

Scilab Textbook Companion for  
Heat And Mass Transfer  
by V. K. Dwivedi<sup>1</sup>

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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.

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# Chapter 1

## Introduction To Heat Transfer

Scilab code Exa 1.1 Rate of heat transfer

```
1 //Exa 1.1
2 clc;
3 clear;
4 close
5 // given data
6 t1=38; // in degree C
7 t2=21; // in degree C
8 k=0.19; // unit less
9 x=4; //in cm
10 x=x*10^-2; // in meter
11 // Formula  $q=k*A*(t1-t2)/x$ ;
12 q_by_A=k*(t1-t2)/x;
13 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

```
1 //Exa 1.2
```

```

2  clc;
3  clear;
4  close
5  // given data
6  t_i=120; // in degree C
7  t_o=40; // in degree C
8  K=0.04; // unit less
9  x=0.06; //in m
10 Q=50; // in W
11 disp("Assuming steady state heat transfer in the
        wall.");
12 // Rate of heat transfer across the wall = Rate of
        electrical energy dissipation in the furnace
13 // Formula  $Q=K*A*(t_i-t_o)/x$ ;
14 A=Q*x/(K*(t_i-t_o));
15 disp(A,"Area of wall in square meter is : ")

```

---

### Scilab code Exa 1.3 Rate of heat loss

```

1  //Exa 1.3
2  clc;
3  clear;
4  close
5  // given data
6  t_f=30; // in degree C
7  t_s=400; // in degree C
8  d=0.04; //in m
9  h=20; // in W/m^2K
10 l=1; //in meter
11 A=%pi*d*l;
12 q=h*A*(t_s-t_f); // in W
13
14 disp(q,"Rate of heat loss in watt is : ")

```

---

#### Scilab code Exa 1.4 Electric power supplied to coil

```
1 //Exa 1.4
2 clc;
3 clear;
4 close
5 // given data
6 t_s=100; // in degree C
7 t_w=80; // in degree C
8 d=2*10^-3; //in m
9 h=3000; // in W/m^2 degree C
10 L=100; //in mm
11 L=L*10^-3; // in meter
12 A=%pi*d*L;
13 // Heat loss by convection = Electric power supplied
14 // Formula  $h*A*(t_s-t_w) = Q$ 
15 Q= h*A*(t_s-t_w);
16 disp(Q,"Electric power supplied in watt is : ")
```

---

#### Scilab code Exa 1.5 Inside Plate temperature

```
1 //Exa 1.5
2 clc;
3 clear;
4 close
5 // given data
6 A=0.6*0.9; // in square meter
7 x=.025; // in meter
8
9 t_s=310; // in degree C
10 t_f=15; // in degree C
11 h=22; // in W/m^2 degree C
```

```

12 K=45; // in W/m degree C
13 Q_rad=250; // in W
14 // Heat transfer through the plate = Convection heat
    loss + radiation heat loss
15 // Formula Q_cond = Q_conv + Q_rad
16 //  $-K*A*dt/dx = h*A*(t_s-t_f) + F_{g12}*\sigma A(T_s^4 - T_a^4)$ 
    )
17 t_i=x*(h*A*(t_s-t_f)+Q_rad)/(K*A)+t_s;
18 disp(t_i," The inside plate temperature in degree C
    is :");

```

---

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

```

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

```

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

---

### Scilab code Exa 1.7 Rate of heat transfer

```
1 //Exa 1.7
2 clc;
3 clear;
4 close
5 // given data
6 T1=1350;// in degree C
7 T2=50;// in degree C
8 L=25*10^-2;//in meter
9 // Formula q= -k*A*dT/dx
10 // or q/A= -k*dT/dx
11 // let q/A = q_by_A
12 q_by_A=(integrate(' -0.838*(1+0.0007*T)', 'T', T1, T2))
    /(integrate('1', 'x', 0, L));
13 disp(q_by_A,"Heat transfer rate per square meter
    through the cylinder in watt is : ");
14
15 // Note : Answer in the book is wrong
```

---

### Scilab code Exa 1.9 Steady state heat transfer

```
1 //Exa 1.9
2 clc;
3 clear;
4 close
5 // given data
6 K_A=0.5;// in W/m degree C
7 K_B=0.8;// in W/m degree C
8 Ti_A=600;// inside temp. of slab A in degree C
```

```

 9 To_B=100; // outside temp. of slab B in degree C
10 t_A=4*10^-2; // thickness of slab A
11 t_B=6*10^-2; // thickness of slab B
12 // Heat transfer rate per square meter through the
    slab A
13 //  $q/A = +K_A * (Ti_A - T) / t_A$  (1)
14 // Heat transfer rate through slab B
15 //  $q/A = +K_B * (T - To_B) / t_B$  (2)
16 // Equating Eqns (1) and (2)
17 //  $K_A*(Ti_A - T)/t_A = K_B*(T - To_B)/t_B$ 
18 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);
19 disp("T, intermediate temperature of slab A and B is
    : "+string(T)+" degree C");
20 //Putting the value of T in Eq(1), we get
21 q_by_A= K_A*( Ti_A - T) / t_A;
22 disp("Steady state heat transfer rate per square
    meter is : "+string(q_by_A)+" W/m^2")
23 //Note : Answer in the book is wrong

```

---

### Scilab code Exa 1.10 Rate of heat transfer

```

1 //Exa 1.10
2 clc;
3 clear;
4 close
5 // given data
6 La=3*10^-2; // in meter
7 Aa=1; // in m^2
8 ka=150; // in W/m-K
9
10 Lb=8*10^-2; // in meter
11 Ab=0.5; // in m^2
12 kb=30; // in W/m-K
13

```

```

14 Lc=8*10^-2; // in meter
15 Ac=0.5; // in m^2
16 kc=65; // in W/m-K
17
18 Ld=5*10^-2; // in meter
19 Ad=1; // in m^2
20 kd=50; // in W/m-K
21
22 T1=400; // in degree C
23 T2=60; // in degree C
24
25 Ra=La/(ka*Aa);
26 Rb=Lb/(kb*Ab);
27 Rc=Lc/(kc*Ac);
28 Rd=Ld/(kd*Ad);
29 //The equivalent resistance for Rb and Rc
30 Re=Rb*Rc/(Rb+Rc);
31 //Total Resistance
32 sigmaR=Ra+Re+Rd;
33 // heat transfer rate per square meter
34 q=(T1-T2)/sigmaR;
35 disp("Heat transfer rate per square meter is : "+
      string(q)+" Watt");

```

---

**Scilab code Exa 1.11** Temperature drop across the contact joint

```

1 //Exa 1.11
2 clc;
3 clear;
4 close
5 // given data
6 k_A1=202; // in W/mK
7 x_A1=0.005; // in m
8 del_T=80; // in degree C
9 R_contact=0.88*10^-4; // in m^2K/W

```

```

10 sigmaR=x_A1/k_A1+R_contact+x_A1/k_A1; // in m^2K/W
11 q=del_T/sigmaR; // in W/m^2
12 //Temperature drop across the rough surface
13 del_T=q*R_contact; //in degree C
14 disp(del_T,"Temperature drop across the rough
    surface in degree C is :")

```

---

### Scilab code Exa 1.12 Heat transfer rate

```

1 //Exa 1.12
2 clc;
3 clear;
4 close
5 // given data
6 T1=100; // in degree C
7 T2=10; // in degree C
8 A=3*5; //in square meter
9 x=40*10^-2; // thickness in m^2
10 k=1.6; // in W/mk
11 h=10; // in W/m^2k
12 // Total resistance in heat flow path
13 sigmaR=x/(k*A)+1/(h*A);
14 // so heat transfer rate
15 q=(T1-T2)/sigmaR; // in Watt
16 q=q*10^-3; //in kW
17 disp(q,"Heat transfer rate in kW is :");//
18
19 // Note: Answer in the book is wrong

```

---

### Scilab code Exa 1.13 Rate of heat transfer

```

1 //Exa 1.13
2 clc;

```



```

3 clear;
4 close
5 // given data
6 k='2.0+0.0005*T';// in W/m-k
7 A=3*5;//in square meter
8
9 T1=150;// in degree C
10 T2=50;// in degree C
11 L=20*10^-2;// thickness in m^2
12 // Formula q= -k*A*dt/dx
13 q=-A*(integrate(k, 'T', T1, T2))/(integrate('1', 'x', 0, L
    ));// in Watt
14 q=q*10^-3;//in kW
15 disp(q,"Rate of heat transfer in kW is : ");

```

---

#### Scilab code Exa 1.14 Heat transfer rate

```

1 //Exa 1.14
2 clc;
3 clear;
4 close
5 // given data
6 T1=300;//in degree C
7 T2=50;//in degree C
8 x2=2*10^-2;// thickness of boiler wall in m
9 tc2=58;// thermal conductivity of wall in W/mk
10 x3=0.5*10^-2;// thickness of outer surface of the
    wall in m
11 tc3=116*10^-3;// thermal conductivity of outer
    surface of the wall in W/mk
12 R1=2.3*10^-3;// in k/W
13 R2=x2/tc2;
14 R3=x3/tc3;
15 sigmaR=R1+R2+R3;// Total Resistance
16 q=(T1-T2)/sigmaR;

```

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

---

#### Scilab code Exa 1.15 Central temperature

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

---

#### Scilab code Exa 1.16 Equilibrium temperature

```
1 //Exa 1.16  
2 clc;  
3 clear;  
4 close  
5 // given data  
6 E=500;//Absorb solar energy in W/m^2  
7 epsilon= 0.9;
```

```
8 T_s= 280; // in K
9 T_infinite=300; // in K
10 h_c=20; // in W/m^2 degree C
11 T_sky=280; // in K
12 sigma=5.67*10^-8;
13 // Formula E= h_c*(T_p-T_infinite)+epsilon*sigma*(
    T_P^4-T_s^4)
14 // On simplification T_P= 340.6-0.255*T_p^4
15 T_p= 315.5; // in K
16 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

```
1 //Exa 2.5
2 clc;
3 clear;
4 close;
5 //given data
6 r1=5; // in cm
7 r2=5+4; // in cm
8 r3= 9+2.5; // in cm
9 k1=0.0701; // in W/mK
10 k2=0.1; // in W/mK
11 L=20; // in m
12 disp("Saturation temperature of steam at  $171 \times 10^4$  N/
      m2 is 204.36 degree C. So temperature of steam
      passing through the pipe is =  $204.36 + 30 = 234.36$ 
      degree C")
13 T1=234.36; // in degree C
14 T3=24; // in degree C
15 sigmaR= (log(r2/r1)/(2*pi*k1*L) + log(r3/r2)/(2*pi
      *k2*L));
```

```

16
17
18 // Part (i)
19 q=(T1-T3)/sigmaR;// in watt
20 disp(q,"Heat transfer rate in watt");
21
22 // Part(ii)
23 // Formula q= (T1-T2)/(log(r2/r1)/(2*%pi*k1*L))
24 T2 =T1- (q*(log(r2/r1)/(2*%pi*k1*L)));
25 disp(T2,"Interface temperature of insulation in
    degree ")

```

---

**Scilab code Exa 2.6** Percentage increase in heat transfer rate

```

1 //Exa 2.6
2 clc;
3 clear;
4 close;
5 //given data
6 k_brick=0.93;// in W/mK
7 k_insulation=0.12;// in W/mK
8 k_wood=0.175;// in W/mK
9 k_Al=204;// in W/mK
10 k1=k_brick;
11 k2=k_insulation;
12 k3=k_wood;
13 T1=200;// in degree C
14 T4=10;// in degree C
15 x1=10*10^-2;// in m
16 x2=25*10^-2;// in m
17 x3=1*10^-2;// in m
18 A=0.1;// in m^2
19 sigmaR= x1/(k1*A)+x2/(k2*A)+x3/(k3*A);
20 q1=(T1-T4)/sigmaR;
21 disp(q1,"Heat transfer rate without rivet in Watt");

```

```

22
23 // Heat transfer rate with rivet
24 d=3*10^-2; // in meter
25 x=x1+x2+x3;
26 k_rivet=k_Al;
27 A_rivet=%pi*d^2/4; // in m^2
28 R_rivet= x/(k_rivet*A_rivet);
29 A_eff=A-A_rivet; // in m^2
30 sigmaRw= 1/A_eff*(x1/k1+x2/k2+x3/k3); // in k/W
31 R_eq= R_rivet*sigmaRw/(R_rivet+sigmaRw); // in k/W
32 q2=(T1-T4)/R_eq; // in watt
33 disp(q2,"Heat transfer rate with rivet in Watt");
34 percentIncrease=(q2-q1)*100/q1; // percent increase
    in heat flow due to rivet
35 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 temperature drom

```

1 //Exa 2.7
2 clc;
3 clear;
4 close;
5 //given data
6 k_cu=384; // in W/mK
7 k_s=1.75; // in W/mK
8 k1=k_cu;
9 k2=k_s;
10 hi=221; // in W/m^2K
11 ho=3605; // in W/m^2K
12 Ti=100; // in degree C
13 To=125; // in degree C
14 r1=0.2; // in m
15 r2=0.02+0.006; // in m

```

```

16 r3=0.026+0.003; // in m
17 ri=0.02; // in m
18 L=1; // in m
19 // Part(i)
20 Ao= 2*pi*r3*L;
21 Ai= 2*pi*r1*L;
22 // Formula Uo= 1/Ao*sigmaR
23 Uo= 1/[ r3/(ri*hi) + r3/k1*log(r2/r1) + r3/k2*log(r3
    /r2) + 1/ho ]; // in w/m^2K
24 disp(Uo,"Overall heat transfer coefficient based on
    outer area in W/m^2K");
25
26 //Part(ii)
27 del_T= To-Ti;
28 q=Uo*Ao*del_T;
29 disp(q,"Water to air heat transfer rate in W/m");
30
31 //Part (iii)
32 // Formula q= T/(log(r3/r2)/(2*pi*k*L)) , where T=
    T2-T3 and k=k_s
33 k=k_s;
34 T= q*log(r3/r2)/(2*pi*k*L);
35 disp(T,"Temperature drop across the scale deposited
    in degree C")
36
37 // 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

```

1 //Exa 2.8
2 clc;
3 clear;

```

```

4 close;
5 //given data
6 k=0.175;// in W/mK
7 h_infinite=9.3;// in W/m^2K
8 T_infinite=30;// in degree C
9 T_s=70;// in degree C
10 d=10*10^-3;// in m
11 r=d/2;
12 L=1;// in m
13 rc=k/h_infinite;// in m
14 CriticalThickness = rc-r;// in meter
15 CriticalThickness=CriticalThickness*10^3;
16 disp(CriticalThickness,"Critical thickness in mm");
17
18 q1=2*pi*r*L*h_infinite*(T_s-T_infinite);// in W/m
19 q2= (T_s-T_infinite)/(log(rc/r)/(2*pi*k*L)+1/(2*pi
    *rc*h_infinite));// in W/m
20 PerIncHeatDiss= (q2-q1)*100/q1;
21 disp(PerIncHeatDiss,"Percentage increase in heat
    dissipation rate in %")
22 //Also q1=I1^2*R with bare cable
23 //      q2=I2^2*R with insulated cable
24 I2_by_I1 = sqrt(q2/q1);
25 // ( I2-I1 ) / I1 = (I2_by_I1 -1) / 1
26 // Percentage increase in current carrying capacity
27 PerIncCurrent = (I2_by_I1 -1) / 1 *100;
28 disp(floor(PerIncCurrent),"Increase in current
    carrying capacity in %")

