

Scilab Textbook Companion for
Heat And Mass Transfer - A Practical
Approach
by Y. A. Cengel¹

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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 and basic concepts

Scilab code Exa 1.1 ab12

```
1 clear;
2 clc;
3
4 //Example 1.1(Heating of a copper ball)
5
6 //(a)
7 //density of the copper ball
8 rho= 8950; //[kg/m^3]
9 //Diameter of the copper ball
10 D=0.1; //[m]
11 //mass of the ball
12 m=rho*(%pi/6)*(D^3); //[kg]
13 //Specific Heat of copper
14 Cp=0.395; //[kJ/Kg/m^3]
15 //Initial Temperature
16 T1=100; //[degree C]
17 //Final Temperature
18 T2=150; //[degree C]
19 // The amount of heat transferred to the copper ball
    is simply the change in it's internal energy and
    is given by
```

```

20 // Energy transfer to the system=Energy increase of
    the system
21 Q=(m*Cp*(T2-T1));
22 disp("kJ",Q,"Heat needs to be transferred to the
    copper ball to heat it from 100 to 150 degree
    celsius is ")
23 //b
24 //Time interval for which the ball is heated
25 dT=1800;//[seconds]
26 Qavg=(Q/dT)*1000;//[W]
27 disp("W",Qavg,"Average Heat Transfer by the iron
    ball is ")
28
29 //(c)
30 //Heat Flux
31 qavg=(Qavg/(%pi*(D^2)));//[W/m^2]
32 disp("W/m^2",qavg,"Average flux is")

```

Scilab code Exa 1.2 ab13

```

1 clear;
2 clc;
3
4 //Example 1.2(Heating of water in an Electric Teapot
    )
5 //Mass of liquid water
6 m1=1.2,m2=0.5;//[Kg]
7 //Initial Temperature
8 t1=15;//[Degree Celcius]
9 //Final Temperature
10 t2=95;//[Degree Celcius]
11 //Specific heat of water
12 cp1=4.186;//[kJ/kG.K]
13 //Specific heat capacity of teapot
14 cp2=.7;//[ ]

```

```

15 Em=(m1*cp1*(t2-t1))+(m2*cp2*(t2-t1));//[kJ]
16 //Rating of Electric Heating Equipment
17 Em1=1.2;//[kJ/s]
18 dt=(Em/Em1)/60;//[seconds]
19 disp("minutes",round(dt)," of heat is","kJ",Em,"Time
    needed for this heater to supply ")

```

Scilab code Exa 1.3 ab14

```

1 clear;
2 clc;
3
4 //Example1.3[Heat Loss from Heating Ducts in a
    Basement]
5 //Given:-
6 T_in=60+273;//Temperature of hot air while entering
    the duct [K]
7 T_out=54+273;//Temperature of hot air while leaving
    the duct [K]
8 T_avg=(T_in+T_out)/2;//Average temperature of air [K]
9 Cp=1.007;//[kJ/kg]
10 disp("kJ/kg",Cp,"K is",T_avg,"The constant pressure
    specific heat of air at the average temperature
    of")
11 P=100;//Pressure of air while entering the duct [kPa]
12 R=0.287;//Universal Gas Constant [kPa.(m^3/kg).K]
13 v=5;//Average velocity of flowing air [m/s]
14 neta=0.8;//Efficiency of natural gas furnace
15 ucost=1.60;//Cost of natural gas in that area [$/
    therm],where 1therm=105,500kJ
16 //Solution;-
17 rho=P/(R*T_in);//The density of air at the inlet
    conditions is [kg/m^3]
18 Ac=0.20*0.25;//Cross sectional area of the duct [m^2]
19 m_=rho*v*Ac;//[kg/s]

```

```

20 disp("kg/s",m_,"mass flow rate of air through the
    duct is")
21 Q_loss=m_*Cp*(T_in-T_out);//[kJ/s]
22 disp("kJ/s",Q_loss,"The rate of heat loss by the air
    is")
23 cost=(Q_loss*3600)*(ucost)*(1/105500)*(1/neta);//[$/
    h]
24 disp("per hour",cost,"$", " Cost of heat loss to the
    home owner is")

```

Scilab code Exa 1.4 ab15

```

1 clear;
2 clc;
3
4 //Example1.4 (Electric Heating of a House at High
    Elevation)
5
6 //(a)
7 t1=10+273;//Initial temperature of house[K]
8 t2=20+273;//Temperature after turning on heater [K]
9 tavg=(t1+t2)/2;//Average temperature [K]
10 cp=1.007;//[kJ/kg.K]
11 cv=.720;//[kJ/kg.K]
12 disp("kJ/kg.K",cp,"and",cv,"K",tavg,"at the average
    temperature of", "The specific heat capacities of
    air")
13 A=200;//The floor area [m^2]
14 h=3;//Height of room [m]
15 V=A*h;//Volume of the air in the house [m^3]
16 P=84.6;//Pressure [kPa]
17 R=0.287;//Universal gas constant [kPa.m^3/kg.K]
18 m=(P*V)/(R*t1);//[kg]
19 disp("kg",m,"Mass of air in the room is")
20 Eincv=m*cv*(t2-t1);

```

```

21 disp("kJ",Eincv,"The amount of energy transferred to
    air at constant volume is ")
22 u_cost=0.075;//Unit cost of energy [$/kWh]
23 Cost1=(Eincv*u_cost)/(3600);//[$]
24 disp(Cost1,"Cost of Energy is $")
25
26 //(b)
27 Eincp=m*cp*(t2-t1);//[kJ]
28 disp("kJ",Eincp,"The amount of energy transferred to
    air at constant is ")
29 Cost2=(Eincp*u_cost)/3600;//[$]
30 disp(Cost2,"Cost of Energy is $")

```

Scilab code Exa 1.5 ab16

```

1 clear;
2 clc;
3
4 //Example1.5 (The cost of Heat loss through a Roof)
5
6 //(a)
7 k=0.8;//The thermal conductivity of the roof[W/m.
    degree.C]
8 A=6*8;//Area of the roof[m^2]
9 t1=15;//temperature of inner surface roof[degree C]
10 t2=4;//temperature of outer surface roof[degree C]
11 L=0.25;//thickness of roof[m]
12 Q_=k*A*(t1-t2)/L;// [W]
13 disp("W",Q_,"The steady rate of heat transfer
    through the roof is")
14
15 //(b)
16 dt=10;//time period [h]
17 Q=Q_*dt/1000;// [kWh]
18 u_cost=0.08;//Unit cost of energy [$/kWh]

```

```
19 Cost=Q*u_cost; //[$]
20 disp(Cost,"and its cost is $", "kWh",Q,"The amount of
    heat lost through the roof")
```

Scilab code Exa 1.6 ab16

```
1 clear;
2 clc;
3
4 //Example1.6 (Measuring the Thermal Conductivity of
    a Material)
5 V=110; //Voltage difference b/w thermocouples [V]
6 I=0.4; //Current drawn by thermocouples [A]
7 We=V*I; // [W]
8 disp("W",We,"The electrical power consumed by the
    resistance heater and converted to heat is")
9 q_=We/2; // [W]
10 disp("W",q_,"The rate of heat flow through each
    sample")
11 dT=15; //Temperature drop in the direction of heat
    flow [degree C]
12 l=.03; //length for which temperature change is
    measured [m]
13 D=.05; //diameter of cylinder [m]
14 a=(%pi*D^2)/4; //Cross-sectional area of the cylinder
    [m^2]
15 K=(q_*l)/(a*dT); // [W/m.degreeC]
16 disp("W/mC",K,"The thermal conductivity of the
    sample is")
```

Scilab code Exa 1.7 ab17

```
1 clear;
```



```

2  clc;
3
4  //Example1.7[ Conversion between SI and English Units
   ]
5  W_to_btu_p_h=3.41214; //Conersion from Watt to btu
   per hour[btu/h]
6  m_to_ft=3.2808; //Conversion from meter to english
   unit feet[ft]
7  deg_C_to_deg_F=1.8; //Conversion from degree Celcius
   to degree Farenhiet
8  W_per_m_deg_C=W_to_btu_p_h/(m_to_ft*deg_C_to_deg_F);
   //Conversion factor for 1W/m.degree Celcius[Btu/h
   .ft.degree Farenhiet]
9  k_brick=0.72*W_per_m_deg_C; // [Btu/h.ft.degree
   Farenhiet]
10 disp("Btu/h.ft.degree Farenhiet",k_brick,"The
   thermal conductivity of the brick in English
   units is")

```

Scilab code Exa 1.8 ab18

```

1  clear;
2  clc;
3
4  //Example1.8[Measuring Convection Heat Transfer
   coefficient]
5  //Given:-
6  T_ambient=15; //Temperature of room[degree Celcius]
7  T_surface=152; //Temperature of surface of wire[
   degree Celcius]
8  L=2; //Length of wire[m]
9  D=0.003; //Diameter of wire[m]
10 V=60; //Voltage drop across the current wire[Volts]
11 I=1.5; //Current flowing in the wire[amp]
12 //Solution:-

```

```

13 //When steady conditions are reached, the rate of
    heat loss from the wire equals the rate of heat
    generation in the wire as a result of resistance
    heating
14 Q_=V*I; // [W]
15 disp("W",Q_,"The rate of heat generated in the wire
    as a result of resistance heating is")
16 As=%pi*D*L; //Surface Area of the wire [m^2]
17 //Using Newton's Law of Cooling
18 //and assuming all heat loss in wire to occur by
    convection
19 h=Q_/(As*(T_surface-T_ambient)); // [W/m^2.degree
    Celcius]
20 disp("W/m^2.degree Celcius",h,"The convection Heat
    Transfer coefficient is" )

```

Scilab code Exa 1.9 ab19

```

1 clear;
2 clc;
3
4 //Example1.9[Radiation Effect on Thermal Comfort]
5 //Given:-
6 T_room=22+273; //Temperature fo room[K]
7 T_wntr=10+273; //Average Temperature of inner
    surfaces of walls ,floors and the cieling in
    winter [K]
8 T_smmr=25+273; //Average Temperature of inner
    surfaces of walls ,floors and the cieling in
    summer [K]
9 T_outr=30+273; //Average outer surface temperature of
    the person [K]
10 A=1.4; //The exposed surface area [m^2]
11 e=0.95; //Emissivity of person
12 sigma=5.67*(10^(-8)); //Stefan's constant

```

```

13 Q_rad_wntr=e*sigma*A*((T_outr^4)-(T_wntr^4)); // [W]
14 Q_rad_smmr=e*sigma*A*((T_outr^4)-(T_smmr^4)); // [W]
15 disp("W",Q_rad_smmr,"and",round(Q_rad_wntr),"The net
      rates of radiation heat transfer from the body
      to the surrounding walls, ceiling, and floor in
      winter and summer are respectively")

```

Scilab code Exa 1.10 ab20

```

1 clear;
2 clc;
3
4 //Example1.10[Heat Loss from a Person]
5 //Given:-
6 T_room=20+273; //Temperature of breezy room [K]
7 T_outr=29+273; //Average outer surface temperature of
      the person [K]
8 As=1.6; //Exposed Surface Area [m^2]
9 h=6; //Convection Heat transfer coefficient [W/m^2.K]
10 e=0.95; //Emissivity of person
11 sigma=5.67*(10^(-8)); //Stephan's constant [W/m^2.
      degree Celcius]
12 Q_conv=h*As*(T_outr-T_room); // [W]
13 disp("W",Q_conv,"Rate of convection heat transfer
      from the person to the air in the room is")
14 Q_rad=e*sigma*As*((T_outr^4)-(T_room^4)); // [W]
15 disp("W",Q_rad,"The rate of convection heat transfer
      from the person to the surrounding walls, cieling
      , fllor is")
16 Q_total=Q_conv+Q_rad; // [W]
17 disp("W",round(Q_total),"The rate of total heat
      transfer from the body is ")

```

Scilab code Exa 1.11 ab21

```
1 clear;
2 clc;
3
4 //Example1.11[Heat transfer between two Isothermal
   Plates]
5 //Given:-
6 T1=300,T2=200;//Temperatures of two large parallel
   isothermal plates [K]
7 L=0.01;//distance between both plates [m]
8 e=1;//Emissivity of plates
9 A=1;//Surface area of plates [m^2]
10 T_avg=(T1+T2)/2;//Average temperature [K]
11 sigma=5.67*(10^(-8)); //Stefan 's constant [W/m^2.K^4]
12 //Solution (a)[space between plates is filled with
   air]
13 k_air=0.0219;//The thermal conductivity of aair at
   the average temperature [W/m.K]
14 Q_cond=k_air*A*(T1-T2)/L;// [W]
15 Q_rad=e*sigma*A*((T1^4)-(T2^4)); // [W]
16 disp("W",round(Q_rad),"and",Q_cond,"The rates of
   conduction and radiation heat transfer between
   the plates through the air layer are respectively
   ")
17 Q_total_a=Q_cond+Q_rad;// [W]
18 disp("W",round(Q_total_a),"Net rate of heat transfer
   is")
19 disp("The heat transfer rate in reality will be
   higher because of the natural convection currents
   that are likely to occur in the air space
   between the plates")
20 //Solution (b)[space between the plates is evacuated
   ]
21 disp("when the air space b/w the plates is evacuated
   there is no conduction or convection ,and the only
   heat transfer between the plates will be by
   radiation. ")
```

```

22 disp(" Therefore")
23 Q_total_b=Q_rad;// [W]
24 disp("W",round(Q_total_b),"Net rate of heat transfer
      is")
25 //Solution (c)[space between the plates is filled
      with urethane insulation]
26 k_insu=0.026;//At average temperature thermal
      conductivity of urethane insulation [W/m.K]
27 disp("An opaque solid material placed b/w the two
      plates blocks direct radiation heat transfer
      between the plates")
28 Q_cond_c=k_insu*A*(T1-T2)/L;// [W]
29 Q_total_c=Q_cond_c;// [W]
30 disp("W",round(Q_total_c),"The net rate of heat
      transfer through the urethane insulation is")
31 //Solution (d)[the distance between the plates is
      filled with superinsulation]
32 k_super=0.00002;//At average temperature thermal
      conductivity of superinsulation [W/m.K]
33 disp("The layers of superinsulation prevent any
      direct radiation heat transfer between the plates
      ")
34 Q_cond_d=k_super*A*(T1-T2)/L;// [W]
35 Q_total_d=Q_cond_d;// [W]
36 disp("W",Q_total_d,"The net rate of heat transfer
      through the layer of superinsulation is")

```

Scilab code Exa 1.13 ab22

```

1 clear;
2 clc;
3
4 //Example1.13[Heating of a Plate by Solar Energy]
5 //Given:-
6 a=0.6;//absorptivity of exposed surface of plate

```

```

7 q_incident=700;//Rate at which solar radiation
  incident on the plate [W/m^2]
8 T_surr=25+273;//Surrounding air temperature [K]
9 h=50;//Combined radiation and convection heat
  transfer coefficient [W/m^2.K]
10 //Solution
11 //Temperature keeps on increasing till a point comes
  at which the rate of heat loss from the plate
  equals the rate of solar energy absorbed, and the
  temperature of the plate no longer changes
12 T_surface=T_surr+(a*(q_incident)/h);// [K]
13 disp("degree Celcius",T_surface-273,"The plate
  surface temperature is")

```

Scilab code Exa 1.14 ab23

```

1 clear;
2 clc;
3
4 //Example1.14[Non-linear equation in two variable]
5 //x1=x, x2=y
6 function [f]=f2(x)
7 f(1)=x(1)-x(2)-4;
8 f(2)=x(1)^2+x(2)^2-x(1)-x(2)-20;
9 deff(' [f]=f2(x) ', ['f_1=x(1)-x(2)-4', 'f_2=x(1)^2+x(2)
  ^2-x(1)-x(2)-20'])
10 //To get the desired output assign an initial value
  such as x0=[1,1], [xs,fxs,m]=fsolve(x0',f2)

```

Chapter 2

Heat Conduction Equation

Scilab code Exa 2.2 ab24

```
1 clear;
2 clc;
3
4 //Example2.2[Heat Generation in a Hair Dryer]
5 //Given:-
6 E_gen=1200;//[Total rate of heat generation]
7 L=80;//[Length of wire [cm]
8 D=0.3;//[Diameter of wire [cm]
9 //Solution:-
10 V_wire=%pi*(D^2)*L/4;//[Volume of the wire [cm^3]
11 e_gen=E_gen/V_wire;//[W/cm^3]
12 As=%pi*D*L;//[Surface Area of wire [m^2]
13 Q_=E_gen/As;//[W/cm^2]
14 disp("W/cm^2",Q_," and ", "W/cm^3", round(e_gen), "The
    rate of heat generation in the wire per unit
    volume and heat flux on the outer surface of the
    wire as a result of this heat generation are
    respectively")
```

Scilab code Exa 2.4 ab25

```
1 clear;
2 clc;
3
4 //Example2.3[Heat Conduction in a Resistance Heater]
5 //Given:-
6 E_gen=2000; //Total rate of heat generation in the
   wire [W]
7 L=0.5; //Length of cylindrical shaped wire [m]
8 D=0.004; //Diameter of wire [m]
9 k_heater=15; //Thermal conductivity of wire [W/m.K]
10 //Solution:-
11 //The resistance wire is considered to be a very
   long cylinder since its length is more than 100
   times its diameter.Heat is generated uniformly in
   the wire and the conditions on the outer surface
   of the wire are uniform.Hence it is reasonable
   to expect the temperature int he wire to vary in
   radial r direction only and thus heat transfer to
   be one dimensional , $T=T(r)$ 
12 V_wire=%pi*(D^2)*L/4; //Volume of the wire [m^3]
13 e_gen=E_gen/V_wire; // [W/m^3]
14 disp("W/m^3",e_gen,"The rate of heat generation in
   the wire per unit volume is")
15 const=e_gen/k_heater;
16 disp("= 0",const,"The equation governing the
   variation of temperature int he wire is simply
   (1/r)d/dr(r.dT/dr)+")
```

Scilab code Exa 2.5 ab26

```
1 clear;
2 clc;
3
```



```

4 //Example2.5[Cooling of a Hot Metal Ball in Air]
5 //Given:-
6 T_ball=300;//Tempeprature of ball[degree Celcius]
7 T_surr=25;//Temperature of ambient air[degree
  Celcius]
8 //Solution:-
9 //The ball in initially at a uniform temperature and
  is cooled uniformly from the entire outer
  surface.Also, the temperature within the ball
  changes with the radial distance r and the time t
  . T=T(r,t)
10 disp("The thermal conductivity is given to be
  variable ,and there is no heat generation in the
  ball , therefore the differential equation
  governing the variation of temperature in the
  ball is")
11 disp("(1/(r^2)d/dr((r^2)k(dT/dr))=rho*c(dT/dt)")

```

Scilab code Exa 2.6 ab27

```

1 clear;
2 clc;
3
4 //Example2.6[Heat Conduction in a Short Cylinder]
5 //Given:-
6 //Radius R and height h of the small cylinder
7 T=300;//Temperature of cylinder[degree Celcius]
8 T_ambient=20;//Temperature of ambient air[degree
  Celcius]
9 //Variation is thermal conductivity is negligible
10 //The cylinder is cooled unifromly from the top and
  bottom surfaces in the z-direction as well as the
  lateral surface in the radial r-direction.Also
  Temperature at any point in the ball changes with
  time during cooling. Therefore this is a two

```

```

        dimensional transient heat conduction problem i.e
        . T=T(r,z,t)
11 disp("The differential equation governing the
        variation of temperature in the billet is ")
12 disp("((1/r)(d/dr)(k*r(dT/dr)))+(d/dz)(k(dT/dz))=
        rho*c(dT/dt)")
13 disp("In case of constant thermal conductivity it
        reduces to")
14 disp("((1/r)(d/dr)(r(dT/dr)))+(d^2)T/(dz^2)=(1/a)(dT
        /dt)")

```

Scilab code Exa 2.7 ab28

```

1 clear;
2 clc;
3
4 //Example2.7[Heat Flux boundary Condition]
5 //Given:-
6 Q=800; //Heat transfer rate [W]
7 D=0.2; //Diameter of pan [m]
8 L=0.003; //Thickness of pan [m]
9 T_in=110; //T(L) Temperature of the inner surface of
        the pan [degree Celcius]
10 neta=0.9; //Percent of total heat transferred to the
        pan
11 //Solution;-
12 //The inner and outer surfaces of the bottom section
        of the pan can be represented by x=0 and x=L,
        respectively. During steady operation the
        temperature will depend on x only and thus T=T(x)
        .
13 //Solution:-
14 actual_Q=neta*Q; //90 percent of the 800W is
        transferred to the pan at that surface
15 A=%pi*(D^2)/4; //Bottom Surface Area [m^2]

```

```

16 disp("-k*dT(0)/dx=q_")
17 q_=actual_Q/(1000*A);//[kW/m^2]
18 //The boundary condition on this surface can be
    expressed as
19 disp("degree Celcius",T_in,"T(L)=")
20 disp("m",L,"where L=")

