilab code Exa 3.12 Minimum length of pocket

```
//Exa 3.12
clc;
clear;
close;
//given data
k=30;// in W/mK
h=100;// in W/m^2K
T_infinite=300;// in degree C
d=2*10^-2;// in m
t=1*10^-3;// in m
err=1;// in % of applied temperature difference
// Formula m=sqrt(h*rho/(K*A)) and rho=%pi*d and A=%pi*d*t, putting value of rho and A
```

```
m=sqrt(h/(k*t));

// From (T_L-T_infinite)/(T_0-T_infinite)= 1/100 = 1/cosh(m*L)
L=acosh(100)/m;// in meter
L=L*10^3;// in mm
disp("Minimum length os pocket is : "+string(L)+" mm ");
```

Scilab code Exa 3.13 `Length of shaft`

```
//Exa 3.13
clc;
clear;
close;
//given data
k=32;// in W/m^2 degree C
h=14.8;// in W/m^2 degree C
t_o=480;// in degree C
t_i=55;// in degree C
t_a=20;// in degree C
d=2.5*10^-2;// in m
rho=%pi*d;// in m
Ac=%pi*d^2/4;// in m^2
m=sqrt(h*rho/(k*Ac));
disp("In this case, the shaft heat from the pump towards motor");
disp("The temperature distribution considering the shaft as a fin insulated at the tip is given by")
disp("Q/Q_o= (t-t_a)/(t_o-t_a) = cosh(m(L-x))/cosh(m*L)")
// From (t-t_a)/(t_o-t_a) = cosh(m(L-x))/cosh(m*L)
L=acosh((t_o-t_a)/(t_i-t_a))/m;  // at x=L,t=t_i
disp("Length of shaft specified between the motor and the pump is : "+string(L)+" meter");
```

Chapter 4

Transient Heat Conduction

Scilab code Exa 4.1 `Rate of change of energy storage in the wall`

```
//Exa 4.1
clc;
clear;
close;
//given data
format('v',9)
L=1;// in m
rho=1600;// in kg/m^3
k=40;// in w/mK
Cp=4*10^3;// in J/kgK
a=900;// in  degree C
b=-300;// in  degree C/m
c=-50;// in  degree C/m^2
Qg=1*10^3;// in kW/m^2
A=10;// area in m^2
//t=a+b*x+c*x^2 at any instant , so
// dtBYdx= b+2*c*x
// d2tBYdx2 = 2*c, then

// Part(a)
//q1= -k*A*dtBYdx , at
```

```
x=0;
q1= -k*A*(b+2*c*x);// in w
//q2= -k*A*dtBYdx , at
x=L;
q2= -k*A*(b+2*c*x);// in w
E_stored= (q1-q2)+Qg*A*L;// in watt
disp(E_stored,"The rate of change of energy storage in watt")

// Part(b)
alpha= k/(rho*Cp);// in m^2s
d2tBYdx2 = 2*c;
dtBYdtoh= alpha*(d2tBYdx2+Qg/k );// in degree C/sec
disp(dtBYdtoh,"Rate of change of temperature in degree C/sec");
disp("Since dt by dx is independent of x. Hence time rate of charge of temperature throughout wall will remain same.")
```

Scilab code Exa 4.2 `Time required to cool the sphere Initial rate of cooling and I`

```
//Exa 4.2
clc;
clear;
close;
//given data
k=40;// in W/mK
rho=7800;// in kg/m^3
C=450;// in J/kgK
d=20*10^-3;// in m
r=d/2;
t_i=400;// in degree C
t=85;// in degree C
t_infinite=25;// in degree C
h=80;// in W/m^2K
```

```
//l_s=V/A = (4/3*%pi*r^3)/(4*%pi*r^2) = r/3
l_s=r/3;// in m
Bi= h*l_s/k;
// since Biot number is less than 0.1, hence lumped heat capacity system analysis can be applied

// Part(a)
// Formula (t-t_infinite)/(t_i-t_infinite)= %e^(-h*A*toh/(rho*V*C)) = %e^(-h*toh/(rho*l_s*C))
toh= -log((t-t_infinite)/(t_i-t_infinite))*(rho*l_s*C)/h;// in sec
disp(toh,"The time require to cool the sphere in sec");

// Part(b)
// dtBYdtoh = h*A*(t_i-t_infinite)/(rho*V*C) = h*(t_i-t_infinite)/(rho*l_s*C)
dtBYdtoh = h*(t_i-t_infinite)/(rho*l_s*C);// in degree C/sec
disp(dtBYdtoh,"Initial rate of cooling in degree C/sec");

// Part(c)
A=4*%pi*r^2;
toh=60;
q_in= h*A*(t_i-t_infinite)*%e^(-h*toh/(rho*l_s*C));// in watt
disp(q_in,"Instantaneous heat transfer rate in watt");

// Part(d) Total energy transferred during first one minute
V=4/3*%pi*r^3;
TotalEnergy = rho*C*V*(t_i-t_infinite)*(1-%e^(-h*toh/(rho*C*l_s)));
disp(TotalEnergy,"Total energy transferred during first one minute in watt")

```

```
// Note: Answer of first and last part in the book is wrong
```

Scilab code Exa 4.3 `Time constant and temp attained by junction`

```
//Exa 4.3
clc;
clear;
close;
//given data
k=40;// in W/mK
rho=8200;// in kg/m^3
C=400;// in J/kgK
D=6*10^-3;// in m
R=D/2;
t_i=30;// in degree C
t_infinite1=400;// for 10 sec in degree C
t_infinite2=20;// for 10 sec in degree C
h=50;// in W/m^2K

// Part(a)
//l_s= V/A = R/3
l_s= R/3;// in m
//toh= rho*V*C/(h*A) = rho*C*l_s/h
toh= rho*C*l_s/h;// in sec
disp(toh,"Time constance in sec")

// Part (b)
Bi= h*l_s/k;
// since Bi < 0.1 , hence lumped heat capacity analysis is valid. Now , temperature attained by junction in 10 seconds when exposed to hot air at 400 degree C
toh=10;// in sec
// (t-t_infinite1)/(t_i-t_infinite1)= %e^(-h*A*toh/(
```

```
rho*V*C)) = %e^(-h*toh/(rho*l_s*C))
t= %e^(-h*toh/(rho*l_s*C))*(t_i-t_infinite1)+t_infinite1;// in degree C

disp("The junction is taken out from hot air stream and placed in stream of still air 20 degree C. The initial temperature in this case will be "+string(t)+" .")
t_i=t;
toh=20;// in sec
t= %e^(-h*toh/(rho*l_s*C))*(t_i-t_infinite2)+t_infinite2;// in degree C
disp(t,"The temperature attained by junction in degree C");

// Note: In the last , calculation to find the value of t is wrong so Answer in the book is wrong
```

Scilab code Exa 4.4 `Time constant and time required to the temp change`

```
//Exa 4.4
clc;
clear;
close;
//given data
k=8;// in W/mK
alpha=4*10^-6;// in m^2/s
h=50;// in W/m^2K
D=6*10^-3;// in m
R=D/2;
T=0.5;// where T = (t-t_infinite)/(t_i-t_infinite)
//l_s= V/A = R/3
l_s= R/2;// in m
Bi= h*l_s/k;
// since Bi < 0.1 , hence lumped heat capacity
```

```
analysis can be applied
// toh= rho∗V∗C/(h∗A) = rho∗C∗l_s/h = k∗l_s/(h∗alpha)
toh=  k*l_s/(h*alpha);// in seconds
disp(toh,"time constant in seconds");
// It is given that (t−t_infinite)/(t_i−t_infinite) = 0.5 =  %eˆ(−h∗A∗c /(rho∗V∗C)) = %eˆ(−h∗c/(rho∗l_s∗C)) = %eˆ(−h∗alpha∗c/(l_s))
// or (t−t_infinite)/(t_i−t_infinite) = %eˆ(−h∗alpha∗c/(l_s);
c= -log(T)*l_s/(h*alpha);// in sec
disp(c,"The time required to temperature change to reach half of its initial value in seconds");
```

Scilab code Exa 4.5 `Rate of heat energy stored`

```
//Exa 4.5
clc;
clear;
close;
//given data
//t=450−500∗x+100∗xˆ2+150∗xˆ3 at any instant , so
// dtBYdx= −500+200∗x+450∗xˆ2

L=0.5;// thickness of the wall in meter
k=10;// in W/mK
// Rate of heating entering in the wall per unit area , at
x=0;
//q1= −k∗dtBYdx
q1= -k*(-500+200*x+450*x^2);// in W/mˆ2
// Rate of heat going out of the wall per unit area , at
x=L;
q2= -k*(-500+200*x+450*x^2);// in W/mˆ2
```

```
E=q1-q2;// in W/m^2
disp(E,"Heat energy stored per unit area in W/m^2")
```

Scilab code Exa 4.6 Time constant and time required for the plate to reach the tem

```
//Exa 4.6
clc;
clear;
close;
//given data
k=385;// in W/mK
h=100;// in W/m^2K
delta =2*10^-3;// thickness of plate in meter
A=25*25;// area of plate in square meter
rho=8800;// kg/m^3
C=400;// J/kg-K
// l_s= V/A= L*B*delta/(2*L*B) = delta/2
l_s= delta/2;// in meter
Bi= h*l_s/k;
// since Bi < 0.1 , hence lumped heat capacity analysis can be applied

// Part(i)
// toh= rho*V*C/(h*A) = rho*C*l_s/h
toh= rho*C*l_s/h;// in second
disp(toh,"Time constant in seconds");

// Part(ii)
t_i=400;// in degree C
t=40;// in degree C
t_infinite=25;// in degree C
// (t-t_infinite)/(t_i-t_infinite) = %e^(-h*A*toh/(rho*V*C)) = %e^(-h*toh/(rho*l_s*C))
toh= -log((t-t_infinite)/(t_i-t_infinite))*rho*C*l_s/h;// in sec
```

```
disp(toh,"The time required for the plate to reach
    the temperature of 40 degree C in seconds");
```

Scilab code Exa 4.7 `Time required to cool plate to 80 deg C and in air`

```
//Exa 4.7
clc;
clear;
close;
//given data
k=380;// in W/mK
delta =6*10^-2;// thickness of plate in meter
rho=8800;// kg/m^3
C=400;// J/kg-K
// l_s= V/A = delta/2
l_s= delta/2;// in meter
t=80;// in degree C
t_i=200;// in degree C
t_inf=30;// in degree C
hw= 75;// in W/m^2K
ha= 10;// in W/m^2K

// Part(i)
// ha*A*(t-t_inf_a)+ hw*A*(t-t_inf_w) = -rho*V*C*
    dtBYdtho, since t_ini_a = t_inf_w = t_inf = 30
    degree C
// (ha+hw)*A*(t-t_inf)= -rho*V*C*dtBYdtho
// (ha+hw)/(rho*C*V)*A*dtoh = -dt/(t-t_inf)
// integrate('(ha+hw)/(rho*V*C)*A','toh',0,toh) =
    integrate('1/(t-t_inf)','t',t_i,t)
toh= -rho*l_s*C/(ha+hw)*log((t-t_inf)/(t_i-t_inf));
disp("Time required to cool plate to 80 degree C is
    : "+string(toh)+" seconds = "+string(toh/60)+"
    minutes");

```

```
// Part (ii)
t= -rho*l_s*C/(2*ha)*log((t-t_inf)/(t_i-t_inf));
disp("Time required to cool plate in only air is : "+string(t)+" seconds = "+string(t/60)+" minutes");
```