```

---

**Scilab code Exa 2.9** Maximum value of thermal conductivity

```

1 //Exa 2.9
2 clc;
3 clear;
4 close;

```



```

5 //given data
6 k_in=0.3; // in W/mK
7 k_gw=0.038; // in W/mK
8 ro=1.5; // in cm
9 ho=12; // in W/m^2 degree C
10 rc=k_in/ho; // in m
11 rc=rc*10^2; // in cm
12 disp(rc,"Critical radius in cm")
13 if ro<rc then
14     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");
15     disp("and hence it is not effective")
16 end
17 ro=ro*10^-2; // in meter
18 // For effective insulation
19 // ro>=rc
20 // Kin/ho<= ro
21 roho=ro*ho; // in W/mK
22 /// Kin<= ro*ho
23 disp(roho,"Maximum value of thermal conductivity in
        W/mK")

```

---

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

```

1 //Exa 2.10
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',9)
7 d=1.2*10^-3; // in m
8 r=d/2; // in m

```

```

9 rc=1.8*10^-3; // in m
10 T1=100; // in degree C
11 T_infinite=30; // in degree C
12 k=0.3; // in W/mK
13 h=10; // in W/m^2K
14 L=1; // in m
15 ke=5.1*10^7;
16 q=(T1-T_infinite)/(log(rc/r)/(2*pi*k)+1/(2*pi*rc*h
    )); // in W/m
17 // Volume of wire for one meter length
18 vol= %pi*r^2*L; // in m^3
19 disp("in steady state heat transfer process, the
    heat produced by the wire is dissipated to
    surrounding.")
20 // Heat produced per unit volume of the wire
21 HeatProduced= q/vol; // in w/m^2
22 // Formula HeatProduced= I^2*R = I^2/ke
23 I=sqrt(HeatProduced*ke); // in amp/m^2
24 // Area of wire
25 A= %pi*r^2;
26 // so current carrying capacity of the given wire
27 Current= I*A;
28 disp(Current,"The current carried by the copper wire
    in ampere")

```

---

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

```

1 //Exa 2.11
2 clc;
3 clear;
4 close;
5 //given data
6 d_i=.1; // inner dia in m
7 r_i=d_i/2; // in m
8 Ti=473; // in K

```

```

 9 T_infinite=293; // in K
10 k=1; // in W/mK
11 h=8; // in W/m^2K
12 rc=k/h; // in m
13 disp(rc," Critical radius in meter");
14 //when
15 ro=rc;
16 q_by_L= (Ti-T_infinite)/(log(rc/r_i)/(2*pi*k)+1/(2*
    pi*rc*h)); // in W/m
17 disp(q_by_L,"Heat loss per meter length of pipe in W
    /m")
18
19 // 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

```

1 //Exa 2.12
2 clc;
3 clear;
4 close;
5 //given data
6 r1=100*10^-3; // in m
7 r2=200*10^-3; // in m
8 q1=1.16*10^5; // in W/m^2
9 t2=30; // in degree C
10 k=50; // in W/mK
11 L=1; // in m
12 // Total heat passing through the cylinder q
13 //q=q1*2*pi*r1*L (1)
14 // and heat conducted through the cylinder
15 // q= 2*pi*k*L(t1-t2)/log(r2/r1) (2)
16 // From (1) and (2)
17 t1= t2+ q1*2*pi*r1*L*log(r2/r1)/(2*pi*k*L); // in

```

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

---

**Scilab code Exa 2.13** Maximum steady state current

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

---

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

```
1 //Exa 2.16
2 clc;
3 clear;
```

```

4 close;
5 //given data
6 d1=10*10^-3;// in mm
7 r1=d1/2;
8 K=0.2;// in W/mK
9 T_max=177;// in degree C
10 T_infinite=27;// in degree C
11 ho=10;// in W/m^2K
12 R=10; // in W/m
13 rc=K/ho;// in m
14 x=rc-r1;// in m
15 q_by_L= (T_max-T_infinite)/(log(rc/r1)/(2*%pi*K)
           +1/(2*%pi*ho*rc));
16 // Also q_by_L = I^2*R
17 I= sqrt(q_by_L/R);// in amp
18 disp(I,"The maximum possible current in ampere")
19
20 // 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

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

```

19 disp("m = "+string(m));
20 disp("Temperature distribution equation is ")
21 disp("theta/theta_0= (T-T_infinite)/(T_0-T_infinite)
      = %e^-"+string(m)+"*x");
22
23 //(ii)Heat loss from the rod
24 t_0=100;// in degree C
25 t_infinite=20;// in degree C
26 q=sqrt(K*A*h*rho)*(t_0-t_infinite);
27 disp("(ii) Heat loss from the road is : "+string(q)+
      " watt");

```

---

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

```

1 //Exa 3.2
2 clc;
3 clear;
4 close
5 // given data
6 format('v',13);
7 d=3;// in cm
8 d=d*10^-2;//in m
9 h=20;// in W/m^2K
10 T1=140;// in degree C
11 T2=100;// in degree C
12 L=15*10^-2;// in meter
13 T_infinite=30;// in degree C
14 // Let at
15 x=0;T_0=T1;
16 x=15;//in cm
17 x=x*10^-2;// in m
18 T=100;// in degree C
19 rho=%pi*d;
20 A=%pi*d^2/4;
21 // Formula (T-T_infinite)/(T_0-T_infinite) = %e^-m*x

```

```

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

```

---

### Scilab code Exa 3.3 Fin efficiency

```

1 //Exa 3.3
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',9);
7 t=1;// in mm
8 t=t*10^-3;// in meter
9 L= 10;// in mm
10 L= L*10^-3;// in meter
11 k= 380;// W/mK
12 To= 230;// in C
13 T_inf= 30;// in C
14 h= 40;// in W/m^2K
15 B= 1;// in meter
16 Ac= B*t;// in m^2
17 rho= 2*(B+t);
18 m= sqrt(h*rho/(k*Ac));
19 // Part(a)
20 nita= tanh(m*L)/(m*L)*100;// fin efficiency in %
21 disp(nita,"Fin efficiency in %");
22
23 // Part(b)
24 N=1000/9+1;// number of fin
25 Af= N*rho*L;// in square meter
26 A1= 1;// plate area in m^2
27 A2= N*1*1*10^-3;// Area where fins are attached in

```



```

    square meter
28 Au= A1-A2;// in square meter
29 q_T= N*sqrt(h*rho*k*Ac)*(To-T_inf)*tanh(m*L)+Au*h*(
    To-T_inf);// in W/m^2
30 disp(q_T*10^-3,"Total heat transfer per square meter
    of plane wall surface in kW/m^2")
31
32 // Part(c)
33 A=1*1;// in m^2
34 q= h*A*(To-T_inf);// in W/m^2
35 disp(q*10^-3,"Heat transfer if there were no fins
    attached in kW/m^2")
36
37 // Note : Answer of part(b) in the book is wrong

```

---

#### Scilab code Exa 3.4 Heat loss by the fin

```

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

```

```
18 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

```
1 //Exa 3.5
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',13)
7 w=1;// in meter
8 L=2.5*10^-2;// in meter
9 t=0.8*10^-3;// in meter
10 l=1;// in meter
11 T_0=150;// in degree C
12 T_infinite=40;// in degree C
13 h=20;// in W/m^2K
14 k=65;// in W/mK (for 18.8 steel)
15 Ac=w*t;
16 d=5*10^-2;// Cylinder dia in meter
17 rho=2*(w+t);
18 rho=floor(rho);
19
20 m=sqrt(h*rho/(k*Ac));
21 mL=m*L;
22 // heat transfer rate from 12 fins
23 q_fin=12*k*Ac*m*(T_0-T_infinite)*[(tanh(m*L)+h/(k*m)
    )/(1+h/(m*k)*tanh(m*L))];
24 disp("Heat transfer rate from 12 fins si : "+string(
    q_fin)+" watt");
25 Au=%pi*d*l-12*w*t;
26 qu=h*Au*(T_0-T_infinite);
27 disp("Now heat transfer from unfinned surface area
    is : "+string(qu)+" watt");
```

```

28 q=q_fin+qu;
29 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 rod

```

1 //Exa 3.6
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',5)
7 T_0=100;// in degree C
8 T_infinite=30;// in degree C
9 T_L=100;// in degree C
10 d=6*10^-3;// copper rod dia in meter
11 L=50*10^-2;// developed length in meter
12 Ac=%pi*d^2/4;// in square meter
13 rho=%pi*d;// in meter
14 h=30;// in W/m^2K
15 k=330;// in W/mK
16 m=sqrt(h*rho/(k*Ac));
17 //(i) Temperature distribution equation for the fin
18 // (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)
19 //Temperature at
20 x=0.25;// in m
21 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;
22 disp("(i) Temperature at the centre of the rod is :
      "+string(T)+" degree C");
23 disp("(ii) Heat transfer rate from the fin- This is

```

```

    equivalent to two fins of length 25 cm long with
    insulated tip")
24 L=25*10^-2; // in meter
25 q=2*sqrt(h*rho*k*Ac)*(T_0-T_infinite)*tanh(m*L);
26 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 flow out the source and heat flow rate at the free end

```

1 //Exa 3.7
2 clc;
3 clear;
4 close;
5 //given data
6 T_0=100; // in degree C
7 T_infinite=25; // in degree C
8 d=5*10^-2; // in meter
9 L=15*10^-2; // in meter
10 h=8; // in W/m^2K
11 k=20; // in W/mK
12 rho=%pi*d; // in meter
13 Ac=%pi*d^2/4; // in square meter
14 m=sqrt(h*rho/(k*Ac));
15
16 //(i) Temperature distribution in the rod
17 disp("(i) Temperature distribution in the rod")
18 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))")
19
20 //(ii) Temperature at free end i.e. at
21 x=L;
22 // Formula (T_L-T_infinite)/(T_0-T_infinite)= 1/(
    cosh(m*L)+h/(k*m)*sinh(m*L) )

```

```

23 T_L=(1/(cosh(m*L)+h/(k*m)*sinh(m*L) ))*(T_0-
    T_infinite)+T_infinite;
24 disp("(ii) Temperature at free end is : "+string(T_L
    )+" degree C");
25
26 //(iii) Heat flow out the source means heat transfer
    from the fin
27 q_f=sqrt(h*rho*k*Ac)*(T_0-T_infinite)*[(h/(k*m)+tanh
    (m*L))/(1+h*tanh(m*L)/(k*m))];
28 disp("(iii) Heat flow out the source : "+string(q_f)
    +" watt");
29
30 //(iv) Heat flow rate at free end
31 q_L=h*Ac*(T_L-T_infinite);
32 disp("(iv) Heat flow rate at free end is : "+string(
    q_L)+" watt");

```

---

### Scilab code Exa 3.8 Rate of heat transfer

```

1 //Exa 3.8
2 clc;
3 clear;
4 close;
5 //given data
6 T_0=150;// in degree C
7 T_infinite=40;// in degree C
8 w=1;// in m
9 t=0.75*10^-3;// in m
10 d=5*10^-2;// in meter
11 L=25*10^-3;// in meter
12 k=75;// in W/mK
13 h=23.3;// in W/m^2K
14 N=12;// numbers of fins
15 Ac=w*t;//in square meter
16 rho=2*(w+t);// in meter

```

```

17 delta=Ac/rho;
18 L_c=L+delta;
19 ML_c=L_c*sqrt(h*rho/(k*Ac))
20 q_fin= N*sqrt(h*rho*k*Ac)*(T_0-T_infinite)*tanh(ML_c
    );
21 q_fin=floor(q_fin);
22 A_0=%pi*d*w-12*Ac
23 q_unfin= h*A_0*(T_0-T_infinite);
24 q_total=q_fin+q_unfin;
25 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 flow out the source and heat flow rate

```

1 //Exa 3.9
2 clc;
3 clear;
4 close;
5 disp("Temperature distribution equation for fin with
    insulated end is ");
6 disp("(T-T_infinite)/(T_0-T_infinite)= cosh(m*(L-x))
    /cosh(m*L)");
7
8 //given data
9 L=0.06; // in meter
10 A=4.64*10^-4; // in m^2
11 rho=0.12; // in m
12 h=442; // in W/m^2
13 T_0=773; // in K
14 T_infinite=1143; // in K
15 K=23.2; // in W/mK
16 m=sqrt(h*rho/(K*A));
17 q=sqrt(h*rho*K*A)*(T_0-T_infinite)*tanh(m*L);
18 disp("Heat transfer rate is : "+string(q)+" watt");

```

```
19
20 // Note: Answer in the book is wrong
```

---

### Scilab code Exa 3.10 Measurement error

```
1 //Exa 3.10
2 clc;
3 clear;
4 close;
5 //given data
6 L=0.12; // in meter
7 t=.15*10^-2; // thickness in m
8 K=55.5; // in W/mK
9 h=23.5; // in W/mK
10 T_L=357; // in K
11 T_0=313; // in K
12
13 // Formula  $m=\sqrt{h*\rho/(K*A)}$  and  $\rho=\pi*d$  and  $A=\pi*d*t$ , putting value of rho and A
14 m=sqrt(h/(K*t));
15 mL=m*L;
16 mL=floor(mL);
17 // Formula  $(T_L-T_{infinite})/(T_0-T_{infinite})=1/\cosh(mL)$ 
18 T_infinite=(T_L-T_0/cosh(mL))/(1-1/cosh(mL));
19 T_infinite=ceil(T_infinite);
20 measurement_error=T_infinite-T_L;
21 disp("Measurement Error is : "+string(
    measurement_error)+" K")
22
23 // Note: In the book, Unit of answer is wrong
```

---

### Scilab code Exa 3.11 Measurement error percent

```

1 //Exa 3.11
2 clc;
3 clear;
4 close;
5 //given data
6 k=20; // in W/mK
7 T_L=150; // in degree C
8 T_0=70; // in degree C
9 L=12*10^-2; // in meter
10 h=80; // in W/m^2K
11 t=3*10^-3; // in m
12 // Formula  $m=\sqrt{h*\rho/(K*A)}$  and  $\rho=\pi*d$  and  $A=\pi*d*t$ , putting value of rho and A
13 m=sqrt(h/(k*t));
14 // Formula  $(T_L-T_{infinite})/(T_0-T_{infinite})=1/\cosh(m*L)$ 
15 T_infinite=(T_L-T_0/cosh(m*L))/(1-1/cosh(m*L));
16 PercentageError=(T_infinite-T_L)*100/T_infinite;
17 disp("Percentage Error is : "+string(PercentageError)+" %");