```

Scilab code Exa 2.8 ab29

```

1 clear;
2 clc;
3
4 //Example2.8[Convection and Insulation Boundary
    Conditions]
5 //Given:-
6 T_steam=200;//Temperature of steam[degree Celcius]
7 r_in=0.08;//Inner radii of pipe[m]
8 r_out=0.085;//Outer radii of pipe[m]
9 h=65;//convection heat transfer coefficient on the
    inner surface of the pipe[W/m^2.K]
10 //Heat transfer through the pipe material
    predominantly is in the radial direction and thus
    can be approximated as being one-dimensional
11 disp("Taling the direction of heat transfer to be
    the positive r direction , the boundary condition
    on that surface can be expressed as")
12 disp("-k(dT(r_in ,t)/dr)=h(T_steam-T(r1))")
13 //The pipe is said to be well insulated on the
    outside , and thus heat loss through the outer
    surface of the pipe can be assumed to be
    negligible .
14 disp("Then the boundary at the outer surface can be
    expressed as")
15 disp("dT(r_out ,t)/dr=0")

```

Scilab code Exa 2.9 ab30

```
1 clear;
2 clc;
3
4 //Example2.9[Combined Convection and Radiation
   Condition]
5 //Given:-
6 T_ball=300;//Temperature of spherical metal ball[
   degree Celcius]
7 T_ambient=27;//Temperature of ambient air[degree
   Celcius]
8 k=14.4;//Thermal conductivity of the ball material[W
   /m.K]
9 h=25;//average convection heat transfer coefficient
   on the outer surface of the ball[W/m^2.K]
10 e=0.6;//Emissivity of outer surface of the ball
11 T_surr=290;//
12 //This is one-dimensional transient heat transfer
   problem since the temperature within the ball
   changes with the radial distance r and the time t
   i.e.  $T=T(r,t)$ 
13 //Taking the moment the ball is removed from the
   oven to be t=0
14 disp("The initial condition can be expressed as")
15 disp("T(r,0)=T_ball")
16 disp("degree Celcius",T_ball)
17 //The problem possesses symmetry about the mid point
   (r=0) since the isotherms in this case are
   concentric spheres, and thus no heat is crossing
   the mid point of the ball.
18 disp("The boundary condition at the midpoint i.e. r
   =0 can be expressed as  $dT(0,t)/dr=0$ ")
19 //The heat conducted to the outer surface of the
```

```

    ball is lost to the environment by convection and
    radiation.
20 disp("Taking the direction of heat transfer to be
    the positive r direction , the boundary condition
    on the outer surface can be expressed as")
21 disp("-k(dT(r_out , t)/dr)=h[T(r_out)-T_ambient]+e*
    sigma [(T(r_out) ^4)-(T_ambient ^4)]")

```

Scilab code Exa 2.10 ab31

```

1 clear;
2 clc;
3
4 //Example2.10[Combined Convection , Radiation and
    Heat Flux]
5 //Given:-
6 T_surf1=20;//Ambient temperature in the interior of
    the house[degree Celcius]
7 T_surf2=5;// Ambient temperature outside the house[
    degree Celcius]
8 L=0.2;// Thickness of the wall[m]
9 a=0.5;// absorptivity of outer surface of wall
10 h_in=6;//Convection heat transfer coefficient for
    inner surface of wall[W/m^2.degree Celcius]
11 h_out=25;//Convection heat transfer coefficient for
    outer surface of wall[W/m^2.degree Celcius]
12 k=0.7;//The thermal conductivity of wall material[W/
    m.degree Celcius]
13 e=0.9;//Emissivity of outer surface of wall
14 //Solution:-
15 //The heat transfer though the wall is given to be
    steady and one dimensional and thus temperature
    depends on x only i.e. T=T(x)
16 disp("The boundary condition ont the inner surface
    of the wall at x=0 can be expressed as -k(dT(0)/

```

```

    dx)=h_in [ T_surf1-T(0) ]")
17 disp(" degree Celcius",T_surf1,"and", "W/m^2.degree
    Celcius",h_in,"where h_in and T_surf are
    respectively ")
18 disp("The boundary condition on the outer surface at
    x=L can be expressed as ")
19 disp("-kdT(L)/dx=h_out [T(L)-T_surf2]+e*sigma [(T(L)
    ^4)-(T_sky ^4)]-a*q_solar")
20 disp("where T_sky is temperature of the sky and
    q_solar is the incident solar heat flux")

```

Scilab code Exa 2.11 ab32

```

1 clear;
2 clc;
3
4 //Example2.11[Heat Conduction in a Plane Wall]
5 //Given:-
6 k_wall=1.2;//Thermal conductivity of wall[W/m.degree
    Celcius]
7 L=0.2;//Thickness of wall[m]
8 As=15;//Surface area[m^2]
9 T1=120,T2=50;//The two sides of the wall are
    maintained at these constant temperatures[degree
    Celcius]
10 //Solution (a)
11 disp(" Differential equation can be expressed as d^2(
    T)/(dx^2)=0")
12 disp("with boundary conditions ")
13 disp(" degree Celcius",T1,"T(0)=T1=")
14 disp(" degree Celcius",T2,"T(L)=T2=")
15 disp("integrating this we get,")
16 disp("dT/dx=C1",,"where C1 is an arbitrary constant
    ")
17 disp("integrating we obtain temperature to follow

```

```

    following relation :-")
18 disp("and substituting values in above equation", "T(
    x)=((T2-T1)/L)*x+T1 ")
19 T3=(((T2-T1)/L)*(0.1))+T1;
20 disp("degree Celcius", T3, "The value of temperature
    at x=0.1m is")
21 Q_wall=-k_wall*As*((T2-T1)/L); // [W]
22 disp("W", Q_wall, "The rate of heat conduction through
    the wall is")

```

Scilab code Exa 2.13 ab33

```

1 clear;
2 clc;
3
4 //Example2.13[Heat Conduction in the Base Plate of
    an Iron]
5 //Given:-
6 k=15; // [W/m.degree Celcius]
7 A=300*10^(-4); //Base Area [m^2]
8 L=0.005; //Thickness [m]
9 T_surr=20; //Temp of surrounding [degree Celcius]
10 h=80; //Convection het transfer coefficient [W/m^2.
    degree Celcius]
11 Q=1200; // [W]
12 //Solution:-
13 q=Q/A; // [W/m^2]
14 disp("W/m^2", q, "Uniform Heat Flux to whicj inner
    surface of the base plate is subjected")
15 //Integration Constants
16 C1=-q/k;
17 C2=T_surr+(q/h)+(q*L/k);
18 T_0=T_surr+q*((L/k)+(1/h)); // [degree Celcius]
19 T_L=T_surr+q*(1/h); // [degree Celcius]
20 disp("respectively", "degree Celcius", T_L, "and", ")

```

degree Celcius",`round(T_0)`,"The temperatures at the inner and outer surfaces of the plate i.e. at $x=0$ and $x=L$ are")

Scilab code Exa 2.14 ab34

```

1  clear;
2  clc;
3
4  //Example2.14[Heat Conduction in a Solar Heated Wall
5  ]
6  //Given:-
7  L=0.06;//Thickness of wall [m]
8  k=1.2;//Thermal Conductivity [W/m.degree Celcius]
9  e=0.85;//Emissivity
10 a=0.26;//Solar absorptivity
11 T1=300;//Temp of Inner surface of Wall [K]
12 q_solar=800;//Incident rate of solar radiation [W/m
13 ^2]
14 T_space=0;//Temp of outer space [K]
15 //Solution:-
16 //Integrating results into
17 function [f]=temp(T)
18     f(1)=(((a*q_solar)-(e*5.67*10^(-8)*T(1)^4))*(L/k)
19     )+T1-T(1);
20     deff(' [f]=temp(T) ', [' f_1 (T) =(((a*q_solar)-(e
21     *5.67*10^(-8)*T(1)^4))*(L/k))+T1-T(1) '])
22 endfunction
23 x0=[1]
24 [xs ,fxs ,m]=fsolve(x0',temp);
25 disp("K",xs,"The outer surface temperature is ")
26 //First execute the program with x0=[1] then [xs
27 ,fxs ,m]=fsolve(x0',temp) then re-execute to
28 obtain correct output as for 1st exeution 'xs
29 ' is undefined

```



```
23     q=k*(T1-xs)/L;
24     disp("W/m^2",round(q),"The steady rate of heat
        conduction through the wall is")
```

Scilab code Exa 2.15 ab35

```
1  clear;
2  clc;
3
4  //Example2.15[Heat Loss through a Steam Pipe]
5  //Given:-
6  L=20; //Pipe Length [m]
7  k=20; // [W/m.degree Celcius]
8  r1=0.06; //Inner Radius [m]
9  r2=0.08; //Outer Radius [m]
10 T1=150; //Temp of inner surface [degree Celcius]
11 T2=60; //Temp of outer surface [degree Celcius]
12 //Solution:-
13 //Integrating differential equation we get T(r)=
    C1logr+C2, where C1 and C2 are
14 C1=(T2-T1)/log(r2/r1);
15 C2=T1-((T2-T1/log(r2/r1))*log(r1));
16 Q_cyl=2*%pi*k*L*(T1-T2)/(log(r2/r1));
17 disp("kW",round(Q_cyl/1000),"The rate of heat
    conduction through the pipe is")
```

Scilab code Exa 2.16 ab36

```
1  clear;
2  clc;
3
4  //Example2.16[Heat Conduction through a Spherical
    Shell]
```

```

5 //Given:-
6 r1=0.08;//Inner Radius [m]
7 r2=0.1;//Outer radius [m]
8 k=45;//Thermal conductivity [W/m.degree Celcius]
9 T1=200;//Temperature of inner surface[degree Celcius
]
10 T2=80;//Temperarure of outer surface[degree Celcius]
11 //Solution:-
12 //Integrating the differential equation twicw we get
    T(r)=-C1/r+C2, where
13 C1=r1*r2*(T1-T2)/(r2-r1);
14 C2=((r2*T2)-(r1*T1))/(r2-r1);
15 Q_sphere=4*%pi*k*r1*r2*(T1-T2)/(r2-r1);
16 disp("kW",Q_sphere/1000,"The rate of heat conduction
    through the container wall is")

```

Scilab code Exa 2.17 ab37

```

1 clear;
2 clc;
3
4 //Example2.17[ Centerline Temperature of a Resistance
    Heater]
5 //Given:-
6 k=15;//Thermal conductivity of heater wire [W/m.K]
7 E_gen=2000;//Total heat generation [W]
8 l=0.5;//Length of resistance heater wire [m]
9 D=0.004;//Diameter of wire [m]
10 Ts=105;//Outer surface Temperarure [degree Celcius]
11 //Solution:-
12 V_wire=%pi*(D^2)*l/4;//Volume of wire [m^3]
13 e_gen=E_gen/V_wire;// [W/m^3]
14 disp("W/m^3",e_gen,"The heat generation per unit
    volume of the wire is")
15 Tc=Ts+(e_gen*(D^2)/(4*4*k));//[degree Celcius]

```

```
16 disp(" degree Celcius",round(Tc),"The center
    temperature of the wire is ")
```

Scilab code Exa 2.18 ab38

```
1 clear;
2 clc;
3
4 //Example2.18[Variation of Temperature in a
    Resistance Heater]
5 //Given:-
6 k=13.55;//[W/m.degree Celcius]
7 ro=0.005;//[m]
8 e_gen=4.3*10^7;//rate of resistance heating[W/m^3]
9 Ts=108;//Surface temperature[degree Celcius]
10 //Solution:-
11 //Integrating we get
12 //T(r)=Ts+((e_gen*(ro^2-r^2)/4k))
13 T_0=Ts+((e_gen*ro^2)/(4*k));
14 disp(" degree Celcius",round(T_0),"The temperature at
    the centreline ,r=0 is")
```

Scilab code Exa 2.19 ab39

```
1 clear;
2 clc;
3
4 //Example2.19[Heat Conduction in a two layer medium]
5 //Given:-
6 k_wire=15,k_ceramic=1.2;//[W/m.degree Celcius]
7 r1=0.002,r2=0.007;//[m]
8 e_gen=50*10^6;//[W/m^3]
9 Ts=45;//[degree Celcius]
```

```

10 //Solution:-
11 T1=(((e_gen*(r1^2)*log(r2/r1))/(2*k_ceramic))+Ts);//
    [degree Celcius]
12 disp("degree Celcius",T1,"The Interface temperature
    is")
13 T_wire=T1+(((e_gen*(r1^2))/(4*k_wire)));//[degree
    Celcius]
14 disp("degree Celcius",T_wire,"The temperature at the
    centreline(r=0) is")
15 disp("Thus the temperature of the centreline is
    slightly above the interface temperature")

```

Scilab code Exa 2.21 ab40

```

1 clear;
2 clc;
3
4 //Example2.21[Heat Conduction through a Wall with k(
    T)]
5 //Given:-
6 //k varies with temperature as k=k0(1+bT)
7 k0=38; // [W/m]
8 b=9.21*(10^(-4)); // [k^(-1)]
9 h=2,w=0.7,t=0.1; //Height,width and thickness of
    plates respectively [m]
10 T1=600,T2=400; //Temperature maintained on the two
    sides of the plate [K]
11 //Solution:-
12 A=h*w; //Surface area of plate [m^2]
13 Tavg=(T1+T2)/2; //Average temperature of plate [K]
14 kavg=k0*(1+(b*Tavg)); // [W/m.K]
15 disp("W/m.K",kavg,"The average thermal conductivity
    of the medium is")
16 Q_=kavg*A*(T1-T2)/t; // [W]
17 disp("kW",round(Q_/1000),"The rate of heat

```

conduction through the plate is”)

Chapter 3

steady Heat Conduction

Scilab code Exa 3.1 ab41

```
1 clear;
2 clc;
3 //Example 3.1 [Heat Loss through a Wall]
4
5 //assumptions:-
6 //1)Heat transfer through the wall is steady
7 //2)Heat transfer is one-dimensional
8 //Properties:
9 k=0.9; // [W/m.K]
10 disp("W/m.K",k,"The thermal conductivity is given to
    be")
11 //Heat transfer through the wall is by conduction
12 A=(3*5); // [m^2]
13 disp("m^2",A,"The area of the wall is")
14 T1=16; //temperature of inner wall[degree Celcius]
15 T2=2; //Temperature of Outer wall[degree Celcius]
16 delta_T=T1-T2; //Temperature Gradient[degree Celcius]
17 L=0.3; //Length of wall along which heat is being
    transferred [m]
18 R_wall=L/(k*A); // [degree Celcius/W]
19 disp("degree Celcius/W",R_wall,"Thermal Resistnace")
```

```

    offered by the wall is")
20 Q_=(delta_T/R_wall);//[W]
21 disp("W",Q_,"The steady rate of heat transfer
    through the wall is ")

```

Scilab code Exa 3.2 ab42

```

1 clear;
2 clc;
3
4 //Example 3.2[Heat Loss through a Single Pane Window
  ]
5 //Assumptions :-
6 //1)Heat transfer through the window is steady
7 //2)Heat transfer through the wall is one
  dimensional
8 k=0.78;//[W/m.K]
9 disp("W/m.K",k,"The thermal conductivity is given to
  be")
10 L=0.008;//[Thickness of glass window[m]
11 A=(0.8*1.5);//[Area of the window[m^2]
12 T_1=20;//[Tempeprature of inner surface of glass
  window[dgree Celcius]
13 T_2=-10;//[Tempeprature of outer surface of glass
  window[dgree Celcius]
14 h_in=10;//[Heat transfer coefficient on the inner
  surface of the window[W/m^2]
15 h_out=40;//[Heat transfer coefficient on the outer
  surface of the window[W/m^2]
16 //Convection Resistance
17 R_conv1=1/(h_in*A);//[degree Celcius/W]
18 R_conv2=1/(h_out*A);//[degree Celcius/W]
19 //Conduction Resistance
20 R_cond=L/(k*A);//[degree Celcius/W]
21 //Net Resistance are in series

```

```

22 R_total=R_conv1+R_conv2+R_cond;//[degree Celcius/W]
23 disp("degree Celcius/W",R_total,"The total
    Resistance offered by glass window")
24 Q_=(T_1-T_2)/R_total;//[W]
25 disp("W",Q_,"Steady rate of Heat Transfer through
    the window is")
26 //Knowing the rate of Heat Transfer
27 T1=T_1-(Q_*R_conv1);//[degree Celciusthe inner
    surface temperature of the window glass can be
    determined from]
28 disp("degree Celcius",T1,"Inner Surface Temperature
    of the window glass")

```

Scilab code Exa 3.3 ab43

```

1 clear;
2 clc;
3
4 //Example3.3[:Heat Loss through double pane windows]
5 //Given:-
6 k_g=0.78; //Thermal conductitvity of glass [W/m.K]
7 k_a=0.026; //Thermal conductivity of air space [W/m.K]
8 L_g=.004; //Thickness of glass layer [m]
9 L_a=0.01; //Thickness of air space [m]
10 h_in=10; //ConvectionHeat transfer coefficient on the
    inner surface of the window [W/m^2]
11 h_out=40; //ConvectionHeat transfer coefficient on
    the outer surface of the window [W/m^2]
12 T_1=20; //Outer wall Temperature [degree Celcius]
13 T_2=-10; //Inner wall Temperature [degree Celcius]
14 //Solution:-
15 A=(0.8*1.5); //Area of glass window [m^2]
16 //Convection Resistances
17 R_conv1=1/(h_in*A); //Due to convection heat transfer
    between inner atmosphere and glass [degree

```



```

    Celcius/W]
18 R_conv2=1/(h_out*A); //Due to convection heat
    transfer between outer atmosphere and glass [
    degree Celcius/W]
19 //Conduction Resistances
20 R_cond1=L_g/(k_g*A); //Due to conduction heat
    transfer through the glass [degree Celcius/W]
21 R_cond2=R_cond1; //Glass Medium is seperated by air
    spac hence two glass mediums are created [degree
    Celcius/W]
22 R_cond3=L_a/(k_a*A); //Due to conduction heat
    transfer through the air space [degree Celcius/W]
23 //Net Resistance offered by window is the sum of all
    the individual resistances written in the order
    of their occurence
24 R_total=R_conv1+R_cond1+R_cond2+R_cond3+R_conv2; // [
    degree Celcius/W]
25 disp("degree Celcius/W",R_total,"The net resistance
    offered is")
26 Q_=(T_1-T_2)/R_total; // [W]
27 disp("W",Q_,"The steady rate of Heat transfer
    through the window is")
28 //Inner surface temperature of the window is given
    by
29 T1=T_1-(Q_*R_conv1); // [degree Celcius]
30 disp("degree Celcius",T1,"Inner Surface Temperature
    of the window is")

```

Scilab code Exa 3.4 ab44

```

1 clear;
2 clc;
3
4 //Example3.4 [Equivalent Thickness for Contact
    Resistance]

```

```

5 //Given:-
6 k=237; //Thermal conductivity of aluminium [W/m.K]
7 L=0.01; //Thickness of aluminium plate [m]
8 hc=11000; //Thermal contact conductance [W/m^2.K]
9 //Solution:-
10 Rc=1/hc; // [m^2.K/W]
11 disp(" Since thermal contact resistance is the
        inverse of thermal contact conductance")
12 disp("m^2.K/W" ,Rc," Hence Therml contact Resistance
        is")
13 //For a unit surface area, the thermal resistance of
        a flat plate is defined as
14 R=L/k;
15 //Equivalent thickness for R=Rc
16 L=k*Rc; // [m]
17 disp("cm" ,(100*L)," Equivalent thickness is")

```

Scilab code Exa 3.5 ab45

```

1 clear;
2 clc;
3
4 //Example3.5[Contact Reistance of Transistors]
5 //Given:-
6 k=386; //Thermal Conductivity of Copper [W/m.K]
7 hc=42000; //Contact Conductance coreesponding to
        copper-aluminium interface for the case of
        1.17-1.4 micron roughness and 5MPa[pressure ,
        which is close to given to what we have [W/m^2.K]
8 Ac=.0008; //Contact area b/w the case and the plate [m
        ^2]
9 A=0.01; //Plate area for each resistor [m^2]
10 L=0.01; //Thickness of plate [m]
11 ho=25; //Heat tranfer coefficient for back surface
12 T_1=20; //Ambient Temperature [degree Celcius]

```

```

13 T_2=70; //Maximum temperature of case [degree Celcius]
14 //Solution:-
15 //Resistances Offered
16 R_interface=1/(hc*Ac); //Resistance offered at the
    copper aluminium interface [degree Celcius/W]
17 R_plate=L/(k*A); //conduction resistance offered by
    copprr plate [degree Celcius/W]
18 R_conv=1/(ho*A); //Convection resistance offerd by
    back surface of casing [degree Celcius/W]
19 R_total=R_interface+R_plate+R_conv; //[degree Celcius/
    W]
20 disp("degree Celcius/W",R_total,"The total thermal
    Tesistance is")
21 Q_=(T_2-T_1)/R_total; //[W]
22 disp("W",Q_,"The rate of heat transferred is")
23 delta_T=Q_*R_interface; //[degree Celcius]
24 disp("degree Celcius",delta_T,"The temperature jump
    at the interface is given by")

```

Scilab code Exa 3.6 ab46

```

1 clear;
2 clc;
3
4 //Example3.6[Heat Loss through a Composite Wall]
5 //Given:-
6 //We consider a 1m deep and 0.25 m high portion of
    the wall since it is representative of the entire
    wall
7 //Assuming any cross-section of the wall normal to
    the x-direction to be isothermal
8 k_b=0.72; //thermal conductivity of bricks [W/m.K]
9 k_p=0.22; //thermal conductivity of plaster layers [W/
    m.K]
10 k_f=0.026; //thermal conductivity of foam layers [W/m.