Scilab code Exa 4.8 Maximum speed of ingot passing through the furnace

```
//Exa 4.8
clc;
clear;
close;
//given data
k=45;// in W/m degree C
d =0.1;// in meter
l =0.30;// in meter
t=800;// in degree C
t_i=100;// in degree C
t_infinite=1200;// in degree C
h= 120;// in W/m^2 degree C
alpha=1.2*10^-5;// in meter
rhoC= k/alpha;
V=%pi/4*d^2*l;// in m^3
A= %pi*d*l + 2*%pi/4*d^2;// in m^2
// l_s= V/A = (%pi/4*d^2*l)/(%pi*d*l + 2*%pi/4*d^2) = d*l/(4*l+2*d^2)
l_s = d*l/(4*l+2*d^2);
Bi= h*l_s/k;
// since Bi < 0.1 , hence lumped heat capacity analysis can be applied
// (t-t_infinite)/(t_i-t_infinite) = %e^(-h*A*toh/(rho*V*C)) = %e^(-h*toh/(rho*l_s*C)) = %e^(-h*toh/(rhoC*l_s))
toh = -log((t-t_infinite)/(t_i-t_infinite))*rhoC*l_s/h;// in sec
```

```

// So, the velocity of ingot passing through the furnace
FurnaceLength = 8*100;// in cm
time = toh;
Velocity = FurnaceLength/time;// in cm/sec
disp(Velocity,"Maximum speed in cm/sec")
```

Scilab code Exa 4.9 Junction diamete and time required for the thermocouple juncti

```
//Exa 4.9
clc;
clear;
close;
//given data
rho=8500;// in kg/m^3
C=400;// J/kgK
toh=1;// in sec
h= 400;// in W/m^2 degree C
t=198;// in degree C
t_i=25;// in degree C
t_infinite=200;// in degree C

// Part (1)
// toh =rho*V*C/(h*A) = rho*C*l_s/h
l_s= toh*h/(rho*C);
// l_s = V/A = r/3
r=3*l_s;// in m
r=r*10^3;// in mm
d=2*r;// in m
disp(d,"Junction diameter needed for the thermocouple in mili miter");

// Part(ii)
// toh= -rho*V*C/(h*A)*log((t-t_infinite)/(t_i-
```

```
t_infinite))
toh = -toh*log((t-t_infinite)/(t_i-t_infinite));
disp(toh,"Time required for the thermocouple junction to reach 198 degree C in seconds");
```

Scilab code Exa 4.10 `Heat leaving and entering the slap`

```
//Exa 4.10
clc;
clear;
close;
//given data
L=40*10^-2;// in m
k=1.5;// in W/mK
A=4;// in square meter
alpha=1.65*10^-3;// in m^2/h
//T = 50-40*x+10*x^2+20*x^3-15*x^4 , so
// dtBYdx= -40+20*x+60*x^2-60*x^3
// d2tBYdx2 = 20+120*x-180*x^2

// Part (a) Heat entering the slab
//q1= -k*A*dtBYdx , at
x=0;
qi= -k*A*(-40+20*x+60*x^2-60*x^3);// in w
disp(qi,"Heat entering the slab in watt")
// Heat leaving the slab
//ql= -k*A*dtBYdx , at
x=L;
ql= -k*A*(-40+20*x+60*x^2-60*x^3);// in w
disp(ql,"Heat leaving the slab in watt")

// Part (b) Rate of heat storage
RateOfHeatStorage = qi-ql;// in watt
disp(RateOfHeatStorage,"Rate of heat storage in watt");
```

```

// Part (c) Rate of temperature change
// d2tBYdx2 = 1/alpha*dtBYdtoh
// dtBYdtoh= alpha*d2tBYdx2, at
x=0;
dtBYdtoh = alpha*(20+120*x-180*x^2);// in degree C/h
disp(dtBYdtoh,"The rate of temperature change at
    entering the slab in degree C/h")
// dtBYdtoh= alpha*d2tBYdx2, at
x=L
dtBYdtoh = alpha*(20+120*x-180*x^2);// in degree C/h
disp(dtBYdtoh,"The rate of temperature change at
    leaving the slab in degree C/h")

// Part (d) for the rate of heating or cooling to be
     maximum
// dBYdx of dtBYdtoh = 0
// dBYdx of (alpha*d2tBYdx2) =0
// d3tBYdx3 = 0
x=120/360;// in meter
disp(x,"The point where rate of heating or cooling
    is maximum in meter")
```

Scilab code Exa 4.11 `Time required for cooling process`

```
//Exa 4.11
clc;
clear;
close;
//given data
k=40;// in W/m degree C
d =12*10^-3;// in meter
t=127;// in degree C
t_i=877;// in degree C
t_infinite=52;// in degree C
```

```
h= 20;// in W/m^2 degree C
rho=7800;// in W/m^2K
C=600;// in J/kg K
r=d/2;// in meter
//l_s = V/A = r/3
l_s =  r/3;
Bi= h*l_s/k;
// since Bi < 0.1 , hence lumped heat capacity analysis can be applied
// (t-t_infinite)/(t_i-t_infinite) = %e^(-h*A*toh/(rho*V*C)) = %e^(-h*toh/(rho*l_s*C)) = %e^(-h*toh/(rho*C*l_s))
toh = -log((t-t_infinite)/(t_i-t_infinite))*rho*C*l_s/h;// in sec
disp("Time required for cooling process : "+string(toh)+" seconds or "+string(toh/60)+" minutes")
```

Scilab code Exa 4.12 `Time to keep furnace`

```
//Exa 4.12
clc;
clear;
close;
//given data
D=10*10^-2;// in m
b=D/2;
h= 100;// in W/m^2 degree C
T_o=418;// in degree C
T_i=30;// in degree C
T_infinite=1000;// in degree C

disp(" (A) For copper cylinder ");
k=350;// in W/mK
alpha=114*10^-7;// in m^2/s
Bi= h*b/k;
```

```
theta_0_t = (T_o-T_infinite)/(T_i-T_infinite);
Fo=18.8;
// Formula Fo= alpha*t/b^2
t=Fo*b^2/alpha;
disp("Time required to reach for the cylinder centreline temperature 418 degree C : "+string(t)+" seconds or "+string(t/3600)+" hours")

// (2) Temperature at the radius of 4 cm
theta_0_t = 0.985;
// Formula theta_0_t = (T-T_infinite)/(T_o-T_infinite)
T= theta_0_t*(T_o-T_infinite)+T_infinite;// in degree C
disp(T,"Temperature at the radius of 4 cm ")
disp("It has very less temperature gradients over 4 cm radius")

disp(" (B) For asbestos cylinder ");
k=0.11;// in W/mK
alpha=0.28*10^-7;// in m^2/s
Bi= h*b/k;
theta_0_t = (T_o-T_infinite)/(T_i-T_infinite);
Fo=0.21;
// Formula Fo= alpha*t/b^2
t=Fo*b^2/alpha;
disp("Time required to reach for the cylinder centreline temperature 418 degree C : "+string(t)+" seconds or "+string(t/3600)+" hours")

// (2) Temperature at the radius of 4 cm
theta_x_t = 0.286;
// Formula theta_x_t = (T-T_infinite)/(T_o-T_infinite)
T= theta_x_t*(T_o-T_infinite)+T_infinite;// in degree C
disp(T,"Temperature at the radius of 4 cm ")
disp("It has large temperature gradients")
```

Scilab code Exa 4.13 `Centre temperature`

```
//Exa 4.13
clc;
clear;
close;
//given data
D=5*10^-2;// in m
b=D/2;
h= 500;// in W/m^2 degree C
k=60;// in W/m^2K
rho=7850;// in kg/m^3
C=460;// in J/kg
alpha=1.6*10^-5;// in m^2/s
T_i=225;// in degree C
T_infinite=25;// in degree C
t=2;// in minute

// Part(i)
Bi= h*b/k;
Fo= alpha*t/b^2;
theta_0_t = 0.18;
// Formula theta_0_t = (T_o-T_infinite)/(T_i-
   T_infinite)
T_o= theta_0_t*(T_i-T_infinite)+T_infinite;// in
   degree C
disp(T_o,"Centreline Temperature of the sphere after
    2 minutes of exposure in degree C ") ;

// Part(2)
depth= 10*10^-3;// in meter
r=b-depth;// in meter
rBYb=r/b;
theta_x_t = 0.95;
```

```
// Formula theta_x_t = (T-T_infinite)/(T_o-T_infinite)
T= theta_x_t*(T_o-T_infinite)+T_infinite;// in degree C
disp(T,"The Temperature at the depth of 1 cm from the surface after 2 minutes in degree C ") ;

// Part (3)
BiSquareFo= Bi^2*Fo;
QbyQo= 0.8;// in kJ
A=4/3*%pi*b^3;
Qo= rho*A*C*(T_i-T_infinite);// in J
Qo=Qo*10^-3;// in kJ
// The heat transffered during 2 minute,
Q= Qo*QbyQo;// in kJ
disp(Q,"The heat transffered during 2 minutes in kJ")
```

Chapter 5

Forced Convection Heat Transfer

Scilab code Exa 5.1 `Boundary layer thickness`

```
//Exa 5.1
clc;
clear;
close;
//given data
format('v',9)
rho=1.14;// in kg/m^3
k=2.73*10^-2;// in W/mK
Cp=1.005;// in kg/kgK
v= 16*10^-6;// in m^2/s
Pr=0.67;
// Other data given in the problem are
V=2;// in m/s
w=20*10^-2;// in m
t_infinite= 10;// in degree C
t_s=65;// in degree C
x=0.25;// in m from leading edge
// Re= rho*Vx/miu = V*x/v
Re= V*x/v;
```

```
//Since Re<5*10^5 , hence the flow is a laminar flow
//(a) Boundary layer thickness
delta= 5*x/(sqrt(Re));// in m
delta=delta*10^2;// in cm
disp(delta,"Boundary layer thickness in cm")

//(b) Thermal boundary layer thickness
delta_t= delta/Pr^(1/3);// in cm
disp(delta_t,"Thermal boundary layer thickness in ch")

//(c) Local friction coefficient
Cfx= 0.664/sqrt(Re);
disp(Cfx,"Local friction coefficient");
Cf=2*Cfx;
disp(Cf,"Average friction coefficient");

//(d) Total drag force
A=.25*.2;// in m^2
toh_o=Cf*(rho*V^2/2);
F=toh_o*A;
disp(F,"Total drag force in N");

//(e)
// Formula Nux= hx*x/k = 0.332*Re^(1/2)*Pr^(1/3)
hx= 0.332*k/x*Re^(1/2)*Pr^(1/3);// in W/m^2K
disp(hx,"Local heat transfer coefficient in W/m^2K")
h=2*hx;
disp(h,"Average heat transfer coefficient in W/m^2K")
//(f)
q=h*A*(t_s-t_infinite);
disp(q,"Rate of heat transfer in W/m^2K");

//Note: In the book, they calculated wrong value of Re so all the answer in the book is wrong
```

Scilab code Exa 5.2 `Rate of heat transfer and length of plate`

```
//Exa 5.2
clc;
clear;
close;
//given data
format('v',9)
rho=998;// in kg/m^3
k=.648;// in W/mK
v= 0.556*10^-6;// in m^2/s
Pr=3.54;
V=2;// in m/s
t_infinite= 10;// in degree C
t_s=90;// in degree C
Re=5*10^5;
A=1*1;// in m^2
// Re= rho*Vx/miu = V*x/v
x=Re*v/V;// in m
disp(x,"Length of the plate in m")


// Nu = h*x/k =Pr^(1/3)*(0.037*Re^0.8-872)
x=1;
Re= V*x/v;
h= Pr^(1/3)*(0.037*Re^0.8-873)*k/x;// in W/m^2
q=h*A*(t_s-t_infinite);
disp(q*10^-3,"Heat transfer from entire plate in kW"
   )
```