```

---

**Scilab code Exa 3.12** Minimum length of pocket

```

1 //Exa 3.12
2 clc;
3 clear;
4 close;
5 //given data
6 k=30; // in W/mK
7 h=100; // in W/m^2K
8 T_infinite=300; // in degree C
9 d=2*10^-2; // in m
10 t=1*10^-3; // in m
11 err=1; // in % of applied temperature difference
12 // Formula  $m=\sqrt{h*\rho/(K*A)}$  and  $\rho=\pi*d$  and  $A=\pi*d*t$ 

```



```

    %pi*d*t, putting value of rho and A
13 m=sqrt(h/(k*t));
14
15 // From (T_L-T_infinite)/(T_0-T_infinite)= 1/100 =
    1/cosh(m*L)
16 L=acosh(100)/m;// in meter
17 L=L*10^3;// in mm
18 disp("Minimum length os pocket is : "+string(L)+" mm
    ");

```

---

### Scilab code Exa 3.13 Length of shaft

```

1 //Exa 3.13
2 clc;
3 clear;
4 close;
5 //given data
6 k=32;// in W/m^2 degree C
7 h=14.8;// in W/m^2 degree C
8 t_o=480;// in degree C
9 t_i=55;// in degree C
10 t_a=20;// in degree C
11 d=2.5*10^-2;// in m
12 rho=%pi*d;// in m
13 Ac=%pi*d^2/4;// in m^2
14 m=sqrt(h*rho/(k*Ac));
15 disp("In this case, the shaft heat from the pump
    towards motor");
16 disp("The temperature distribution considering the
    shaft as a fin insulated at the tip is given by")
17 disp("Q/Q_o= (t-t_a)/(t_o-t_a) = cosh(m(L-x))/cosh(m
    *L)")
18 // From (t-t_a)/(t_o-t_a) = cosh(m(L-x))/cosh(m*L)
19 L=acosh((t_o-t_a)/(t_i-t_a))/m; // at x=L,t=t_i
20 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

```
1 //Exa 4.1
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',9)
7 L=1; // in m
8 rho=1600; // in kg/m^3
9 k=40; // in w/mK
10 Cp=4*10^3; // in J/kgK
11 a=900; // in degree C
12 b=-300; // in degree C/m
13 c=-50; // in degree C/m^2
14 Qg=1*10^3; // in kW/m^2
15 A=10; // area in m^2
16 //t=a+b*x+c*x^2 at any instant, so
17 // dtBYdx= b+2*c*x
18 // d2tBYdx2 = 2*c, then
19
20 // Part(a)
21 //q1= -k*A*dtBYdx , at
```

```

22 x=0;
23 q1= -k*A*(b+2*c*x); // in w
24 //q2= -k*A*dtBYdx , at
25 x=L;
26 q2= -k*A*(b+2*c*x); // in w
27 E_stored= (q1-q2)+Qg*A*L; // in watt
28 disp(E_stored,"The rate of change of energy storage
    in watt")
29
30 // Part(b)
31 alpha= k/(rho*Cp); // in m^2s
32 d2tBYdx2 = 2*c;
33 dtBYdtoh= alpha*(d2tBYdx2+Qg/k ); // in degree C/sec
34 disp(dtBYdtoh,"Rate of change of temperature in
    degree C/sec");
35 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 Instantaneous rate of heat transfer

```

1 //Exa 4.2
2 clc;
3 clear;
4 close;
5 //given data
6 k=40; // in W/mK
7 rho=7800; // in kg/m^3
8 C=450; // in J/kgK
9 d=20*10^-3; // in m
10 r=d/2;
11 t_i=400; // in degree C
12 t=85; // in degree C
13 t_infinite=25; // in degree C

```

```

14 h=80; // in W/m^2K
15 //l_s=V/A = (4/3*pi*r^3)/(4*pi*r^2) = r/3
16 l_s=r/3; // in m
17 Bi= h*l_s/k;
18 // since Biot number is less than 0.1, hence lumped
    heat capacity system analysis can be applied
19
20 // Part(a)
21 // Formula (t-t_infinite)/(t_i-t_infinite)= %e^(-h*A
    *toh/(rho*V*C)) = %e^(-h*toh/(rho*l_s*C))
22 toh= -log((t-t_infinite)/(t_i-t_infinite))*(rho*l_s*
    C)/h; // in sec
23 disp(toh,"The time require to cool the sphere in sec
    ");
24
25 // Part(b)
26 // dtBYdtoh = h*A*(t_i-t_infinite)/(rho*V*C) = h*(
    t_i-t_infinite)/(rho*l_s*C)
27 dtBYdtoh = h*(t_i-t_infinite)/(rho*l_s*C); // in
    degree C/sec
28 disp(dtBYdtoh,"Initial rate of cooling in degree C/
    sec");
29
30 // Part(c)
31 A=4*pi*r^2;
32 toh=60;
33 q_in= h*A*(t_i-t_infinite)*%e^(-h*toh/(rho*l_s*C));
    // in watt
34 disp(q_in,"Instantaneous heat transfer rate in watt"
    );
35
36 // Part(d) Total energy transferred during first one
    minute
37 V=4/3*pi*r^3;
38 TotalEnergy = rho*C*V*(t_i-t_infinite)*(1-%e^(-h*toh
    /(rho*C*l_s)));
39 disp(TotalEnergy,"Total energy transferred during
    first one minute in watt")

```

40

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

---

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

```
1 //Exa 4.3
2 clc;
3 clear;
4 close;
5 //given data
6 k=40; // in W/mK
7 rho=8200; // in kg/m^3
8 C=400; // in J/kgK
9 D=6*10^-3; // in m
10 R=D/2;
11 t_i=30; // in degree C
12 t_infinite1=400; // for 10 sec in degree C
13 t_infinite2=20; // for 10 sec in degree C
14 h=50; // in W/m^2K
15
16 // Part(a)
17 //l_s= V/A = R/3
18 l_s= R/3; // in m
19 //toh= rho*V*C/(h*A) = rho*C*l_s/h
20 toh= rho*C*l_s/h; // in sec
21 disp(toh,"Time constance in sec")
22
23 // Part (b)
24 Bi= h*l_s/k;
25 // 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
26 toh=10; // in sec
```

```

27 // (t-t_infinite1)/(t_i-t_infinite1)= %e^(-h*A*toh/(
    rho*V*C)) = %e^(-h*toh/(rho*l_s*C))
28 t= %e^(-h*toh/(rho*l_s*C))*(t_i-t_infinite1)+
    t_infinite1;// in degree C
29
30 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)+" .")
31 t_i=t;
32 toh=20;// in sec
33 t= %e^(-h*toh/(rho*l_s*C))*(t_i-t_infinite2)+
    t_infinite2;// in degree C
34 disp(t,"The temperature attained by junction in
    degree C");
35
36 // 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

```

1 //Exa 4.4
2 clc;
3 clear;
4 close;
5 //given data
6 k=8;// in W/mK
7 alpha=4*10^-6;// in m^2/s
8 h=50;// in W/m^2K
9 D=6*10^-3;// in m
10 R=D/2;
11 T=0.5;// where T = (t-t_infinite)/(t_i-t_infinite)
12 //l_s= V/A = R/3
13 l_s= R/2;// in m
14 Bi= h*l_s/k;

```

```

15 // since Bi < 0.1 , hence lumped heat capacity
    analysis can be applied
16 // toh= rho*V*C/(h*A) = rho*C*l_s/h = k*l_s/(h*alpha
    )
17 toh= k*l_s/(h*alpha); // in seconds
18 disp(toh,"time constant in seconds");
19 // It is given that (t-t_infinite)/(t_i-t_infinite)
    = 0.5 = %e^(-h*A*c/(rho*V*C)) = %e^(-h*c/(rho*
    l_s*C)) = %e^(-h*alpha*c/(l_s))
20 // or (t-t_infinite)/(t_i-t_infinite) = %e^(-h*alpha
    *c/(l_s));
21 c= -log(T)*l_s/(h*alpha); // in sec
22 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

```

1 //Exa 4.5
2 clc;
3 clear;
4 close;
5 //given data
6 //t=450-500*x+100*x^2+150*x^3 at any instant , so
7 // dtBYdx= -500+200*x+450*x^2
8
9 L=0.5; // thickness of the wall in meter
10 k=10; // in W/mK
11 // Rate of heating entering in the wall per unit
    area , at
12 x=0;
13 //q1= -k*dtBYdx
14 q1= -k*(-500+200*x+450*x^2); // in W/m^2
15 // Rate of heat going out of the wall per unit area
    , at
16 x=L;

```



```

17 q2= -k*(-500+200*x+450*x^2); // in W/m^2
18 E=q1-q2; // in W/m^2
19 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 temp of 40 deg C

```

1 //Exa 4.6
2 clc;
3 clear;
4 close;
5 //given data
6 k=385; // in W/mK
7 h=100; // in W/m^2K
8 delta =2*10^-3; // thickness of plate in meter
9 A=25*25; // area of plate in square meter
10 rho=8800; // kg/m^3
11 C=400; // J/kg-K
12 // l_s= V/A= L*B*delta/(2*L*B) = delta/2
13 l_s= delta/2; // in meter
14 Bi= h*l_s/k;
15 // since Bi < 0.1 , hence lumped heat capacity
    analysis can be applied
16
17 // Part(i)
18 // toh= rho*V*C/(h*A) = rho*C*l_s/h
19 toh= rho*C*l_s/h; // in second
20 disp(toh,"Time constant in seconds");
21
22 // Part(ii)
23 t_i=400; // in degree C
24 t=40; // in degree C
25 t_infinite=25; // in degree C
26 // (t-t_infinite)/(t_i-t_infinite) = %e^(-h*A*toh
    /(rho*V*C)) = %e^(-h*toh/(rho*l_s*C))

```

```

27 toh= -log((t-t_infinite)/(t_i-t_infinite))*rho*C*l_s
    /h;// in sec
28 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

```

1 //Exa 4.7
2 clc;
3 clear;
4 close;
5 //given data
6 k=380;// in W/mK
7 delta =6*10^-2;// thickness of plate in meter
8 rho=8800;// kg/m^3
9 C=400;// J/kg-K
10 // l_s= V/A = delta/2
11 l_s= delta/2;// in meter
12 t=80;// in degree C
13 t_i=200;// in degree C
14 t_inf=30;// in degree C
15 hw= 75;// in W/m^2K
16 ha= 10;// in W/m^2K
17
18 // Part(i)
19 // 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
20 // (ha+hw)*A*(t-t_inf) = -rho*V*C*dtBYdtho
21 // (ha+hw)/(rho*C*V)*A*dtho = -dt/(t-t_inf)
22 // integrate('(ha+hw)/(rho*V*C)*A','toh',0,toh) =
    integrate('1/(t-t_inf)','t',t_i,t)
23 toh= -rho*l_s*C/(ha+hw)*log((t-t_inf)/(t_i-t_inf));
24 disp("Time required to cool plate to 80 degree C is
    : "+string(toh)+" seconds = "+string(toh/60)+"

```

```

    minutes");
25
26 // Part (ii)
27 t= -rho*l_s*C/(2*ha)*log((t-t_inf)/(t_i-t_inf));
28 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

```

1 //Exa 4.8
2 clc;
3 clear;
4 close;
5 //given data
6 k=45; // in W/m degree C
7 d =0.1; // in meter
8 l =0.30; // in meter
9 t=800; // in degree C
10 t_i=100; // in degree C
11 t_infinite=1200; // in degree C
12 h= 120; // in W/m^2 degree C
13 alpha=1.2*10^-5; // in meter
14 rhoC= k/alpha;
15 V=%pi/4*d^2*l; // in m^3
16 A= %pi*d*l + 2*%pi/4*d^2; // in m^2
17 // l_s= V/A = (%pi/4*d^2*l)/(%pi*d*l + 2*%pi/4*d^2)
    = d*l/(4*l+2*d^2)
18 l_s = d*l/(4*l+2*d^2);
19 Bi= h*l_s/k;
20 // since Bi < 0.1 , hence lumped heat capacity
    analysis can be applied
21 // (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))

```

```

22 toh = -log((t-t_infinite)/(t_i-t_infinite))*rhoC*l_s
    /h;// in sec
23
24 // So, the velocity of ingot passing through the
    furnace
25 FurnaceLength = 8*100;// in cm
26 time = toh;
27 Velocity = FurnaceLength/time;// in cm/sec
28 disp(Velocity,"Maximum speed in cm/sec")

```

---

**Scilab code Exa 4.9** Junction diamete and time required for the thermo-  
couple junction

```

1 //Exa 4.9
2 clc;
3 clear;
4 close;
5 //given data
6 rho=8500;// in kg/m^3
7 C=400;// J/kgK
8 toh=1;// in sec
9 h= 400;// in W/m^2 degree C
10 t=198;// in degree C
11 t_i=25;// in degree C
12 t_infinite=200;// in degree C
13
14 // Part (1)
15 // toh =rho*V*C/(h*A) = rho*C*l_s/h
16 l_s= toh*h/(rho*C);
17 // l_s = V/A = r/3
18 r=3*l_s;// in m
19 r=r*10^3;// in mm
20 d=2*r;// in m
21 disp(d,"Junction diameter needed for the
    thermocouple in mili miter");

```

```

22
23 // Part(ii)
24 // toh= -rho*V*C/(h*A)*log((t-t_infinite)/(t_i-
    t_infinite))
25 toh = -toh*log((t-t_infinite)/(t_i-t_infinite));
26 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 slab

```

1 //Exa 4.10
2 clc;
3 clear;
4 close;
5 //given data
6 L=40*10^-2;// in m
7 k=1.5;// in W/mK
8 A=4;// in square meter
9 alpha=1.65*10^-3;// in m^2/h
10 //T = 50-40*x+10*x^2+20*x^3-15*x^4 , so
11 // dtBYdx= -40+20*x+60*x^2-60*x^3
12 // d2tBYdx2 = 20+120*x-180*x^2
13
14 // Part (a) Heat entering the slab
15 //q1= -k*A*dtBYdx , at
16 x=0;
17 qi= -k*A*(-40+20*x+60*x^2-60*x^3);// in w
18 disp(qi,"Heat entering the slab in watt")
19 // Heat leaving the slab
20 //q1= -k*A*dtBYdx , at
21 x=L;
22 q1= -k*A*(-40+20*x+60*x^2-60*x^3);// in w
23 disp(q1,"Heat leaving the slab in watt")
24
25 // Part (b) Rate of heat storage