```

```

    K]
11 T_in=20; //Indoor Temperature[degree Celcius]
12 T_out=-10; //Outdoor Temperature[degree Celcius]
13 h_in=10; //Inner heat transfer coefficient [W/m^2.K]
14 h_out=25; //Outer heat transfer coefficient [W/m^2.K]
15 L_f=0.03; //Thickness of foam layer [m]
16 L_p=0.02; //Thickness of plaster [m]
17 L_b=0.16; //Thickness of brick wall [m]
18 L_c=0.16; //Thickness of central plaster layer [m]
19 A1=(0.25*1); // [m^2]
20 A2=(0.015*1); // [m^2]
21 A3=(0.22*1); // [m^2]
22 //Resistances offered:-
23 R_in=1/(h_in*A1); //Resistance to convection heat
    transfer from inner surface [degree Celcius/W]
24 R1=L_f/(k_f*A1); //Conduction Resistance offered by
    outer foam layer [degree Celcius/W]
25 R2=L_p/(k_p*A1); //Conduction Resistance offered by
    Outer side Plaster Wall [degree Celcius/W]
26 R6=R2; //Conduction Resistance offered by Inner side
    Plaster Wall [degree Celcius/W]
27 R3=L_c/(k_p*A2); //Conduction Resistance offered by
    one side central Plaster wall [degree Celcius/W]
28 R5=R3; //Conduction Resistance offered by other side
    central Plaster wall [degree Celcius/W]
29 R4=L_b/(k_b*A3); //Conduction Resistance offered by
    Brick Wall [degree Celcius/W]
30 R_out=1/(h_out*A1); //Convection Resistance from
    outer surface [degree Celcius/W]
31 //R_in,R1,R2,R6,R_out are connected in series
32 //R3,R4,R5 are connected in parallel
33 R_mid=1/((1/R3)+(1/R4)+(1/R5)); //Effective Parallel
    Resistance
34 R_total=(R_in+R1+R2+R_mid+R6+R_out); // [degree
    Celcius/W]
35 disp("degree Celcius/W",R_total,"Net Resistance
    offered is")
36 Q_=(T_in-T_out)/R_total; // [W]

```

```

37 disp("W",Q_,"The steady rate of heat transfer
    through the wall is")
38 Q_p=Q_/A1;// [W/m^2]
39 disp("W/m^2",Q_p,"Heat Transfer per unit area is")
40 A_total=3*5;//Total Area of wall [m^2]
41 Q_total=Q_p*A_total;// [W]
42 disp("W",Q_total,"Thr rate of heat transfer through
    the entire wall")

```

Scilab code Exa 3.7 ab47

```

1 clear;
2 clc;
3
4 //Example3.7[Heat Transfer to a Spherical Container]
5 //Radiation effect is being considered. For the
    black tank emissivity=1
6 //Given:-
7 k=15;//thermal conductivity of stainless steel [W/m.
    degree Celcius]
8 T_ice=0+273;//temeperature of iced water [K]
9 T_tank=22+273;//temperature of tank stored at room
    temperature [K]
10 h_in=80;//Heat Transfer Coefficient at the inner
    surface of the tank [W/m^2.degree Celcius]
11 h_out=10;//Heat Transfer Coefficient at the outer
    surface of the tank [W/m^2.degree Celcius]
12 heat_f=333.7;//Heat of fusion of water at
    atmospheric pressure [kJ/kg]
13 e=1;//emissivity of tank
14 sigma=5.67*(10^(-8)); //Stefan 's [W/m^2.K^4]
15 D1=3;//inner diameter [m]
16 D2=3.04;//Outer diameter [m]
17 //Solution:-
18 //a)

```

```

19 A1=(%pi)*(D1^2); //Inner Surface area of the tank [m
    ^2]
20 A2=(%pi)*(D2^2); //outer Surface area of the tank [m
    ^2]
21 disp("The radiation heat transfer coefficient is
    given by ")
22 disp("h_rad=e*sigma*((T2^2)+(T_tank^2))*(T2+T_tank)"
    )
23 disp("But we dont know the outer surface temperature
    T2 of the tank. hence we assume a T2 value")
24 disp("since heat transfer inside the tank is larger
    ")
25 T2=5+273; // [K]
26 disp("K",T2,"Therefore taking T2 =")
27 h_rad=e*sigma*((T2^2)+(T_tank^2))*(T2+T_tank); // [W/m
    ^2.K]
28 disp("W/m^2.degree Celcius",h_rad,"The radiation
    heat transfer coefficient is determined to be")
29 //Individual Thermal Resistances Offered
30 R_in=1/(h_in*A1); //Resistance to convection from
    inner side of tank [degree Celcius/W]
31 R_sphere=((D2-D1)/2)/(4*%pi*k*(D1/2)*(D2/2)); //
    Resistance to conduction due to ice sphere [degree
    Celcius/W]
32 R_out=1/(h_out*A2); //Resistance to convection from
    outer side of tank [degree Celcius/W]
33 R_rad=1/(h_rad*A2); //Resistance to radiation heat
    transfer [degree Celcius/W]
34 //R_out and R_rad are in parallel connection ,
35 R_eq=(1/((1/R_out)+(1/R_rad))); // [degree Celcius/W]
36 //R_in, R_sphere and R_eq are connected in series
37 R_total=R_in+R_sphere+R_eq; // [degree Celcius/W]
38 Q_=(T_tank-T_ice)/R_total; // [W]
39 disp("W",Q_,"The steady rate of heat transfer to the
    iced water is")
40 disp("We determine outer surface temperature to
    check the validity of assumption")
41 T2=T_tank-(Q_*R_eq); // [K]

```

```

42 disp("K",T2)
43 disp(" which is sufficiently close to 278 K")
44 //b)
45 delta_t=24; //Time duration [h]
46 Q=Q_*delta_t*(3600/1000); // [kJ]
47 disp("kJ",Q,"The total amount of heat transfer
    during a 24 hour period is")
48 //It takes 333.7 kJ of energy to melt 1kg of ice at
    0 degree Celcius
49 m_ice=Q/heat_f; // [kg]
50 disp("kg",m_ice,"The amount of ice that will melt
    during 24h period is")

```

Scilab code Exa 3.8 ab48

```

1 clear;
2 clc;
3
4 //Example3.8[Heat Loss through an Insulated Steam
    Pipe]
5 //Given:-
6 T_steam=320; // [degree Celcius]
7 T_surr=5; // [degree Celcius]
8 k_iron=80; //Thermal conductivity of cast iron [W/m.
    degree Celcius]
9 k_insu=0.05; //Thermal conductivity of glass wool
    insulation [W/m.degree Celcius]
10 h_out=18; //Covection heat transfer coefficient
    outside the pipe [w/m^2.degree Celcius]
11 h_in=60; //Covection heat transfer coefficient
    insideside the pipe [w/m^2.degree Celcius]
12 D_in=0.05; //Inner diameter of pipe [m]
13 D_out=0.055; //Outer diameter of pipe [m]
14 t=0.03; //Thickness of insulation [m]
15 r=(D_out/2)+t; //Effective outer radius [m]

```

```

16 L=1; //Length of pipe [m]
17 //Solution:-
18 //Areas of surfaces exposed to convection
19 A1=2*pi*(D_in/2)*L; //Inner Area of pipe [m^2]
20 A2=2*pi*(r)*L; //Outer Area of pipe [m^2]
21 //Individual Thermal Resistances
22 R_conv_in=1/(h_in*A1); //Resistance to convection from
    inner surface of pipe [degree Celcius/W]
23 R_pipe=(log(D_out/D_in))/(2*pi*k_iron*L); //
    Resistance to conduction through iron pipe [degree
    Celcius/W]
24 R_insu=(log(r/(D_out/2)))/(2*pi*k_insu*L); //
    Resistance to conduction through insulation [
    degree Celcius/W]
25 R_conv_out=1/(h_out*A2); //Resistance to convection
    from outer surface of insulation on pipe [degree
    Celcius/W]
26 //All resistances are in series
27 R_total=R_conv_in+R_pipe+R_insu+R_conv_out; //Total
    Resistance [degree Celcius]
28 Q_=(T_steam-T_surr)/R_total; // [W]
29 disp("W",Q_,"The Steady rate of heat loss from the
    steam per m length of pipe is")
30 delta_T_pipe=Q_*R_pipe; //[degree Celcius]
31 delta_T_insu=Q_*R_insu; //[degree Celcius]
32 disp("degree Celcius",delta_T_insu,"and",
    delta_T_pipe,, "The temperature drop across the
    pipe and the insulation is respectively")

```

Scilab code Exa 3.9 ab49

```

1 clear;
2 clc;
3
4 //Example3.9[Heat Loss from an Insulated Electric

```



```

Wire]
5 //Given:-
6 k_insu=0.15; //[W/m.degree Celcius]
7 V=8; //Voltage drop across wire [Volts]
8 I=10; //Current flowimg through the wire [Amperes]
9 T_atm=30; //Temperature of atmosphere to which wire
   is exposed [degree Celcius]
10 h=12; //heat transfer coefficient [W/m^2.degree
   Celcius]
11 L=5; //length of wire [m]
12 D=0.003; //diameter of wire [m]
13 t=0.002; //thickness of insulation [m]
14 r=(D/2)+t; //Effective radius [m]
15 //Solution:-
16 //Rate of heat generated in the wire becomes equal
   to the rate of heat transfer
17 Q_=V*I; //[W]
18 disp("W",Q_,"Heat generated in the wire is")
19 A2=2*pi*r*L; //Outer surface area [m^2]
20 //Resistances offered
21 R_conv=1/(h*A2); //Convection resistance for the
   outer sufeace of insulation [degree Celcius/W]
22 R_insu=(log(r/(D/2)))/(2*pi*k_insu*L); //Conduction
   resitance for the plastic insulation [degree
   Celcius/W]
23 //Effective Resistance
24 R_total=R_conv+R_insu; //[degree Celcius/W]
25 //Interface Temperature can be determined from
26 T1=T_atm+(Q_*R_total); //[degree Celcius]
27 disp("degree Celcius",T1,"The interface temperature
   is")
28 //Critical radius
29 r_cr=k_insu/h; //[m]
30 disp("mm",r_cr*1000,"The critical radius of
   insulation of the plastic cover is")
31 //Larger value of critical radius ensures that
   increasing the thickness of insulation upto
   critical radius will increase the rate of heat

```

Scilab code Exa 3.10 ab50

```
1 clear;
2 clc;
3
4 //Example3.10[Maximum Power dissipation of a
   Transistor]
5 //Given:-
6 T_ambient=25;//Ambient temperature[degree Celcius]
7 T_case=85;//Maximum temperature of the case[degree
   Celcius]
8 R_case_ambient=20;//Resistance for convection b/w
   case and ambient [degree Celcius/W]
9 //Solution:-
10 Q_=(T_case-T_ambient)/R_case_ambient;// [W]
11 disp("W",Q_,"The given power transistor should not
   be operated at power levels above")
12 disp("if is its case temperature is not to exceed 85
   degree Celcius")
```

Scilab code Exa 3.11 ab51

```
1 clear;
2 clc;
3
4 //Example3.11[Selecting a Heat Sink for a Transistor
   ]
5 //Given:-
6 Q_=60;//Rate of heat transfer from given transistor
   at at full power [W]
```

```

7 T_ambient=30; //Temperature of ambient air [degree
   Celcius]
8 T_case=90; //Maximum temperature of case [degree
   Celcius]
9 //Solution:-
10 R_sink=(T_case-T_ambient)/Q_;//[degree Celcius/W]
11 disp("degree Celcius/W",R_sink,"The thermal
   resistance b/w the transistor attached to the
   heat sink and the ambient air for the specified
   temperature difference is ")

```

Scilab code Exa 3.12 ab52

```

1 clear;
2 clc;
3
4 //Example3.12[Effect of fins on Heat transfer from
   steam pipes]
5 //Given:-
6 k_fin=180; //thermal conductivity of aluminium alloy
   fins [W/m.degree Celcius]
7 D_tout=0.03; //Outer diameter of tube [m]
8 D_fout=0.06; //Outer diameter of circular fins [m]
9 t=0.002; //thickness of fin [m]
10 s=0.003; //distance between fins attached to the tube
   [m]
11 n=200; //number of fins per meter of tube
12 L=1; //length of tube [m]
13 T_surr=25; //Surrounding temperature [degree Celcius]
14 T_wall=120; //Temperature of wall of the tube [degree
   Celcius]
15 h=60; //Combined heat transfer coefficient [W/m^2.
   degree Celcius]
16 //Solution:-
17 disp("In case of no fins")

```

```

18 A_nf=%pi*D_tout*L;//Area of tube with no fins
    attached[m^2]
19 //Using Newton's Law of cooling
20 Q_nf=h*A_nf*(T_wall-T_surr);//[W]
21 disp("W",Q_nf,"Rate of heat transfer when no finis
    attached")
22 //The efficiency of the circular fins attached to a
    circular tube is plotted in Fig 3.43
23 L_fin=(D_fout-D_tout)/2;//[m]
24 //In this case we have following corrected
    parameters
25 r2c=(D_fout+t)/2;//[m]
26 Lc=L_fin+(t/2);//[m]
27 Ap=Lc*t;//[m^2]
28 r=r2c/(D_tout/2);
29 alpha=(Lc*sqrt(Lc))*sqrt(h/(k_fin*Ap));//efficiency
30 disp(alpha)
31 //for above value of alpha efficiency is found out
    from the plot in fig 3.43
32 neta=0.96;
33 A_f=2*%pi*((r2c^2)-((D_tout/2)^2));//Area of tube
    with fins attached to it[m^2]
34 Q_f_max=h*A_f*(T_wall-T_surr);//maximum rate of heat
    transfer[W]
35 Q_f=neta*Q_f_max;//Heat transfer through tube with
    fins is efficiency times the maximum rate of heat
    transfer[W]
36 disp("W",Q_f,"Heat transfer due to the finned tube")
37 //From unfinned portion
38 A_uf=%pi*D_tout*s;//Unfinned area between two
    consecutive fins[m^2]
39 Q_uf=h*A_uf*(T_wall-T_surr);//[W]
40 disp("W",Q_uf,"Heat transfer from the unfinned
    portion of the tube is")
41 //Since there are 200 fins per meter of the tube
    hence 200 interfin spacing
42 Q_tf=n*(Q_f+Q_uf);//[W]
43 disp("W",Q_tf,"The total Heat transfer from the

```

```

    finned tube is")
44 Q_increase=Q_tf-Q_nf; // [W]
45 disp("W",Q_increase,"The increase in heat transfer
    from the tube per meter of length as a result of
    the addition of fins is")
46 eff=Q_tf/Q_nf; // Effectiveness
47 disp(eff,"The rate of heat transfer from the steam
    tube increases by a factor of")
48 disp("as a result of adding fins")

```

Scilab code Exa 3.13 ab53

```

1 clear;
2 clc;
3
4 //Example3.13[Heat Loss from Buried Steam Pipes]
5 //Given:-
6 T_esurf=10; //Surface temperatur of earth[degree
    Celcius]
7 T_psurf=80; //Outer surface temperature of pipe[
    degree Celcius]
8 k_soil=0.9 //Thermal Conductivity of soil [W/m.degree
    Celcius]
9 L=30; //Length of pipe [m]
10 D=0.1; //Diameter of pipe [m]
11 z=0.5; //Depth at which pipe is kept [m]
12 //Solution:-
13 //Calculating shape factor
14 if(z>(1.5*D))
15     S=(2*pi*L)/(log((4*z)/D)), end; // [m]
16     disp(S,"Shape factor is")
17     Q_=S*k_soil*(T_psurf-T_esurf); // [W]
18     disp("W",Q_,"The steady rate of heat transfer from
    the pipe is")

```

Scilab code Exa 3.14 ab54

```
1 clear;
2 clc;
3
4 //Example3.14[Heat Transfer between Hot and Cold
   Water pipes]
5 //Given:-
6 T_hot=70;//Surface Temperature of hot pipe[degree
   Celcius]
7 T_cold=15;//Surface Temperature of cold pipe[degree
   Celcius]
8 L=5;//Length of both pipes[m]
9 D=0.05;//Diameter of both the pipes[m]
10 z=0.3;//Distance between centreline of both the
   pipes [m]
11 k=0.75;//Thermal Conductivity of the concrete [W/m.
   degree Celcius]
12 //Solution:-
13 //Calculating Shape Factor
14 S=(2*%pi*L)/(acosh(((4*(z^2))-(D^2)-(D^2))/(2*D*D)))
   ;//[m]
15 disp("m",S,"Shape factor for given configuration is"
   )
16 Q_=S*k*(T_hot-T_cold);// [W]
17 disp("W",Q_,"The steady rate of heat transfer
   between the pipes becomes")
```

Scilab code Exa 3.15 ab55

```
1 clear;
2 clc;
```

```

3
4 //Example3.15[Cost of Heat Loss through walls in
   winter]
5 //Given:-
6 R_va_insu=2.3;//thickness to thermal conductivity
   ratio [m^2.degreeCelcius/W]
7 L1=12;//length of first wall of house[m]
8 L2=12;//length of second wall of house[m]
9 L3=9;//length of third wall of house[m]
10 L4=9;//length of fourth wall of house[m]
11 H=3;//height of all the walls[m]
12 T_in=25;//Temperature inside house[degree Celcius]
13 T_out=7;;//average temperature of outdoors on a
   certain day[degree Celcius]
14 ucost=0.075;//Unit Cost of elctricity [$/kWh]
15 h_in=8.29,h_out=34.0;//Heat transfer coefficients
   for inner and outer surface of the walls
   respectively [W/m^2.degree Celcius]
16 v=24*(3600/1000);//velocity of wind[m/s]
17 //Solution:-
18 //Heat transfer Area of walls=(Perimeter*Height)
19 A=(L1+L2+L3+L4)*H;// [m^2]
20 //Individual Resistances
21 R_conv_in=1/(h_in*A);//Convection Resistance on
   inner surface of wall[degree Celcius/W]
22 R_conv_out=1/(h_out*A);//Convection Resistance on
   outer surface of wall[degree Celcius/W]
23 R_wall=R_va_insu/A;//Conduction resistance to wall[
   degree Celcius/W]
24 //All resistances are in series
25 R_total=R_conv_in+R_wall+R_conv_out;// [degree
   Celcius/W]
26 Q_=(T_in-T_out)/R_total;// [W]
27 disp("W",Q_,"The steady rate of heat transfer
   through the walls of the house is")
28 delta_t=24;//Time period[h]
29 Q=(Q_/1000)*delta_t;// [kWh/day]
30 disp("kWh/day",Q,"The total amount of heat lost

```

```

    through the walss during a 24 hour period ")
31 cost=Q*ucost; //[$/day]
32 disp("per day",cost,"Cost of heat consumption is $")

```

Scilab code Exa 3.16 ab56

```

1 clear;
2 clc;
3
4 //Example3.16[The R-value of a Wood Frame Wall]
5 //Given:-
6 f_area_insu=0.75; //area fraction for the insulation
   section
7 f_area_stud=0.25; //area fraction for the stud
8 R_bstud=3.05; //Total unit thermal resistance of
   section between studs[m^.degree Celcius/W]
9 R_atstud=1.23; //Total unit thermal resistance of
   section at studs[m^.degree Celcius/W]
10 P=50; //Perimeter of the building [m]
11 H=2.5; //height of the walls [m]
12 T_in=22; //Temperature inside the walls [degree
   Celcius]
13 T_out=-2; //Temperature outside the walls [degree
   Celcius]
14 //Solution:-
15 U_bstud=1/R_bstud; // [W/m^2.degree Celcius]
16 U_atstud=1/R_atstud; // [W/m^2.degree Celcius]
17 Total_U=(f_area_insu*U_bstud)+(f_area_stud*R_atstud)
   ; // [W/m^2.degree Celcius]
18 disp("W/m^",Total_U,"Overall U factor is")
19 disp("degree Celcius.m^2/W", (1/Total_U),"Overall
   unit thermal Resistance is")
20 ///Since glazing constitutes 20% of the walls ,
21 A_wall=(0.80)*P*H; // [m^2]
22 Q_=Total_U*A_wall*(T_in-T_out); // [W]

```



```
23 disp("W",Q_,"The rate of heat loss through the walls
    under design conditions is")
24 //Answer is slightly different from book because of
    no of digits after decimal pont used here is
    quite large
```

Scilab code Exa 3.17 ab57

```
1 clear;
2 clc;
3
4 //Example13.17[The R value of a Wall with Rigid Foam
    ]
5 //Given:-
6 //using values from previous example
7 R_old=2.23;//AS written in book[m^2.degree Celcius/W
    ]
8 //R value of of the fibreboard and the foam
    insulation , respectively
9 R_removed=0.23;//[m^2.degree Celcius/W]
10 R_added=0.98;//[m^2.degree Celcius/W]
11 //Solution:-
12 R_new=R_old-R_removed+R_added;//[m^2.degree Celcius/
    W]
13 increase=((R_new-R_old)/R_old)*100;
14 disp("m^2.degree Celcius/W",R_old,"Old R value is")
15 disp("m^2.degree Celcius/W",R_new,"New R value is")
16 disp(increase,"Percent increase in R-value")
```