Scilab code Exa 5.3 `Heat transfer rate`

```
//Exa 5.3
clc;
clear;
close;
//given data

rho=1.06;// in kg/m^3
K=.0289;
v= 18.97*10^-6;// in m^2/s
Pr=0.696;
V=2.2;// in m/s
L=0.9;// in m
B=0.45;// in m
t_infinite= 30;// in degree C
t_s=90;// in degree C
//(a) For first half of the plate
x=L/2;// in m
Re=V*x/v;
// Nu = h*x/K = 0.664*Re^(1/2)*Pr^(1/3)
h= 0.664*Re^(1/2)*Pr^(1/3)*K/x;// in W/m^2 degree C
A=x*B;
Q1=h*A*(t_s-t_infinite);// in watt
disp(Q1,"Heat transfer rate from first half of the plate in watt");

//(b) Heat transfer from entire plate
x=L;// in m
Re=V*x/v;
// Nu = h*x/K = 0.664*Re^(1/2)*Pr^(1/3)
h= 0.664*Re^(1/2)*Pr^(1/3)*K/x;// in W/m^2 degree C
A=L*B;
Q2=h*A*(t_s-t_infinite);// in watt
disp(Q2,"Heat transfer rate from entire plate in watt");

//(c) From next half of the plate
Q3= Q2-Q1;
disp(Q3,"Heat transfer rate from next half of the
```

```
plate”)
```

Scilab code Exa 5.4 `Length of tube`

```
//Exa 5.4
clc;
clear;
close;
//given data
rho=985;// in kg/m^3
k=.654;// in W/mK
Cp=4.18;// in kgJ/kgK
Cp=Cp*10^3;// in J/kgK
v= 0.517*10^-6;// in m^2/s
Pr=3.26;
V=1.2;// in m/s
t_s=85;// in degree C
t_i=40;// in degree C
t_o=70;// in degree C
Ax=15*35;// in mm
P=15+35;
de=4*Ax/(2*P);// in mm
de=de*10^-3;// in m
Re=V*de/v;
// Formula Nu= h*de/k = 0.023Re^0.8*Pr^0.4
h=0.023*Re^0.8*Pr^0.4*k/de;// in W/m^2K
m=%pi*de^2*V*rho/4;
d=de;
L=m*Cp*log((t_s-t_i)/(t_s-t_o))/(%pi*d*h);
disp(L,”The length of tube in meter”)
```

Scilab code Exa 5.5 `Average heat transfer coefficient`

```
//Exa 5.5
clc;
clear;
close;
//given data
k=.026;// in W/mK
v= 16.8*10^-6;// in m^2/s
miu=2*10^-5;// in kg/ms
Pr=0.708;
V=15;// in m/s
x=2;// in m
A=2*1;// in m^2
Re=V*x/v;
del_t=40-10;// in degree C
// since Re > 3 *10^5, hence turbulent flow at x=2 m length of laminar flow region is x_L then
Re_1=3*10^5;
// Re_1 = 3*10^5 = V*x_L/v
x_L= Re_1*v/V;

// Part (a)
//Nu= h*x_L/k = 0.664*Re_1^(1/2)*Pr^(1/3);
h= 0.664*Re_1^(1/2)*Pr^(1/3)*k/x_L;// in W/m^2
disp(h,"The average heat transfer coefficient over the laminar boundary layer in W/m^2 ");

// Part(b)
//Nu= h*x/k = (0.037*Re^0.8-872)*Pr^(1/3);
h= (0.037*Re^0.8-872)*Pr^(1/3)*k/x;// in W/m^2
disp(h,"The average heat transfer coefficient over entire plate in W/m^2 ");

// Part (c)
q=h*A*del_t;
disp(q,"Total heat transfer rate in watt");

// Note: Calculation of the part(a) in this book is wrong, so answer of the part(a) in the book is
```

```
   wrong
```

Scilab code Exa 5.6 `Heat transfer coefficient and friction factor`

```
//Exa 5.6
clc;
clear;
close;
//given data
rho=997;// in kg/m^3
k=0.608;// in W/mK
Cp= 4180;// in J/kg K
miu=910*10^-6;// in Ns/m^2
d=30*10^-3;// in m
m=0.02;// in kg/s
t_o=30;// in degree C
t_i=20;// in degree C
Re= 4*m/(%pi*d*miu);
q_desh=12*10^3;// in W/m^2
// since Re < 2300, flow is laminar one

// Part(a)
// Nu = h*d/k = 4.36
h=4.36*k/d;
disp(h,"Heat transfer coefficient in W/m^2K");

// Part (b)
L=m*Cp*(t_o-t_i)/(q_desh*%pi*d);
disp(L,"Length of pipe in meter");

// Part(c)
// q_desh= h*(t_infinite-t_o)
t_infinite = q_desh/h+t_o;
disp(t_infinite,"The inner tube surface temperature
   at the outlet in degree C");
```

```

// Part(d)
f=64/Re;
disp(f,"Friction Factor ");

// Part(e)
V=4*m/(%pi*d^2*rho);// in m/s  ( because m= rho*V*A , m= rho*V*%pi*d^2/4 )
del_P= f*L*rho*V^2/(d*2);// in N/m^2
disp(del_P,"The pressure drop in the pipe in N/m^2");

// Note: In part(b) value of L is miss printed actual value is .739 m
```

Scilab code Exa 5.7 `Average heat transfer coefficient and tube length`

```
//Exa 5.7
clc;
clear;
close;
//given data
rho=977.3;// in kg/m^3
kf=0.665;// in W/mK
Cp= 4186;// in J/kg K
miu=4.01*10^-4;// in kg/m-s
Pr=2.524;
d=0.02;// in m
m=0.5;// in kg/s
t_o=70;// in degree C
t_i=20;// in degree C
t_s=100;// in degree C
Re= 4*m/(%pi*d*miu);

// Since Re > 2300, flow is turbulent flow. Then
```

```
Nusselt Number
// Nu = h*d/k = 0.023*Re^0.8*Pr^0.4
h=0.023*Re^0.8*Pr^0.4*kf/d;// in W/m^2
disp(h,"Average heat transfer coefficient in W/m^2");
L=m*Cp*log((t_s-t_i)/(t_s-t_o))/(%pi*d*h);// in meter
disp(L,"Length of tube in meter");


// Note: Calculation of Re is wrong so the answer in the book is wrong
```

Scilab code Exa 5.8 Reynold number heat transfer coefficient and pipe length

```
//Exa 5.8
clc;
clear;
close;
//given data
rho=977;// in kg/m^3
k=0.608;// in W/mK
Cp= 4180;// in J/kg K
miu=910*10^-6;// in poise
d=0.02;// in m
m=0.02;// in kg/s
t_o=40;// in degree C
t_i=10;// in degree C
q_desh= 20*10^3;// in W/m^2

// Part (a)
Re= 4*m/(%pi*d*miu);
disp(Re,"Reynold number is :")

// Part(b)
```

```
// Nu = h*d/k = 4.364
h=4.364*k/d;
disp(h,"Heat transfer coefficient in W/m^2K");

// Part (c)
// q= q_desh*A = m*Cp*(t_o-t_i)
// q_desh *( %pi*d*l) = m*Cp*(t_o-t_i)
l=m*Cp*(t_o-t_i)/(q_desh*%pi*d);
disp(l,"Length of pipe in meter");
```

Scilab code Exa 5.9 `Tube length`

```
//Exa 5.9
clc;
clear;
close;
//given data
rho=7.7*10^3;// in kg/m^3
k=12;// in W/mK
Cp= 130;// in J/kg degree C
Pr=0.011;
delta=8*10^-8;// in m^2/s


d=0.06;// in m
m=4;// in kg/s
t_i=200;// in degree C
del_t=25;// in degree C
miu=rho*delta;
Re= 4*m/(%pi*d*miu);
// From correlation  Nu =h*d/k = 4.82+0.0185*Pe^0.827
Pe=Re*Pr;
h=(4.82+0.0185*Pe^0.827)*k/d;// in W/m^2K
// Length of tube required by doing every balance
```

```
//  m*Cp*del_t = h*A*(t_s-t_b) = h*(%pi*d*l)*(t_s-t_b)   // its given (t_s-t_b) = 40 degree C
l= m*Cp*del_t/(h*(%pi*d)*40);// in meter
disp(l,"Length of tube in meter");
```

Scilab code Exa 5.10 Heat transfer rate from the cylinder

```
//Exa 5.10
clc;
clear;
close;
//given data
d=0.058;// in m
t_infinite=30;// in degree C
t_s=155;// in degree C
V=52;// in m/s
T_f=(t_s+t_infinite)/2;// in degree C
T_f=T_f+273;// in K
// Fluid properties at 92.5 degree C and 1 atm
miu= 2.145*10^-5;// in kg/ms
Pr=0.696;
P=1.0132*10^5;
R=287;
k=0.0312;// in W/mK
rho=P/(R*T_f);// in kg/m^3
Re=rho*V*d/miu;
C=0.0266;
n=0.805;
// Nu = h*d/k = C*(Re)^n*Pr^(1/3)
h=C*(Re)^n*Pr^(1/3)*k/d;// in W/m^2K
//So, heat transfer rate per unit length from cylinder
q_by_L= h*(%pi*d)*(t_s-t_infinite);// in W/m
disp(q_by_L,"Heat transfer rate per unit length from cylinder in W/m");
```

```


// Note: Calculation of q_by_L in the book is wrong, so the answer in the book is wrong
```

Scilab code Exa 5.11 Heat loss by the sphere

```
//Exa 5.11
clc;
clear;
close;
//given data
delta=15.68*10^-6;// in m^2/s
t_infinite=25+273;// in K
t_s=80+273;// in K
t_infinite=25+273;// in K
k=0.02625;// in W/m degree C
Pr=0.708;
miu_infinite=1.846*10^-5;//in kg/ms
miu_s= 2.076*10^-5;// in kg/ms
d=10*10^-3;// in m
V=5;// in m/s
A=4*%pi*(d/2)^2;
Re=V*d/delta;
Nu= 2+ (0.4*Re^(1/2)+0.06*Re^(2/3))*Pr^0.4*(miu_infinite/miu_s)^(1/4);
// Nu = h*d/k
h=Nu*k/d;// in W/m^2K
// heat transfer rate
q=h*A*(t_s-t_infinite);// in watt
disp(q,"Heat transfer rate in watt")
```

Scilab code Exa 5.12 Heat transfer coefficient

```
//Exa 5.12
clc;
clear;
close;
//given data
Cp=4179;// in J/kg-K
rho= 997;// in kg/m^3
V=2;// in m/s
miu= 855*10^-6;// in Ns/m^2
Pr=5.83;
k=0.613;
Do=6;//outer dia in cm
Di=4;//inner dia in cm
// de= 4*A/P = 4*%pi/4*(Do^2-Di^2)/(%pi*(Do+Di))
// or
de= Do-Di;// in cm
de=de*10^-2;// in m
Re= rho*V*de/miu;
// Since Re > 2300, hence flow is turbulent. Hence
   using Dittus Boelter equation
// Nu= 0.023*Re^0.8*Pr^0.4 =h*de/k
h= 0.023*Re^0.8*Pr^0.4*k/de;// in W/m^2K
disp(floor(h),"Heat transfer coefficient in W/m^2K")
   ;
```

Scilab code Exa 5.13 `Heat transfer rate`

```
//Exa 5.13
clc;
clear;
close;
//given data
Cp=0.138;// in KJ/kg-K
m=8.33;// in kg/sec
Pr=0.0238;
```

```
k=8.7;// in W/mk
d=1.5*10^-2;// in m
miu=1.5*10^-3;// in kg/ms

Re=4*m/(%pi*miu*d);
Pe=Re*Pr;
// Nu = h*d/k = 7+0.025*Pe^0.8
h= (7+0.025*Pe^0.8)*k/d;// in W/m^2 degree C
disp(h,"Heat transfer coefficient in W/m^2 degree C");
```

Scilab code Exa 5.14 `Heat transfer rate`

```
//Exa 5.14
clc;
clear;
close;
//given data
rho=887;// in kg/m^3
Pr=0.026;
k=25.6;// in W/mk
d=2.5*10^-2;// in m
miu=0.58*10^-3;// in kg/ms
V=3;// in m/s

Re=rho*V*d/(miu);
Pe=Re*Pr;
Nu = 4.8+0.015*Pe^0.85*Pr^0.08
h= Nu*k/d;// in W/m^2 degree C
disp(h,"Heat transfer coefficient in W/m^2 degree C");

//Note: There is some difference in coding and book answer because they did not take aqurate calculation
```