```

```

26 RateOfHeatStorage = qi-ql; // in watt
27 disp(RateOfHeatStorage,"Rate of heat storage in watt
    ");
28
29 // Part (c) Rate of temperature change
30 // d2tBYdx2 = 1/alpha*dtBYdtoh
31 // dtBYdtoh= alpha*d2tBYdx2, at
32 x=0;
33 dtBYdtoh = alpha*(20+120*x-180*x^2); // in degree C/h
34 disp(dtBYdtoh,"The rate of temperature change at
    entering the slab in degree C/h")
35 // dtBYdtoh= alpha*d2tBYdx2, at
36 x=L
37 dtBYdtoh = alpha*(20+120*x-180*x^2); // in degree C/h
38 disp(dtBYdtoh,"The rate of temperature change at
    leaving the slab in degree C/h")
39
40 // Part (d) for the rate of heating or cooling to be
    maximum
41 // dBYdx of dtBYdtoh = 0
42 // dBYdx of (alpha*d2tBYdx2) =0
43 // d3tBYdx3 = 0
44 x=120/360; // in meter
45 disp(x,"The point where rate of heating or cooling
    is maximum in meter")

```

---

**Scilab code Exa 4.11** Time required for cooling process

```

1 //Exa 4.11
2 clc;
3 clear;
4 close;
5 //given data
6 k=40; // in W/m degree C
7 d =12*10^-3; // in meter

```

```

8 t=127; // in degree C
9 t_i=877; // in degree C
10 t_infinite=52; // in degree C
11 h= 20; // in W/m^2 degree C
12 rho=7800; // in W/m^2K
13 C=600; // in J/kg K
14 r=d/2; // in meter
15 //l_s = V/A = r/3
16 l_s = r/3;
17 Bi= h*l_s/k;
18 // since Bi < 0.1 , hence lumped heat capacity
    analysis can be applied
19 // (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))
20 toh = -log((t-t_infinite)/(t_i-t_infinite))*rho*C*
    l_s/h; // in sec
21 disp("Time required for cooling process : "+string(
    toh)+" seconds or "+string(toh/60)+" minutes")

```

---

#### Scilab code Exa 4.12 Time to keep furnace

```

1 //Exa 4.12
2 clc;
3 clear;
4 close;
5 //given data
6 D=10*10^-2; // in m
7 b=D/2;
8 h= 100; // in W/m^2 degree C
9 T_o=418; // in degree C
10 T_i=30; // in degree C
11 T_infinite=1000; // in degree C
12
13 disp(" (A) For copper cylinder ");

```

```

14 k=350; // in W/mK
15 alpha=114*10^-7; // in m^2/s
16 Bi= h*b/k;
17 theta_0_t = (T_o-T_infinite)/(T_i-T_infinite);
18 Fo=18.8;
19 // Formula Fo= alpha*t/b^2
20 t=Fo*b^2/alpha;
21 disp("Time required to reach for the cylinder
        centreline temperature 418 degree C : "+string(t)
        +" seconds or "+string(t/3600)+" hours")
22
23 // (2) Temperature at the radius of 4 cm
24 theta_0_t = 0.985;
25 // Formula theta_0_t = (T-T_infinite)/(T_o-
        T_infinite)
26 T= theta_0_t*(T_o-T_infinite)+T_infinite; // in
        degree C
27 disp(T,"Temperature at the radius of 4 cm ")
28 disp("It has very less temperature gradients over 4
        cm radius")
29
30 disp(" (B) For asbestos cylinder ");
31 k=0.11; // in W/mK
32 alpha=0.28*10^-7; // in m^2/s
33 Bi= h*b/k;
34 theta_0_t = (T_o-T_infinite)/(T_i-T_infinite);
35 Fo=0.21;
36 // Formula Fo= alpha*t/b^2
37 t=Fo*b^2/alpha;
38 disp("Time required to reach for the cylinder
        centreline temperature 418 degree C : "+string(t)
        +" seconds or "+string(t/3600)+" hours")
39
40 // (2) Temperature at the radius of 4 cm
41 theta_x_t = 0.286;
42 // Formula theta_x_t = (T-T_infinite)/(T_o-
        T_infinite)
43 T= theta_x_t*(T_o-T_infinite)+T_infinite; // in

```



```

    degree C
44 disp(T,"Temperature at the radius of 4 cm ")
45 disp("It has large temperature gradients")

```

---

#### Scilab code Exa 4.13 Centre temperature

```

1 //Exa 4.13
2 clc;
3 clear;
4 close;
5 //given data
6 D=5*10^-2;// in m
7 b=D/2;
8 h= 500;// in W/m^2 degree C
9 k=60;// in W/m^2K
10 rho=7850;// in kg/m^3
11 C=460;// in J/kg
12 alpha=1.6*10^-5;// in m^2/s
13 T_i=225;// in degree C
14 T_infinite=25;// in degree C
15 t=2;// in minute
16
17 // Part(i)
18 Bi= h*b/k;
19 Fo= alpha*t/b^2;
20 theta_0_t = 0.18;
21 // Formula theta_0_t = (T_o-T_infinite)/(T_i-
    T_infinite)
22 T_o= theta_0_t*(T_i-T_infinite)+T_infinite;// in
    degree C
23 disp(T_o,"Centreline Temperature of the sphere after
    2 minutes of exposure in degree C ") ;
24
25 // Part(2)
26 depth= 10*10^-3;// in meter

```

```

27 r=b-depth;// in meter
28 rBYb=r/b;
29 theta_x_t = 0.95;
30 // Formula theta_x_t = (T-T_infinite)/(T_o-
    T_infinite)
31 T= theta_x_t*(T_o-T_infinite)+T_infinite;// in
    degree C
32 disp(T,"The Temperature at the depth of 1 cm from
    the surface after 2 minutes in degree C ") ;
33
34 // Part (3)
35 BiSquareFo= Bi^2*Fo;
36 QbyQo= 0.8;// in kJ
37 A=4/3*pi*b^3;
38 Qo= rho*A*C*(T_i-T_infinite);// in J
39 Qo=Qo*10^-3;// in kJ
40 // The heat transffered during 2 minute ,
41 Q= Qo*QbyQo;// in kJ
42 disp(Q,"The heat transffered during 2 minutes in kJ"
    )

```

---

# Chapter 5

## Forced Convection Heat Transfer

Scilab code Exa 5.1 Boundary layer thickness

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

```

20 //Since  $Re < 5 \times 10^5$  , hence the flow is a laminar flow
21 //(a) Boundary layer thickness
22 delta= 5*x/(sqrt(Re)); // in m
23 delta=delta*10^2; // in cm
24 disp(delta,"Boundary layer thickness in cm")
25
26 //(b) Thermal boundary layer thickness
27 delta_t= delta/Pr^(1/3); // in cm
28 disp(delta_t,"Thermal boundary layer thickness in ch
    ")
29
30 //(c) Local friction coefficient
31 Cfx= 0.664/sqrt(Re);
32 disp(Cfx,"Local friction coefficient");
33 Cf=2*Cfx;
34 disp(Cf,"Average friction coefficient");
35
36 //(d) Total drag force
37 A=.25*.2; // in m^2
38 toh_o=Cf*(rho*V^2/2);
39 F=toh_o*A;
40 disp(F,"Total drag force in N");
41
42 //(e)
43 // Formula  $Nux = hx*x/k = 0.332*Re^{(1/2)}*Pr^{(1/3)}$ 
44 hx= 0.332*k/x*Re^(1/2)*Pr^(1/3); // in W/m^2K
45 disp(hx,"Local heat transfer coefficient in W/m^2K")
46 h=2*hx;
47 disp(h,"Average heat transfer coefficient in W/m^2K"
    )
48 //(f)
49 q=h*A*(t_s-t_infinite);
50 disp(q,"Rate of heat transfer in W/m^2K");
51
52 //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

```
1 //Exa 5.2
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',9)
7 rho=998; // in kg/m^3
8 k=.648; // in W/mK
9 v= 0.556*10^-6; // in m^2/s
10 Pr=3.54;
11 V=2; // in m/s
12 t_infinite= 10; // in degree C
13 t_s=90; // in degree C
14 Re=5*10^5;
15 A=1*1; // in m^2
16 // Re= rho*Vx/miu = V*x/v
17 x=Re*v/V; // in m
18 disp(x,"Length of the plate in m")
19
20
21 // Nu = h*x/k =Pr^(1/3)*(0.037*Re^0.8-872)
22 x=1;
23 Re= V*x/v;
24 h= Pr^(1/3)*(0.037*Re^0.8-873)*k/x; // in W/m^2
25 q=h*A*(t_s-t_infinite);
26 disp(q*10^-3,"Heat transfer from entire plate in kW"
    )
```

---

### Scilab code Exa 5.3 Heat transfer rate

```

1 //Exa 5.3
2 clc;
3 clear;
4 close;
5 //given data
6
7 rho=1.06; // in kg/m^3
8 K=.0289;
9 v= 18.97*10^-6; // in m^2/s
10 Pr=0.696;
11 V=2.2; // in m/s
12 L=0.9; // in m
13 B=0.45; // in m
14 t_infinite= 30; // in degree C
15 t_s=90; // in degree C
16 //(a) For first half of the plate
17 x=L/2; // in m
18 Re=V*x/v;
19 // Nu = h*x/K = 0.664*Re^(1/2)*Pr^(1/3)
20 h= 0.664*Re^(1/2)*Pr^(1/3)*K/x; // in W/m^2 degree C
21 A=x*B;
22 Q1=h*A*(t_s-t_infinite); // in watt
23 disp(Q1,"Heat transfer rate from first half of the
    plate in watt");
24
25 //(b) Heat transfer from entire plate
26 x=L; // in m
27 Re=V*x/v;
28 // Nu = h*x/K = 0.664*Re^(1/2)*Pr^(1/3)
29 h= 0.664*Re^(1/2)*Pr^(1/3)*K/x; // in W/m^2 degree C
30 A=L*B;
31 Q2=h*A*(t_s-t_infinite); // in watt
32 disp(Q2,"Heat transfer rate from entire plate in
    watt");
33
34 //(c) From next half of the plate
35 Q3= Q2-Q1;
36 disp(Q3,"Heat transfer rate from next half of the

```

plate”)

---

#### Scilab code Exa 5.4 Length of tube

```
1 //Exa 5.4
2 clc;
3 clear;
4 close;
5 //given data
6 rho=985;// in kg/m^3
7 k=.654;// in W/mK
8 Cp=4.18;// in kgJ/kgK
9 Cp=Cp*10^3;// in J/kgK
10 v= 0.517*10^-6;// in m^2/s
11 Pr=3.26;
12 V=1.2;// in m/s
13 t_s=85;// in degree C
14 t_i=40;// in degree C
15 t_o=70;// in degree C
16 Ax=15*35;// in mm
17 P=15+35;
18 de=4*Ax/(2*P);// in mm
19 de=de*10^-3;// in m
20 Re=V*de/v;
21 // Formula Nu= h*de/k = 0.023Re^0.8*Pr^0.4
22 h=0.023*Re^0.8*Pr^0.4*k/de;// in W/m^2K
23 m=%pi*de^2*V*rho/4;
24 d=de;
25 L=m*Cp*log((t_s-t_i)/(t_s-t_o))/(%pi*d*h);
26 disp(L,"The length of tube in meter")
```

---

#### Scilab code Exa 5.5 Average heat transfer coefficient

```

1 //Exa 5.5
2 clc;
3 clear;
4 close;
5 //given data
6 k=.026; // in W/mK
7 v= 16.8*10^-6; // in m^2/s
8 miu=2*10^-5; // in kg/ms
9 Pr=0.708;
10 V=15; // in m/s
11 x=2; // in m
12 A=2*1; // in m^2
13 Re=V*x/v;
14 del_t=40-10; // in degree C
15 // since Re > 3 *10^5, hence turbulent flow at x=2 m
    length of laminar flow region is x_L then
16 Re_1=3*10^5;
17 // Re_1 = 3*10^5 = V*x_L/v
18 x_L= Re_1*v/V;
19
20 // Part (a)
21 //Nu= h*x_L/k = 0.664*Re_1^(1/2)*Pr^(1/3);
22 h= 0.664*Re_1^(1/2)*Pr^(1/3)*k/x_L; // in W/m^2
23 disp(h,"The average heat transfer coefficient over
    the laminar boundary layer in W/m^2 ");
24
25 // Part(b)
26 //Nu= h*x/k = (0.037*Re^0.8-872)*Pr^(1/3);
27 h= (0.037*Re^0.8-872)*Pr^(1/3)*k/x; // in W/m^2
28 disp(h,"The average heat transfer coefficient over
    entire plate in W/m^2 ");
29
30 // Part (c)
31 q=h*A*del_t;
32 disp(q,"Total heat transfer rate in watt");
33
34 // 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

```
1 //Exa 5.6
2 clc;
3 clear;
4 close;
5 //given data
6 rho=997; // in kg/m^3
7 k=0.608; // in W/mK
8 Cp= 4180; // in J/kg K
9 miu=910*10^-6; // in Ns/m^2
10 d=30*10^-3; // in m
11 m=0.02; // in kg/s
12 t_o=30; // in degree C
13 t_i=20; // in degree C
14 Re= 4*m/(%pi*d*miu);
15 q_desh=12*10^3; // in W/m^2
16 // since Re < 2300, flow is laminar one
17
18 // Part(a)
19 // Nu = h*d/k = 4.36
20 h=4.36*k/d;
21 disp(h,"Heat transfer coefficient in W/m^2K");
22
23 // Part (b)
24 L=m*Cp*(t_o-t_i)/(q_desh*%pi*d);
25 disp(L,"Length of pipe in meter");
26
27 // Part(c)
28 // q_desh= h*(t_infinite-t_o)
29 t_infinite = q_desh/h+t_o;
30 disp(t_infinite,"The inner tube surface temperature
    at the outlet in degree C");
```

```

31
32 // Part(d)
33 f=64/Re;
34 disp(f,"Friction Factor ");
35
36 // Part(e)
37 V=4*m/(%pi*d^2*rho); // in m/s ( because m= rho*V*A
    , m= rho*V*%pi*d^2/4 )
38 del_P= f*L*rho*V^2/(d*2); // in N/m^2
39 disp(del_P,"The pressure drop in the pipe in N/m^2")
    ;
40
41 // 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

```

1 //Exa 5.7
2 clc;
3 clear;
4 close;
5 //given data
6 rho=977.3; // in kg/m^3
7 kf=0.665; // in W/mK
8 Cp= 4186; // in J/kg K
9 miu=4.01*10^-4; // in kg/m-s
10 Pr=2.524;
11 d=0.02; // in m
12 m=0.5; // in kg/s
13 t_o=70; // in degree C
14 t_i=20; // in degree C
15 t_s=100; // in degree C
16 Re= 4*m/(%pi*d*miu);
17
18 // Since Re > 2300, flow is turbulent flow. Then

```