Chapter 4

Transient Heat Conduction

Scilab code Exa 4.1 ab61

```
1 clear;
2 clc;
3
4 //Example4.1[Temperature Measurement by
   Thermocouples]
5 //Given:-
6 //Temperature of a gas stream is to be measured by a
   thermocouple whose junction can be approximated
   as a sphere
7 D=0.001;//Diameter of junction sphere[m]
8 //Properties of the junction
9 k=35;//Thermal conductivity[W/m.degree Celcius]
10 rho=8500;//desity [kg/m^3]
11 Cp=320;//Specific heat[J/kg.degree Celcius]
12 h=210;//Convection heat transfer coefficient between
   junction and the gas[W/m^2.degree Celcius]
13 //Solution:-
14 //V=(%pi/6)*(D^3)
15 Lc=(((%pi/6)*(D^3))/(%pi*(D^2)));//The
   characteristic length of the junction [m]
16 Bi=h*Lc/k;//Biot Number
```

```

17 if(Bi<0.1) then,
18 disp(Bi," Since Bi=")
19 disp("is less than 0.1 hence lumped system is
      applicable and the error involved in this
      approximation is negligible")
20 end;
21 b=h/(rho*Cp*Lc); //Exponent time constant[s(-1)]
22 disp("s(-1)",b,"Time constant for given lumped heat
      capacity system")
23 //In order to read 99% of intial temperature
      difference between the junction and the gas we
      must have ((T(t)-T_end)/(Ti-T_end))=0.01
24 t=-1*(log(0.01))/b;
25 disp("seconds",round(t),"Required time is")

```

Scilab code Exa 4.2 ab62

```

1 clear;
2 clc;
3
4 //Example4.2[Predicting the time of Death]
5 //Given:-
6 T_room=20; //Temperature of room[degree Celcius]
7 T_body_f=25; //Temperature of dead body after some
      time[degree Celcius]
8 T_body_i=37; //Temperature of dead body just after
      death[degree Celcius]
9 h=8; //Heat transfer Coefficient[W/m2.degree Celcius
]
10 L=1.7; //Length of body which is assumed to be
      cylindrical in shape[m]
11 r=0.15; //Radius of cylindrical body
12 //Average human body is 72% water by mass, thus we
      assumne body to have properties of water
13 rho=996; //Density[kg/m3]

```

```

14 k=0.617; //Thermal conductivity [W/m.degree Celcius]
15 Cp=4178; //Specific Heat [J/kg.degree Celcius]
16 //Solution:-
17 Lc=(%pi*(r^2)*L)/((2*%pi*r*L)+(2*%pi*(r^2))); //
    Characteristic length of body [m]
18 Bi=(h*Lc)/k; //Biot no
19 if(Bi>0.1) then,
20     disp("lumped system analysis is not applicable ,
           but we can still use it to get a rough
           estimate of time of death")
21     b=h/(rho*Cp*Lc); // [s^(-1)]
22     x=(T_body_i-T_room)/(T_body_f-T_room);
23 //exp(-b*t)=x;
24 t=(1/b)*log(x); //time elapsed [seconds]
25 disp("hour",t/3600,"As a rough estimate the person
       dies about")
26 disp("before the body was found")

```

Scilab code Exa 4.3 ab63

```

1 clear;
2 clc;
3
4 //Example4.3 [ Boiling Eggs]
5 //Given:-
6 T1=5; //Initial temperature of egg [degree Celcius]
7 T2=95; //Temperature of Boiling Water [degree Celcius]
8 h=1200; //Convection heat transfer coefficient of egg
           [W/m^2.degree Celcius]
9 r=0.025; //Radius of egg [m]
10 T3=70; //Final temperature attained by centre of egg [
           degree Celcius]
11 k=0.627; //Thermal conductivity [W/m.degree Celcius]
12 a=0.151*(10^(-6)); //Thermal diffusivity [m^2/s]
13 //Solution:-

```

```

14 Bi=(h*r)/k;//Biot Number
15 if(Bi>0.1) then,
16 disp("the lumped system analysis is not applicable")
17 //Findinf coefficient for a sphere corresponding to
    this bi are,
18 lambda1=3.0754,A1=1.9959;
19 x=(T3-T2)/(T1-T2);
20 tau=(-1/(lambda1^2))*log(x/A1);
21 disp(tau,"Fourier no is")
22 //Since fourier no is greater than 0.2, cooking time
    is determined from the definition of fourier no
    to be
23 t=(tau*(r^2))/a;//[seconds]
24 disp("minutes",(t/60),"The time taken for center of
    egg to reach 70 degree Celcius temperature")
25 else,
26     disp("the lumped system is not applicable")
27 end

```

Scilab code Exa 4.4 ab64

```

1 clear;
2 clc;
3
4 //Example4.4[Heating of Brass Plates in an Oven]
5 T_in=20;//Initial uniform temperature of brass plate
    [degree Celcius]
6 T_f=500;//Temperature of the oven[degree Celcius]
7 t=7*60;//[seconds]
8 h=120;//combined convection and radiation heat
    transfer coefficient [W/m^2.degree Celcius]
9 L=0.04/2;//Thickness of plate 2L=0.004[m]
10 //Properties of brass at room temperature are:-
11 k=110;//Thermal conductivity [W/m.degree Celcius]
12 rho=8530;//density [kg/m^3]

```

```

13 Cp=380; // Specific Heat Capacity [J.kg.degree Celcius]
14 a=33.9*(10^(-6)); // Thermal Diffusivity [m^2/s]
15 // Solution:-
16 Bi1=1/(k/(h*L));
17 tau1=(a*t)/(L^2);
18 // For above values of biot no and fourier no we have
19 p=0.46; // p=(T0-T_f)/(T_in-T_f), where T0 is
    temperature of inner surface of plate at time t
20 x=L;
21 Bi2=Bi1;
22 // For above condition of x/L ratio and Biot number
    we have
23 q=0.99; // q=(T-T_f)/(T_in-T_f), where T is
    temperature of outer surface of plate after time
    t
24 T=T_f+((p*q)*(T_in-T_f)); // [degree Celcius]
25 disp("degree Celcius",ceil(T),"The surface
    temperature of the plates when they leave the
    oven will be")

```

Scilab code Exa 4.5 ab65

```

1 clear;
2 clc;
3
4 //Example4.5 [Cooling of a long Stainless Steel
    Cylindrical Shaft]
5 //Given:-
6 Ti=600; //Temperature of cylinder just after taking
    it out of the oven [degree Celcius]
7 h=80; //average heat transfer coefficient [W/m^2.
    degree Celcius]
8 t=45*60; //Time for cooling [seconds]
9 r=0.1; //Radius of cylinder [m]
10 l=1; //Length of cylinder [m]

```

```

11 //Properties of stainless steel cylinder
12 k=14.9; //Thermal conductivity [W/m.degree Celcius]
13 rho=7900; //Density [kg/m^3]
14 Cp=477; //Specific Heat Capacity [J/kg.degree Celcius]
15 a=3.95*(10^(-6)); //Thermal diffusivity [m^2/s]
16 T_f=200; //Ambient temperature [degree Celcius]
17 //Solution:-
18 Bi1=(h*r)/k;
19 tau1=(a*t)/(r^2);
20 //For biot no=Bi1 and fourier no=tau1, we have
21 p=0.40; //p=(T(0)-T_f)/(T_i-T_f)
22 T_0=T_f+(p*(T_i-T_f)); // [degree Celcius]
23 disp("degree Celcius",T_0,"The center temperature of
      the shaft after 45 minutes is")
24 //Determining actual heat transfer
25 m=rho*pi*(r^2)*l; // [kg]
26 Q_max=m*Cp*(T_i-T_f)*(1/1000); // [kJ]
27 x=(Bi1^2)*tau1;
28 //For biot no= Bi1 and (h^2)at/(k^2)=x, we have
29 y=0.62; //y=Q/Q_max
30 Q=y*Q_max; // [kJ]
31 disp("kJ",round(Q),"The total heat transfer from the
      shaft during 45 minutes of cooling is")

```

Scilab code Exa 4.6 ab66

```

1 clear;
2 clc;
3
4 //Example4.6[Minimum Burial Depth of Water Pipes to
  avoid Freezing]
5 //Given:-
6 //Soil properties:-
7 k=0.4; //Thermal conductivity [W/m.degree Celcius]
8 a=0.15*(10^(-6)); //Thermal diffusivity [m^2/s]

```

```

 9 T_in=15; //Initial uniform temperature of ground[
    degree Celcius]
10 T_x=0; //Temperature after 3 months[degree Celcius]
11 Ts=-10; //Temperature of surface[degree Celcius]
12 h = %inf;
13 t = 7.78 *10^6;
14 //Solution:-
15 //The temperature of the soil surrounding the pipes
    will be 0 degree Celcius after three months in the
    case of minimum burial depth, therefore we have
16 x=(h/k)*(sqrt(a*t));
17 //Since h tends to infinity
18 x=%inf;
19 y=(T_x-T_in)/(Ts-T_in);
20 //For values of x and y we have
21 neta=0.36;
22 t=90*24*60*60; //[seconds]
23 x=2*neta*sqrt(a*t); //[m]
24 disp("m",x,"Water pipes must be burried to a depth
    of at least ")
25 disp("so as to avoid freezing under the specified
    harsh winter conditions")

```

Scilab code Exa 4.7 ab67

```

1 clear;
2 clc;
3
4 //Example4.7[Surface Temperature Rise of Heated
    Blocks]
5 //Given:-
6 flux=1250; //Constant solar heat flux [W/m^2]
7 T=20; //Temperature of black painted wood block[
    degree Celcius]
8 k_wood=1.26; //Thermal conductivity of wood at room

```



```

    temperature [W/m.K]
9  a_wood=1.1*(10^(-5)); // Diffusivity of wood at room
    temperature [m^2/s]
10 k_aluminium=237; // Thermal conductivity of aluminium
    at room temperature [W/m.K]
11 a_aluminium=9.71*(10^(-5)); // Diffusivity of
    aluminium at room temperature [m^2/s]
12 t=20*60; // [seconds]
13 // Solution:-
14 Ts_wood=T+((flux/k_wood)*(sqrt((4*a_wood*t)/%pi)));
    // [degree Celcius]
15 Ts_aluminium=T+((flux/k_aluminium)*(sqrt((4*
    a_aluminium*t)/%pi))); // [degree Celcius]
16 disp(" respectively ", "degree Celcius", round (
    Ts_aluminium), " and", ceil (Ts_wood), "The surface
    temperature fro both the wood and aluminium
    blocks are ")

```

Scilab code Exa 4.8 ab68

```

1  clear;
2  clc;
3
4  //Example4.8 [Cooling of a Short Brass Cylinder]
5  //Given:-
6  Ti=120; // Initial Temperature [degree Celcius]
7  T_ambient=25; // Temperature of atmospheric air [degree
    Celcius]
8  h=60; // convetcion heat transfer coefficient [W/m^2.
    degree Celcius]
9  r=0.05; // radius of cylinder [m]
10 L=0.06; // thickness [m]
11 a=3.39*(10^(-5)); // Diffusivity of brass [m^2/s]
12 k=110; // Thermal conductivity of brass [W/m. degree
    Celcius]

```

```

13 t=900; //[seconds]
14 //Solution (a):-
15 disp("At the center of the plane wall")
16 tau1=(a*t)/(L^2);
17 Bi1=(h*L)/k;
18 disp(" respectively ",Bi1," and ",tau1," Fourier no and
      Biot no are")
19 disp("At the center of the cylinder")
20 tau2=(a*t)/(r^2);
21 Bi2=(h*r)/k;
22 disp(" respectively ",Bi2," and ",tau2," Fourier no and
      Biot no are")
23 theta_wall_c=0.8; //(T(0,t)-T_ambient)/(Ti-T_ambient)
24 theta_cyl_c=0.5; //(T(0,t)-T_ambient)/(Ti-T_ambient)
25 T_center=T_ambient+((theta_wall_c*theta_cyl_c)*(Ti-
      T_ambient)); //[degree Celcius]
26 disp(" degree Celcius",round (T_center),"The
      temperature at the center of the short cylinder
      is")
27 //Solution (b):-
28 //The centre of the top surface of the cylinder is
      still at the center of the lonf cylinder(r=0),but
      at the outer surface of the plane wall(x=L).
29 x=L; //[m]
30 y=x/L;
31 //For Bi=Bi1 and x=1
32 theta_wall_L=0.98*theta_wall_c; //(T(L,t)-T_ambient)
      /(Ti-T_ambient)
33 T_surface=T_ambient+((theta_wall_L*theta_cyl_c)*(Ti-
      T_ambient)); //[degree Celcius]
34 disp(" degree Celcius",round (T_surface),"The
      temperature at the top surface of the cylinder")

```

Scilab code Exa 4.9 ab69

```

1 clear;
2 clc;
3
4 //Example4.9[Heat transfer from a Short Cylinder]
5 //Given:-
6 Ti=120;//Initial Temperature[degree Celcius]
7 T_ambient=25;//Temperature of atmospheric air[degree
    Celcius]
8 rho=8530;//density of brass cyliner[kg/m^3]
9 Cp=0.380;//Specific heat of brass cylinder[kJ/kg.
    degree Celcius]
10 r=0.05;//radius[m]
11 H=0.12;//Height of cylinder[m]
12 h=60;//convetcion heat transfer coefficient [W/m^2.
    degree Celcius]
13 a=3.39*(10^(-5));//Diffusivity of brass [m^2/s]
14 k=110;//Thermal conductivity of brass [W/m.degree
    Celcius]
15 L=0.06;//[m]
16 t=900;//[seconds]
17 //Solution:-
18 m=rho*(%pi*(r^2)*H);//mass of cylinder[kg]
19 Q_max=m*Cp*(Ti-T_ambient);//[kJ]
20 disp("At the center of the plane wall")
21 tau1=(a*t)/(L^2);
22 Bi1=(h*L)/k;
23 x=(Bi1^2)*tau1;
24 //For given x and Bi1
25 p=0.23;//(Q/Qmax) for plane wall
26 disp("At the center of the cylinder")
27 tau2=(a*t)/(r^2);
28 Bi2=(h*r)/k;
29 y=(Bi2^2)*tau2;
30 //For given y and Bi2
31 q=0.47;//(Q/Qmax) for infinite cylinder
32 Q=Q_max*(p+(q*(1-p)));//[kJ]
33 disp("kJ",ceil(Q),"The total heat transfer from the
    cylinder during the first 15 minutes of cooling

```

is”)

Scilab code Exa 4.10 ab70

```
1 clear;
2 clc;
3
4 //Example4.10[Cooling of a Long Cylinder by Water]
5 Ti=200;//Initial Temperature of aluminium cylinder [
    degree Celcius]
6 Tf=15;//Temperature of water in which cylinder is
    kept[degree Celcius]
7 h=120;//Heat transfer Coefficient [W/m^2.degree
    Celcius]
8 t=5*60;//[seconds]
9 //Properties of aluminium at room temperature
10 k=237;//Thermal conductivity [W/m.degree Celcius]
11 a=9.71*(10^(-5));//Thermal diffusivity [m^2/s]
12 r=0.1;//Radius of cylinder [m]
13 x=0.15;//[m]
14 //Solution:-
15 Bi=(h*r)/k;//Biot number
16 //Corresponding to this biot no coefficients for a
    cylinder
17 lambda=0.3126 , A=1.0124;
18 tau=(a*t)/(r^2);
19 //Using one term approximation
20 theta0=A*exp(-(lambda^2)*tau);
21 neta=x/(2*sqrt(a*t));
22 u=(h*sqrt(a*t))/k;
23 v=(h*x)/k;
24 w=(u^2);
25 theta_semiinfinite=1-erfc(neta)+(exp(v+w)*erfc(neta+
    u));
26 theta=theta_semiinfinite*theta0;
```

```

27 T_x_t=Tf+(theta*(Ti-Tf));//[degree Celcius]
28 disp("degree Celcius",ceil (T_x_t),"the temperature
    at the center of the cylinder 15cm from the
    exposed bottom surface")

```

Scilab code Exa 4.11 ab71

```

1 clear;
2 clc;
3
4 //Example4.11[Refrigerating Steaks while Avoiding
    Frostbite]
5 //Given:-
6 Ti=25;//Initial temperature of steaks[degree Celcius
    ]
7 Tf=-15;//Temperature of refrigerator[degree Celcius]
8 L=0.015;//Thickness of steaks[m]
9 //Properties of steaks
10 k=0.45;//[W/m.degree Celcius]
11 rho=1200;//density[kg/m^3]
12 a=9.03*(10^(-8));//Thermal diffusivity[m^2/s]
13 Cp=4.10;//Specific Heat [kJ/kg]
14 T_L=2,T_0=8;//[degree Celcius]
15 //Solution:-
16 //In the limiting case the surface temperature at x=
    L from the centre will be 2 degree C,while
    midplane temperature is 8 degree C in an
    environment at -15 degree C we have
17 x=L;
18 p=(T_L-Tf)/(T_0-Tf);
19 //For this value of p we have
20 Bi=1/1.5;//Biot number
21 h=(Bi*k)/L;//[W/m^2.degree Celcius]
22 disp("W/m^2.degree Celcius",h,"The convection heat
    transfer coefficient should be kept below the

```

```
value")  
23 disp("to satisfy the constraints on the temperature  
of the steak during refrigeration")
```

Chapter 5

Numerical Methods in Heat Conduction

Scilab code Exa 5.1 ab71

```
1 clear;
2 clc;
3
4 //Example5.1[Steady Heat Conduction in a Large
   Uranium Plate]
5 //Given:-
6 L=0.04;//Thickness of plate [m]
7 k=28;//Thermal conductivity [W/m.degree Celcius]
8 e_gen=5*(10^6);//Rate of heat generation per unit
   volume [W/m^3]
9 h=45;//Heat transfer coefficient [W/m^2]
10 T_ambient=30;//Ambient temperature [degree Celcius]
11 //Solutio:-
12 M=3;//No of nodes
13 //These nodes are chosen to be at the two surfaces
   of the plate and the mid point
14 del_x=L/(M-1);//Nodal Spacing [m]
15 //Let the nodes be 0,1 and 2. and temperatures at
   these nodes are
```

```

16 T0=0; //Temperature at node 0[degree Celcius]
17 //Finding temperatures at other two nodes using
    finite difference method
18 c1=e_gen*(del_x^2)/k;
19 c2=(-h*del_x*T_ambient/k)-(c1/2);
20 function [temp]=f1(T)
21 temp(1)=2*T(1)-T(2)-c1;
22 temp(2)=T(1)-1.032*T(2)-c2;
23 deff(' [temp]=f1(T) ', ['temp_1=2*T(1)-T(2)-c1 ', 'temp_2
    =T(1)-1.032*T(2)-c2 '])
24 //To find the solution assume an initial value x0=[a
    ,b]
25 //then equate [xs,fxs,m]=fsolve(x0',f1)

```

Scilab code Exa 5.2 ab72

```

1 clear;
2 clc;
3
4 //Example5.2[Heat transfer from triangular fins]
5 //Given:-
6 k=180; //Thermal conductivity of aluminium alloy [W/m.
    degree Celcius]
7 L=0.05; //length of fin [m]
8 b=0.01; //Base thickness of fin [m]
9 T_surr=25; //Temperature of surrounding [degree
    Celcius]
10 h=15; //heat transfer coefficient [W/m^2.degree
    Celcius]
11 M=6; //No of equally spaced nodes along the fin
12 //Solution (a)
13 del_x=L/(M-1); //Nodal Spacing [m]
14 T0=200; //Temperature at node 0[degree Celcius]
15 theta=atan(b/2*L);
16 //sigmaQ_all_sides=kA_left((T_(m-1)-T_m)/del_X)+((T_

```



```

    (m+1)-T_m)/del_x)+(hA_conv(T_surr-T_m))=0
17 //Simplifying above equation we get
18 disp("((5.5-m)T_(m-1))-((10.008-2m)Tm)+((4.5-m)T_m
    +1)=-0.29")
19 //Putting m=1,2,3,4 we get five equations in five
    unknowns
20 //Solving these five equations we get temperatures
    at node 1,2,3,4 and 5 respectively
21 function [node]=f5(T)
22     node(1)=-8.008*T(1)+3.5*T(2)+0*T(3)+0*T(4)+0*T
        (5)+900.209;
23     node(2)=3.5*T(1)-6.008*T(2)+2.5*T(3)+0*T(4)+0*T
        (5)+0.209;
24     node(3)=0*T(1)+2.5*T(2)-4.008*T(3)+1.5*T(4)+0*T
        (5)+0.209;
25     node(4)=0*T(1)+0*T(2)+1.5*T(3)-2.008*T(4)+0.5*T
        (5)+0.209;
26     node(5)=0*T(1)+0*T(2)+0*T(3)+1*T(4)-1.008*T(5)
        +0.209;
27     deff(' [node]=f5(T) ', [' f_1=-8.008*T(1)+3.5*T(2)
        +0*T(3)+0*T(4)+0*T(5)+900.209 ', ' f_2=3.5*T(1)
        -6.008*T(2)+2.5*T(3)+0*T(4)+0*T(5)+0.209 ', '
        f_3=0*T(1)+2.5*T(2)-4.008*T(3)+1.5*T(4)+0*T
        (5)+0.209 ', ' f_4=0*T(1)+0*T(2)+1.5*T(3)-2.008*
        T(4)+0.5*T(5)+0.209 ', ' f_5=0*T(1)+0*T(2)+0*T
        (3)+1*T(4)-1.008*T(5)+0.209 '])
28     //Solution(b)
29     T1=T(1),T2=T(2),T3=T(3),T4=T(4),T5=T(5);
30     w=1; //width [m]
31     Q_fin=(h*w*del_x/cos(theta))*[(T0+2*(T1+T2+T3+T4
        )+T5-10*T_surr)]; // [W]
32     disp("W",Q_fin,"The total rate of heat transfer
        from the fin is")
33     //Solution(c)
34     Q_max=(h*2*w*L/cos(theta)*(T0-T_surr)); // [W]
35     neta=Q_fin/Q_max;
36     disp(neta,"Efficiency of the fin is")