Scilab code Exa 5.15 `Initial rate of heat loss`

```
//Exa 5.15
clc;
clear;
close;
//given data
delta=38.1*10^-6;// in m^2/s
Pr=501;
Prs=98;
K=0.138;// in W/mk
T_infinite=353;// in K
T_s=423;// in K
V=2;// in m/s
d=12.5*2*10^-3;// in m
Re=V*d/delta;
n=0.36// for Pr >= 10
C=0.26;// for Re between 10^3 and 2*10^5
m=0.6;// for Re between 10^3 and 2*10^5
Nu= C*Re^m*Pr^n*(Pr/Prs)^(1/4);
h= Nu*K/d;// in W/m^2 degree C
A=%pi*25*10^-3;
del_t=T_s-T_infinite;
// Formula q=h*A*del_t
q_by_L = h*A*del_t;
disp(q_by_L,"Initial rate of heat loss per meter
   length of cylinder");

// Note: calculation in the book is wrong  so answer
    in the book is wrong
```

Chapter 6

Free Convection

Scilab code Exa 6.1 `Heat transfer rate from the plate in two oriention`

```
//Exa 6.1
clc;
clear;
close;
//given data
// (i) when
x=.3;// in m
T_s=100;// in degree C
T_infinite=30;// in degree C
T_f=(T_s+T_infinite)/2;// in degree C
T_f=T_f+273;// in K
Bita=1/T_f;
// Other fluid properties at film temperature
Pr=0.703;
K=0.0301;// in W/mK
T=1.8*10^-5    ;// in m^2/s
g=9.81;
del_T=T_s-T_infinite;
Gr=(g*Bita*del_T*x^3)/T^2;
Ra=Gr*Pr;
disp("Rayleigh Number is : "+string(Ra));
```

```
//Since Ra<10^9, hence flow is laminar, then correlation for vertical plate in laminar flow
// Formula Nu=0.59*Ra^(1/4)=h*x/K
h=0.59*Ra^(1/4)*K/x;// in W/m^2K
A=2*.3*.5;
q1=h*A*(T_s-T_infinite);
disp(”Heat transfer rate from the plate, when the vertical height is 0.3 m : ”+string(q1)+” W”);

//(ii) when
x=0.5;// in m
Gr=(g*Bita*del_T*x^3)/T^2;
Ra=Gr*Pr;
// Formula Nu=0.59*Ra^(1/4)=h*x/K
h=0.59*Ra^(1/4)*K/x;// in W/m^2K
q2=h*A*(T_s-T_infinite);
disp(”Heat transfer rate from the plate, when the vertical height is 0.5 m : ”+string(q2)+” W”);
PercentageDecrease=(q1-q2)/q1*100;
disp(”Percentage decreases in heat transfer rate when x=0.5 m as compared to when x=0.3 m is : ”+string(PercentageDecrease)+” %”)

//Note : In the book ,In part (b), calculation of getting the value of h is wrong
```

Scilab code Exa 6.2 `Heat loss from the two surface of the plate`

```
//Exa 6.2
clc;
clear;
close;
//given data
Pr=0.694;
K=0.0296;// in W/mK
```

```
rho=1.029;// in kg/m^3
miu=20.6*10^-6;// in poise
x=.2;// in m
T_s=110;// in degree C
T_infinite=30;// in degree C
T_f=(T_s+T_infinite)/2;// in degree C
T_f=T_f+273;// in K
Bita=1/T_f;
g=9.81;
del_T=T_s-T_infinite;
Gr=(rho^2*g*Bita*del_T*x^3)/miu^2;
Ra=Gr*Pr;
//since Rayleigh number is less than 10^10, hence
Nu=0.68*Pr^(1/2)*Gr^(1/4)/((.952+Pr)^(1/4));
h=Nu*K/x;
A=2*0.2*1;
q=h*A*(T_s-T_infinite);
disp("Heat transfer rate is : "+string(q)+" W");
```

Scilab code Exa 6.3 Heat loss from the pipe

```
//Exa 6.3
clc;
clear;
close;
//given data
d=7.5*10^-2;// in m
x=2;// in m
T_s=70;// in degree C
T_infinite=10;// in degree C
del_T=T_s-T_infinite;
g=9.81;
calculation=4.5*10^10; // value of g*Bita*rho^2*C_p/(miu*k)
K=2.75*10^-2;// in W/mK
```

```
// g*Bita*rho^2*C_p/(miu*k) = g*Bita*rho^2/miu^2 * miu*C_p/k = (g*Bita*del_T*x^3/T^2 * miu*C_p/k)/(del_T*x^3)
GrxPr= calculation*del_T*x^3; // value of Gr*Pr
Nu= 0.13*(GrxPr)^(1/3);
// Formula Nu = h*x/k
h= Nu*K/x;// in W/m^2K
A=2*%pi*d;
q=h*A*(del_T);// in W
q=q*60*60;// in J/h
disp("Heat transfer rate is : "+string(q)+" J/h");
```

Scilab code Exa 6.4 Heat transfer coefficient and initial rate of cooling of the p

```
//Exa 6.4
clc;
clear;
close;
//given data
m=15;// in kg
C_p=420;// in J/kg K
T_s=200;// in degree C
T_infinite=30;// in degree C
T_f=(T_s+T_infinite)/2;// in degree C
T_f=T_f+273;// in K
Pr=0.688;
K=0.0321;// in W/mK
delta=23.18*10^-6;// in m^2/s
Bita=1/T_f;
g=9.81;
x=0.3;// in m
del_T=T_s-T_infinite;
Gr=(g*Bita*del_T*x^3)/delta^2;
Ra=Gr*Pr;
//Since Ra<10^9, hence it is laminar flow using the
```

```
relation
// Formula Nu=0.59*Ra^(1/4)=h*x/K
h=0.59*Ra^(1/4)*K/x;// in W/m^2K
disp("(i) Heat transfer coefficient is : "+string(h)+" W/m^2K")

// (b) Initial rate of cooling
// Formula h*A*(T_s-T_infinite) = m*C_p*dt_by_toh
A=2*0.3*0.5;
dt_by_toh = h*A*(T_s-T_infinite)/(m*C_p);// in degree C/sec
dt_by_toh=dt_by_toh*60;// in degree C /min
disp("(ii) Initial rate of cooling of the plate is : "+string(dt_by_toh)+" degreeC /min");

//(c) Time taken by plate to cool from 200 degree C to 50 degree C
T_i=200;// in degree C
T=50;// in degree C
// Formula (T-T_infinite)/(T_i-T_infinite)= %e^(-h*A*toh/(m*C_p));
toh= -log((T-T_infinite)/(T_i-T_infinite))*m*C_p/(h*A);// in sec
toh=toh/60;// in min
disp("(iii) Time required to cool plate from 200 degree C to 50 degree C is : "+string(toh)+" minutes");
```

Scilab code Exa 6.5 `Total rate of heat loss from the pipe`

```
//Exa 6.5
clc;
clear;
close;
//given data
```

```
rho=0.8;// in kg/m^3;
C_p=1.01;// in KJ/kg K
Pr=0.684;
d=15*10^-2;// diameter in meter
K=0.035;// in W/mK
delta=2.78*10^-5;// in m^2/s
g=9.81;
x=2;// in m
T_s=250;// in degree C
T_infinite=30;// in degree C
T_f=(T_s+T_infinite)/2;// in degree C
T_f=T_f+273;// in K
Bita=1/T_f;
del_T=T_s-T_infinite;
disp("Heat Transfer (loss) from plate= heat loss from vertical part + heat transfer from horizontal part by convection + heat transfer by radiation ")

//Heat loss from vertical part by free convection

Gr=(g*Bita*del_T*x^3)/delta^2;
Ra=Gr*Pr;
//Since Ra>10^9, hence turbulent flow
// Formula Nu= h*x/K =0.13*Ra^(1/3)
h=0.13*Ra^(1/3)*K/x;// in W/m^2K
A=2*%pi*d;
q1=h*A*del_T;// w
q1=q1*10^-3;// in kW
disp("Heat loss from vertical part is : "+string(q1)+" kW")

//Heat loss for Horizontal part
// here
x=d;
Gr=(g*Bita*del_T*x^3)/delta^2;
Ra=Gr*Pr;
//Since Ra<10^9, hence laminar fluid flow
```

```
// Formula Nu= h*x/K =0.53*Ra^(1/4)
h=0.53*Ra^(1/4)*K/x;// in W/m^2K
A=%pi*d*8;
q2=h*A*del_T;// w
q2=q2*10^-3;// in kW
disp("Heat loss for horizontal part is : "+string(q2)+" kW")

//Heat loss by radiation
sigma=5.67*10^-8;
epsilon=0.65;// emissivity of steel
A=%pi*d*10;
T_s=T_s+273;// in K
T_infinite=T_infinite+273;// in K
q3=sigma*A*epsilon*(T_s^4-T_infinite^4);// in w
q3=q3*10^-3;// in kW
disp("Heat loss by radiation is : "+string(q3)+" kW")

//Total heat loss
theta=q1+q2+q3;
disp("Total heat loss is : "+string(theta)+" kW");


//Note : value of q3 and theta in the book is wrong so answer in the book is wrong
```

Scilab code Exa 6.6 `Heat gained by the duct per meter`

```
//Exa 6.6
clc;
clear;
close;
//given data
rho=1.205;// in kg/m^3;
```

```
C_p=1006;// in J/kg K
Pr=0.71;
K=0.0256;// in W/mK
delta=1.506*10^-5;// in m^2/s
T_s=35;// in degree C
T_infinite=5;// in degree C
T_f=(T_s+T_infinite)/2;// in degree C
T_f=T_f+273;// in K
Bita=1/T_f;
del_T=T_s-T_infinite;
g=9.81;
// Formula 1/x= 1/Lh + 1/Lv
Lh=50;// in cm
Lv=50;// in cm
x=Lh*Lv/(Lh+Lv);// in cm
x=x*10^-2;// in m

// Formula Gr=(g*Bita*del_T*x^3)/delta^2;
Gr=(g*Bita*del_T*x^3)/delta^2;
Ra=Gr*Pr;
// Formula Nu= h*x/K =0.53*Ra^(1/4)
h=0.53*Ra^(1/4)*K/x;// in W/m^2K
A=2*(0.5+0.5);
q=h*A*del_T;// w
disp("Heat loss per meter length of pipe is : "+
   string(q)+" watt")

// Note: In the book, value of h is wrong due to
   place miss value of x, so the answer in the book
   is wrong
```

Scilab code Exa 6.7 Average heat transfer coefficient and Local heat flux

```
//Exa 6.7
clc;
```

```
clear;
close;
//given data
L=3;// in m
delta=0;
hx='10*x^(-1/4)'
// (a) Average heat transfer coefficient
h=1/L*integrate(hx,'x',delta,L);
disp("(a) Average heat transfer coefficient is : "+
   string(h)+" W/m^2K")

// (b) Heat transfer rate
A=3*.3;// in m^2
Tp=170;// plate temp. in degree C
Tg=30;// gas temp. in degree C
del_T=Tp-Tg;
q=h*A*del_T;// in W
disp("(b) Heat transfer rate is : "+string(q)+" W")

// (c)
x=2;// in m
qx_by_A= 10*x^(-1/4)*(Tp-Tg);
disp("Local heat flux 2 m from the leading edge is :
    "+string(qx_by_A)+" W/m^2");
```

Scilab code Exa 6.8 `Heat transfer by natural convection`

```
//Exa 6.8
clc;
clear;
close;
//given data
Pr=0.712;
K=0.026;// in W/mK
delta=1.57*10^-5;// in m^2/s
```

```
T_s=320;// in K
T_infinite=280;// in K
del_T=T_s-T_infinite;
T_f=(T_s+T_infinite)/2;// in K
Bita=1/T_f;
d1=20;// in cm
d2=30;// in cm
x=(d2-d1)/2;// in cm
x=x*10^-2;// in m
g=9.81;
Gr=(g*Bita*del_T*x^3)/delta^2;
Ra=Gr*Pr;

// Formula Nu= h*x/K =0.228*Ra^(0.226)
h=0.228*Ra^(0.226)*K/x;// in W/m^2K
A=%pi*(d1*10^-2)^2;
q=h*A*del_T;// w
disp("Heat transfer rate is : "+string(q)+" watt");
```