```

    Nusselt Number
19 // Nu = h*d/k = 0.023*Re^0.8*Pr^0.4
20 h=0.023*Re^0.8*Pr^0.4*kf/d; // in W/m^2
21 disp(h,"Average heat transfer coefficient in W/m^2")
    ;
22 L=m*Cp*log((t_s-t_i)/(t_s-t_o))/(%pi*d*h); // in
    meter
23 disp(L,"Length of tube in meter");
24
25
26 // 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

```

1 //Exa 5.8
2 clc;
3 clear;
4 close;
5 //given data
6 rho=977; // in kg/m^3
7 k=0.608; // in W/mK
8 Cp= 4180; // in J/kg K
9 miu=910*10^-6; // in poise
10 d=0.02; // in m
11 m=0.02; // in kg/s
12 t_o=40; // in degree C
13 t_i=10; // in degree C
14 q_desh= 20*10^3; // in W/m^2
15
16 // Part (a)
17 Re= 4*m/(%pi*d*miu);
18 disp(Re,"Reynold number is :")
19

```

```

20 // Part(b)
21 // Nu = h*d/k = 4.364
22 h=4.364*k/d;
23 disp(h,"Heat transfer coefficient in W/m^2K");
24
25 // Part (c)
26 // q= q_desh*A = m*Cp*(t_o-t_i)
27 // q_desh *( %pi*d*l) = m*Cp*(t_o-t_i)
28 l=m*Cp*(t_o-t_i)/(q_desh*%pi*d);
29 disp(l,"Length of pipe in meter");

```

---

#### Scilab code Exa 5.9 Tube length

```

1 //Exa 5.9
2 clc;
3 clear;
4 close;
5 //given data
6 rho=7.7*10^3; // in kg/m^3
7 k=12; // in W/mK
8 Cp= 130; // in J/kg degree C
9 Pr=0.011;
10 delta=8*10^-8; // in m^2/s
11
12
13 d=0.06; // in m
14 m=4; // in kg/s
15 t_i=200; // in degree C
16 del_t=25; // in degree C
17 miu=rho*delta;
18 Re= 4*m/(%pi*d*miu);
19 // From correlation Nu =h*d/k = 4.82+0.0185*Pe
    ^0.827
20 Pe=Re*Pr;
21 h=(4.82+0.0185*Pe^0.827)*k/d; // in W/m^2K

```

```

22 // Length of tube required by doing every balance
23 //  $m \cdot C_p \cdot \Delta t = h \cdot A \cdot (t_s - t_b) = h \cdot (\pi \cdot d \cdot l) \cdot (t_s - t_b)$  // its given  $(t_s - t_b) = 40$  degree C
24 l= m*Cp*del_t/(h*(%pi*d)*40); // in meter
25 disp(l,"Length of tube in meter");

```

---

**Scilab code Exa 5.10** Heat transfer rate from the cylinder

```

1 //Exa 5.10
2 clc;
3 clear;
4 close;
5 //given data
6 d=0.058; // in m
7 t_infinite=30; // in degree C
8 t_s=155; // in degree C
9 V=52; // in m/s
10 T_f=(t_s+t_infinite)/2; // in degree C
11 T_f=T_f+273; // in K
12 // Fluid properties at 92.5 degree C and 1 atm
13 miu= 2.145*10^-5; // in kg/ms
14 Pr=0.696;
15 P=1.0132*10^5;
16 R=287;
17 k=0.0312; // in W/mK
18 rho=P/(R*T_f); // in kg/m^3
19 Re=rho*V*d/miu;
20 C=0.0266;
21 n=0.805;
22 //  $Nu = h \cdot d / k = C \cdot (Re)^n \cdot Pr^{(1/3)}$ 
23 h=C*(Re)^n*Pr^(1/3)*k/d; // in W/m^2K
24 //So, heat transfer rate per unit length from
    cylinder
25 q_by_L= h*(%pi*d)*(t_s-t_infinite); // in W/m
26 disp(q_by_L,"Heat transfer rate per unit length from

```

```

        cylinder in W/m");
27
28
29 // 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

```

1 //Exa 5.11
2 clc;
3 clear;
4 close;
5 //given data
6 delta=15.68*10^-6; // in m^2/s
7 t_infinite=25+273; // in K
8 t_s=80+273; // in K
9 t_infinite=25+273; // in K
10 k=0.02625; // in W/m degree C
11 Pr=0.708;
12 miu_infinite=1.846*10^-5; //in kg/ms
13 miu_s= 2.076*10^-5; // in kg/ms
14 d=10*10^-3; // in m
15 V=5; // in m/s
16 A=4*%pi*(d/2)^2;
17 Re=V*d/delta;
18 Nu= 2+ (0.4*Re^(1/2)+0.06*Re^(2/3))*Pr^0.4*(
    miu_infinite/miu_s)^(1/4);
19 // Nu = h*d/k
20 h=Nu*k/d; // in W/m^2K
21 // heat transfer rate
22 q=h*A*(t_s-t_infinite); // in watt
23 disp(q,"Heat transfer rate in watt")

```

---

### Scilab code Exa 5.12 Heat transfer coefficient

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

---

### Scilab code Exa 5.13 Heat transfer rate

```
1 //Exa 5.13
2 clc;
3 clear;
4 close;
5 //given data
6 Cp=0.138; // in KJ/kg-K
```

```

7 m=8.33; // in kg/sec
8 Pr=0.0238;
9 k=8.7; // in W/mk
10 d=1.5*10^-2; // in m
11 miu=1.5*10^-3; // in kg/ms
12
13 Re=4*m/(%pi*miu*d);
14 Pe=Re*Pr;
15 // Nu = h*d/k = 7+0.025*Pe^0.8
16 h= (7+0.025*Pe^0.8)*k/d; // in W/m^2 degree C
17 disp(h,"Heat transfer coefficient in W/m^2 degree C"
    );

```

---

#### Scilab code Exa 5.14 Heat transfer rate

```

1 //Exa 5.14
2 clc;
3 clear;
4 close;
5 //given data
6 rho=887; // in kg/m^3
7 Pr=0.026;
8 k=25.6; // in W/mk
9 d=2.5*10^-2; // in m
10 miu=0.58*10^-3; // in kg/ms
11 V=3; // in m/s
12
13 Re=rho*V*d/(miu);
14 Pe=Re*Pr;
15 Nu = 4.8+0.015*Pe^0.85*Pr^0.08
16 h= Nu*k/d; // in W/m^2 degree C
17 disp(h,"Heat transfer coefficient in W/m^2 degree C"
    );
18
19 //Note: There is some difference in coding and book

```



answer because they did not take accurate calculation

---

**Scilab code Exa 5.15** Initial rate of heat loss

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

```
1 //Exa 6.1
2 clc;
3 clear;
4 close;
5 //given data
6 // (i) when
7 x=.3; // in m
8 T_s=100; // in degree C
9 T_infinite=30; // in degree C
10 T_f=(T_s+T_infinite)/2; // in degree C
11 T_f=T_f+273; // in K
12 Beta=1/T_f;
13 // Other fluid properties at film temperature
14 Pr=0.703;
15 K=0.0301; // in W/mK
16 T=1.8*10^-5 ; // in m^2/s
17 g=9.81;
18 del_T=T_s-T_infinite;
19 Gr=(g*Beta*del_T*x^3)/T^2;
20 Ra=Gr*Pr;
21 disp(" Rayleigh Number is : "+string(Ra));
```

```

22 //Since Ra<10^9, hence flow is laminar , then
    correlation for vertical plate in laminar flow
23 // Formula Nu=0.59*Ra^(1/4)=h*x/K
24 h=0.59*Ra^(1/4)*K/x;// in W/m^2K
25 A=2*.3*.5;
26 q1=h*A*(T_s-T_infinite);
27 disp("Heat transfer rate from the plate , when the
    vertical height is 0.3 m : "+string(q1)+" W");
28
29 //(ii) when
30 x=0.5;// in m
31 Gr=(g*Beta*del_T*x^3)/T^2;
32 Ra=Gr*Pr;
33 // Formula Nu=0.59*Ra^(1/4)=h*x/K
34 h=0.59*Ra^(1/4)*K/x;// in W/m^2K
35 q2=h*A*(T_s-T_infinite);
36 disp("Heat transfer rate from the plate , when the
    vertical height is 0.5 m : "+string(q2)+" W");
37 PercentageDecrease=(q1-q2)/q1*100;
38 disp("Percentage decreases in heat transfer rate
    when x=0.5 m as compared to when x=0.3 m is : "+
    string(PercentageDecrease)+" %")
39
40 //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

```

1 //Exa 6.2
2 clc;
3 clear;
4 close;
5 //given data
6 Pr=0.694;
7 K=0.0296;// in W/mK

```

```

8 rho=1.029; // in kg/m^3
9 miu=20.6*10^-6; // in poise
10 x=.2; // in m
11 T_s=110; // in degree C
12 T_infinite=30; // in degree C
13 T_f=(T_s+T_infinite)/2; // in degree C
14 T_f=T_f+273; // in K
15 Bita=1/T_f;
16 g=9.81;
17 del_T=T_s-T_infinite;
18 Gr=(rho^2*g*Bita*del_T*x^3)/miu^2;
19 Ra=Gr*Pr;
20 //since Rayleigh number is less than 10^10, hence
21 Nu=0.68*Pr^(1/2)*Gr^(1/4)/((.952+Pr)^(1/4));
22 h=Nu*K/x;
23 A=2*0.2*1;
24 q=h*A*(T_s-T_infinite);
25 disp("Heat transfer rate is : "+string(q)+" W");

```

---

### Scilab code Exa 6.3 Heat loss from the pipe

```

1 //Exa 6.3
2 clc;
3 clear;
4 close;
5 //given data
6 d=7.5*10^-2; // in m
7 x=2; // in m
8 T_s=70; // in degree C
9 T_infinite=10; // in degree C
10 del_T=T_s-T_infinite;
11 g=9.81;
12 calculation=4.5*10^10; // value of g*Bita*rho^2*C_p
    /(miu*k)
13 K=2.75*10^-2; // in W/mK

```

```

14 //  $g \cdot \text{Beta} \cdot \rho^2 \cdot C_p / (\text{miu} \cdot k) = g \cdot \text{Beta} \cdot \rho^2 / \text{miu}^2 \cdot$ 
     $\text{miu} \cdot C_p / k = (g \cdot \text{Beta} \cdot \text{del}_T \cdot x^3 / T^2 \cdot \text{miu} \cdot C_p / k) /$ 
     $(\text{del}_T \cdot x^3)$ 
15 GrxPr= calculation*del_T*x^3; // value of Gr*Pr
16 Nu= 0.13*(GrxPr)^(1/3);
17 // Formula Nu = h*x/k
18 h= Nu*K/x; // in W/m^2K
19 A=2*%pi*d;
20 q=h*A*(del_T); // in W
21 q=q*60*60; // in J/h
22 disp("Heat transfer rate is : "+string(q)+" J/h");

```

---

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

```

1 //Exa 6.4
2 clc;
3 clear;
4 close;
5 //given data
6 m=15; // in kg
7 C_p=420; // in J/kg K
8 T_s=200; // in degree C
9 T_infinite=30; // in degree C
10 T_f=(T_s+T_infinite)/2; // in degree C
11 T_f=T_f+273; // in K
12 Pr=0.688;
13 K=0.0321; // in W/mK
14 delta=23.18*10^-6; // in m^2/s
15 Beta=1/T_f;
16 g=9.81;
17 x=0.3; // in m
18 del_T=T_s-T_infinite;
19 Gr=(g*Beta*del_T*x^3)/delta^2;
20 Ra=Gr*Pr;

```

```

21 //Since Ra<10^9, hence it is laminar flow using the
    relation
22 // Formula Nu=0.59*Ra^(1/4)=h*x/K
23 h=0.59*Ra^(1/4)*K/x;// in W/m^2K
24 disp("(i) Heat transfer coefficient is : "+string(h)
    +" W/m^2K")
25
26 // (b) Initial rate of cooling
27 // Formula h*A*(T_s-T_infinite) = m*C_p*dt_by_toh
28 A=2*0.3*0.5;
29 dt_by_toh = h*A*(T_s-T_infinite)/(m*C_p);// in
    degree C/sec
30 dt_by_toh=dt_by_toh*60;// in degree C /min
31 disp("(ii) Initial rate of cooling of the plate is :
    "+string(dt_by_toh)+" degreeC /min");
32
33 //(c) Time taken by plate to cool from 200 degree C
    to 50 degree C
34 T_i=200;// in degree C
35 T=50;// in degree C
36 // Formula (T-T_infinite)/(T_i-T_infinite)= %e^(-h*A
    *toh/(m*C_p));
37 toh= -log((T-T_infinite)/(T_i-T_infinite))*m*C_p/(h*
    A);// in sec
38 toh=toh/60;// in min
39 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

```

1 //Exa 6.5
2 clc;
3 clear;
4 close;

```

```

5 //given data
6 rho=0.8;// in kg/m^3;
7 C_p=1.01;// in KJ/kg K
8 Pr=0.684;
9 d=15*10^-2;// diameter in meter
10 K=0.035;// in W/mK
11 delta=2.78*10^-5;// in m^2/s
12 g=9.81;
13 x=2;// in m
14 T_s=250;// in degree C
15 T_infinite=30;// in degree C
16 T_f=(T_s+T_infinite)/2;// in degree C
17 T_f=T_f+273;// in K
18 Bita=1/T_f;
19 del_T=T_s-T_infinite;
20 disp("Heat Transfer (loss) from plate= heat loss
      from vertical part + heat transfer from
      horizontal part by convection + heat transfer by
      radiation ")
21
22 //Heat loss from vertical part by free convection
23
24 Gr=(g*Bita*del_T*x^3)/delta^2;
25 Ra=Gr*Pr;
26 //Since Ra>10^9, hence turbulent flow
27 // Formula Nu= h*x/K =0.13*Ra^(1/3)
28 h=0.13*Ra^(1/3)*K/x;// in W/m^2K
29 A=2*%pi*d;
30 q1=h*A*del_T;// w
31 q1=q1*10^-3;// in kW
32 disp("Heat loss from vertical part is : "+string(q1)
      +" kW")
33
34 //Heat loss for Horizontal part
35 // here
36 x=d;
37 Gr=(g*Bita*del_T*x^3)/delta^2;
38 Ra=Gr*Pr;

```

```

39 //Since Ra<10^9, hence laminar fluid flow
40 // Formula Nu= h*x/K =0.53*Ra^(1/4)
41 h=0.53*Ra^(1/4)*K/x; // in W/m^2K
42 A=%pi*d*8;
43 q2=h*A*del_T; // w
44 q2=q2*10^-3; // in kW
45 disp("Heat loss for horizontal part is : "+string(q2
    )+" kW")
46
47 //Heat loss by radiation
48 sigma=5.67*10^-8;
49 epsilon=0.65; // emissivity of steel
50 A=%pi*d*10;
51 T_s=T_s+273; // in K
52 T_infinite=T_infinite+273; // in K
53 q3=sigma*A*epsilon*(T_s^4-T_infinite^4); // in w
54 q3=q3*10^-3; // in kW
55 disp("Heat loss by radiation is : "+string(q3)+" kW"
    )
56
57 //Total heat loss
58 theta=q1+q2+q3;
59 disp("Total heat loss is : "+string(theta)+" kW");
60
61
62 //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

```

1 //Exa 6.6
2 clc;
3 clear;
4 close;
5 //given data