```

Scilab code Exa 5.3 ab73

```
1 clear;
2 clc;
3
4 //Example5.3[SteadLy Two-Dimensional Heat Conduction
   in L-Bars]
5 //Given:-
6 e_gen=2*(10^6); //Heat generated per unit volume [W/m
   ^3]
7 k=15; //Thermal heat conductivity [W/m.degree Celcius]
8 T_ambient=25; //Temperature of ambient air [degree
   Celcius]
9 T_surface=90; //Temperature of the bottom surface [
   degree Celcius]
10 h=80 //convection coefficient [W/m^2]
11 q_R=5000; //Heat flux to which right surface is
   subjected [W/m^2]
12 del_x=0.012, del_y=0.012; //Distance between equally
   spaced nodes [m]
13 //Solution:-
14 //After substituing values in equations of all nodal
   points finally we have nine equation and nine
   unknowns
15 function [temp]=f9(T)
16     temp(1)=-2.064*T(1)+1*T(2)+0*T(3)+1*T(4)+0*T(5)
       +0*T(6)+0*T(7)+0*T(8)+0*T(9)+11.2;
17     temp(2)=1*T(1)-4.128*T(2)+1*T(3)+0*T(4)+2*T(5)
       +0*T(6)+0*T(7)+0*T(8)+0*T(9)+22.4;
18     temp(3)=0*T(1)+1*T(2)-2.128*T(3)+0*T(4)+0*T(5)
       +1*T(6)+0*T(7)+0*T(8)+0*T(9)+12.8;
19     temp(4)=1*T(1)+0*T(2)+0*T(3)-4*T(4)+2*T(5)
       +109.2;
20     temp(5)=0*T(1)+1*T(2)+0*T(3)+1*T(4)-4*T(5)+1*T
```

```

(6)+0*T(7)+0*T(8)+0*T(9)+109.2;
21 temp(6)=0*T(1)+0*T(2)+1*T(3)+0*T(4)+2*T(5)
    -6.128*T(6)+1*T(7)+0*T(8)+0*T(9)+212.0;
22 temp(7)=0*T(1)+0*T(2)+0*T(3)+0*T(4)+0*T(5)+1*T
    (6)-4.128*T(7)+1*T(8)+0*T(9)+202.4;
23 temp(8)=0*T(1)+0*T(2)+0*T(3)+0*T(4)+0*T(5)+0*T
    (6)+1*T(7)-4.128*T(8)+T(9)+202.4;
24 temp(9)=0*T(1)+0*T(2)+0*T(3)+0*T(4)+0*T(5)+0*T
    (6)+0*T(7)+1*T(8)-2.064*T(9)+105.2;
25 def f(' [temp]=f9(T) ', [' f_1= -2.064*T(1)+1*T(2)+0*
    T(3)+1*T(4)+0*T(5)+0*T(6)+0*T(7)+0*T(8)+0*T
    (9)+11.2 ', ' f_2=1*T(1)-4.128*T(2)+T(3)+0*T(4)
    +2*T(5)+0*T(6)+0*T(7)+0*T(8)+0*T(9)+22.4 ', '
    f_3=0*T(1)+T(2)-2.128*T(3)+0*T(4)+0*T(5)+T(6)
    +0*T(7)+0*T(8)+0*T(9)+12.8 ', ' f_4=T(1)+0*T(2)
    +0*T(3)-4*T(4)+2*T(5)+109.2 ', ' f_5=0*T(1)+T(2)
    +0*T(3)+T(4)-4*T(5)+T(6)+0*T(7)+0*T(8)+0*T(9)
    +109.2 ', ' f_6=0*T(1)+0*T(2)+T(3)+0*T(4)+2*T(5)
    -6.128*T(6)+T(7)+0*T(8)+0*T(9)+212.0 ', ' f_7=0*
    T(1)+0*T(2)+0*T(3)+0*T(4)+0*T(5)+T(6)-4.128*T
    (7)+T(8)+0*T(9)+202.4 ', ' f_8=0*T(1)+0*T(2)+0*T
    (3)+0*T(4)+0*T(5)+0*T(6)+T(7)-4.128*T(8)+T(9)
    +202.4 ', ' f_9=0*T(1)+0*T(2)+0*T(3)+0*T(4)+0*T
    (5)+0*T(6)+0*T(7)+T(8)-2.064*T(9)+105.2 '])

```

Scilab code Exa 5.4 ab74

```

1 clear;
2 clc;
3
4 //Example5.4[Heat Loss through Chimneys]
5 //Given:-
6 k=1.4; //Thermal conductivity of concrete [W/m. degree
    Celcius]
7 A=0.2*0.2; //Area of flow section [m^2]

```

```

8 t=0.2; // Thickness of the wall [m]
9 Ti=300+273; // Average temperature of gases [K]
10 hi=70; // Convection heat transfer coefficient inside
    the chimney [W/m^2]
11 ho=21; // Convection heat transfer coefficient outside
    the chimney [W/m^2]
12 To=20+273; // Temperature of outer air [Kelvin]
13 e=0.9; // Emissivity
14 delx=0.1, dely=0.1; // Nodal spacing [m]
15 // Solution:-
16 // Substituting values in all nodal equations and
    solving these equations we get temperature at all
    nodes
17 function [temp]=fu9(T)
18     temp(1)=7*T(1)-T(2)-T(3)-2865;
19     temp(2)=-T(1)+8*T(2)-2*T(4)-2865;
20     temp(3)=-T(1)+4*T(3)-2*T(4)-T(6);
21     temp(4)=-T(2)-T(3)+4*T(4)-T(5)-T(7);
22     temp(5)=-2*T(4)+4*T(5)-2*T(8);
23     temp(6)=-T(2)-T(3)+3.5*T(6)+(0.3645*(10^(-9))*(T
        (6)^4))-456.2;
24     temp(7)=-2*T(4)-T(6)+7*T(7)+(0.729*(10^(-9))*(T
        (7)^4))-T(8)-912.4;
25     temp(8)=-2*T(5)-T(7)+7*T(8)+(0.729*(10^(-9))*(T
        (8)^4))-912.4;
26     temp(9)=-T(8)+2.5*T(9)+(0.3645*(10^(-9))*(T(9)
        ^4))-456.2;
27     deff(' [temp]=fu9(T) ', [ ' f_1=7*T(1)-T(2)-T(3)-2865
        ', ' f_2=-T(1)+8*T(2)-2*T(4)-2865 ', ' f_3=-T(1)
        +4*T(3)-2*T(4)-T(6) ', ' f_4=-T(2)-T(3)+4*T(4)-T
        (5)-T(7) ', ' f_5=-2*T(4)+4*T(5)-2*T(8) ', ' f_6=-T
        (2)-T(3)+3.5*T(6)+(0.3645*(10^(-9))*(T(6)^4))
        -456.2 ', ' f_7=-2*T(4)-T(6)+7*T(7)
        +(0.729*(10^(-9))*(T(7)^4))-T(8)-912.4 ', ' f_8
        =-2*T(5)-T(7)+7*T(8)+(0.729*(10^(-9))*(T(8)
        ^4))-912.4 ', ' f_9=-T(8)+2.5*T(9)
        +(0.3645*(10^(-9))*(T(9)^4))-456.2 ' ])
28 T1=T(1), T2=T(2), T3=T(3), T4=T(4), T5=T(5), T6=T(6), T7=T

```

```

    (7), T8=T(8), T9=T(9);
29 T_wall=(0.5*T6+T7+T8+0.5*T9)/(0.5+1+1+0.5);
30 disp("Kelvin",T_wall,"The average temperature at the
    outer surface of the chimney weighed by the
    surface area is")
31 Q_chimney=(ho*4*0.6*1*(T_wall-To))+(e*5.67*(10^-8)
    *0.6*1*((T_wall^4)-((260^4)))); // [W]
32 disp("W",Q_chimney,"The heat transfer is")

```

Scilab code Exa 5.5 ab75

```

1 clear;
2 clc;
3
4 //Example5.5[Transient Heat Conduction in a Large
    Uranium Plate]
5 //Given:-
6 k=28; // [W/m.degree Celcius]
7 a=12.5*10^(-6); //Thermal diffusivity [m^2/s]
8 T1_0=200, T2_0=200; //Initial Temperature [degree
    Celcius]
9 e_gen=5*10^6; //Heat generated per unit volume [W/m^3]
10 h=45; //heat transfer coefficient [W/m^2.degree
    Celcius]
11 T0=0; //Temperature at node 0 [degree Celcius]
12 L=0.04; // [m]
13 M=3; //No of nodes
14 t=15; // [seconds]
15 //Solution (a):-
16 delx=L/(M-1); // [m]
17 //The nodes are 0,1 and 2
18 tau=(a*t)/(delx^2); //Fourier no
19 //Substituting this value of tau in nodal equations
20 //The nodal temperatures T1_1 and T2_1 at t=15sec
21 T1_1=0.0625*T1_0+0.46875*T2_0+33.482; // [degree

```

```

    Celcius]
22 T2_1=0.9375*T1_0+0.032366*T2_0+34.386; //[degree
    Celcius]
23 //Similarly the nodal temperatures T1_2,T2_2 at t1
    =2*t=30sec are
24 T1_2=0.0625*T1_1+0.46875*T2_1+33.482; //[degree
    Celcius]
25 T2_2=0.9375*T1_1+0.032366*T2_1+34.386; //[degree
    Celcius]
26 disp("degree Celcius",T2_2,T1_2,"and",T2_1,T1_1,"
    Temperatures at node 1 and 2 are respectively")

```

Scilab code Exa 5.6 ab76

```

1 clear;
2 clc;
3
4 //Example5.6[Solar Energy Storage in Trombe Walls]
5 //Given:-
6 hin=10; //[W/m^2]
7 A=3*75; //[m^2]
8 Tin=21; //[degree Celcius]
9 k=0.69; //[W/m.degree Celcius]
10 a=4.44*10^(-7); //diffusivity [m^2/s]
11 kappa=0.77;
12 delx=0.06; //The nodal spacing [m]
13 L=0.3; //Length of wall [m]
14 Tout=0.6, q_solar=360; //Ambient temperature in degree
    Celcius and Solar Radiation between 7am to 10 am
15 //Solution:-
16 M=(L/delx)+1;
17 disp(M,"No of nodes are")
18 //Stability Criterion
19 del_t=(delx^2)/(3.74*a); //[seconds]
20 disp("s",del_t,"The maximum allowable value of the

```

```

    time step is")
21 //Therefore any step less than del_t can be used to
    solve this problem,for convinience let 's choose
22 del_t=900;//[seconds]
23 tao=a*del_t/(del_x^2);
24 disp(tao,"The mesh Fourier number is")
25 //Initially at 7am or t=0,the temperature of the
    wall is said to vary linearly between 21 degree
    Celcius at node 0 and -1 at node 5
26 //Temp between two neighbouring nodes is
27 temp=(21-(-1))/5;//[degree Celcius]
28 T0_0=Tin;
29 T1_0=T0_0-temp;
30 T2_0=T1_0-temp;
31 T3_0=T2_0-temp;
32 T4_0=T3_0-temp;
33 T5_0=T4_0-temp;
34 T0_1=((1-3.74*tao)*T0_0)+(tao*(2*T1_0+36.5));
35 T1_1=(tao*(T0_0+T2_0))+(T1_0*(1-(2*tao)));
36 T2_1=(tao*(T1_0+T3_0))+(T2_0*(1-(2*tao)));
37 T3_1=(tao*(T2_0+T4_0))+(T3_0*(1-(2*tao)));
38 T4_1=(tao*(T3_0+T5_0))+(T4_0*(1-(2*tao)));
39 T5_1=(T5_0*(1-(2.70*tao)))+(tao*((2*T4_0)+(0.70*Tout
    )+(0.134*q_solar)));
40 disp("Nodal temperatures at 7:15am are")
41 disp("degree Celcius",T0_1,"Node0:")
42 disp("degree Celcius",T1_1,"Node1:")
43 disp("degree Celcius",T2_1,"Node2:")
44 disp("degree Celcius",T3_1,"Node3:")
45 disp("degree Celcius",T4_1,"Node4:")
46 disp("degree Celcius",T5_1,"Node5:")
47 Q_wall=hin*A*del_t*((round(T0_1)+T0_0)/2)-Tin);//[J]
48 disp("J",Q_wall,"The amount of heat transfer during
    the first time step or during the first 15 min
    period is")
49 //Similarly using values from the table given we can
    find temperature at various nodes after required
    time interval

```


Chapter 6

Fundamentals of Convection

Scilab code Exa 6.1 ab81

```
1 clear;
2 clc;
3
4 //Example6.1[Temperature Rise of Oil in a Journal
   Bearing]
5 //Given:-
6 k=0.145; // [W/m.K]
7 mu=0.8374; // [kg/m.s] or [N.s/m^2]
8 T1=20; //Temperature of both the plates [degree
   Celcius]
9 t=0.002; //Thickness of oil film between the plates [m
   ]
10 v=12; //Velocity with which plates move [m/s]
11 //Solution (a):-
12 //Relation between velocity and temperature
   variation
13 disp("T(y)=T0+(mu*(v^2)/(2*k)) [(y/L) - ((y/L)^2)]")
14 //Solution (b):-
15 //The location of maximum temperature is determined
   by setting dT/dy=0 and solving for y
16 //((mu*(v^2)/(2*k*L))*(1-(2*y/L))=0
```

```

17 L=1;//Random initialisation of variable L, where L
    is length of plates
18 y=L/2;
19 //T_max=T(L/2)
20 T_max=T1+((mu*(v^2)/(2*k))*(((L/2)/L)-(((L/2)^2)/(L
    ^2)))));
21 disp("degree Celcius",ceil(T_max),"Maximum
    temperature occurs at mid plane and its value is"
    )
22 //heat flux q0=-kdt/dy|y=0;=-kmu*v^2/(2*k*L)
23 q0=-((mu*k*(v^2)/(2*k*t))/1000);//Heat flux from one
    plate [kW/m^2]
24 qL=-((k*mu*(v^2))*(1-2)/(2*k*t*1000));//Heat flux
    from another plate [kW/m^2]
25 disp("kW/m^2",qL,"Heat fluxes at the two plates are
    equal in magnitude but opposite in sign and the
    value of magnitude is")

```

Scilab code Exa 6.2 ab82

```

1 clear;
2 clc;
3
4 //Example6.2[Finding Convection Coefficient from
    Drag Measurement]
5 //Given:-
6 //Properties of air
7 rho=1.204;//[kg/m^3]
8 Cp=1007;//[J/kg.K]
9 Pr=0.7309;//Prandtl number
10 w=2;//Width of plate [m]
11 L=3;//Characteristic length of plate [m]
12 v=7;//velocity of air [m/s]
13 Fd=0.86;//Total drag force [N]
14 //Solution:-

```

```
15 As=2*w*L; //Since both sides of plate are exposed to
    air flow [m^2]
16 //For flat plates drag force is equivalent to
    friction coefficient Cf
17 Cf=Fd/(rho*As*(v^2)/2);
18 h=(Cf*rho*v*Cp)/(2*(Pr^(2/3))); // [W/m^2.degree
    Celcius]
19 disp("respectively", "W/m^2.degree Celcius", h, "and",
    Cf, "Friction Factor and average heat transfer
    coefficient are")
```

Chapter 7

External Forced Convection

Scilab code Exa 7.1 ab91

```
1 clear;
2 clc;
3
4 //Example7.1[Flow of hot oil over a Flat Plate]
5 //Given:-
6 T_oil=60; //Temp of engine oil[degree Celcius]
7 T_plate=20; //Temp of flat plate[degree Celcius]
8 Rec=5*10^5; //Critical reynolds number for laminar
   flow
9 Tf=(T_oil+T_plate)/2; //Film temperature[degree
   Celcius]
10 v=2; // [m/s]
11 //Properties of engine oil at film temperature
12 rho=876; // [kg/m^3]
13 Pr=2962; //Prandtl number
14 k=0.1444; // [W/m.degree Celcius]
15 nu=2.485*10^(-4); //dynamic viscosity [m^2/s]
16 L=5; //Length of plate [m]
17 ReL=(v*L)/nu;
18 if(ReL<Rec) then,
19     disp("We have laminar flow over the entire plate
```

```

    ")
20     Cf=1.33*(ReL^(-0.5));
21     disp(Cf,"The average friction coefficient is")
22     //Pressure Drag is zero and thus Cd=Cf for
        parallel floe over a flat plate
23     Fd=Cf*5*1*rho*(v^2)/2;//[N]
24     disp("N",Fd,"The drag force acting on the plate
        per unit width is")
25 else ,
26     disp("flow is turbulent")
27 end
28 Nu=0.664*(ReL^(0.5))*(Pr^(1/3)); //Nusselt Number
29 disp(ceil(Nu),"Nusselt Number is")
30 h=k*Nu/L; // [W/m^2.degree Celcius]
31 disp("W/m^.degree Celcius",h,"Convective heat
        transfer coefficient is")
32 Q=h*(5*1)*(T_oil-T_plate);// [W]
33 disp("W",round(Q),"Heat flow rate is")

```

Scilab code Exa 7.2 ab92

```

1 clear;
2 clc;
3
4 //Example7.2[Cooling of a Hot Block by Forced Air at
        High Elevation]
5 //Given:-
6 ReC=5*10^5;//critical Reynolds number
7 v=8;//Velocity of air [m/s]
8 T_air=20;//Initial Temperature of air[degree Celcius
    ]
9 T_plate=140;//Temperature of flat plate[degree
    Celcius]
10 T_film=(T_air+T_plate)/2;//Film Temperature of air [
    degree Celcius]

```

```

11 //Properties of air at film temperature [degree
    Celcius]
12 k=0.02953; // [W/m.degree Celcius]
13 Pr=0.7154; //Prandtl Number
14 nu=2.097*10^(-5); //Kinematic Viscosity at 1 atm
    Pressure [m^2/s]
15 nu_ac=nu/0.823; //Kinematic viscosity at pressure
    0.823 atm[m^2/s]
16 //Solution(a)
17 L1=6; // Characteristic length of plate along the flow
    of air [m]
18 w1=1.5; //width [m]
19 ReL1=(v*L1)/nu_ac; //Reynolds number
20 if(ReL1>ReC) then,
21     disp("Flow is not laminar")
22     //We have average Nusselt Number
23     Nu1=((0.037*(ReL1^(0.8)))-871)*(Pr^(1/3));
24     disp(ceil(Nu1),"Nusselt Number is")
25     h1=k*Nu1/L1; // [W/m^2.degree Celcius]
26     As1=w1*L1; //Flow Area of plate [m^2]
27     Q1=h1*As1*(T_plate-T_air);
28     disp("W",Q1,"Heat Flow Rate is")
29 else,
30     disp("Flow is laminar")
31 end
32 //Solution(b)
33 L2=1.5; // Characteristic length of plate along flow
    of air [m]
34 ReL2=v*L2/nu_ac; //Reynolds Number
35 if(ReL2<ReC) then,=" " disp("flow=" " is=" " laminar")=
    " " nu2=" 0.664*(ReL2^(0.5))*(Pr^(1/3));" disp(ceil
    (nu2),"nusselt=" " number=" " is")=" " h2=" k*Nu2/L2
    ;//[W/m^2.degree celcius]=" " q2=" h2*As1*(T_plate
    -T_air);" disp("w",ceil(q2),"the=" " heat=" "
    transfer=" " rate=" " else,=" " turbulent")=" " end="
    " <=" " div=" " ></rec>