Scilab code Exa 6.9 Heat transfer and overall heat transfer coefficient

```
//Exa 6.9
clc;
clear;
close;
//given data
K=0.0278;// in W/mK
rho=1.092;// in kg/m^3
miu=19.57*10^-6;// in kg/ms
Cp=1007;// in kg/kg degree C
epsilon=0.9;
sigma=5.67*10^-8;
d=75+2*25;// in mm
d=d*10^-3;// in meter
T_s=80;// in degree C
```

```
T_infinite=20;// in degree C
T_f=(T_s+T_infinite)/2;// in degree C
T_f=T_f+273;// in K
Bita=1/T_f;
g=9.81;
del_T=T_s-T_infinite;
Pr=miu*Cp/K;
Gr=(rho^2*g*Bita*del_T*d^3)/miu^2;

// Formula Nu= h*d/K = 0.53*(Gr*Pr)^(1/4);
h= 0.53*(Gr*Pr)^(1/4)*K/d;

//(a) Heat loss from 6 m length of pipe
A=%pi*d*6;
Q_conv=h*A*del_T;
Q_rad=epsilon*sigma*A*((T_s+273)^4-(T_infinite+273)^4);
//total heat transfer rate
Q=Q_conv+Q_rad;
disp("Total heat transfer rate is : "+string(Q)+" W");

// (b) Overall heat transfer coefficient
// Formula Q=U*A*del_T
U=Q/(A*del_T);
disp("Overall heat transfer coefficient is : "+string(U)+" W/m^2 degree C");
```

Chapter 7

Radiation Heat Transfer

Scilab code Exa 7.1 `Monochromatic emissive power and Maximum emissive power`

```
//Exa 7.1
clc;
clear;
close;
//given data
lamda=2*10^-6;// in m
C1=0.374*10^-15;
T=2000+273;// in K'
C2=1.4388*10^-2;

//(a)
// Formula Eb_lamda= (C1*lamda^-5)/[exp(C2/(lamda*T))-1]
Eb_lamda= (C1*lamda^-5)/[exp(C2/(lamda*T))-1];
disp(Eb_lamda,"Monochromatic emissive power at 2 micro wavelength in W/m^2 is :");

//(b)
// Formula lamda_max * T =2898 // in micro m K
lamda_max= 2898/T;// in micro m
disp(lamda_max,"Wave-length at which the emission is
```

```
    maximum in micro m");

//(c)
Elamdab_max=1.285*10^-5*T^5;// in W/m^2-m
disp(Elamdab_max,"Maximum emissive power in W/m^2-m : ");

//(d)
sigma=5.67*10^-8;
E=sigma*T^4;
disp(E,"Total emissive power in W/m^2 :");

//Note: Answer of  part (a) in the book is wrong
```

Scilab code Exa 7.2 `Heat transfer by radiation and natural convection`

```
//Exa 7.2
clc;
clear;
close;
//given data
lamda=2*10^-6;// in m
C1=0.374*10^-15;
T=2000+273;// in K'
C2=1.4388*10^-2;

epsilon=0.3;
sigma=5.67*10^-8;
T1=300;// in K
T2=200;// in K
del_T=T1-T2;
h=12;// in W/m^2 degree C
d=4*10^-2;// diameter in m
l=1;// in m
A=%pi*d*l;
```

```
// Heat transfer rate by radiation,
q_r= epsilon*sigma*A*(T1^4-T2^4);// in W
// Heat transfer rate by convection,
q_c=h*A*del_T;// in W
// Total heat transfer,
q=q_r+q_c;
// Formula q=U*A*del_T
U=q/(A*del_T);// Overall heat tranfer coefficient
disp(U,"Overall heat tranfer coefficient in W/m^2 degree C");

//Note: Value of q_c is wrong in the book, so the answer in the book is wrong
```

Scilab code Exa 7.3 Heat transfer rate

```
//Exa 7.3
clc;
clear;
close;
//given data
epsilon=0.5;
T1=1200;// in K
T2=300;// in K
//(a) Heat transfer rate between the two plates is
// Formula Fg12=1/((1/epsilon1+(1/epsilon2-1)*A1/A2))
epsilon1=epsilon;
epsilon2=epsilon;
A1byA2=1;
Fg12=1/(1/epsilon1+(1/epsilon2-1)*A1byA2);
// Formula q12= sigma*A*Fg12*(T1^4-T2^4)
sigma=5.67*10^-8;
q12byA=sigma*Fg12*(T1^4-T2^4);// in W/m^2
disp(q12byA,"Heat transfer rate between the two
```

```
plates in W/m^2")

//(b)
epsilon3=.05;
Fg13=1/(1/epsilon1+(1/epsilon3-1)*A1byA2);
Fg32=1/(1/epsilon3+(1/epsilon2-1)*A1byA2);
// q13=q32
// sigma*A*Fg13*(T1^4-T3^4) = sigma*A*Fg32*(T3^4-T2^4)
T3= ((T1^4+T2^4)/2)^(1/4);
T3=floor(T3);
q13byA=sigma*Fg13*(T1^4-T3^4);// in W/m^2
disp(q13byA,"Heat transfer rate if a radiation shield with an emissivity of 0.05 on both sides is placed between the two plates in W/m^2")
```

Scilab code Exa 7.4 Energy emitted by a grey surface

```
//Exa 7.4
clc;
clear;
close;
//given data
format('v',9);
T1=800+273;// in K
A= 5*6;// in square meter
epsilon=0.45;
sigma=5.67*10^-8;
q=epsilon*sigma*A*T1^4;//in watt
disp(q,"Energy emitted by a grey surface in watt : ");
```

Scilab code Exa 7.5.1 Absorbed Transmitted and emitted energy

```
//Exa 7.4
clc;
clear;
close;
//given data
A=5;// in m^2
intensity=660;// in W/m^2

disp("alpha= 2*rho    or     rho=alpha/2")
disp("alpha= 3*toh    or     toh=alpha/3")
disp("as alpha + rho + toh =1")
disp("then alpha+alpha/2+alpha/3 = 1")
disp("alpha = 6/11")
disp("rho = 6/22")
disp("toh = 6/33")
alpha=6/11;
rho=6/22;
toh=6/33;
energy_absorbed= intensity*alpha*A;// in watt
disp(energy_absorbed, "Energy absorbed in watt : ")
energy_transmitted=intensity*rho*A;//in watt
disp(energy_transmitted,"Energy transmitted in watt
   :")
energy_emitted= intensity*toh*A;// in watt
disp(energy_emitted,"Energy emitted in watt: ")
```

Scilab code Exa 7.5.2 `Net heat exchange between the two surface`

```
//Exa 7.5
clc;
clear;
close;
//given data
T1=200+273;// in K
T2=100+273;// in K
```

```
A= 1*2;// in square meter
sigma=5.67*10^-8;
x_D= 1/4;
y_D= 1/2;
Fg12= 0.033;
q12= Fg12*sigma*A*(T1^4-T2^4);// in watt
disp(q12,"The net heat exchange between two surfaces in watt")
```

Scilab code Exa 7.6 `heat loss and net heat transfer between pipe and duct`

```
//Exa 7.6
clc;
clear;
close;
//given data
d=20*10^-2;//diameter of pipe in m
l=1;// length of pipe in m
s=30*10^-2;// side of duct in m
A1=%pi*d*l;// area of pipe in m^2
A2=4*s*s;// area of duct in m^2
epsilon1=0.8;
epsilon2=0.9;
T1=200+273;// in K
T2=20+273;// in K
// Formula Fg12=1/((1/epsilon1+(1/epsilon2 -1)*A1/A2))
Fg12=1/((1/epsilon1+(1/epsilon2-1)*A1/A2));
// Heat transfer rate between pipe and duct
sigma=5.67*10^-8;
q12=sigma*Fg12*A1*(T1^4-T2^4);// in W
disp(q12,"Heat transfer rate between pipe and duct in W");

//Note: Answer in the book is wrong
```

Scilab code Exa 7.10 `Shape factor of a cylinderical cavity`

```
//Exa 7.10
clc;
clear;
close;
//given data
D=150*10^-3;// in m
H=400*10^-3;// in m
T1=500;// in K
epsilon=0.7;
// Formula F11=(4*H)/(4*H+D)
F11=(4*H)/(4*H+D);
sigma=5.67*10^-8;
A1=%pi*D*H;
q=sigma*A1*epsilon*T1^4*[(1-F11)/(1-F11*(1-epsilon))];
disp(q,"Heat Heat loss for cavity in W");

//Note: There is some difference between Code answer and book answer because value of F11 is wrong in the book
```

Scilab code Exa 7.11 `Net heat transfer rate and rate of evaporation of liquid oxyg`

```
//Exa 7.11
clc;
clear;
close;
//given data
epsilon1=.04;
```

```
epsilon2=epsilon1;
T1=-153+273;// in K
T2=27+273;// in K
h_fg=209;// in kJ/kg
h_fg=h_fg*10^3;// in J/kg
d1=20*10^-2;// in m
d2=30*10^-2;// in m
A1=d1^2;// in square meter
A2=d2^2;// in square meter
A=4*%pi*(d2-d1)^2;
Fg12=1/((1/epsilon1+(1/epsilon2-1)*A1/A2));
sigma=5.67*10^-8;
q12=sigma*A*Fg12*(T1^4-T2^4);// in W
disp(q12,"Net radiant heat transfer rate in watt")
disp("Negative sign indicates that heat flows into
   the sphere")
q12=-q12;
m=q12*60/h_fg;
disp(m,"Rate of evaporation per minutes in kg/min")
```

Scilab code Exa 7.12 Radiation heat transfer

```
//Exa 7.12
clc;
clear;
close;
//given data
T1=500;// in K
T2=300;// in K
sigma=5.67*10^-8;
A=2;// surface area of each plate in m^2
//(a) If the plates are perfectly black
F12=1;
q12=sigma*A*F12*(T1^4-T2^4);
disp(q12,"Radiation heat transfer between two black
```

```
parellel plates in watt");

//(b) If the plates are gray surface
//in this case
F12=1;
//A1=A2, so
A1byA2=1
epsilon1=.4;
epsilon2=epsilon1;
//Fg12=1/(1/epsilon1+(1/epsilon2 -1)*A1byA2);
Fg12=1/((1-epsilon1)/epsilon1 + 1/F12 + [(1-epsilon2)/epsilon2]*A1byA2);
q12=sigma*A*Fg12*(T1^4-T2^4);// in W
disp(q12,"Heat transfer rate in watt")
```

Scilab code Exa 7.13 Steady state temperature

```
//Exa 7.13
clc;
clear;
close;
format('v',6)
//given data
T1=800;// in K
T3=200;// in K
sigma=5.67*10^-8;
d1=20*10^-2;// in m
d2=30*10^-2;// in m
d3=40*10^-2;// in m
A1=4*%pi*(d1/2)^2;// in m^2
A2=4*%pi*(d2/2)^2;// in m^2
A3=4*%pi*(d3/2)^2;// in m^2
epsilon1=0.2;
epsilon2=epsilon1
epsilon3=epsilon1
```

```
Fg12=1/(1/epsilon1+(1/epsilon2-1)*A1/A2);
Fg23=1/(1/epsilon2+(1/epsilon3-1)*A2/A3);
// Under steady state condition
// q12 = q23
// A1∗Fg12∗sigma∗(T1ˆ4−T2ˆ4) = A2∗Fg23∗sigma∗(T2ˆ4−T3ˆ4)
T2 = ((A2*Fg23*T3^4/(A1*Fg12)+T1^4)/(A2*Fg23/(A1*Fg12) + 1))^(1/4)
disp(T2,”Steady state temperature of the intermediate sphere in K”);
```