```



```

6 rho=1.205; // in kg/m^3;
7 C_p=1006; // in J/kg K
8 Pr=0.71;
9 K=0.0256; // in W/mK
10 delta=1.506*10^-5; // in m^2/s
11 T_s=35; // in degree C
12 T_infinite=5; // in degree C
13 T_f=(T_s+T_infinite)/2; // in degree C
14 T_f=T_f+273; // in K
15 Beta=1/T_f;
16 del_T=T_s-T_infinite;
17 g=9.81;
18 // Formula 1/x= 1/Lh + 1/Lv
19 Lh=50; // in cm
20 Lv=50; // in cm
21 x=Lh*Lv/(Lh+Lv); // in cm
22 x=x*10^-2; // in m
23
24 // Formula Gr=(g*Beta*del_T*x^3)/delta^2;
25 Gr=(g*Beta*del_T*x^3)/delta^2;
26 Ra=Gr*Pr;
27 // Formula Nu= h*x/K =0.53*Ra^(1/4)
28 h=0.53*Ra^(1/4)*K/x; // in W/m^2K
29 A=2*(0.5+0.5);
30 q=h*A*del_T; // w
31 disp("Heat loss per meter length of pipe is : "+
      string(q)+" watt")
32
33 // 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

```
1 //Exa 6.7
```

```

2  clc;
3  clear;
4  close;
5  //given data
6  L=3; // in m
7  delta=0;
8  hx='10*x^(-1/4)';
9  // (a) Average heat transfer coefficient
10 h=1/L*integrate(hx,'x',delta,L);
11 disp("(a) Average heat transfer coefficient is : "+
      string(h)+" W/m^2K")
12
13 // (b) Heat transfer rate
14 A=3*.3; // in m^2
15 Tp=170; // plate temp. in degree C
16 Tg=30; // gas temp. in degree C
17 del_T=Tp-Tg;
18 q=h*A*del_T; // in W
19 disp("(b) Heat transfer rate is : "+string(q)+" W")
20
21 // (c)
22 x=2; // in m
23 qx_by_A= 10*x^(-1/4)*(Tp-Tg);
24 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

```

1 //Exa 6.8
2 clc;
3 clear;
4 close;
5 //given data
6 Pr=0.712;
7 K=0.026; // in W/mK

```

```

8 delta=1.57*10^-5; // in m^2/s
9 T_s=320; // in K
10 T_infinite=280; // in K
11 del_T=T_s-T_infinite;
12 T_f=(T_s+T_infinite)/2; // in K
13 Bita=1/T_f;
14 d1=20; // in cm
15 d2=30; // in cm
16 x=(d2-d1)/2; // in cm
17 x=x*10^-2; // in m
18 g=9.81;
19 Gr=(g*Bita*del_T*x^3)/delta^2;
20 Ra=Gr*Pr;
21
22 // Formula Nu= h*x/K =0.228*Ra^(0.226)
23 h=0.228*Ra^(0.226)*K/x; // in W/m^2K
24 A=%pi*(d1*10^-2)^2;
25 q=h*A*del_T; // w
26 disp("Heat transfer rate is : "+string(q)+" watt");

```

---

### Scilab code Exa 6.9 Heat transfer and overall heat transfer coefficient

```

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

```

```

14 T_s=80; // in degree C
15 T_infinite=20; // in degree C
16 T_f=(T_s+T_infinite)/2; // in degree C
17 T_f=T_f+273; // in K
18 Bita=1/T_f;
19 g=9.81;
20 del_T=T_s-T_infinite;
21 Pr=miu*Cp/K;
22 Gr=(rho^2*g*Bita*del_T*d^3)/miu^2;
23
24 // Formula Nu= h*d/K = 0.53*(Gr*Pr)^(1/4);
25 h= 0.53*(Gr*Pr)^(1/4)*K/d;
26
27 //(a) Heat loss from 6 m length of pipe
28 A=%pi*d*6;
29 Q_conv=h*A*del_T;
30 Q_rad=epsilon*sigma*A*((T_s+273)^4-(T_infinite+273)
    ^4);
31 //total heat transfer rate
32 Q=Q_conv+Q_rad;
33 disp("Total heat transfer rate is : "+string(Q)+" W"
    );
34
35 // (b) Overall heat transfer coefficient
36 // Formula Q=U*A*del_T
37 U=Q/(A*del_T);
38 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

```
1 //Exa 7.1
2 clc;
3 clear;
4 close;
5 //given data
6 lamda=2*10^-6; // in m
7 C1=0.374*10^-15;
8 T=2000+273; // in K'
9 C2=1.4388*10^-2;
10
11 //(a)
12 // Formula Eb_lamda= (C1*lamda^-5)/[exp(C2/(lamda*T))
13 // -1]
13 Eb_lamda= (C1*lamda^-5)/[exp(C2/(lamda*T))-1];
14 disp(Eb_lamda,"Monochromatic emissive power at 2
15 // micro wavelength in W/m^2 is :");
16
17 //(b)
17 // Formula lamda_max * T =2898 // in micro m K
18 lamda_max= 2898/T; // in micro m
```

```

19 disp(lamda_max,"Wave-length at which the emission is
      maximum in micro m");
20
21 //(c)
22 Elamdab_max=1.285*10^-5*T^5;// in W/m^2-m
23 disp(Elamdab_max,"Maximum emissive power in W/m^2-m
      : ");
24
25 //(d)
26 sigma=5.67*10^-8;
27 E=sigma*T^4;
28 disp(E,"Total emissive power in W/m^2 :");
29
30 //Note: Answer of part (a) in the book is wrong

```

---

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

```

1 //Exa 7.2
2 clc;
3 clear;
4 close;
5 //given data
6 lamda=2*10^-6;// in m
7 C1=0.374*10^-15;
8 T=2000+273;// in K'
9 C2=1.4388*10^-2;
10
11 epsilon=0.3;
12 sigma=5.67*10^-8;
13 T1=300;// in K
14 T2=200;// in K
15 del_T=T1-T2;
16 h=12;// in W/m^2 degree C
17 d=4*10^-2;// diameter in m
18 l=1;// in m

```

```

19 A=%pi*d*l;
20 // Heat transfer rate by radiation ,
21 q_r= epsilon*sigma*A*(T1^4-T2^4);// in W
22 // Heat transfer rate by convection ,
23 q_c=h*A*del_T;// in W
24 // Total heat transfer ,
25 q=q_r+q_c;
26 // Formula q=U*A*del_T
27 U=q/(A*del_T);// Overall heat tranfer coefficient
28 disp(U,"Overall heat tranfer coefficient in W/m^2
    degree C");
29
30 //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

```

1 //Exa 7.3
2 clc;
3 clear;
4 close;
5 //given data
6 epsilon=0.5;
7 T1=1200;// in K
8 T2=300;// in K
9 //(a) Heat transfer rate between the two plates is
10 // Formula Fg12=1/((1/epsilon1+(1/epsilon2 -1)*A1/A2)
    )
11 epsilon1=epsilon;
12 epsilon2=epsilon;
13 A1byA2=1;
14 Fg12=1/(1/epsilon1+(1/epsilon2 -1)*A1byA2);
15 // Formula q12= sigma*A*Fg12*(T1^4-T2^4)
16 sigma=5.67*10^-8;
17 q12byA=sigma*Fg12*(T1^4-T2^4);// in W/m^2

```

```

18 disp(q12byA,"Heat transfer rate between the two
    plates in W/m^2")
19
20 //(b)
21 epsilon3=.05;
22 Fg13=1/(1/epsilon1+(1/epsilon3-1)*A1byA2);
23 Fg32=1/(1/epsilon3+(1/epsilon2-1)*A1byA2);
24 // q13=q32
25 // sigma*A*Fg13*(T1^4-T3^4) = sigma*A*Fg32*(T3^4-T2
    ^4)
26 T3= ((T1^4+T2^4)/2)^(1/4);
27 T3=floor(T3);
28 q13byA=sigma*Fg13*(T1^4-T3^4);// in W/m^2
29 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

```

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

```

---



### Scilab code Exa 7.5.1 Absorbed Transmitted and emitted energy

```
1 //Exa 7.4
2 clc;
3 clear;
4 close;
5 //given data
6 A=5; // in m^2
7 intensity=660; // in W/m^2
8
9 disp("alpha= 2*rho    or    rho=alpha/2")
10 disp("alpha= 3*toh    or    toh=alpha/3")
11 disp("as alpha + rho + toh =1")
12 disp("then alpha+alpha/2+alpha/3 = 1")
13 disp("alpha = 6/11")
14 disp("rho = 6/22")
15 disp("toh = 6/33")
16 alpha=6/11;
17 rho=6/22;
18 toh=6/33;
19 energy_absorbed= intensity*alpha*A; // in watt
20 disp(energy_absorbed, "Energy absorbed in watt : ")
21 energy_transmitted=intensity*rho*A; //in watt
22 disp(energy_transmitted, "Energy transmitted in watt
    :")
23 energy_emitted= intensity*toh*A; // in watt
24 disp(energy_emitted, "Energy emitted in watt: ")
```

---

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

```
1 //Exa 7.5
2 clc;
3 clear;
4 close;
5 //given data
```

```

6 T1=200+273; // in K
7 T2=100+273; // in K
8 A= 1*2; // in square meter
9 sigma=5.67*10^-8;
10 x_D= 1/4;
11 y_D= 1/2;
12 Fg12= 0.033;
13 q12= Fg12*sigma*A*(T1^4-T2^4); // in watt
14 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

```

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

```

21  
22 //Note: Answer in the book is wrong

---

**Scilab code Exa 7.10** Shape factor of a cylindrical cavity

```
1 //Exa 7.10
2 clc;
3 clear;
4 close;
5 //given data
6 D=150*10^-3; // in m
7 H=400*10^-3; // in m
8 T1=500; // in K
9 epsilon=0.7;
10 // Formula  $F_{11}=(4*H)/(4*H+D)$ 
11 F11=(4*H)/(4*H+D);
12 sigma=5.67*10^-8;
13 A1=%pi*D*H;
14 q=sigma*A1*epsilon*T1^4*[(1-F11)/(1-F11*(1-epsilon))]
    ];
15 disp(q,"Heat Heat loss for cavity in W");
16
17 //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 oxygen

```
1 //Exa 7.11
2 clc;
3 clear;
4 close;
```

```

5 //given data
6 epsilon1=.04;
7 epsilon2=epsilon1;
8 T1=-153+273;// in K
9 T2=27+273;// in K
10 h_fg=209;// in kJ/kg
11 h_fg=h_fg*10^3;// in J/kg
12 d1=20*10^-2;// in m
13 d2=30*10^-2;// in m
14 A1=d1^2;// in square meter
15 A2=d2^2;// in square meter
16 A=4*%pi*(d2-d1)^2;
17 Fg12=1/((1/epsilon1+(1/epsilon2-1)*A1/A2));
18 sigma=5.67*10^-8;
19 q12=sigma*A*Fg12*(T1^4-T2^4);// in W
20 disp(q12,"Net radiant heat transfer rate in watt")
21 disp("Negative sign indicates that heat flows into
    the sphere")
22 q12=-q12;
23 m=q12*60/h_fg;
24 disp(m,"Rate of evaporation per minutes in kg/min")

```

---

### Scilab code Exa 7.12 Radiation heat transfer

```

1 //Exa 7.12
2 clc;
3 clear;
4 close;
5 //given data
6 T1=500;// in K
7 T2=300;// in K
8 sigma=5.67*10^-8;
9 A=2;// surface area of each plate in m^2
10 //(a) If the plates are perfectly black
11 F12=1;

```

```

12 q12=sigma*A*F12*(T1^4-T2^4);
13 disp(q12,"Radiation heat transfer between two black
    parellel plates in watt");
14
15 //(b) If the plates are gray surface
16 //in this case
17 F12=1;
18 //A1=A2, so
19 A1byA2=1
20 epsilon1=.4;
21 epsilon2=epsilon1;
22 //Fg12=1/(1/epsilon1+(1/epsilon2-1)*A1byA2);
23 Fg12=1/((1-epsilon1)/epsilon1 + 1/F12 + [(1-epsilon2
    )/epsilon2]*A1byA2);
24 q12=sigma*A*Fg12*(T1^4-T2^4); // in W
25 disp(q12,"Heat transfer rate in watt")

```

---

### Scilab code Exa 7.13 Steady state temperature

```

1 //Exa 7.13
2 clc;
3 clear;
4 close;
5 format('v',6)
6 //given data
7 T1=800; // in K
8 T3=200; // in K
9 sigma=5.67*10^-8;
10 d1=20*10^-2; // in m
11 d2=30*10^-2; // in m
12 d3=40*10^-2; // in m
13 A1=4*pi*(d1/2)^2; // in m^2
14 A2=4*pi*(d2/2)^2; // in m^2
15 A3=4*pi*(d3/2)^2; // in m^2
16 epsilon1=0.2;

```

```

17 epsilon2=epsilon1
18 epsilon3=epsilon1
19 Fg12=1/(1/epsilon1+(1/epsilon2-1)*A1/A2);
20 Fg23=1/(1/epsilon2+(1/epsilon3-1)*A2/A3);
21 // Under steady state condition
22 // q12 = q23
23 // A1*Fg12*sigma*(T1^4-T2^4) = A2*Fg23*sigma*(T2^4-
    T3^4)
24 T2 = ((A2*Fg23*T3^4/(A1*Fg12)+T1^4)/(A2*Fg23/(A1*
    Fg12) + 1))^(1/4)
25 disp(T2,"Steady state temperature of the
    intermediate sphere in K");

```

---

#### Scilab code Exa 7.14 Rate of absorption and emission

```

1 //Exa 7.14
2 clc;
3 clear;
4 close;
5 format('v',9);
6 //given data
7 T1=400;// in K
8 T2=500;// in K
9 T3=1200;// in K
10 alpha1=0.70;
11 alpha2=0.6;
12 alpha3=0.4;
13 // First part
14 disp("Radiation falling on the body is emitted by
    the furnace wall at 1200 K ")
15 disp("The absorptivity of the body for this
    radiation is 0.4.")
16 sigma=5.67*10^-8;
17 qa=alpha3*sigma*T3^4;
18 disp(qa,"The rate of energy absorption in W/m^2");

```

```

19
20 // Second part
21 disp("The emissivity of surface equals its
      absoptivity at 127 degree")
22 qa=alpha1*sigma*T1^4;
23 disp(qa,"The rate of emission of radiation energy in
      W/m^2");
24
25
26 // Note : Answer of the first part in the book is
      wrong

```

---

#### Scilab code Exa 7.15 Radiant Heat transfer