```

Scilab code Exa 7.3 ab93

```
1 clear;
2 clc;
3
4 //Example7.3[Cooling of Plastic Sheets by Forced Air
5 ]
6 //Given:-
7 T_p=95;//Temp of plastic Sheet[degree Celcius]
8 T_air=25;//Temp of air[degree Celcius]
9 v=3;//Velocity of flowing air [m/s]
10 L=0.6;//Length of plastic sheet [m]
11 w=1.2;//width [m]
12 k=0.02808;// [W/m.degree Celcius]
13 Pr=0.7202;//Prandtl Number
14 nu=1.896*10^(-5);// [m^2/s]
15 rho=1200;// [kg/m^3]
16 Cp=1700;// [J/kg.degree Celcius]
17 vp=(9/60);//Velocity of moving plastic [m/s]
18 tp=0.001;//Thickness of plastic [m]
19 ReC=5*10^5;//Critical Reynolds Number
20 e=0.9;//emissivity
21 //Solution(a)
22 L1=2*L;//Considering both sides of plastic sheet [m]
23 ReL1=v*L1/nu;//Reynolds number
24 if(ReL1<ReC) then,
25     disp("(a) Flow is laminar")
26     Nu1=0.664*(ReL1^0.5)*(Pr^(1/3));
27     disp(Nu1,"The nusselt number is")
28     h=k*Nu1/L1;// [W/m^2.degree Celcius]
29     As=L1*w;// [m^2]
30     Q_conv=h*As*(T_p-T_air);// [W]
31     disp("W",ceil(Q_conv),"The convection heat flow
32         rate is")
```

```

31     Q_rad=e*(5.67*10^(-8))*As*(((T_p+273)^4)-((T_air
        +273)^4));//[W]
32     disp("W", (Q_rad), "Radiation heat transfer rate
        is")
33     Q_total=Q_conv+Q_rad;//[W]
34     disp("W", ceil(Q_total), "The rate of cooling of
        the plastic sheet by combined convection and
        radiation is")
35 else
36     disp("(a) The Flow is turbulent")
37 end
38 //Solution(b)
39 At=w*tp;//[m^2]
40 m=rho*At*vp; //ass of th plastic rolling out per unit
        time[kg/s]
41 T2=T_p+(-Q_total/(m*Cp));//[degree Celcius]
42 disp("degree Celcius", T2, "(b) The temperature of the
        plastic sheet as it leaves the cooling section
        is")

```

Scilab code Exa 7.4 ab94

```

1  clear;
2  clc;
3
4  //Example7.4[Drag Force Acting on a Pipe in a River]
5  //Given:-
6  T_water=15;//[degree Celcius]
7  vw=4; //Velocity of water[m/s]
8  od=0.022; //Outer diameter of pipe[m]
9  w=30; //width of river[m]
10 //At 15 degree C properties of water
11 rho=999.1; // [kg/m^3]
12 mu=1.138*10^(-3); // viscosity [kg/m.s]
13 Re=(rho*vw*od)/mu; //Reynolds number

```



```

14 Cd=1.0; //Dreag coefficient
15 A=w*od; //Frontal area for flow past a cylinder [m^2]
16 Fd=Cd*A*rho*(vw^2)/2; // [N]
17 disp("kN",Fd/1000,"The drag force acting on the pipe
      is")

```

Scilab code Exa 7.5 ab95

```

1 clear;
2 clc;
3
4 //Example7.5[Heat Loss from a Steam Pipe in Windy
      Air]
5 d=0.1 //diameter of pipe [m]
6 Ts=110; //Temp of ecternal surface of pipe [degree
      Celcius]
7 Ta=10; //Temp of air [degree Celcius]
8 va=8; //Velocity of air [m/s]
9 Tf=(Ts+Ta)/2; //Film temperature [degree Celcius]
10 k=0.02808; // [W/m.degree Celcius]
11 Pr=0.7202; //Prandtl Number
12 nu=1.896*10^(-5); //Kinematic viscosity [m^2/s]
13 //Solution:-
14 Re=(va*d)/nu; //Reynolds Number
15 Nu=0.3+((0.62*(Re^(0.5))*(Pr^(1/3)))/((1+((0.4/Pr)
      ^ (2/3))))^(1/4))*[(1+((Re/282000)^(5/8)))^(4/5)];
16 disp(round(Nu),"The nusselt number is")
17 h=k*Nu/d; // [W/m^2.degree Celcius]
18 As=%pi*d*1; //Area of pipe per unit length [m^2]
19 Q=h*As*(Ts-Ta); // [W]
20 disp("W",ceil(Q),"The rate of heat loss from the
      pipe per unit of its length is")

```

Scilab code Exa 7.6 ab96

```
1 clear;
2 clc;
3
4 //Example7.6[ Cooling of a Steel Ball by Forced Air]
5 //Given:-
6 rho=8055; // [kg/m^3]
7 Pr = 0.7296;
8 Cp=480; // [J/kg.degree Celcius]
9 To=300; //Temp of oven [degree Celcius]
10 Ta=25; //Temp of air [degree Celcius]
11 va=3; // Velocity of air [m/s]
12 Ts=200; //Dropped temp of surface of ball [degree
    Celcius]
13 Ts_avg=(Ts+To)/2; // [degree Celcius]
14 d=0.25; // [m]
15 mu_s=2.76*10^(-5); //Dynamic Viscosity at average
    surface temperature [kg/m.s]
16 //Properties of air at 25 degree Celcius
17 k=0.02551; // [W/m.degree Celcius]
18 nu=1.562*10^(-5); //kinematic viscosity [m^2/s]
19 mu=1.849*10^(-5); //Dynamic viscosity of air at 25
    degree C [kg/m.s]
20 //Solution:-
21 Re=va*d/nu; // [Reynolds Number]
22 Nu=2+[(0.4*(Re^(1/2)))+(0.06*(Re^(2/3)))]*(Pr^(0.4))
    *((mu/mu_s)^(1/4));
23 disp(ceil(Nu), "The Nusselt number is")
24 h=k*Nu/d; // [W/m^2.degree Celcius]
25 As=%pi*(d^2); // [m^2]
26 Q_avg=h*As*(Ts_avg-Ta); // [W]
27 disp("W", ceil(Q_avg), "The average rate of heat
    transfer from Newtons Law of cooling is")
28 m=rho*%pi*(d^3)/6; // [kg]
29 Q_total=m*Cp*(To-Ts); // [J]
30 disp("J", Q_total, "The total heat transferred from
    the ball is")
```

```

31 delta_t=Q_total/Q_avg;//[s]
32 disp("hour",delta_t/3600,"The time of cooling is")

```

Scilab code Exa 7.7 ab97

```

1 clear;
2 clc;
3
4 //Example7.7[Preheating Air by Geothermal Water in a
   Tube Bank]
5 //Given:-
6 Ta_in=20;//Temp of air whileentering the duct[degree
   Celcius]
7 v=4.5;//mean velocity [m/s]
8 T_tw=120;//Temp of geothermal water[degree Celcius]
9 od=0.015;//Outer Diameter of tubes [m]
10 SL=0.05,ST=0.05;//Longitudinal and transverse
   pitches [m]
11 //Properties of air at mean temp
12 k=0.02808;// [W/m.K]
13 rho=1.059;// [kg/m^3]
14 Cp=1007;// [J/kg.K]
15 Pr=0.7202;//Prandtl no
16 Pr_s=0.7073;//Prandtl no at temp = 120 degree C
17 mu=2.008*10^(-5);//Viscosity [kg/m.s]
18 rho_in=1.204;//density of air at inlet conditions [kg
   /m^3]
19 //Solution:-
20 v_max=(ST*v)/(ST-od);//maximu velocity [m/s]
21 Re=rho*v_max*od/mu;//Reynolds Number
22 disp(Re,"Reynolds number is")
23 Nu=0.27*(Re^(0.63))*(Pr^(0.36))*((Pr/Pr_s)^0.25);
24 disp(Nu,"The nusselt number is")
25 Nl=6;//No of rows of tubes
26 Nt=10;//No of tubes in each row

```

```

27 F=0.945; //For Nl=6, correction factor
28 Nu_Nl=F*Nu;
29 h=Nu_Nl*k/od; // [W/m^2.degree Celcius]
30 N=Nl*Nt; //Total no of tubes
31 //For unit tube length
32 As=N*pi*od*1; // [m^2]
33 m=rho_in*v*(Nt*ST*1); // [kg/s]
34 disp("kg/s",m,"Mass flow rate of air is")
35 Te=T_tw-((T_tw-Ta_in)*exp((-As*h)/(m*Cp))); // [degree
    Celcius]
36 disp("degree Celcius",Te,"Fluid exit temperature is"
    )
37 T_ln=(((T_tw-Te)-(T_tw-Ta_in))/(log((T_tw-Te)/(T_tw-
    Ta_in)))); // [degree Celcius]
38 disp("degree Celcius",T_ln,"Log mean temperature
    difference is")
39 Q=h*As*T_ln; // [W]
40 disp("W",Q,"Rate of heat transfer is")
41 //For given Re and SL/od ratio friction coefficient
    is
42 f=0.16;
43 delta_P=Nl*f*rho*(v_max^2)/2; // [Pa]
44 disp("Pa",delta_P,"The pressure drop across the tube
    bank is")

```

Scilab code Exa 7.8 ab98

```

1 clear;
2 clc;
3
4 //Example7.8[Effect of insulation on Surface
    Temperature]
5 //Given:-
6 Ti=120; //Initial temp of hot water [degree Celcius]
7 k_pipe=15; //W/m.degree Celcius

```

```

8 ri=0.008,ro=0.01;//Inner and outer radii [m]
9 t=0.002;//Thickness of pipe [m]
10 To=25;//Ambient temperature [degree Celcius]
11 Ts=40;//Maximum Temp of outer surface of insulation [
    degree Celcius]
12 hi=70,ho=20;//Heat transfer coefficients inside and
    outside of the pipe [W/m^2.degree Celcius]
13 k_insu=0.038;// [W/m.degree Celcius]
14 L=1;//section of pipe [m]
15 //Solution:-
16 //Areas of surfaces exposed to convection
17 A1=2*%pi*ri*L;// [m^2]
18 //Individual Thermal Resistances
19 R_conv1=1/(hi*A1);// [degree Celcius/W]
20 R_pipe=(log(ro/ri))/(2*%pi*k_pipe*L);// [degree
    Celcius/W]
21 //R_insu=(log(r3/ri))/(2*%pi*k_insu*L)
22 //R_conv2=1/(ho*2*%pi*r3*L)
23 //R_total=R_conv1+R_conv2+R_pipe+R_insu
24 //Q=(Ti-To)/R_total;
25 //Q=(Ts-To)/R_conv2;
26 //Equating both Q we get
27 function [r]=radius(r3)
28     r(1)=1884*r3(1)*(0.284+0.0024+4.188*log((r3(1))
        /0.01)+(1/(125.6*r3(1))))-95;
29     deff(' [r]=radius(r3) ',' radius_3=1884*r3(1)
        *(0.284+0.0024+4.188*log((r3(1))/0.01)
        +(1/(125.6*r3(1))))-95'] )
30 endfunction
31 x0=[1]
32 [xs,fxs,m]=fsolve(x0',radius)
33     disp("m",xs,"The outer radius of the insulation
        is")
34     t=xs-ro;// [m]
35     disp("cm",100*t,"The minimum thickness of
        fibreglass insulation required is")
36     ///Correct output will be displayed after
        executing the codes once and then re-executin

```

them

Scilab code Exa 7.9 ab99

```
1 clear;
2 clc;
3
4 //Example7.9[Optimum Thickness of insulation]
5 //Given:-
6 k_insu=0.024;//[Btu/h.ft ^2.degree Farenhiet]
7 Ts=180; //temp of exposed surface of oven[degree F]
8 Ta=75; //temp of ambient air[degree F]
9 L=12; //length [ft]
10 d=8; //Diameter [m]
11 time=5840; //[h/year]
12 ho=3.58; //Heat transfer coefficient on the outer
    surface [tu/h.ft ^2.degree F]
13 unit_c1=0.75; //[$/therm]
14 unit_c2=2.70; //Unit cost of insulation [4/ft ^2]
15 neta=0.8; //Efficiency
16 //Solution:-
17 As=(2*%pi*((d/2)^2))+(2*%pi*L*d/2); //Exposed surface
    area [ft ^2]
18 disp(As)
19 Q=ho*ceil(As)*(Ts-Ta); //[Btu/h]
20 Q_total=(1/neta)*Q*time/(100000); //[therms]
21 disp("Therms",Q_total,"The total amount of heat loss
    from the surrounding is")
22 annual_c1=Q_total*unit_c1; //[$/year]
23 disp("per year",annual_c1,"The annual fuel cost of
    the oven before insulation is $")
24 R_conv=1/(ho*ceil(As));
25 R_insu=(1/12)/(k_insu*ceil(As)); //Thickness id lynch
    or 1/12 ft
26 Q_insu=(Ts-Ta)/(R_conv+R_insu); //[Btu/hr]
```

```
27 Q_insu_total=(1/neta)*Q_insu*time*(1/100000);//[
    therms]
28 disp("therms",Q_insu_total,"Total energy consumption
    by oven on being insulated")
29 annual_c2=Q_insu_total*unit_c1;/>[$/yr]
30 insu_cost=(unit_c2*ceil(As));/>Insulation cost[$]
31 Total_c=annual_c2+insu_cost;/>[$]
32 disp(Total_c,"The sum of insulation cost and heat
    loss costs is $")
```

Chapter 8

Internal Forced Convection

Scilab code Exa 8.1 ab101

```
1 clear;
2 clc;
3
4 //Example8.1[Heating of water in a tube by Steam]
5 //Given:-
6 id=0.025; //Internal diameter [m]
7 Tin=15; //Initial temp [degree Celcius]
8 m_=0.3; //Flow rate [kg/s]
9 h=800/1000; //avg heat transfer coefficient [W/m^2.
    degree Celcius]
10 Tf=115; //Final temp of water [degree Celcius]
11 Ts=120; //[degree Celcius]
12 Hs=2203; //Heat of condensation of steam at 120
    degree Celcius [kJ/kg]
13 Tavg=(Tin+Tf)/2; //[degree Celcius]
14 Cp=4187; //Sp Heat of water at Tavg [J/kg.degree
    Celcius]
15 //Solution:-
16 Q_=m_*Cp*(Tf-Tin)/1000; //[kW]
17 disp("kW", Q_, "The rate of heat transfer is")
18 del_Tf=Ts-Tf; //[degree Celcius]
```



```

19 del_Tin=Ts-Tin;//[degree Celcius]
20 ln_del_T=(del_Tf-del_Tin)/(log(del_Tf/del_Tin));//[
    degree Celcius]
21 disp("degree Celcius",ln_del_T,"Logrithmic Mean
    temperature difference is")
22 A=Q_/(h*ln_del_T);//[m^2]
23 disp("m^2",A,"Heat Transfer surface area is")
24 l=A/(%pi*id);//[m]
25 disp("m",round(l),"Required tube length is")

```

Scilab code Exa 8.2 ab102

```

1 clear;
2 clc;
3
4 //Example8.2[Pressure Drop in a tube]
5 //Given:-
6 Tw=5;//Temperature of water[degree Celcius]
7 //Properties of water at Tw
8 rho=999.9;//[kg/m^3]
9 mu=1.519*10^(-3);//Viscosity[kg/m.s]
10 d=0.003;//diameter[m]
11 l=10;//length[m]
12 v_avg=0.9;//Average flow velocity[m/s]
13 //Solution:-
14 Re=(rho*v_avg*d)/mu;
15 disp(Re,"The reynolds number is ")
16 f=64/ceil(Re);
17 disp(f,"Friction factor is")
18 del_P=f*l*rho*(v_avg^2)/(2*d);//[N/m^2]
19 disp("kPa",del_P/1000,"The Pressure drop is ")
20 V=v_avg*(%pi*(d^2))/4;//[m^3/s]
21 disp("m^3/s",V,"Volumetric flow rate is")
22 W_pump=V*del_P;//[W]
23 disp("W",W_pump,"Mechanical Power Input of")

```

24 `disp("is needed to overcome the frictional losses in
the flow due to viscosity")`

Scilab code Exa 8.3 ab103

```
1 clear;
2 clc;
3
4 //Example8.3[Flow of Oil in a Pipeline through a
   Lake]
5 //Given:-
6 Ts=0;//Temp of lake[degree Celcius]
7 Ti=20;//Temp of oil[degree Celcius]
8 d=0.3;//Diameter [m]
9 l=200;//length of pipe [m]
10 //At 20 degree Celcius
11 rho=888.1;//[kg/m^3]
12 nu=9.429*10^(-4);//Kinematic viscosity [m^2/s]
13 k=0.145;//[W/m.degree Celcius]
14 Cp=1880;//[J/kg.degree Celcius]
15 Pr=10863;//Prandtl Number
16 v_avg=2;//[m/s]
17 //Solution(a)
18 Re=v_avg*d/nu;
19 disp(ceil(Re),"The Reynolds number is")
20 Lt=0.05*Re*Pr*d;//[m]
21 disp("m",Lt,"The thermal entry length is")
22 Nu=3.66+((0.065*(d/l)*Re*Pr)/(1+(0.04*(((d/l)*Re*Pr)
   ^ (2/3)))));
23 h=(k*Nu)/d;//[W/m^2.degree Celcius]
24 As=%pi*d*l;//[m^2]
25 m_=rho*%pi*((d/2)^2)*v_avg;//[kg/s]
26 Te=Ts-((Ts-Ti)*exp((-h*As)/(m_*Cp)));//[degree
   Celcius]
27 disp("degree Celcius",Te,"Exit temperature of oil is
```

```

    ")
28 //Solution(b):-
29 ln_del_T=(Ti-Te)/(log((Ts-Te)/(Ts-Ti)));//[degree
    Celcius]
30 disp("degree Celcius",ln_del_T,"The logarithmic mean
    temperature difference is")
31 Q=h*As*ln_del_T;//[W]
32 disp("W",Q,"The rate of heat loss from the oil are")
33 //Solution(c)
34 f=64/Re;//Friction factor is
35 del_P=l*rho*(v_avg^2)/(2*d);//[N/m^2]
36 disp(del_P);
37 W_pump=m*del_P/rho;//[kW]
38 disp("pump just to overcome the friction in the pipe
    as the oil flows","kW",W_pump/1000,"We need a")

```

Scilab code Exa 8.4 ab104

```

1 clear;
2     clc;
3
4     //Example8.4[Pressure Drop in a Water tube]
5     Tw=15;//temp of water while entering[degree
        Celcius]
6     rho=999.1;//[kg/m^3]
7     mu=1.138*10^(-3);//Viscosity[kg/m.s]
8     id=0.05;//Internal diameter[m]
9     V=5.5*10^(-3);//Flow rate[m^3/s]
10    l=60;//length of tube[m]
11    e=0.002*10^(-3);//[m]
12    //Solution:-
13    v=V/(%pi*(id^2)*(1/4));//Mean Velocity[m/s]
14    Re=rho*v*id/mu;
15    disp(Re,"Reynolds Number is")
16    //Flow is turbulent

```

```

17     r=e/id;//Relative roughness of the tube
18     function[Func]=fric(fac)
19         Func(1)=(1/(fac(1)^(1/2)))+(2*log
                ((0.00004/3.7)+(2.51/(122900*fac(1)^(1/2)
                ))));
20         deff(' [Func]=fric(fac) ', ['fric_1=(1/(fac(1)
                ^ (1/2)))+(2*log((0.00004/3.7)
                +(2.51/(122900*fac(1)^(1/2))))')])
21     endfunction
22
23     xa = 3.99*10^-3;
24     xs = fric(xa);)
25
26     disp(xs,"Friction Factor is")
27     del_P=xs*l*rho*(v^2)/(2*id);// [kPa]
28     disp("Pa",del_P,"The pressure drop is")
29     W_pump=V*del_P;// [W]
30     disp("W",W_pump,"The required poer input tp
        overcome the frictional losses in the tube is
        ")

```

Scilab code Exa 8.5 ab105

```

1  clear;
2  clc;
3
4  //Example8.5[Heating of water by Resistance Heaters
   in a tube]
5  Ti=15;//Initial Temp[degree Celcius]
6  Tf=65;//Final Temp[degree Celcius]
7  d=0.03;//Internal diameter [m]
8  l=5;//length [m]
9  V=10*10^(-3);//flow rate of water [m^3/s]
10 Tav=(Ti+Tf)/2;// [degree Celcius]
11 //Properties of water at Tav

```

```

12 rho=992.1; // [kg/m^3]
13 Cp=4170; // [J/kg.degree Celcius]
14 k=0.631; // [W/m.degree Celcius]
15 nu=0.658*10^(-6); // [m^2/s]
16 Pr=4.32; // Prandtl Number
17 //Solution:-
18 Ac=%pi*(d^2)*(1/4); // [m^2]
19 As=%pi*d*l; // [m^2]
20 m_=rho*V*(1/60); // [kg/s]
21 Q_=m_*Cp*(Tf-Ti)/1000; // [kW]
22 disp("kW",Q_,"The power rating of the heater is")
23 qs=Q_/As; // [kW/m^2]
24 disp("kW/m^2",qs,"Heat flux is")
25 v_avg=V/(Ac*60); // [m/s]
26 Re=v_avg*d/nu; // [Reynolds Number]
27 Lt=10*d; //Entry length [m]
28 Nu=0.023*(Re^(0.8))*(Pr^(0.4));
29 disp(Nu,"The nussel number is")
30 h=k*Nu/d; // [W/m^2]
31 Ts=Tf+(qs*1000/h); // [degree Celcius]
32 disp("degree Celcius",round(Ts),"The surface
    temperature of the pipe at the exit becomes")

```

Scilab code Exa 8.6 ab106

```

1 clear;
2 clc;
3
4 //Example8.6[Heat Loss from the ducts of a Heating
    System]
5 Ti=80; //Inlet temp[degree Celcius]
6 A=0.2*0.2; //Area of cross section [m^2]
7 l=8; //Length of tube [m]
8 V=0.15; // [m^3/s]
9 Td=60; //Temperature of duct [degree Celcius]