Scilab code Exa 7.14 `Rate of absorption and emission`

```
//Exa 7.14
clc;
clear;
close;
format(’v’,9);
//given data
T1=400;// in K
T2=500;// in K
T3=1200;// in K
alpha1=0.70;
alpha2=0.6;
alpha3=0.4;
// First part
disp(”Radiation falling on the body is emitted by the furnace wall at 1200 K ”)
disp(”The absorptivity of the body for this radiation is 0.4.”)
sigma=5.67*10^-8;
qa=alpha3*sigma*T3^4;
disp(qa,”The rate of energy absorption in W/mˆ2”);

// Second part
```

```
disp("The emissivity of surface equals its absoptivity at 127 degree")
qa=alpha1*sigma*T1^4;
disp(qa,"The rate of emission of radiation energy in W/m^2");


// Note : Answer of the first part in the book is wrong
```

Scilab code Exa 7.15 `Radient Heat transfer`

```
//Exa 7.15
clc;
clear;
close;
format('v',9)
//given data
d1=100;// in mm
d1=d1*10^-3;// in m
d2=100+10*2;// in mm
d2=d2*10^-3;// in m
l=1;// in m
A1byA2=d1^2/d2^2;
A1=%pi*d1*l;// in m^2
sigma=5.67*10^-8;
T1=120+273;// in K
T2=35+273;// in K
epsilon1=.8;
epsilon2=.1;
Fg12=1/(1/epsilon1+(1/epsilon2-1)*A1byA2);
// Radiant heat transfer from the tube
q=A1*Fg12*sigma*(T1^4-T2^4)
disp(q," Radiant heat transfer from the tube in W/m");
```

```


//Note: Answer in the book is wrong
```

Chapter 8

Heat Exchangers

Scilab code Exa 8.1 `Surface area of heat exchanger`

```
//Exa 8.1
clc;
clear;
close;
//given data
t_hi=80;// in degree C
t_ci=30;// in degree C
t_ho=40;// in degree C
Mh=0.278;// in kg/s
Mc=0.278;// in kg/s
Cph=2.09; // in kJ/kg degree C
Cpc=4.18;//  in kJ/kg degree C
U=24;// in W/m^2 degree C
// Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-t_ci)
t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci;// in degree C
del_t1=t_hi-t_co;//in degree C
del_t2=t_ho-t_ci;//in degree C
del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
Cph=Cph*10^3;// in J/kg degree C
```

```
q=Mh*Cph*(t_hi-t_ho);
//Formula q=U*A*del_tm
A=q/(U*del_tm);// in m^2
disp(A,"Surface area of heat exchange in square
   meter")
```

Scilab code Exa 8.2 Length of heat exchanger

```
//Exa 8.2
clc;
clear;
close;
//given data
t_hi=160;// in degree C
t_ci=25;// in degree C
t_ho=60;// in degree C
Mh=2;// in kg/s
Mc=2;// in kg/s
Cph=2.035; // in kJ/kg degree C
Cpc=4.187;//  in kJ/kg degree C
U=250;// in W/m^2 K
d=0.5;// in m
// Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-
   t_ci)
t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci;// in degree
   C
del_t1=t_hi-t_co;//in degree C
del_t2=t_ho-t_ci;//in degree C
del_tm= (del_t1-del_t2)/log(del_t1/del_t2);


Cph=Cph*10^3;// in J/kg degree C
q=Mh*Cph*(t_hi-t_ho);

//Formula q=U*%pi*d*l*del_tm
```

```
l=q/(U*%pi*d*del_tm);
disp(l,"Length of the heat exchanger in meter")
```

Scilab code Exa 8.3 `Area of heat exchanger tube`

```
//Exa 8.3
clc;
clear;
close;
//given data
t_hi=110;// in degree C
t_ci=35;// in degree C
t_co=75;// in degree C
Mh=2.5;// in kg/s
Mc=1;// in kg/s
Cph=1.9; // in kJ/kg K
Cpc=4.18;//  in kJ/kg K
U=300;// in W/m^2 K

// Energy balance Mc*Cpc*(t_co-t_ci) = Mh*Cph*(t_hi-t_ho)
t_ho=t_hi- Mc*Cpc*(t_co-t_ci)/(Mh*Cph);// in degree C
del_t1=t_hi-t_co;//in degree C
del_t2=t_ho-t_ci;//in degree C
del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
Cph=Cph*10^3;// in J/kg degree C
q=Mh*Cph*(t_hi-t_ho);
//Formula q=U*A*del_tm
A=q/(U*del_tm);
disp(A,"Area of the heat exchanger in square meter")
```

Scilab code Exa 8.4 `The overall heat transfer`

```
//Exa 8.4
clc;
clear;
close;
//given data
Fi=0.00014;// in m^2 degree C/W
hi=2000;// in W/m^2degree C
Fo=0.00015;// in m^2 degree C/W
ho=1000;// in W/m^2degree C
di=3*10^-2;// in m
do=4*10^-2;//in m
ro=do/2;
ri=di/2;
k=53;// in W/m degree C
Uo=1/(do/di*1/hi+ do/(2*k)*log(ro/ri) + 1/ho + do*Fi/di + Fo);
disp(Uo,"The overall heat transfer coefficient in W/m^2 degree C")
```

Scilab code Exa 8.5 `Heat transfer rate`

```
//Exa 8.5
clc;
clear;
close;
//given data
V=0.15;// in m/s
di=2.5*10^-2;// in m

delta=0.364*10^-6;// in m^2/s
k=0.668;// in W/m degree C
Pr=2.22;

Re=V*di/delta;
// Formula Nu= hi*di/k = 0.023*Re^0.8*Pr^0.3
```

```
hi=0.023*Re^0.8*Pr^0.3*k/di;// in W/m^2 degree C

// Now, Reynold number for flow of air across the tube
delta=18.22*10^-6;// in m^2/s
k=0.0281;// in W/m degree C
Pr=0.703;
d=2.5*10^-2;// in m
u=10;// in m/s
Re=u*d/delta;
Re=floor(Re);
//The Nusselt number for this case
Nu=[0.04*Re^0.5+ 0.006*Re^(2/3)]*Pr^0.4
// Formula Nu= ho*do/k
do=di;
ho=Nu*k/do;// in W/m^2 degree C
disp(ho,"Heat transfer coefficient in W/m^2 degree C");
U=1/(1/hi+1/ho);
disp(U,"The overall heat transfer coefficient neglecting the wall resistance in W/m^2 degree C");
l=1;// in m
Ti=90;// in degree C
To=10;// in degree C
q=U*%pi*d*l*(Ti-To);
disp(q,"Heat loss per meter length of the tube in W/m")

// Note: Answer in the book is wrong
```

Scilab code Exa 8.6 `Type of heat exchanger required`

```
//Exa 8.6
clc;
```

```
clear;
close;
//given data
t_hi=83;// in degree C
t_ho=45;// in degree C
t_ci=25;// in degree C
Mh=5;// in kg/min
Mc=9;// in kg/min
Cph=4.18; // in kJ/kg K
Cpc=2.85;//  in kJ/kg K
// Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-t_ci)
t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci;// in degree C
disp(t_co,"t_co in degree C");
if(t_co>t_ho)

   disp("since t_co > t_ho, hence counter flow arrangment will be suitable")
end
```

Scilab code Exa 8.7 `Heat transfer area`

```
//Exa 8.7
clc;
clear;
close;
//given data
// (a) For parallel flow arrangment
del_t1=60-10;// in degree C
del_t2=40-30;// in degree C
del_tm=(del_t1-del_t2)/log(del_t1/del_t2);// in degree C
q=100*10^3;// in W
U=75;// in W/m^2 degree C
```

```
// Formula q=U*A*del_tm;
A=q/(U*del_tm);
disp(A,”Area for paraller flow arrangment in square
   meter”);
// (b) For counter flow heat exchange
del_t1=60-30;// in degree C
del_t2=40-10;// in degree C
// In this case
del_tm=(del_t1+del_t2)/2;// in degree C
A=q/(U*del_tm);
disp(A,”Area For counter flow heat exchange in
   square meter”);
disp(”In counter flow arrangment less area is
   required for the above purpose”)
```

Scilab code Exa 8.8 `Rate of heat condensation`

```
//Exa 8.8
clc;
clear;
close;
//given data
Cp=4180;// in J/kg degree C
miu=0.86*10^-3;// in kg/m-s
Pr=60;
k=0.60;// in W/m degree C
h_fg=2372400;// in W
ho=6000;// in W/m^2 degree C
di=2*10^-2;// in m
d_o=3*10^-2;// in m
t_co=35;// in degree C
t_ci=15;// in degree C

M=0.9;
Re=4*M/(%pi*di*miu);
```

```
// since Re > 2300, hence flow inside tube is a turbulent flow.
// Hence  Nu= hi*di/k = 0.023*Re^0.8*Pr^0.4
hi= 0.023*Re^0.8*Pr^0.4*k/di;
Uo= 1/(1/10213.6*(d_o/di)+1/ho);
del_t1=50-15;// in degree C
del_t2=50-35;// in degree C
del_tm=(del_t1-del_t2)/log(del_t1/del_t2);// in degree C
// Formula q= Uo*%pi*d_i*L*del_tm = M*Cp*(t_co-t_ci)
L= M*Cp*(t_co-t_ci)/(Uo*%pi*d_o*del_tm);
disp(L,"Length of tube in meter")
q=M*Cp*(t_co-t_ci);// in watt
m=q/h_fg;
disp(m,"Rate of condensation in kg/sec")
```

Scilab code Exa 8.9 Heat transfer area

```
//Exa 8.9
clc;
clear;
close;
//given data
Cph=3850; // in J/kg degree C
t_hi=100;// in degree C
t_ci=20;// in degree C
t_ho=50;// in degree C
Mh=8;// in kg/s
Mc=10;// in kg/s
Cpc=4.18*10^3;//  in J/kg degree C
U=400;// in W/m^2 degree C
// Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-t_ci)
t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci;// in degree C
```

```
// Heat load
q=Mh*Cph*(t_hi-t_ho);// in W

// (a) Parallel flow
del_t1=90;// in degree C
del_t2=3.16;// in degree C
del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
A=q/(U*del_tm);
disp(A,"Surface area for parallel flow in meter
   square");

// (b) Counter flow heat exchanger
del_t1=53.16;// in degree C
del_t2=40;// in degree C
del_tm_counter= (del_t1-del_t2)/log(del_t1/del_t2);
A=q/(U*del_tm_counter);
disp(A,"Surface area for counter flow heat exchanger
    in meter square");

//(c) One shell pass and two tube pass.
//here
t1=10;// in degree C
t2=46.84;// in degree C
T1=100;// in degree C
T2=50;// in degree C
P=(t2-t1)/(T1-t1);
R=(T1-T2)/(t2-t1);
F=0.88;
del_tm=F*del_tm_counter;// in degree C
A=q/(U*del_tm);
disp(A,"Surface area for one shell pass and two tube
    pass in meter square");

// (d) For cross flow, correction factor
F=0.9;
del_tm=F*del_tm_counter;
A=q/(U*del_tm);
disp(A,"Surface area for cross flow in meter square"
```

```
);
```

Scilab code Exa 8.10 `Exit temperature of water`

```
//Exa 8.10
clc;
clear;
close;
format('v',13)
//given data
Cpc=4.18*10^3;//  in J/kg degree C
Mc=1;// in kg/s
Mh=2.4;// in kg/s
Cph=2050; // in J/kg degree C
t_hi=100;// in degree C
t_ci=20;// in degree C
C_c=Mc*Cpc;// in W/degree C
C_h=Mh*Cph;// in W/degree C
U=300;// in W/m^2 degree C
A=10;// in m^2
C_min=C_c;
C_max=C_h;
N= A*U/C_min;
C=C_min/C_max;
// Effectiveness for counter flow heat exchanger
epsilon= (1-%e^(-N*(1-C)))/(1-C*%e^(-N*(1-C)));
// Total heat transfer
q=epsilon*C_min*(t_hi-t_ci);// in watt
disp(q*10^-3,"Total heat transfer in kW");
t_co=t_ci+epsilon*C*(t_hi-t_ci);
disp(t_co,"Exit temperature of water in degree C");
```