```

1 //Exa 7.15
2 clc;
3 clear;
4 close;
5 format('v',9)
6 //given data
7 d1=100;// in mm
8 d1=d1*10^-3;// in m
9 d2=100+10*2;// in mm
10 d2=d2*10^-3;// in m
11 l=1;// in m
12 A1byA2=d1^2/d2^2;
13 A1=%pi*d1*l;// in m^2
14 sigma=5.67*10^-8;
15 T1=120+273;// in K
16 T2=35+273;// in K
17 epsilon1=.8;
18 epsilon2=.1;
19 Fg12=1/(1/epsilon1+(1/epsilon2-1)*A1byA2);
20 // Radiant heat transfer from the tube
21 q=A1*Fg12*sigma*(T1^4-T2^4)

```

```
22 disp(q," Radiant heat transfer from the tube in W/m"  
    );  
23  
24  
25 //Note: Answer in the book is wrong
```

---



# Chapter 8

## Heat Exchangers

Scilab code Exa 8.1 Surface area of heat exchanger

```
1 //Exa 8.1
2 clc;
3 clear;
4 close;
5 //given data
6 t_hi=80; // in degree C
7 t_ci=30; // in degree C
8 t_ho=40; // in degree C
9 Mh=0.278; // in kg/s
10 Mc=0.278; // in kg/s
11 Cph=2.09; // in kJ/kg degree C
12 Cpc=4.18; // in kJ/kg degree C
13 U=24; // in W/m^2 degree C
14 // Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-
    t_ci)
15 t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci; // in degree
    C
16 del_t1=t_hi-t_co; //in degree C
17 del_t2=t_ho-t_ci; //in degree C
18 del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
19 Cph=Cph*10^3; // in J/kg degree C
```

```

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

```

---

### Scilab code Exa 8.2 Length of heat exchanger

```

1 //Exa 8.2
2 clc;
3 clear;
4 close;
5 //given data
6 t_hi=160; // in degree C
7 t_ci=25; // in degree C
8 t_ho=60; // in degree C
9 Mh=2; // in kg/s
10 Mc=2; // in kg/s
11 Cph=2.035; // in kJ/kg degree C
12 Cpc=4.187; // in kJ/kg degree C
13 U=250; // in W/m^2 K
14 d=0.5; // in m
15 // Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-
t_ci)
16 t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci; // in degree
C
17 del_t1=t_hi-t_co; //in degree C
18 del_t2=t_ho-t_ci; //in degree C
19 del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
20
21
22 Cph=Cph*10^3; // in J/kg degree C
23 q=Mh*Cph*(t_hi-t_ho);
24
25 //Formula q=U*%pi*d*l*del_tm

```

```

26 l=q/(U*%pi*d*del_tm);
27 disp(1,"Length of the heat exchanger in meter")

```

---

### Scilab code Exa 8.3 Area of heat exchanger tube

```

1 //Exa 8.3
2 clc;
3 clear;
4 close;
5 //given data
6 t_hi=110;// in degree C
7 t_ci=35;// in degree C
8 t_co=75;// in degree C
9 Mh=2.5;// in kg/s
10 Mc=1;// in kg/s
11 Cph=1.9; // in kJ/kg K
12 Cpc=4.18;// in kJ/kg K
13 U=300;// in W/m^2 K
14
15 // Energy balance Mc*Cpc*(t_co-t_ci) = Mh*Cph*(t_hi-
    t_ho)
16 t_ho=t_hi- Mc*Cpc*(t_co-t_ci)/(Mh*Cph);// in degree
    C
17 del_t1=t_hi-t_co;//in degree C
18 del_t2=t_ho-t_ci;//in degree C
19 del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
20 Cph=Cph*10^3;// in J/kg degree C
21 q=Mh*Cph*(t_hi-t_ho);
22 //Formula q=U*A*del_tm
23 A=q/(U*del_tm);
24 disp(A,"Area of the heat exchanger in square meter")

```

---

### Scilab code Exa 8.4 The overall heat transfer

```

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

```

---

#### Scilab code Exa 8.5 Heat transfer rate

```

1 //Exa 8.5
2 clc;
3 clear;
4 close;
5 //given data
6 V=0.15; // in m/s
7 di=2.5*10^-2; // in m
8
9 delta=0.364*10^-6; // in m^2/s
10 k=0.668; // in W/m degree C
11 Pr=2.22;
12
13 Re=V*di/delta;
14 // Formula Nu= hi*di/k = 0.023*Re^0.8*Pr^0.3

```

```

15 hi=0.023*Re^0.8*Pr^0.3*k/di;// in W/m^2 degree C
16
17 // Now, Reynold number for flow of air across the
    tube
18 delta=18.22*10^-6;// in m^2/s
19 k=0.0281;// in W/m degree C
20 Pr=0.703;
21 d=2.5*10^-2;// in m
22 u=10;// in m/s
23 Re=u*d/delta;
24 Re=floor(Re);
25 //The Nusselt number for this case
26 Nu=[0.04*Re^0.5+ 0.006*Re^(2/3)]*Pr^0.4
27 // Formula Nu= ho*do/k
28 do=di;
29 ho=Nu*k/do;// in W/m^2 degree C
30 disp(ho,"Heat transfer coefficient in W/m^2 degree C
    ");
31 U=1/(1/hi+1/ho);
32 disp(U,"The overall heat transfer coefficient
    neglecting the wall resistance in W/m^2 degree C"
    );
33 l=1;// in m
34 Ti=90;// in degree C
35 To=10;// in degree C
36 q=U*pi*d*l*(Ti-To);
37 disp(q,"Heat loss per meter length of the tube in W/
    m")
38
39 // Note: Answer in the book is wrong

```

---

### Scilab code Exa 8.6 Type of heat exchanger required

```

1 //Exa 8.6
2 clc;

```

```

3 clear;
4 close;
5 //given data
6 t_hi=83; // in degree C
7 t_ho=45; // in degree C
8 t_ci=25; // in degree C
9 Mh=5; // in kg/min
10 Mc=9; // in kg/min
11 Cph=4.18; // in kJ/kg K
12 Cpc=2.85; // in kJ/kg K
13 // Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-
    t_ci)
14 t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci; // in degree
    C
15 disp(t_co,"t_co in degree C");
16 if(t_co>t_ho)
17
18     disp("since t_co > t_ho, hence counter flow
        arrangment will be suitable")
19 end

```

---

#### Scilab code Exa 8.7 Heat transfer area

```

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

```

```

12 // Formula  $q=U*A*\Delta t_m$ ;
13  $A=q/(U*\Delta t_m)$ ;
14 disp(A,"Area for parallel flow arrangement in square
    meter");
15 // (b) For counter flow heat exchange
16  $\Delta t_1=60-30$ ; // in degree C
17  $\Delta t_2=40-10$ ; // in degree C
18 // In this case
19  $\Delta t_m=(\Delta t_1+\Delta t_2)/2$ ; // in degree C
20  $A=q/(U*\Delta t_m)$ ;
21 disp(A,"Area For counter flow heat exchange in
    square meter");
22 disp("In counter flow arrangement less area is
    required for the above purpose")

```

---

### Scilab code Exa 8.8 Rate of heat condensation

```

1 //Exa 8.8
2 clc;
3 clear;
4 close;
5 //given data
6  $C_p=4180$ ; // in J/kg degree C
7  $\mu=0.86*10^{-3}$ ; // in kg/m-s
8 Pr=60;
9  $k=0.60$ ; // in W/m degree C
10  $h_{fg}=2372400$ ; // in W
11  $h_o=6000$ ; // in W/m^2 degree C
12  $d_i=2*10^{-2}$ ; // in m
13  $d_o=3*10^{-2}$ ; // in m
14  $t_{co}=35$ ; // in degree C
15  $t_{ci}=15$ ; // in degree C
16
17 M=0.9;
18  $Re=4*M/(\pi*d_i*\mu)$ ;

```

```

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

```

---

#### Scilab code Exa 8.9 Heat transfer area

```

1 //Exa 8.9
2 clc;
3 clear;
4 close;
5 //given data
6 Cph=3850; // in J/kg degree C
7 t_hi=100;// in degree C
8 t_ci=20;// in degree C
9 t_ho=50;// in degree C
10 Mh=8;// in kg/s
11 Mc=10;// in kg/s
12 Cpc=4.18*10^3;// in J/kg degree C
13 U=400;// in W/m^2 degree C
14 // Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-
    t_ci)
15 t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci;// in degree
    C

```



```

16 // Heat load
17 q=Mh*Cph*(t_hi-t_ho); // in W
18
19 // (a) Parallel flow
20 del_t1=90; // in degree C
21 del_t2=3.16; // in degree C
22 del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
23 A=q/(U*del_tm);
24 disp(A,"Surface area for parallel flow in meter
    square");
25
26 // (b) Counter flow heat exchanger
27 del_t1=53.16; // in degree C
28 del_t2=40; // in degree C
29 del_tm_counter= (del_t1-del_t2)/log(del_t1/del_t2);
30 A=q/(U*del_tm_counter);
31 disp(A,"Surface area for counter flow heat exchanger
    in meter square");
32
33 //(c) One shell pass and two tube pass.
34 //here
35 t1=10; // in degree C
36 t2=46.84; // in degree C
37 T1=100; // in degree C
38 T2=50; // in degree C
39 P=(t2-t1)/(T1-t1);
40 R=(T1-T2)/(t2-t1);
41 F=0.88;
42 del_tm=F*del_tm_counter; // in degree C
43 A=q/(U*del_tm);
44 disp(A,"Surface area for one shell pass and two tube
    pass in meter square");
45
46 // (d) For cross flow, correction factor
47 F=0.9;
48 del_tm=F*del_tm_counter;
49 A=q/(U*del_tm);
50 disp(A,"Surface area for cross flow in meter square"

```

);

---

### Scilab code Exa 8.10 Exit temperature of water

```
1 //Exa 8.10
2 clc;
3 clear;
4 close;
5 format('v',13)
6 //given data
7 Cpc=4.18*10^3; // in J/kg degree C
8 Mc=1; // in kg/s
9 Mh=2.4; // in kg/s
10 Cph=2050; // in J/kg degree C
11 t_hi=100; // in degree C
12 t_ci=20; // in degree C
13 C_c=Mc*Cpc; // in W/degree C
14 C_h=Mh*Cph; // in W/degree C
15 U=300; // in W/m^2 degree C
16 A=10; // in m^2
17 C_min=C_c;
18 C_max=C_h;
19 N= A*U/C_min;
20 C=C_min/C_max;
21 // Effectiveness for counter flow heat exchanger
22 epsilon= (1-%e^(-N*(1-C)))/(1-C*%e^(-N*(1-C)));
23 // Total heat transfer
24 q=epsilon*C_min*(t_hi-t_ci); // in watt
25 disp(q*10^-3,"Total heat transfer in kW");
26 t_co=t_ci+epsilon*C*(t_hi-t_ci);
27 disp(t_co,"Exit temperature of water in degree C");
```

---

### Scilab code Exa 8.11 Exit temperature

```

1 //Exa 8.11
2 clc;
3 clear;
4 close;
5 format('v',13)
6 //given data
7 t_hi=135;// in degree C
8 t_ci=20;// in degree C
9 t_ho=65;// in degree C
10 t_co=50;// in degree C
11 // Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co
    -t_ci)
12 // C =C_min/C_max = Mh*Cph/( Mc*Cpc)
13 C= (t_co-t_ci)/(t_hi-t_ho);
14 epsilon=(t_hi-t_ho)/(t_hi-t_ci);
15 // Also epsilon = epsilon_parallel = (1-exp(-NTU*(1+
    C)))/(1+C)
16 NTU= -log(1-epsilon*(1+C))/(1+C);
17 // if the existing heat exchanger is to be used as
    counter flow mode, its NTU will not change, i.e.
18 epsilon_c= (1-exp(-NTU*(1-C)))/((1-C*exp(-NTU*(1-C))
    ));
19 // Exit temperature
20 // (i) Hot fluid
21 t_ho=t_hi-epsilon_c*(t_hi-t_ci);// in degree C
22 disp(t_ho,"Exit temperature for hot fluid in degree
    C")
23
24 //(ii) Cold fluid
25 t_co= t_ci+epsilon_c*C*(t_hi-t_ci);
26 disp(t_co,"Exit temperature for cold fluid in degree
    C")
27
28 // (iii) // If the parallel flow heat exchanger is
    too long, then body fluid will have common outlet
    temperature (t)
29 // From MCp_h*(t_hi-t) = MCp_c*(t-t_ci)
30

```

```

31 t=(C*t_hi+t_ci)/(1+C);
32 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

```

1 //Exa 8.12
2 clc;
3 clear;
4 close;
5 format('v',13)
6 //given data
7 t_hi=78;// in degree C
8 t_ci=23;// in degree C
9 t_ho=65;// in degree C
10 t_co=36;// in degree C
11 // Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co
    -t_ci)
12 // C =C_min/C_max = Mh*Cph/( Mc*Cpc)
13 C= (t_co-t_ci)/(t_hi-t_ho);
14 epsilon=(t_hi-t_ho)/(t_hi-t_ci);
15 // Formula epsilon = (1-exp(-N*(1+C)))/(1+C)
16 N= -log(1-epsilon*(1+C))/(1+C);
17 // When flow rates of both fluids are doubled , the
    deat capacity ratio will not change, i.e.
18 // C=1
19 // MCp_new =2* MCp_old
20 // N=U*A/C_min=N/2
21 N=N/2;
22 epsilon=(1-exp(-N*(1+C)))/(1+C);
23 // exit temperature
24 t_ho=t_hi-epsilon*(t_hi-t_ci);// in degree C
25 t_co= t_ci+epsilon*(t_hi-t_ci);
26 disp("Exit temperature in degree C : "+string(t_ho)

```

```

    +” and ”+string(t_co));
27
28 // 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

```

1 //Exa 8.13
2 clc;
3 clear;
4 close;
5 format('v',13)
6 //given data
7 t_hi=125;// in degree C
8 t_ci=22;// in degree C
9 Mh=21;// in kg/s
10 Mc=5;// in kg/s
11 C_ph=2100;// in J/kg K
12 C_pc=4100;// in J/kg K
13 Ch=Mh*C_ph;// in Js/kg
14 Cc=Mc*C_pc;// in Js/kg
15 C_min=Cc;// in Js/kg
16 C_max=Ch;// in Js/kg
17 U=325;// in W/m^2 K
18 d=2.2*10^-2;// in m
19 l=5;// in m
20 total_tube=195;// number of total tubes
21 A=%pi*d*l*total_tube
22 NTU=U*A/C_min;
23 C=C_min/C_max;
24 epsilon = (1-exp(-NTU*(1-C)))/(1-C*exp(-NTU*(1-C)));
25 t_co= t_ci+epsilon*(t_hi-t_ci);
26 t_ho= t_hi-epsilon*Cc/Ch*(t_hi-t_ci);
27 disp("Exit temperature in degree C : "+string(t_co)
    +” and ”+string(t_ho));

```

```

28
29 // Total heat transfer
30 q=epsilon*C_min*(t_hi-t_ci);
31 disp(q*10^-3,"Total heat transfer in kW")

```

---

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