```

```

10 //Properties of air at inlet conditions
11 rho=0.9994; //[kg/m^3]
12 Cp=1008; //[J/kg.degree Celcius]
13 k=0.02953; //[W/m.degree Celcius]
14 nu=2.097*10^(-5); //[m^2/s]
15 Pr=0.7154; //Prandtl number
16 //Solution:-
17 Dh=4*A/(4*0.2); //Hydraulic Diameter [m]
18 v_avg=V/A; //[m/s]
19 Re=v_avg*Dh/nu;
20 disp(Re," Reynolds number is")
21 Lt=10*Dh; //Entry length
22 Nu=0.023*(Re^(0.8))*(Pr^(0.3));
23 h=Nu*k/Dh; //[W/m^2.degree Celcius]
24 As=4*0.2*1; //[m^2]
25 m_=rho*V; //[kg/s]
26 Te=Td-((Td-Ti)*exp((-h*As)/(m_*Cp))); //[degree
    Celcius]
27 disp("degree Celcius",Te,"The exit temperature of
    air is")
28 ln_delT=(Ti-Te)/(log((Td-Te)/(Td-Ti))); //[degree
    Celcius]
29 Q=h*As*ln_delT; //[W]
30 disp("respectively","W",round(Q),"and","degree
    Celcius",ln_delT,"The logrithmic mean temperature
    difference and the rate of heat loss from the
    air are")

```

Scilab code Exa 8.7 ab107

```

1 clear;
2 clc;
3
4 //Example8.7[Non-isothermal fully developed Friction
    in the Transition Region]

```

```

5 //Given:-
6 q=8; //Wall heat flux [kW/m^2]
7 xm=0.34; //Mass fraction
8 d=0.0158; //Inside diameter [m]
9 V=1.32*10^(-4); //Flow rate [m^3/s]
10 Pr=11.6; //Prandtl Number
11 nu=1.39*10^(-6); // [m^2/s]
12 p=1.14; //(mu_b/mu_s) i.e. ratio of viscosities of two
    substances
13 Gr=60800; //Grashof number
14 //Solution:-
15 Ac=%pi*(d^2)*(1/4); // [m^2]
16 Re=(V/Ac)*d/nu;
17 disp(Re," Reynolds number is")
18 //For bell mouth inlet shape
19 Cf1=((1+((round(Re)/5340)^(-0.099)))^(-6.32))*(p
    ^(-2.58-0.42*(60.800^(-0.41))*(11.6^0.265)));
20 disp(Cf1," For bell mouth inlet friction coefficient
    is")
21 //For square edged inlet Case
22 Cf2=(0.0791/(Re^(0.25)))*(p^(-0.25));
23 disp(Cf2," For square edged inlet case coefficient of
    friction is")

```

Scilab code Exa 8.8 ab108

```

1 clear;
2 clc;
3
4 //Example8.8[Heat transfer in the Transition Region]
5 //Given:-
6 xm=0.6; //mass fraction of glycol
7 V=2.6*10^(-4); //Flow rate [m^3/s]
8 d=0.0158; //inside diameter [m]
9 Gr=51770; //grashof number

```

```

10 Pr=29.2; //Prandtl number
11 nu=3.12*10^(-6); // [m^2/s]
12 p=1.77; //mu_t/mu_s
13 q=90; //A particular location x with x/d=q
14 //Solution:-
15 Ac=%pi*(d^2)/4;
16 Re=(V/Ac)*d/nu;
17 disp(Re," Reynolds Number is")
18 //Value of Re lies in transition Region
19 Nu_lam=1.24*(((Re*Pr/q)+(0.025*((Gr*Pr)^(0.75))))
    ^((1/3)))*(p^(0.14));
20 Nu_tur=0.023*(Re^(0.8))*(Pr^0.385)*(q^(-0.0054))*(p
    ^((0.14)));
21 //(a)
22 Nu_tran_a=Nu_lam+((exp((1766-Re)/276)+(Nu_tur
    ^(-0.955)))^(-0.955));
23 disp(Nu_tran_a,"(a) Nusselt number for re-entrant
    inlet is")
24 Nu_tran_b=Nu_lam+((exp((2617-Re)/207)+(Nu_tur
    ^(-0.950)))^(-0.950));
25 disp(Nu_tran_b,"(b) Nusselt number for square edged
    inlet is")
26 Nu_tran_c=Nu_lam+((exp((6628-Re)/237)+(Nu_tur
    ^(-0.980)))^(-0.980));
27 disp(Nu_tran_c,"(c) Nusselt number for bell mouth
    inlet is")

```

Chapter 9

Natural Convection

Scilab code Exa 9.1 ab111

```
1 clear;
2 clc;
3
4 //Example9.1[Heat Loss from Hot Water Pipes]
5 //Given:-
6 l=6; //Length [m]
7 d=0.08; //diameter [m]
8 T_room=20; //[degree Celcius]
9 Ts=70; //Surface temperature of pipe[degree Celcius]
10 Tf=(Ts+T_room)/2; //Film temperature[degree Celcius]
11 //Properties of air at Tf
12 k=0.02699; // [W/m.degree Celcius]
13 Pr=0.7241; //Prandtl number
14 nu=1.750*10^(-5); // [m^2/s]
15 b=(1/(Tf+273)); // [K^-1]
16 g=9.81; //Acc dur to gravity [m/s^2]
17 e=1; //Emissivity
18 //Solution:-
19 Lc=d; // Characteristic length [m]
20 Ra_d=g*b*(Ts-T_room)*(d^3)*Pr/(nu^2);
21 disp(Ra_d,"The Rayleigh number is")
```

```

22 Nu=((0.6+((0.387*(Ra_d^(1/6))))/((1+((0.559/Pr)
    ^((9/16))))^(8/27))))^2);
23 disp(Nu," The natural convection Nusselt number is")
24 h=k*Nu/d; // [W/m^2.degree Celcius]
25 As=%pi*d*l; // [m^2]
26 Q=h*As*(Ts-T_room); // [W]
27 disp("by natural convection", "W", round(Q), "The pipe
    loses heat to the air in the room at a rate of")
28 Q_rad=e*As*(5.76*10^(-8))*(((Ts+273)^4)-((T_room
    +273)^4)); // [W]
29 disp("W", ceil(Q_rad), "The radiation heat transfer is
    ")

```

Scilab code Exa 9.2 ab112

```

1 clear;
2 clc;
3
4 //Example9.2[Cooling of a Plate in different
    orientaions]
5 L=0.6; //side of square plate [m]
6 T_surr=30; // [degree Celcius]
7 Tp=90; //Temp of plate [degree Celcius]
8 Tf=(Tp+T_surr)/2; //Film temperature [degree Celcius]
9 //Properties of air at Tf
10 k=0.02808; // [W/m.degree Celcius]
11 Pr=0.7202; //Prandtl number
12 nu=1.896*10^(-5); //Kinematic viscosity [m^2/s]
13 b=1/(Tf+273); // [K^-1]
14 g=9.81; //Acc due to gravity [m/s^2]
15 //Solution (a)
16 Lc_a=L; //Characteristic length
17 Ra_1=g*b*(Tp-T_surr)*(L^3)*Pr/(nu^2);
18 disp(Ra_1,"(a) The Rayleigh no is")
19 Nu_a=((0.825+(0.387*(Ra_1^(1/6))))/((1+((0.492/Pr)

```

```

    ^((9/16)))^(8/27)))^2);
20 disp(Nu_a,"The natural convection Nusselt number is"
    )
21 h_a=k*Nu_a/L; // [W/m^2.degree Celcius]
22 As=L^2; // [m^2]
23 Q_a=h_a*As*(Tp-T_surr); // [W]
24 disp("W",ceil(Q_a),"Heat loss to the surrounding is"
    )
25 //Solution (b)
26 Lc_b=As/(4*L); // [m]
27 Ra_2=g*b*(Tp-T_surr)*(Lc_b^3)*Pr/(nu^2);
28 disp(Ra_2,"(b) The Rayleigh number is")
29 Nu_b=0.54*(Ra_2^(1/4));
30 disp(Nu_b,"The natural convection Nusselt number is"
    )
31 h_b=k*Nu_b/Lc_b; // [W/m^2.degree Celcius]
32 Q_b=h_b*As*(Tp-T_surr); // [W]
33 disp("W",round(Q_b),"Heat Loss is")
34 //Solution (c)
35 Lc_c=Lc_b
36 Nu_c=(0.27*Ra_2^(1/4));
37 disp(Nu_c,"(c) Natural convection Nusselt number")
38 h_c=k*Nu_c/Lc_c; // [W/m^2.degree Celcius]
39 Q_c=h_c*As*(Tp-T_surr); // [W]
40 disp("W",Q_c,"Heat Loss is")
41 Q_rad=e*(5.67*10^(-8))*As*(((Tp+273)^4)-((T_surr
    +273)^4)); // [W]
42 disp("W",round(Q_rad),"Radiation heat loss is")

```

Scilab code Exa 9.3 ab113

```

1 clear;
2 clc;
3
4 //Example9.3[Optimum Fin Spacing of a Heat Sink]

```

```

5 //Given:-
6 w=0.12; //width [m]
7 l=0.18; //length [m]
8 t=0.001; //thickness [m]
9 H=0.024; //height [m]
10 Ts=80; //Bast temperature[degree Celcius]
11 T_surr=30; //[degree Celcius]
12 Tf=(Ts+T_surr)/2; //[degree Celcius]
13 //Properties of air at film temperature
14 k=0.02772; // [W/m.degree Celcius]
15 Pr=0.7215; //Prandtl number
16 nu=1.847*10^(-5); // [m^2/s]
17 b=1/(Tf+273); // [K^-1]
18 g=9.81; // [m/s^2]
19 //Solution:-
20 Ra_1=g*b*(Ts-T_surr)*(l^3)*Pr/(nu^2);
21 disp(Ra_1,"The Rayleigh number is")
22 S_opt=2.714*l/(Ra_1^(0.25)); // [m]
23 disp("mm",S_opt*100,"The optimum spacing is")
24 n=w/(S_opt+t);
25 disp(round(n),"The no of for this optimum fin
    spacing are")
26 Nu_opt=1.307; //Optimum Nusselt number
27 h=Nu_opt*k/S_opt; // [W/m^2.degree Celcius]
28 Q=h*2*round(n)*l*H*(Ts-T_surr); // [W]
29 disp("W",Q,"The rate of natural convection heat
    transfer")

```

Scilab code Exa 9.4 ab114

```

1 clear;
2 clc;
3
4 //Example9.4[Heat Loss through a Double Pane Window]
5 //Given:-

```

```

6 H=0.8; //Height [m]
7 L=0.02; //Air gap [m]
8 w=2; //Width [m]
9 T1=12,T2=2; //Glass Surface temperatures across the
    air gap
10 Tavg=(T1+T2)/2; //[degree Celcius]
11 k=0.02416; // [W/m.degree Celcius]
12 Pr=0.7344; //Prandtl Number
13 nu=1.4*10^(-5); //Kinematic Viscosity [m^2/s]
14 g=9.81; // [m/s^2]
15 //Solution:-
16 Lc=L; // Characteristic length
17 b=1/(Tavg+273); // [K^-1]
18 Ra_L=g*b*(T1-T2)*Pr*(Lc^3)/(nu^2);
19 disp(Ra_L,"The Rayleigh Number is")
20 Nu=0.42*(Ra_L^(1/4))*(Pr^(0.012))*((H/L)^(-0.3));
21 disp(Nu,"The Nusselt Number is")
22 As=H*w; // [m^2]
23 h=k*Nu/L; // [W/m^2.degree Celcius]
24 Q=h*As*(T1-T2);
25 disp("W",Q,"Rate at which Heat is Lost through the
    window is")

```

Scilab code Exa 9.5 ab115

```

1 clear;
2 clc;
3
4 //Example9.5[Heat Transfer through a Spherical
    Enclosure]
5 //Given:-
6 Di=0.2; //Inner Diameter [m]
7 Do=0.3; //Outer Diameter [m]
8 Ti=320,To=280; //The surface temperatures of two
    spheres enclosing the air [K]

```

```

 9  Tavg=(Ti+To)/2; // [K]
10  // Properties at Tavg
11  k=0.02566; // [W/m.K]
12  Pr=0.7290; // Prandtl Number
13  nu=1.58*10^(-5); // [m^2/s]
14  b=(1/Tavg);
15  g=9.81; // [m/s^2]
16  // Solution:-
17  Lc=(Do-Di)/2; // Characteristic length [m]
18  Ra_L=g*b*(Ti-To)*(Lc^3)*Pr/(nu^2);
19  disp(Ra_L,"The Rayleigh Number is")
20  Fsph=Lc/(((Di*Do)^4)*(((Di^(-7/5))+(Do^(-7/5))))^5)
    );
21  keff=0.74*k*((Pr/(0.861+Pr))^(1/4))*((Fsph*Ra_L)
    ^ (1/4)); // [W/m.K]
22  disp(Fsph,keff)
23  Q=keff*(%pi*Di*Do/Lc)*(Ti-To); // [W]
24  disp("W",Q,"The rate of heat transfer between the
    spheres is")

```

Scilab code Exa 9.6 ab116

```

1  clear;
2  clc;
3  //Example9.6[Heating Water in a Tube by Solar Enegy]
4  //Given:-
5  Ts=40; //Glass Temp[degree Celcius]
6  T_surr=20; //Surrounding temperature[degree Celcius]
7  Tavg=(Ts+T_surr)/2; // [degree Celcius]
8  Do=0.1; // [m]
9  Di=0.05; // [m]
10 L=1; // [m]
11 // Properties of glass at Tavg
12 k=0.02588; // [W/m.degree Celcius]
13 Pr=0.7282; // Prandtl Number

```

```

14 nu=1.608*10^(-5);//[m^2/s]
15 b=1/(Tavg+273);//[K^-1]
16
17 Q=30; //Rate pof absorpt\ion of solar radiation [W]
18 g=9.81; //[m/s^2]
19 //Solution:-
20 Ao=%pi*Do*L; //Heat transfer surface area of the
    glass cover [m^2]
21 Ra_D=g*b*(Ts-T_surr)*(Do^3)*Pr/(nu^2);
22 disp(Ra_D,"The Rayleigh Number is")
23 Nu=((0.6+((0.387*(Ra_D^(1/6))))/((1+((0.550/Pr)
    ^((9/16))))^(8/27))))^2);
24 disp(Nu,"The Nusselt number is")
25 ho=k*Nu/Do; //[W/m^2.degree Celcius]
26 Qo=ho*Ao*(Ts-T_surr); //[W]
27 disp("W",Qo,"The rate of natural convection heat
    transfer from the glass cover to the ambient air
    is")
28 //Value of Qo is less than 30W so assuming a higher
    temp of glass cover
29 T_surr1=41; //[degree Celcius]
30 Ts1=90; //[degree Celcius]
31 Tavg1=(T_surr1+Ts1)/2; //[degree Celcius]
32 b1=1/(Tavg1+273); //[K^-1]
33 Lc=(Do-Di)/2; //Characteristic length [m]
34 Ra_L1=g*b1*(Ts1-T_surr1)*(Lc^3)*Pr/(nu^2);
35 disp(Ra_L1,"The Rayleigh number on assuming higher
    temperatures")
36 Fcyl=((log(Do/Di))^4)/((Lc^3)*(((Di^(-3/5)))+(Do
    ^(-3/5)))^5));
37 keff=0.386*k*((Pr/(0.861+Pr))^(1/4))*((Fcyl*Ra_L1)
    ^((1/4))); //[W/m.degree Celcius]
38 Q1=2*pi*keff*(Ts1-T_surr1)/(log(Do/Di)); //[W]
39 disp("W",Q1,"The rate of heat transfer between the
    cylinders is")
40 //Obtained value of Q1 is more than 30 W, so using
    hit and trial aand suuming more values we get the
    tube temperature to be 82 degree Celcius ,

```

```
41 disp("Therefore tube will reach an equilibrium
    temperature of 82 degree Celcius when the pump
    fails")
```

Scilab code Exa 9.7 ab117

```
1 clear;
2 clc;
3
4 //Example9.7[U factor for Center of glass Section of
    Windows]
5 //Given:-
6 e=0.84;//Emissivity
7 //For winter season
8 hi=8.29;//[W/m^2.degree Celcius]
9 ho=34.0;//[W/m^2.degree Celcius]
10 //Solution:-
11 e_eff=1/((1/e)+(1/e)-1);//Effective emissivity of
    air space
12 //the effective emissivity and an average air space
    temperature of 0 degree Celcius read
13 h_space=7.2;//[W/m^2.degree Celcius]
14 U_center=1/((1/hi)+(1/ho)+(1/h_space));//[W/m^s.
    degree Celcius]
15 disp("W/m^2.degree Celcius",U_center,"The center of
    glass U-factor value is")
```

Scilab code Exa 9.8 ab118

```
1 clear;
2 clc;
3
```



```

4 //Example9.8[Heat Loss through Aluminium Framed
  Windows]
5 //Given:-
6 H=1.2; //Height [m]
7 w=1.8; //Width [m]
8 Ti=22; //Inside temp[degree Celcius]
9 To=-10; //Outside temp[degree Celcius]
10 U_a=6.63,U_b=3.51,U_c=1.92,hi=8.3; // [W/m^.degree
  Celcius]
11 //Solution:-
12 A_win=h*w; // [m^2]
13 Q_win_a=U_a*A_win*(Ti-To); // [W]
14 T_glass_a=Ti-(Q_win_a/(hi*A_win)); // [degree Celcius]
15 disp("degree Celcius",T_glass_a,"(a) The Inner
  surface temperature of the window glass is")
16 Q_win_b=U_b*A_win*(Ti-To); // [W]
17 T_glass_b=Ti-(Q_win_b/(hi*A_win)); // [degree Celcius]
18 disp("degree Celcius",T_glass_b,"(b) The Inner
  surface temperature of the window glass is")
19 Q_win_c=U_c*A_win*(Ti-To); // [W]
20 T_glass_c=Ti-(Q_win_c/(hi*A_win)); // [degree Celcius]
21 disp("degree Celcius",T_glass_c,"(c) The Inner
  surface temperature of the window glass is")

```

Scilab code Exa 9.9 ab119

```

1 clear;
2 clc;
3
4 //Example9.9[U-Factor of a Double-Door Window]
5 //Given:-
6 A_win=1.8*2.0; // [m^2]
7 A_glazing=2*1.72*0.94; // [m^2]
8 U_c=3.24,U_e=3.71,U_f=2.8; //U factors for the center
  edge and frame sections respectively [W/m^2.