Scilab code Exa 8.11 `Exit temperature`

```
//Exa 8.11
clc;
clear;
close;
format('v',13)
//given data
t_hi=135;// in degree C
t_ci=20;// in degree C
t_ho=65;// in degree C
t_co=50;// in degree C
// Energy balance  Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-t_ci)
// C =C_min/C_max = Mh*Cph/( Mc*Cpc)
C= (t_co-t_ci)/(t_hi-t_ho);
epsilon=(t_hi-t_ho)/(t_hi-t_ci);
// Also epsilon = epsilon_parallel = (1-exp(-NTU*(1+C)))/(1+C)
NTU= -log(1-epsilon*(1+C))/(1+C);
// if the existing heat exchanger is to be used as counter flow mode, its NTU will not change, i.e.
epsilon_c= (1-exp(-NTU*(1-C)))/((1-C*exp(-NTU*(1-C))));
// Exit temperature
// (i) Hot fluid
t_ho=t_hi-epsilon_c*(t_hi-t_ci);// in degree C
disp(t_ho,"Exit temperature for hot fluid in degree C")

//(ii) Cold fluid
t_co= t_ci+epsilon_c*C*(t_hi-t_ci);
disp(t_co,"Exit temperature for cold fluid in degree C")

// (iii) // If the parallel flow heat exchanger is too long, then body fluid will have common outlet temperature (t)
// From MCp_h*(t_hi-t) = MCp_c*(t-t_ci)

```

```
t=(C*t_hi+t_ci)/(1+C);
disp(t,"The minimum temperature to which the oil may
    be cooled by increasing the tube length with
   parallel flow operation , in degree C ")
```

Scilab code Exa 8.12 `Exit temperature`

```
//Exa 8.12
clc;
clear;
close;
format('v',13)
//given data
t_hi=78;// in degree C
t_ci=23;// in degree C
t_ho=65;// in degree C
t_co=36;// in degree C
// Energy balance  Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co
   -t_ci)
// C =C_min/C_max = Mh*Cph/( Mc*Cpc)
C= (t_co-t_ci)/(t_hi-t_ho);
epsilon=(t_hi-t_ho)/(t_hi-t_ci);
// Formula epsilon = (1-exp(-N*(1+C)))/(1+C)
N= -log(1-epsilon*(1+C))/(1+C);
// When flow rates of both fluids are doubled , the
   deat capacity ratio will not change, i.e.
// C=1
//  MCp_new =2* MCp_old
// N=U*A/C_min=N/2
N=N/2;
epsilon=(1-exp(-N*(1+C)))/(1+C);
// exit temperature
t_ho=t_hi-epsilon*(t_hi-t_ci);// in degree C
t_co= t_ci+epsilon*(t_hi-t_ci);
disp("Exit temperature  in degree C : "+string(t_ho)
```

```
+" and "+string(t_co));

// Note: Answer in the book is wrong due to put wrong value of t_ci in second last line
```

Scilab code Exa 8.13 `Outlet temperature`

```
//Exa 8.13
clc;
clear;
close;
format('v',13)
//given data
t_hi=125;// in degree C
t_ci=22;// in degree C
Mh=21;// in kg/s
Mc=5;// in kg/s
C_ph=2100;// in J/kg K
C_pc=4100;// in J/kg K
Ch=Mh*C_ph;// in Js/kg
Cc=Mc*C_pc;// in Js/kg
C_min=Cc;// in Js/kg
C_max=Ch;// in Js/kg
U=325;// in W/m^2 K
d=2.2*10^-2;// in m
l=5;// in m
total_tube=195;// number of total tubes
A=%pi*d*l*total_tube
NTU=U*A/C_min;
C=C_min/C_max;
epsilon = (1-exp(-NTU*(1-C)))/(1-C*exp(-NTU*(1-C)));
t_co= t_ci+epsilon*(t_hi-t_ci);
t_ho= t_hi-epsilon*Cc/Ch*(t_hi-t_ci);
disp("Exit temperature  in degree C : "+string(t_co)+" and "+string(t_ho));
```

```

// Total heat transfer
q=epsilon*C_min*(t_hi-t_ci);
disp(q*10^-3,”Total heat transfer in kW”)
```

Scilab code Exa 8.14 `Total heat transfer and outlet temperature`

```
//Exa 8.14
clc;
clear;
close;
format(’v’,13)
//given data
t_hi=94;// in degree C
t_ci=15;// in degree C
Mw=0.36;// in kg/s
Mo=0.153;// in kg/s
C_po=2*10^3;// in J/kg K
C_pw=4.186*10^3;// in J/kg K
U=10.75*10^2;// in W/m^2 K
A=1;// in m^2
Ch=Mo*C_po;// in kW/K
Cc=Mw*C_pw;// in kW/K
C_min=Ch;// in W/K
C_max=Cc;// in W/K
C=C_min/C_max;
NTU=U*A/C_min;
// Effectiveness
N=NTU;
epsilon = (1-exp(-N*(1-C)))/(1-C*exp(-N*(1-C)));
mCp_min=C_min;
q_max= mCp_min*(t_hi-t_ci);// in W
q_actual= epsilon*q_max;// in W
disp(q_actual,”Total heat transfer in watt”)
// Outlet temp. of water
```

```
t_co= q_actual/Cc+t_ci;// in degree C
disp(t_co,”Outlet temperature of water in degree C”)
// Outlet temp. of oil
t_ho=t_hi-q_actual/Ch;//in degree C
disp(t_ho,”Outlet temperature of oil in degree C”)


//Note: Evaluation of Cc and Ch in the book is wrong so the Answer in the book is wrong
```

Scilab code Exa 8.15 `Surface area of heat exchanger`

```
//Exa 8.15
clc;
clear;
close;
//given data
U=1800;// in W/m^2 degree C
h_fg=2200*10^3;// in J/kg
t_ci=20;// in degree C
t_co=90;// in degree C
del_t1=120-20;// in degree C
del_t2=120-90;// in degree C
del_tm=(del_t1-del_t2)/log(del_t1/del_t2);// in degree C
Mc=1000/3600;// in kg/s
Cc=4180;// in kg/s
// Rate of heat transfer
q=Mc*Cc*(t_co-t_ci);// in watt
// Formula q=U*A*del_tm
A=q/(U*del_tm);
disp(A,”Surface area in square meter”);
//Rate of condensation of steam
ms=q/h_fg;// in kg/sec
disp(ms,”Rate of condensation of steam in kg/sec”);
```

Scilab code Exa 8.16 Heat exchanger area

```
//Exa 8.16
clc;
clear;
close;
//given data
Mh=10000/3600;// in kg/sec
Mc=8000/3600;// in kg/sec
Cph=2095;// in J/kg K
Cpc=4180;// in J/kg K
t_hi=80;// in degree C
t_ci=25;// in degree C
t_ho=50;// in degree C
U=300;// in W/m^2 K
// Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-t_ci)
t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci;// in degree C
del_t1=t_hi-t_co;//in degree C
del_t2=t_ho-t_ci;//in degree C
del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
q=Mh*Cph*(t_hi-t_ho);
//Formula q=U*A*del_tm
A=q/(U*del_tm);// in m^2
disp(A,"Surface area of heat exchange in square meter")
```

Scilab code Exa 8.17 Overall heat transfer coefficient

```
//Exa 8.17
```

```
clc;
clear;
close;
//given data
ho=5000;// in W/m^2 degree C
rho=988.1;// in kg/m^3
K=0.6474;
D=555*10^-9;// in m^2/s
Pr=3.54;
n=100;
d_i=2.5*10^-2;// in m
ri=d_i/2;
d_o=2.9*10^-2;// in m
ro=d_o/2;
Cp=4174;// in J/kg degree C
Mc=8.333;// in kg/s
Mw=Mc;
t_c1=30;// in degree C
t_c2=70;// in degree C
t_n1=100;// in degree C
t_n2=t_n1;// in degree C
R_fi=0.0002;// in m^2 degree C/W (In the book, there
    is miss print in this line,they took here R_fi =
    .002)
// Heat gain by water
Q=Mc*Cp*(t_c2-t_c1);
// Also Q= U*A*del_tm
del_t1=t_n1-t_c1;//in degree C
del_t2=t_n2-t_c2;//in degree C
del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
// Mw= 1/4*%pi*d_i^2*V*rho*N, here
N=n;
V=4*Mw/(%pi*d_i^2*rho*N);
// Formula Re=V*d_i/v, here
v=D;
Re=V*d_i/v;
// Formula Nu= hi*d_i/K = 0.023*Re^0.8*Pr^0.33
hi= 0.023*Re^0.8*Pr^0.33*K/d_i;
```

```
// Formula 1/Vi= 1/hi + R_fi + ri/ro*1/ho
Vi= 1/(1/hi + R_fi + ri/ro*1/ho);// in W/m^2 degree C
//Formula Q = Vi*(N*%pi*d_i*L)*del_tm
L= Q/(Vi*(N*%pi*d_i)*del_tm);
disp(L,"Length of the tube bundle in m");
```

Chapter 9

Condensation and Boiling

Scilab code Exa 9.1 `Rate of heat transfer`

```
//Exa 9.1
clc;
clear;
close;
format('v',9)
//given data
h_fg=2256*10^3;// in J/kg
rho=970;// in kg/m^3
rho_v=0.596;// in kg/m^3
k=0.66;// in W/mK
miu=3.7*10^-4;// in kg/m-s
T_sat=100;// in degree C
T_s=40;// in degree C
L=1.5;// in m
d=0.09;// in m
g=9.81;
// heat transfer coefficient
//h_bar = 1.13*[ rho*g*(rho-rho_v)*h_fg*k^3/(miu*L*(T_sat-T_s))]^(1/4);// in W/m^2k
h_bar= 1.13*[      rho*g*(rho-rho_v)*h_fg*k^3/(   miu*L*(T_sat-T_s)           )          ]^(1/4);
```

```
// heat transfer rate
q=h_bar*%pi*d*L*(T_sat-T_s);// in watt
disp(q*10^-3,"Heat transfer rate in kW")
//rate of condensation
m=q/h_fg;// in kg/s
disp(m,"Rate of condenstion in kg/s")
```

Scilab code Exa 9.2 Condensation rate

```
//Exa 9.2
clc;
clear;
close;
format('v',9)
//given data
h_fg=2310*10^3;// in J/kg
rho=980;// in kg/m^3
k=0.67;// in W/mK
Cp=4.18;
delta=.41*10^-6;// in m^2/s
miu=rho*delta;
T_sat=70;// in degree C
T_s=55;// in degree C
L=1;// in m
d=0.03;// in m
g=9.81;
N=5;
// (a) for Horizontal tube
h_bar = 0.725*[ rho^2*g*h_fg*k^3/(N*miu*d*(T_sat-T_s))]^(1/4);// in W/m^2k
// heat transfer rate
q=h_bar*%pi*d*L*N^2*(T_sat-T_s);// in watt
disp(q*10^-3,"Heat transfer rate for horizontal tube in kW")
//rate of condensation
```

```
m=q/h_fg;// in kg/s
disp(m,”Rate of condenstion in kg/s”);

// (b) For Vertical tube
h_bar = 1.13*[ rho^2*g*h_fg*k^3/(miu*L*(T_sat-T_s))]^(1/4);// in W/mˆ2k
// heat transfer rate
q=h_bar*%pi*d*L*N^2*(T_sat-T_s);// in watt
disp(q*10^-3,”Heat transfer rate for vertical tube in kW”)
//rate of condensation
m=q/h_fg;// in kg/s
disp(m,”Rate of condenstion in kg/s”);
```