```

1 //Exa 8.14
2 clc;
3 clear;
4 close;
5 format('v',13)
6 //given data
7 t_hi=94; // in degree C
8 t_ci=15; // in degree C
9 Mw=0.36; // in kg/s
10 Mo=0.153; // in kg/s
11 C_po=2*10^3; // in J/kg K
12 C_pw=4.186*10^3; // in J/kg K
13 U=10.75*10^2; // in W/m^2 K
14 A=1; // in m^2
15 Ch=Mo*C_po; // in kW/K
16 Cc=Mw*C_pw; // in kW/K
17 C_min=Ch; // in W/K
18 C_max=Cc; // in W/K
19 C=C_min/C_max;
20 NTU=U*A/C_min;
21 // Effectiveness
22 N=NTU;
23 epsilon = (1-exp(-N*(1-C)))/(1-C*exp(-N*(1-C)));
24 mCp_min=C_min;
25 q_max= mCp_min*(t_hi-t_ci); // in W
26 q_actual= epsilon*q_max; // in W
27 disp(q_actual,"Total heat transfer in watt")
28 // Outlet temp. of water

```

```

29 t_co= q_actual/Cc+t_ci;// in degree C
30 disp(t_co,"Outlet temperature of water in degree C")
31 // Outlet temp. of oil
32 t_ho=t_hi-q_actual/Ch;//in degree C
33 disp(t_ho,"Outlet temperature of oil in degree C")
34
35
36 //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

```

1 //Exa 8.15
2 clc;
3 clear;
4 close;
5 //given data
6 U=1800;// in W/m^2 degree C
7 h_fg=2200*10^3;// in J/kg
8 t_ci=20;// in degree C
9 t_co=90;// in degree C
10 del_t1=120-20;// in degree C
11 del_t2=120-90;// in degree C
12 del_tm=(del_t1-del_t2)/log(del_t1/del_t2);// in
    degree C
13 Mc=1000/3600;// in kg/s
14 Cc=4180;// in kg/s
15 // Rate of heat transfer
16 q=Mc*Cc*(t_co-t_ci);// in watt
17 // Formula q=U*A*del_tm
18 A=q/(U*del_tm);
19 disp(A,"Surface area in square meter");
20 //Rate of condensation of steam
21 ms=q/h_fg;// in kg/sec
22 disp(ms,"Rate of condensation of steam in kg/sec");

```

---

**Scilab code Exa 8.16** Heat exchanger area

```
1 //Exa 8.16
2 clc;
3 clear;
4 close;
5 //given data
6 Mh=10000/3600; // in kg/sec
7 Mc=8000/3600; // in kg/sec
8 Cph=2095; // in J/kg K
9 Cpc=4180; // in J/kg K
10 t_hi=80; // in degree C
11 t_ci=25; // in degree C
12 t_ho=50; // in degree C
13 U=300; // in W/m^2 K
14 // Energy balance Mh*Cph*(t_hi-t_ho) = Mc*Cpc*(t_co-
    t_ci)
15 t_co= Mh*Cph*(t_hi-t_ho)/(Mc*Cpc)+t_ci; // in degree
    C
16 del_t1=t_hi-t_co; //in degree C
17 del_t2=t_ho-t_ci; //in degree C
18 del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
19 q=Mh*Cph*(t_hi-t_ho);
20 //Formula q=U*A*del_tm
21 A=q/(U*del_tm); // in m^2
22 disp(A," Surface area of heat exchange in square
    meter")
```

---

**Scilab code Exa 8.17** Overall heat transfer coefficient

```
1 //Exa 8.17
```



```

2  clc;
3  clear;
4  close;
5  //given data
6  ho=5000; // in W/m^2 degree C
7  rho=988.1; // in kg/m^3
8  K=0.6474;
9  D=555*10^-9; // in m^2/s
10 Pr=3.54;
11 n=100;
12 d_i=2.5*10^-2; // in m
13 r_i=d_i/2;
14 d_o=2.9*10^-2; // in m
15 r_o=d_o/2;
16 Cp=4174; // in J/kg degree C
17 Mc=8.333; // in kg/s
18 Mw=Mc;
19 t_c1=30; // in degree C
20 t_c2=70; // in degree C
21 t_n1=100; // in degree C
22 t_n2=t_n1; // in degree C
23 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)
24 // Heat gain by water
25 Q=Mc*Cp*(t_c2-t_c1);
26 // Also Q= U*A*del_tm
27 del_t1=t_n1-t_c1; //in degree C
28 del_t2=t_n2-t_c2; //in degree C
29 del_tm= (del_t1-del_t2)/log(del_t1/del_t2);
30 // Mw= 1/4*%pi*d_i^2*V*rho*N, here
31 N=n;
32 V=4*Mw/(%pi*d_i^2*rho*N);
33 // Formula Re=V*d_i/v, here
34 v=D;
35 Re=V*d_i/v;
36 // Formula Nu= hi*d_i/K = 0.023*Re^0.8*Pr^0.33
37 hi= 0.023*Re^0.8*Pr^0.33*K/d_i;

```

```
38 // Formula  $1/V_i = 1/h_i + R_{fi} + r_i/r_o * 1/h_o$ 
39  $V_i = 1 / (1/h_i + R_{fi} + r_i/r_o * 1/h_o)$ ; // in  $W/m^2$  degree
    C
40 //Formula  $Q = V_i * (N * \pi * d_i * L) * \Delta T_m$ 
41  $L = Q / (V_i * (N * \pi * d_i) * \Delta T_m)$ ;
42 disp(L,"Length of the tube bundle in m");
```

---

# Chapter 9

## Condensation and Boiling

Scilab code Exa 9.1 Rate of heat transfer

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

```

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

```

---

### Scilab code Exa 9.2 Condensation rate

```

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

```

```

25 m=q/h_fg;// in kg/s
26 disp(m,"Rate of condenstion in kg/s");
27
28 // (b) For Vertical tube
29 h_bar = 1.13*[ rho^2*g*h_fg*k^3/(miu*L*(T_sat-T_s))
    ]^(1/4);// in W/m^2k
30 // heat transfer rate
31 q=h_bar*%pi*d*L*N^2*(T_sat-T_s);// in watt
32 disp(q*10^-3,"Heat transfer rate for vertical tube
    in kW")
33 //rate of condensation
34 m=q/h_fg;// in kg/s
35 disp(m,"Rate of condenstion in kg/s");

```

---

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

```

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

```

```

19 q=m*h_fg;
20 disp(q*10^-3,"Heat transfer rate in kW")
21 // Formula q=h_bar*%pi*d*L*N^2*(T_sat-T_s)
22 L=q/(h_bar*%pi*d*N^2*(T_sat-T_s));
23 disp(L,"Length of tube in m");
24
25 // Note: Answer in the book is wrong

```

---

#### Scilab code Exa 9.4 Film thickness

```

1 //Exa 9.4
2 clc;
3 clear;
4 close;
5 format('v',9)
6 //given data
7 h_fg=2400*10^3;// in J/kg
8 rho=993;// in kg/m^3
9 rho_v=0.0563;// in kg/m^3
10 t_mf=(40+30)/2;// in degree C
11 k=0.625;// in W/mK
12 miu=728*10^-6;// in kJ/m-s
13 x=0.25;
14 T_sat=40;// in degree C
15 T_s=30;// in degree C
16 g=9.81;
17
18 // (a) Thickness of condensate film
19 delta=[ 4*k*(T_sat-T_s)*miu*x/(rho*(rho-rho_v)*g*
20         h_fg) ]^(1/4);// in meter
21
22 // (b) Local value of heat transfer coefficient
23 hx=k/delta;// in W/m^2

```

```

24 L=0.5; // in m
25 hm=4/3*(L/x)^(1/4)*hx;
26 disp(hm,"Average heat transfer coefficient in W/m^2"
    );
27 // The heat transfer rate
28 A=0.5*0.5; // in m^2
29 q=hm*A*(T_sat-T_s); // in watt
30 disp(q*10^-3,"The heat transfer rate in kW")
31
32 // (c)
33 theta=45; // in degree
34 h_vertical=hm;
35 h_inclined=h_vertical*(sind(theta))^(1/4);
36 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

```

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

```

```
16 h_P=h_A*(rho/rho_a)^0.4; // in W/m^2
17 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

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

```

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

```

---

### Scilab code Exa 10.2 Diffusion coefficient of hydrogen

```

1 //Exa 10.2
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',13);
7 T=25;// in degree C
8 T=T+273;// in K
9 P=1;
10 V1=12;//Molecular volume of H2 in cm^3/gm mole
11 V2=30;//Molecular volume of Air in cm^3/gm mole
12 M1=2;// Molecular weight of H2
13 M2=29;// Molecular weight of Air
14 //The diffusion coefficient for gases in terms of
    molecular volumes may be express as
15 D_AB= .0043*T^(3/2)/(P*(V1^(1/3)+V2^(1/3)))*(1/M1+1/
    M2)^(1/2);
16 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

```

1 //Exa 10.3

```

```

2  clc;
3  clear;
4  close;
5  //given data
6  format('v',13);
7  T=300;// temp of gas mixture in K
8  D_HN2=18*10^-6;// in m^2/s at 300 K, 1 bar
9  T1=300;// in K
10 D_HO2=16*10^-6;// in m^2/s at 273 K, 1 bar
11 T2=273;// in K
12 O_2=0.2;
13 N_2=0.7;
14 H_2=0.1;
15 //The diffusivity at the mixture temperature and
    pressure are calculated as
16 //  $D_1/D_2 = (T_1/T_2)^{(3/2)}*(P_2/P_1)$ 
17 D_HO2= (T/T2)^(3/2)*1/4*D_HO2;
18 D_HN2= (T/T1)^(3/2)*1/4*D_HN2;
19 //The composition of oxygen and nitrogen on a H2
    free basis is
20 x_O= O_2/(1-H_2);
21 x_N= N_2/(1-H_2);
22
23 // The effective diffusivity for the gas mixture at
    given temperature and pressure is
24 D= 1/(x_O/D_HO2+x_N/D_HN2);// in m^2/s
25 disp(D,"Effective diffusivity in m^2/s")

```

---

#### Scilab code Exa 10.4 Mass flow rate

```

1  //Exa 10.4
2  clc;
3  clear;
4  close;
5  //given data

```

```

6  format('v',9);
7  d=3; // in mm
8  d=d*10^-3; // in meter
9  T=25; // in C
10 T=T+273; // in K
11 D= 0.4*10^-4; // in m^2/s
12 R= 8314;
13 P_A1=1; // in atm
14 P_A1=P_A1*10^5; // in w/m^2
15 P_A2=0;
16 C_A2=0;
17 x2= 15; // in meter
18 x1= 0;
19 A= %pi/4*d^2;
20 M_A= D*A/(R*T)*(P_A1-P_A2)/(x2-x1); // in kg mole/sec
21 N_B= M_A;
22 M_B= M_A*29; // in kg/sec
23 disp(N_B," Value of N_B in kg mole/sec")
24 disp(M_B," Value of M.B in kg /sec")

```

---

### Scilab code Exa 10.5 Diffusion flux rate

```

1  //Exa 10.5
2  clc;
3  clear;
4  close;
5  //given data
6  format('v',13);
7  P=3; // in atm
8  P=P*10^5; // in N/m^2
9  r1=10; // in mm
10 r1=r1*10^-3; // in m
11 r2=20; // in mm
12 r2=r2*10^-3; // in m
13 R=4160; // in J/kg-K

```

```

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

```

---

#### Scilab code Exa 10.6 Loss of H2 by diffusion

```

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

```

```

15 T=T+273; // in K
16 r1=2.5; // in mm
17 r1=r1*10^-3; // in m
18 r2=5; // in mm
19 r2=r2*10^-3; // in m
20 del_x=r2-r1; // in m
21 L=1; // in m
22 //Formula P*V= m*R*T
23 V=S;
24 m=P*V/(R*T); // in kg/m^3 of pipe
25 // So, Concentration of H2 at inner surface of the
    pipe
26 C_A1=0.0176; // in kg/m^3
27 // The resistance of diffusion of H2 away from the
    outer surface is negligible i.e.
28 C_A2=0;
29 Am=2*%pi*L*del_x/log(r2/r1);
30 // Loss of H2 by diffusion
31 M_A= D_AB*(C_A1-C_A2)*Am/del_x;
32 disp(M_A,"Loss of H2 by diffusion in kg/s");
33
34
35 //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

```

1 //Exa 10.7
2 clc;
3 clear;
4 close;
5 //given data
6 format('v',15);
7 Px1= 0.14; // in bar

```

```

8 Px2= 0;
9 P=1.013; // in bar
10 Py1=P-Px1; // in bar
11 Py2=P-Px2; // in bar
12 D=8.5*10^-6; // in m^2/s
13 d=5; // diameter in meter
14 L=1; // in mm
15 L=L*10^-3; //in meter
16 M=78; // molecular weight
17 Am_x= 1/4*%pi*d^2*M;
18 R=8314;
19 del_x=3; // thickness in mm
20 del_x=del_x*10^-3; // in m
21 T=20; // in degree C
22 T=T+273; // in K
23 P=P*10^5; // in N/m^2
24 m_x= D*Am_x*P*log(Py2/Py1)/(R*T*del_x);
25 // The mass of the benzene to be evaporated
26 mass= 1/4*%pi*d^2*L;
27 density=880; // in kg/m^3
28 m_b= mass*density;
29 toh=m_b/m_x; // in sec
30 disp(toh,"Time taken for the entire organic compound
      to evaporate in seconds")
31
32
33 // Note: Answer in the book is wrong

```

---

### Scilab code Exa 10.8 Diffusion Flux rate of air

```

1 //Exa 10.8
2 clc;
3 clear;
4 close;
5 //given data

```

```

6  format('v',8);
7  A=0.5; // in m^2
8  Pi=2.2; // in bar
9  Pi=Pi*10^5; // in N/m^2
10 Pf=2.18; // in bar
11 Pf=Pf*10^5; // in N/m^2
12
13 T=300; // in K
14 S=0.072; // in m^3
15 V=0.028; // in m^3
16 L=10; // in mm
17 L=L*10^-3; // in meter
18 R=287;
19 // Diffusivity of air in rubber D
20 // Initial mass of air in the tube
21 mi= Pi*V/(R*T); // in kg
22 //final mass of air in the tube
23 mf= Pf*V/(R*T); // in kg
24 // Mass of air escaped
25  ma = mi-mf; //in kg
26 // Formula Na = ma/A = mass of air escaped / Time
    elapsed * area
27 A=6*24*3600*0.5;
28 Na = ma/A; //in kg/sm^2
29 // Solubility of air should be calculated at mean
    temperature
30 S_meanTemperature=(2.2+2.18)/2; // in bar
31 //Solubility of air at the mean inside Pressure is
32 S=S*S_meanTemperature; // in m^3/m^3 of rubber
33 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");
34 V1=S;
35 V2=0.072;
36 T1=T;
37 T2=T;
38 P1=2.19*10^5; // in N/m^2
39 P2=1*10^5; // in N/m^2

```



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

---