Scilab code Exa 9.3 `Length of tube and total heat transfer rate`

```
//Exa 9.3
clc;
clear;
close;
format('v',9)
//given data
h_fg=2392*10^3;// in J/kg
rho=993;// in kg/mˆ3
k=0.63;// in W/mK
miu=728*10^-6;// in kJ/m–s
N=10;
T_sat=45.7;// in degree C
T_s=25;// in degree C
d=4*10^-3;// in m
g=9.81;
h_bar = 0.725*[ rho^2*g*h_fg*k^3/(N*miu*d*(T_sat-T_s))]^(1/4);// in W/mˆ2k
m=300/(60*60);
// Formula m=q/h_fg
```

```
q=m*h_fg;
disp(q*10^-3,"Heat transfer rate in kW")
// Formula q=h_bar*%pi*d*L*N^2*(T_sat-T_s)
L=q/(h_bar*%pi*d*N^2*(T_sat-T_s));
disp(L,"Length of tube in m");

// Note: Answer in the book is wrong
```

Scilab code Exa 9.4 `Film thickness`

```
//Exa 9.4
clc;
clear;
close;
format('v',9)
//given data
h_fg=2400*10^3;// in J/kg
rho=993;// in kg/m^3
rho_v=0.0563;// in kg/m^3
t_mf=(40+30)/2;// in degree C
k=0.625;// in W/mK
miu=728*10^-6;// in kJ/m-s
x=0.25;
T_sat=40;// in degree C
T_s=30;// in degree C
g=9.81;

// (a) Thickness of condensate film
delta=[  4*k*(T_sat-T_s)*miu*x/(rho*(rho-rho_v)*g*
   h_fg)     ]^(1/4);// in meter
disp(delta*10^3,"Thickness of condensate film in mm"
   );

//(b) Local value of heat transfer coefficient
hx=k/delta;// in W/m^2
```

```
L=0.5;// in m
hm=4/3*(L/x)^(1/4)*hx;
disp(hm,"Average heat transfer coefficient in W/m^2");
// The heat transfer rate
A=0.5*0.5;// in m^2
q=hm*A*(T_sat-T_s);// in watt
disp(q*10^-3,"The heat transfer rate in kW")

// (c)
theta=45;// in degree
h_vertical=hm;
h_inclined=h_vertical*(sind(theta))^(1/4);
disp(h_inclined,"Average heat transfer coefficient when plate is inclined at 45 degree in W/m^2K");
```

Scilab code Exa 9.5 `Heat transfer rate`

```
//Exa 9.5
clc;
clear;
close;
format('v',9)
//given correlataion
//h_A=5.56*(det_T)^3
//h_P=h_A*(rho/rho_a)^0.4
disp("When temperature excess is 25 degree C at atmospheric pressure")
del_T=25;// in degree C
h_A=5.56*(del_T)^3;// in W/m^2K
disp(h_A*10^-3,"The heat transfer coefficient in kW/m^2K");
// and at 20 bar
rho=20;
rho_a=1;
```

```
h_P=h_A*(rho/rho_a)^0.4;// in W/m^2
disp(h_P*10^-3,"Value of h_P in kW/m^2")
```

Chapter 10

Mass Transfer

Scilab code Exa 10.1 `Molar concentration and molar and mass diffusion`

```
//Exa 10.1
clc;
clear;
close;
//given data
format('v',13);
P1=4;// in bar
P2=2;// in bar
T=25;// in degree C
Dhp=9*10^-8;// in m^2/s
S=3*10^-3;// in kg mole/m^3 bar
del_x=0.5*10^-3;// thickness in m
//(a) The molar concentration of a gas in terms of solubility
CH1=S*P1;// in kg mole/m^3
CH2=S*P2;// in kg mole/m^3
//(b) Molar diffusion flux of hydrogen through plastic memberence is given by Fick's law of diffision
//N_H= N_h/A = Dhp*(CH1-CH2)/del_x;
N_H= Dhp*(CH1-CH2)/del_x;// in kg mole/s-m^2
```

```
disp(N_H,"Molar diffusion flux of hydrogen through the membrane in kg mole/s-m^2");
//Mass_d_Flux= N_H*Molecular_Weight
Molecular_Weight=2;
Mass_d_Flux= N_H*Molecular_Weight
disp(Mass_d_Flux,"Molar diffusion flux in kg/s-m^2");
```

Scilab code Exa 10.2 `Diffusion coefficient of hydrogen`

```
//Exa 10.2
clc;
clear;
close;
//given data
format('v',13);
T=25;// in degree C
T=T+273;// in K
P=1;
V1=12;//Molecular volume of H2 in cm^3/gm mole
V2=30;//Molecular volume of Air in cm^3/gm mole
M1=2;// Molecular weight of H2
M2=29;// Molecular weight of Air
//The diffusion coefficient for gases in terms of molecular volumes may be express as
D_AB= .0043*T^(3/2)/(P*(V1^(1/3)+V2^(1/3)))*(1/M1+1/M2)^(1/2);
disp(D_AB,"The diffusion coefficient for gases in terms of molecular volumes in cm^2/sec");
```

Scilab code Exa 10.3 `Diffusion coefficient of NH3`

```
//Exa 10.3
```

```
clc;
clear;
close;
//given data
format('v',13);
T=300;// temp of gas mixture in K
D_HN2=18*10^-6;// in m^2/s at 300 K, 1 bar
T1=300;// in K
D_HO2=16*10^-6;// in m^2/s at 273 K, 1 bar
T2=273;// in K
O_2=0.2;
N_2=0.7;
H_2=0.1;
//The diffusivity at the mixture temperature and pressure are calculated as
// D1/D2 = (T1/T2)^(3/2)*(P2/P1)
D_HO2= (T/T2)^(3/2)*1/4*D_HO2;
D_HN2= (T/T1)^(3/2)*1/4*D_HN2;
//The composition of oxygen and nitrogen on a H2 free basis is
x_O= O_2/(1-H_2);
x_N= N_2/(1-H_2);

// The effective diffusivity for the gas mixture at given temperature and pressure is
 D= 1/(x_O/D_HO2+x_N/D_HN2);// in m^2/s
 disp(D,"Effective diffusivity in m^2/s")
```

Scilab code Exa 10.4 `Mass flow rate`

```
//Exa 10.4
clc;
clear;
close;
//given data
```

```
format('v',9);
d=3;// in mm
d=d*10^-3;// in meter
T=25;// in  C
T=T+273;// in K
D= 0.4*10^-4;// in m^2/s
R= 8314;
P_A1=1;// in atm
P_A1=P_A1*10^5;// in w/m^2
P_A2=0;
C_A2=0;
x2= 15;// in meter
x1= 0;
A= %pi/4*d^2;
M_A= D*A/(R*T)*(P_A1-P_A2)/(x2-x1);// in kg mole/sec
N_B= M_A;
M_B= M_A*29;// in kg/sec
disp(N_B,"Value of N_B in kg mole/sec")
disp(M_B,"Value of M_B in kg /sec")
```

Scilab code Exa 10.5 `Diffusion flux rate`

```
//Exa 10.5
clc;
clear;
close;
//given data
format('v',13);
P=3;// in atm
P=P*10^5;// in N/m^2
r1=10;// in mm
r1=r1*10^-3;// in m
r2=20;// in mm
r2=r2*10^-3;// in m
R=4160;// in J/kg–K
```

```
T=303;// in K
D=3*10^-8;// in m^2/s
S=3*0.05; // Solubility of hydrogen at a pressure of 3 atm in m^3/m^3 of rubber tubing
del_x=r2-r1;// in m
L=1;// in m
Am=2*%pi*L*del_x/log(r2/r1);
//Formula P*V= m*R*T
V=S;
m=P*V/(R*T);// in kg/m^3 of rubber tubing at the inner surface of the pipe
C_A1=m;
C_A2=0;
//Diffusion flux through the cylinder is given
M=D*(C_A1-C_A2)*Am/del_x;
disp(M,"Diffusion flux through the cylinder in kg/sm")
```

Scilab code Exa 10.6 `Loss of H2 by diffusion`

```
//Exa 10.6
clc;
clear;
close;
//given data
format('v',15);
R=4160;// in J/kg-K
M=2;
D_AB=1.944*10^-8;// in m^2/s
R_H2=R/M;
S=2*0.0532; // Solubility of hydrogen at a pressure of 2 atm in cm^3/cm^3 of pipe
P=2;// in atm
P=P*1.03*10^5;// N/m^2
T=25;// in degree C
```

```
T=T+273;// in K
r1=2.5;// in mm
r1=r1*10^-3;// in m
r2=5;// in mm
r2=r2*10^-3;// in m
del_x=r2-r1;// in m
L=1;// in m
//Formula P*V= m*R*T
V=S;
m=P*V/(R*T);// in kg/m^3 of pipe
// So, Concentration of H2 at inner surface of the
    pipe
C_A1=0.0176;// in kg/m^3
// The resistance of diffusion of H2 away from the
    outer surface is negligible i.e.
C_A2=0;
Am=2*%pi*L*del_x/log(r2/r1);
// Loss of H2 by diffusion
M_A= D_AB*(C_A1-C_A2)*Am/del_x;
disp(M_A,"Loss of H2 by diffusion in kg/s");


//Note: In the book , they put wrong value of C_A1
    to calculate M_A, so the answer in the book is
    wrong
```

Scilab code Exa 10.7 `Time taken to evaporate`

```
//Exa 10.7
clc;
clear;
close;
//given data
format('v',15);
Px1= 0.14;// in bar
```

```
Px2= 0;
P=1.013;// in bar
Py1=P-Px1; // in bar
Py2=P-Px2; // in bar
D=8.5*10^-6;// in m^2/s
d=5;// diameter in meter
L=1;// in mm
L=L*10^-3;//in meter
M=78;// molecular weight
Am_x= 1/4*%pi*d^2*M;
R=8314;
del_x=3;// thickness in mm
del_x=del_x*10^-3;// in m
T=20;// in degree C
T=T+273;// in K
P=P*10^5;// in N/m^2
m_x= D*Am_x*P*log(Py2/Py1)/(R*T*del_x);
// The mass of the benzene to be evaporated
mass= 1/4*%pi*d^2*L;
density=880;// in kg/m^3
m_b= mass*density;
toh=m_b/m_x;// in sec
disp(toh,"Time taken for the entire organic compound
    to evaporate in seconds")


// Note: Answer in the book is wrong
```

Scilab code Exa 10.8 Diffusion Flux rate of air

```
//Exa 10.8
clc;
clear;
close;
//given data
```

```
format('v',8);
A=0.5;// in m^2
Pi=2.2;// in bar
Pi=Pi*10^5;// in N/m^2
Pf=2.18;// in bar
Pf=Pf*10^5;// in N/m^2

T=300;// in K
S=0.072;// in m^3
V=0.028;// in m^3
L=10;// in mm
L=L*10^-3;// in meter
R=287;
// Diffusivity of air in rubber D
// Initial mass of air in the tube
mi= Pi*V/(R*T);// in kg
//final mass of air in the tube
mf= Pf*V/(R*T);// in kg
// Mass of air escaped
 ma = mi-mf;//in kg
// Formula Na = ma/A = mass of air escaped / Time elapsed * area
A=6*24*3600*0.5;
Na = ma/A;//in kg/sm^2
// Solubility of air should be calculated at mean temperature
S_meanTemperature=(2.2+2.18)/2;// in bar
//Solubility of air at the mean inside Pressure is
S=S*S_meanTemperature;// in m^3/m^3 of rubber
disp("The air which escapes to atmosphere will be 1 bar and its solubility will remain at 0.72 m^3 of air per m^3 of rubber");
V1=S;
V2=0.072;
T1=T;
T2=T;
P1=2.19*10^5;// in N/m^2
P2=1*10^5;// in N/m^2
```

```
// The corresponding mass concentration at the inner and outer surface of the tube, from gas equation are calculated as
Ca1= P1*V1/(R*T1);// in kg/m^3
Ca2= P2*V2/(R*T2);// in kg/m^3
// The diffusion flux rate of air through the rubber is given by
// Na = ma/A = D*(Ca1-Ca2)/del_x , here
del_x=L;
D=Na*del_x/(Ca1-Ca2);
disp(D,"Diffusivity of air in rubber in m^2/s");
```