```

```
    degree Celcius]
9 //Solution:-
10 A_frame=A_win-A_glazing; // [m^2]
11 A_center=2*(1.72-0.13)*(0.94-0.13); // [m^2]
12 A_edge=A_glazing-A_center; // [m^2]
13 U_win=((U_c*A_center)+(U_e*A_edge)+(U_f*A_frame))/
    A_win; // [W/m^2.degree Celcius]
14 disp("W/m^2.degree Celcius",U_win,"The overall U
    factor of the entire window is")
```

Chapter 10

Boiling and Condensation

Scilab code Exa 10.1 ab121

```
1 clear;
2 clc;
3
4 //Example10.1[Nucleate Boiling of Water in a Pan]
5 Ts=108;//Temp of surface of bottom of pan[degree
   Celcius]
6 Tsat=100;//Saturation temp of water[degree Celcius]
7 D=0.3;//Diameter [m]
8 //Properties of water at the saturation temp
9 rho_l=957.9;//Density of liquid [kg/m^3]
10 rho_v=0.6;//Density of vapour [kg/m^3]
11 Pr_l=1.75;//Prandtl no of liquid
12 mu_l=0.282*10^(-3);//Viscosity of liquid [kg/m.s]
13 Cp_l=4217;//Specific Heat of liquid [J/kg.degree
   Celcius]
14 h_fg=2257*10^3;// [J/kg]
15 sigma=0.0589;// [N/m]
16 g=9.81;//Acc due to gravity [m/s^2]
17 Csf=0.0130,n=1.0;
18 //Solution(a):-
19 q_nuc=mu_l*h_fg*((g*(rho_l-rho_v)/sigma)^(1/2))*((
```

```

    Cp_l*(Ts-Tsat)/((Csf*h_fg*(Pr_l^n)))^3); // [W/m^2]
20 A=%pi*(D^2)/4; // Surface Area of bottom of the pan[m
    ^2]
21 Q_boiling=A*q_nuc; // [W]
22 disp("W",Q_boiling,"(a) The rate of heat transfer
    during nucleate boiling becomes ")
23 //Solution(b):-
24 m=Q_boiling/h_fg; // [kg/s]
25 disp("kg/s",m,"The rate of Evaporation of water is")

```

Scilab code Exa 10.2 ab122

```

1 clear;
2 clc;
3
4 //Example10.2[Peak Heat Flux in Nucleate Boiling]
5 D=0.01; // [m]
6 Tsat=100; // Saturation Temperature[degree Celcius]
7 sigma=0.0589; // [N/m]
8 //Properties of water at saturation temperature
9 rho_l=957.9; // [kg/m^3]
10 rho_v=0.6; // [kg/m^3]
11 h_fg=2257*10^3; // [J/kg]
12 mu_l=0.282*10^(-3); // [kg/m.s]
13 Pr_l=1.75; // Prandtl number
14 Cp_l=4217; // [J/kg.degree Celcius]
15 Csf=0.0130,n=1.0;
16 g=9.81; // [m/s^2]
17 //Solution:-
18 L_=(D/2)*((g*(rho_l-rho_v)/sigma)^(1/2)); //
    dimensionless Parameter
19 //For this value of L_ we have
20 C_cr=0.12; // Constant
21 q_max=C_cr*h_fg*((sigma*g*(rho_v^2)*(rho_l-rho_v))
    ^(1/4)); // [W/m^2]

```

```

22 disp("W/m^2",q_max,"The maximum or critical heat
    flux is")
23 Ts=(((q_max/(mu_l*h_fg*((g*(rho_l-rho_v)/sigma)
    ^(1/2))))^(1/3))*(Csf*h_fg*Pr_l^n)/Cp_l)+Tsat;//[
    degree Celcius]
24 disp("degree Celcius",round(Ts),"The surface
    temperature is")

```

Scilab code Exa 10.3 ab123

```

1 clear;
2 clc;
3
4 //Example10.3[Film Boiling of Water on a Heating
    Element]
5 //Given:-
6 D=0.005;//[m]
7 e=0.05;//[Emissivity]
8 Ts=350;//[Surface temperature[degree Celcius]
9 Tsat=100;//[degree Celcius]
10 Tf=(Ts+Tsat)/2;//[degree Celcius]
11 g=9.81;//[m/s^2]
12 //Properties of water at Tsat
13 rho_l=957.9;//[kg/m^3]
14 h_fg=2257*10^3;//[J/kg]
15 //Properties of vapor at film temp
16 rho_v=0.444;//[kg/m^3]
17 Cp_v=1951;//[J/kg.degree Celcius]
18 mu_v=1.75*10^(-5);//[kg/m.s]
19 k_v=0.0388;//[W/m.degree Celcius]
20 //Solution:-
21 q_film=0.62*(((g*(k_v^3)*rho_v*(rho_l-rho_v)*(h_fg
    +(0.4*Cp_v*(Ts-Tsat))))/(mu_v*D*(Ts-Tsat)))^(1/4)
    *(Ts-Tsat));//[W/m^2]
22 disp("W/m^2"),q_film,"The film boiling heat flux is"

```

```

    )
23 q_rad=e*(5.67*10^(-8))*(((Ts+273)^4)-((Tsat+273)^4))
    ;// [W/m^2]
24 disp("W/m^2",q_rad,"The radiation heat flux is")
25 q_total=q_film+(3/4)*q_rad;// [W/m^2]
26 disp("W/m^2",q_total,"The total heat flux is")
27 Q_total=(%pi*D*1)*q_total;// [W]
28 disp("W",Q_total,"The rate of heat transfer from the
    heating element to the water is")

```

Scilab code Exa 10.4 ab124

```

1 clear;
2 clc;
3
4 //Example10.4[Condensation of steam on a Vertical
    Plate]
5 //Given:-
6 Tsat=100,Ts=80;//[degree Celcius]
7 Tf=(Ts+Tsat)/2;//[degree Celcius]
8 L=2,w=3;//Dimensions of Plate [m]
9 g=9.81;//[m/s^2]
10 //Properties of water at Tsat
11 h_fg=2257*10^3;//[J/kg]
12 rho_v=0.60;//[kg/m^3]
13 //Properties of liquid water at Tf
14 rho_l=965.3;//[kg/m^3]
15 mu_l=0.315*10^(-3);//[kg/m.s]
16 Cp_l=4206;//[J/kg.degree Celcius]
17 k_l=0.675;//[W/m.degree Celcius]
18 nu_l=0.326*10^(-6);//[m^2/s]
19 //Solution (a)
20 h_fg_m=h_fg+0.68*Cp_l*(Tsat-Ts);//[J/kg]
21 disp("J/kg",h_fg_m,"The modified latent heat of
    vapourization is")

```

```

22 Re=((4.81+((3.70*L*k_1*(Tsat-Ts)*((g/nu_1^2)^(1/3))))
    /(mu_1*h_fg_m)))^(0.820));
23 disp(ceil(Re),"For wavy laminar flow Reynolds number
    is")
24 h=(Re*k_1*((g/nu_1^2)^(1/3)))/((1.08*(Re^(1.22)))
    -5.2);//[W/m^2.degree Celcius]
25 disp("W/m^2.degree Celcius",h,"The conensation heat
    transfer coefficient is")
26 As=w*L;//[m^2]
27 Q=h*As*(Tsat-Ts);//[W]
28 disp("W",Q,"The rate of heat transfer during
    condensation process is")
29 //Solution (b)
30 m=Q/h_fg_m;//[kg/s]
31 disp("kg/s",m,"The rate of condensation of steam is"
    )

```

Scilab code Exa 10.5 ab125

```

1 clear;
2 clc;
3
4 //Example10.5[Condensation of steam on a Vertical
    Tilted Plate]
5 //Given:-
6 Tsat=100,Ts=80;//[degree Celcius]
7 Tf=(Ts+Tsat)/2;//[degree Celcius]
8 L=2,w=3;//[Dimensions of Plate[m]
9 g=9.81;//[m/s^2]
10 //Properties of water at Tsat
11 h_fg=2257*10^3;//[J/kg]
12 rho_v=0.60;//[kg/m^3]
13 //Properties of liquid water at Tf
14 rho_l=965.3;//[kg/m^3]
15 mu_1=0.315*10^(-3);//[kg/m.s]

```

```

16 Cp_1=4206; //[J/kg.degree Celcius]
17 k_1=0.675; //[W/m.degree Celcius]
18 nu_1=0.326*10^(-6); //[m^2/s]
19 theta=(%pi/6); //Angle at which plate is tilted [
    radians]
20 //Solution (a)
21 h_fg_m=h_fg+0.68*Cp_1*(Tsat-Ts); //[J/kg]
22 disp("J/kg",h_fg_m,"The modified latent heat of
    vapourization is")
23 Re=((4.81+((3.70*L*k_1*(Tsat-Ts)*((g/nu_1^2)^(1/3))))
    /(mu_1*h_fg_m))^(0.820));
24 disp(ceil(Re),"For wavy laminar flow Reynolds number
    is")
25 h=((Re*k_1*((g/nu_1^2)^(1/3)))/((1.08*(Re^(1.22))
    -5.2))*((cos(theta))^(1/4))); //[W/m^2.degree
    Celcius]
26 disp("W/m^2.degree Celcius",h,"The conensation heat
    transfer coefficient is")
27 As=w*L; //[m^2]
28 Q=h*As*(Tsat-Ts); //[W]
29 disp("W",Q,"The rate of heat transfer during
    condensation process is")
30 //Solution (b)
31 m=Q/h_fg_m; //[kg/s]
32 disp("kg/s",m,"The rate of condensation of steam is"
    )

```

Scilab code Exa 10.6 ab126

```

1 clear;
2 clc;
3
4 //Example10.6[Condensation of Steam on horizontal
    Tubes]
5 //Given:-

```



```

6 Tsat=40;//[degree Celcius]
7 D=0.03;//[m]
8 Ts=30; //Outer Surface temperature of tube[degree
    Celcius]
9 Tf=(Ts+Tsat)/2; //Film Temperature[degree Celcius]
10 g=9.81; //[m/s^2]
11 //Properties of water at the saturation temp
12 h_fg=2407*10^3; //[J/kg]
13 rho_v=0.05; //[kg/m^3]
14 //Properties of liquid water at the film temperature
15 rho_l=994; //[kg/m^3]
16 Cp_l=4178; //[J/kg.degree Celcius]
17 mu_l=0.720*10^(-3); //[kg/m.s]
18 k_l=0.623; //[W/m.degree Celcius]
19 //Solution (a)
20 h_fg_m=h_fg+0.68*Cp_l*(Tsat-Ts); //[J/kg]
21 disp("J/kg",h_fg_m,"(a) The modified latent heat of
    vapourisation is")
22 h_hori=0.729*(((g*(rho_l^2)*h_fg_m*(k_l^3))/(mu_l*D
    *(Tsat-Ts)))^(1/4)); //[W/m^2.degree Celcius]
23 disp("W/m^2.degree Celcius",h_hori,"The heat
    transfer coefficient for condensation on a single
    horizontal tube is")
24 As=%pi*D*1; //[m^2]
25 Q=h_hori*As*(Tsat-Ts); //[W]
26 disp("W",Q,"The rate of heat transfer during
    condensation Process is")
27 //Solution (b)
28 m=Q/h_fg_m; //[kg/s]
29 disp("kg/s",m,"(b) The rate of condensation of steam
    is")

```

Scilab code Exa 10.7 ab127

```
1 clear;
```

```

2  clc;
3
4  //Example10.7[Condensation of Steam on horizontal
   Tube Banks]
5  //Given:–
6  Tsat=40;//[degree Celcius]
7  D=0.03;//[m]
8  Ts=30;//Outer Surface temperature of tube[degree
   Celcius]
9  Tf=(Ts+Tsat)/2;//Film Temperature[degree Celcius]
10 g=9.81;//[m/s^2]
11 N=3;//No of tubes in a vertical tier
12 N_total=12;//Total number of tubes
13 //Properties of water at the saturation temp
14 h_fg=2407*10^3;//[J/kg]
15 rho_v=0.05;//[kg/m^3]
16 //Properties of liquid water at the film temperature
17 rho_l=994;//[kg/m^3]
18 Cp_l=4178;//[J/kg.degree Celcius]
19 mu_l=0.720*10^(-3);//[kg/m.s]
20 k_l=0.623;//[W/m.degree Celcius]
21 //Solution (a)
22 h_fg_m=h_fg+0.68*Cp_l*(Tsat-Ts);//[J/kg]
23 disp("J/kg",h_fg_m,"(a) The modified latent heat of
   vapourisation is")
24 h_hori_N=(0.729*(((g*(rho_l^2)*h_fg_m*(k_l^3))/(mu_l
   *D*(Tsat-Ts)))^(1/4)))*(1/(N^(1/4))));//[W/m^2.
   degree Celcius]
25 disp("W/m^2.degree Celcius",h_hori_N,"The heat
   transfer coefficient for condensation 12
   horizontal tube is")
26 As=%pi*D*1*N_total;//[m^2]
27 Q=h_hori_N*As*(Tsat-Ts);//[W]
28 disp("W",Q,"The rate of heat transfer during
   condensation Process is")
29 //Solution (b)
30 m=Q/h_fg_m;//[kg/s]
31 disp("kg/s",m,"(b) The rate of condensation of steam

```

is”)

Scilab code Exa 10.8 ab128

```
1 clear;
2 clc;
3
4 //Example10.8[Replacing a Heat Pipe by a Copper Rod]
5 //Given:–
6 L=0.3; // [m]
7 D=0.006; // [m]
8 Q=180; // [W]
9 del_T=3; //Temperature Difference [degree Celcius]
10 //Properties of copper at room temperature
11 rho=8933; // [kg/m^3]
12 k=401; // [W/m.degree Celcius]
13 //Solution:–
14 A=Q*L/(k*del_T); // [m^2]
15 d=sqrt(4*A/%pi); // [m]
16 disp("cm", ceil(100*d), "The diameter of the copper
    pipe is")
17 m=rho*A*L; // [kg]
18 disp("kg", round(m), "Mass of the copper rod is")
```

Chapter 11

Heat Exchangers

Scilab code Exa 11.1 ab131

```
1 clear;
2 clc;
3
4 //Example11.1[Overall Heat Transfer Coefficient of a
   Heat Exchanger]
5 D_in=0.02;//Diameter of inner tubes[m]
6 Di_out=0.03;//Inner Diameter of Outer tubes [m]
7 mw=0.5;//Mass Flow Rate of water[kg/s]
8 mo=0.8;//Mass Flow rate of oil[kg/s]
9 Tw=45;//Average Temp of water[degree Celcius]
10 To=80;//Average Temp of oil [degree Celcius]
11 //Properties of water at Tw
12 rho_w=990.1;//[kg/m^3]
13 Pr_w=3.91;//Prandtl Number
14 k_w=0.637;//[W/m.degree Celcius]
15 nu_w=0.602*10^(-6);//[m^2/s]
16 //Properties of oil at To
17 rho_o=852;//[kg/m^3]
18 Pr_o=499.3;//Prandtl Number
19 k_o=0.138;//[W/m.degree Celcius]
20 nu_o=3.794*10^(-5);//[m^2/s]
```

```

21 //Solution:-
22 Vw=mw/(rho_w*(%pi*(D_in^2)/4));//[m/s]
23 disp("m/s",Vw,"The average velocity of water in the
    tube is")
24 Re_w=Vw*D_in/nu_w;
25 disp(Re_w,"The Reynolds number for flow of water in
    the tube is")
26 Nu_w=0.023*(Re_w^(0.8))*(Pr_w^(0.4));
27 disp(Nu_w,"The nusselt no for turbulent water flow")
28 hi=k_w*Nu_w/D_in;//[W/m^2.degree Celcius]
29 //For oil flow
30 Dh=Di_out-D_in; //Hydraulic Diameter for the annular
    space [m]
31 Vo=mo/(rho_o*(%pi*((Di_out^2)-(D_in^2))/4));//[m/s]
32 disp("m/s",Vo,"The average velocity for flow of oil
    is")
33 Re_o=Vo*Dh/nu_o;
34 disp(Re_o,"The Reynolds number for flow of oil is")
35 Nu_o=5.45; //Nusselt number for flow of oil usign the
    table 11.3 and interpolating for value
    corresponding to Di_out/D_in
36 ho=Nu_o*k_o/Dh;//[W/m^2.degree Celcius]
37 U=(1/((1/hi)+(1/ho)));//[W/m^2.degree Celcius]
38 disp("W/m^2.degree Celcius",U,"The overall heat
    transfer Coefficient for the given heat exchanger
    is")

```

Scilab code Exa 11.2 ab132

```

1 clear;
2 clc;
3
4 //Example11.2[Effect of Fouling on the Overall Heat
    Transfer Coefficient]
5 //Given:-

```

```

6 k=15.1; // [W/m^2.degree Celcius]
7 Di=0.015; // Inner Diameter [m]
8 Do=0.019; // Outer Diameter [m]
9 Di_s=0.032; // Inner diameter of outer shell [m]
10 L=1; // [m]
11 hi=800; // W/m^2.degree Celcius
12 ho=1200; // [W/m^2.degree Celcius]
13 Rfi=0.0004; // [m^2.degree Celcius/W]
14 Rfo=0.0001; // [m^2.degree Celcius/W]
15 // Solution (a):-
16 Ai=%pi*Di*L; // [m^2]
17 Ao=%pi*Do*L; // [m^2]
18 Ra=(1/(hi*Ai))+(Rfi/Ai)+((log(Do/Di))/(2*%pi*k*L))+
    (Rfo/Ao)+(1/(ho*Ao)); // [m^2.degree Celcius/W]
19 disp("m^2.degree Celcius/W",Ra,"The thermal
    Resistance for an unfinned shell and tube heat
    exchanger with fouling on both heat transfer
    surfaces is")
20 // Solution (b):-
21 Ui=1/(Ra*Ai); // [W/m^2.degree Celcius]
22 Uo=1/(Ra*Ao); // [W/m^2.degree Celcius]
23 disp("respectively", "W/m^2.degree Celcius",Uo,"and",
    Ui,"The overall Heat transfer Coefficients based
    on the inner and outer surfaces of the tube are")

```

Scilab code Exa 11.3 ab133

```

1 clear;
2 clc;
3
4 //Example11.3[The Condensation of Steam in a
    Condenser]
5 //Given:-
6 Th_in=30,Th_out=30,Tc_in=14,Tc_out=22; //Inlet and
    Outlet temperatures of hot and cold liquids [

```

```

    degree Celcius]
7 A=45; //[m^2]
8 U=2100; //[W/m^2.degree Celcius]
9 h_fg=2431; //Heat of vapourisation of water at Th_i[
    kJ/kg]
10 Cp=4184; //Specific heat of cold water [J/kg]
11 //Solution:-
12 del_T1=Th_in-Tc_out; //[degree Celcius]
13 del_T2=Th_out-Tc_in; //[degree Celcius]
14 del_T_lm=(del_T1-del_T2)/(log(del_T1/del_T2)); //[
    degree Celcius]
15 disp("degree Celcius",del_T_lm,"The logarithmic Mean
    temperature difference is")
16 Q=U*A*del_T_lm; //[W]
17 disp("W",Q,"The heat transfer rate in the condenser
    is")
18 mw=Q/(Cp*(Tc_out-Tc_in)); //[kg/s]
19 disp("kg/s",mw,"The mass flow rate of the cooling
    water is")
20
21 ms=(Q/(1000*h_fg)); //[kg/s]
22 disp("kg/s",ms,"The rate of condensation of steam is
    ")

```

Scilab code Exa 11.4 ab134

```

1 clear;
2 clc;
3
4 //Example11.4[Heating Water in a Counter Flow Heat
    Exchanger]
5 //Given:-
6 mw=1.2,mgw=2; //Mass Flow rate of water and
    geothermal fluid[kg/s]
7 U=640; //Overall Heat transfer Coefficient [W/m^2.

```

```

    degree Celcius]
8 Di=0.015; //[m]
9 Tw_out=80,Tw_in=20; //Outlet and Inlet temp of water[
    degree Celcius]
10 Tgw_in=160; //Inlet temp of geothermal fluid [degree
    Celcius]
11 Cp_w=4.18,Cp_gw=4.31; //Specific Heats of water and
    geothermal fluid [kJ/kg.degree Celcius]
12 //Solution:-
13 Q=mw*Cp_w*(Tw_out-Tw_in); //[kW]
14 disp("kW",ceil(Q),"The rate of heat transfer in the
    heat exchanger is")
15 Tgw_out=(Tgw_in-(ceil(Q)/(mgw*Cp_gw))); //[degree
    Celcius]
16 disp("degree Celcius",Tgw_out,"The outlet temp of
    geothermal fluid is")
17 del_T1=Tgw_in-Tw_out; //[degree Celcius]
18 del_T2=Tgw_out-Tw_in; //[degree Celcius]
19 del_T_lm=(del_T1-del_T2)/(log(del_T1/del_T2)); //[
    degree Celcius]
20 disp("degree Celcius",del_T_lm,"The logarithmic Mean
    temperature difference is")
21 As=1000*ceil(Q)/(U*del_T_lm); //[m^2]
22 disp("m^2",As,"The surface area of the heat
    exchanger is")
23 L=As/(%pi*Di); //[m]
24 disp("m",round(L),"The length of the tube is")

```

Scilab code Exa 11.5 ab135

```

1 clear;
2 clc;
3
4 //Example11.5[Heating of Glycerine in a Multipass
    Heat Exchanger]

```



```

5 //Given:-
6 //A 2,4 shell and tube heat exchanger
7 D=0.02; //Diameter [m]
8 L=60; //Length of tube [m]
9 Th_in=80, Th_out=40, Tc_in=20, Tc_out=50; //Inlet and
    Outlet temperatures water and glycerine [degree
    Celcius]
10 hi=160, ho=25; //Convective Heat transfer coefficients
    on both side of tube [W/m^2.degree Celcius]
11 Rf=0.0006; //Fouling Resistance [m^2.degree Celcius/W]
12 //Solution:-
13 As=%pi*D*L; // [m^2]
14 del_T1=Th_in-Tc_out; // [degree Celcius]
15 del_T2=Th_out-Tc_in; // [degree Celcius]
16 del_T_lm=(del_T1-del_T2)/log(del_T1/del_T2); // [
    degree Celcius]
17 disp("degree Celcius", del_T_lm, "The log mean
    temperature difference for the counter flow
    arrangement is")
18 F=0.91; //Correction Factor
19 //(a)
20 Ua=1/((1/hi)+(1/ho)); // [W/m^2.degree Celcius]
21 disp("W/m^2.degree Celcius", Ua, "In case of no
    fouling, the over all heat transfer coefficient
    is")
22 Qa=Ua*As*F*del_T_lm; // [W]
23 disp("W", ceil(Qa), "And the rate of heat transfer is")
    )
24 //(b)
25 Ub=1/((1/hi)+(1/ho)+(Rf)); // [W/m^2.degree Celcius]
26 disp("W/m^2.degree Celcius", Ub, "When there is
    fouling on one of the surfaces, the overall heat
    transfer coefficient is")
27 Qb=Ub*As*F*del_T_lm; // [W]
28 disp("W", round(Qb), "And the rate of heat transfer is
    ")

```

Scilab code Exa 11.6 ab136

```
1 clear;
2 clc;
3
4 //Example11.6[ Cooling of Water in an Automotive
   Radiator]
5 //Given:-
6 m=0.6; //Mass Flow rate of water[kg/s]
7 Th_in=90, Th_out=65, Tc_in=20, Tc_out=40; // [degree
   Celcius]
8 Di=0.005; // [m]
9 L=0.65; // [m]
10 n=40; //No of tubes
11 Cp=4195; // [J/kg.degree Celcius]
12 //Solution:-
13 Q=m*Cp*(Th_in-Th_out); // [W]
14 disp("W",Q,"The rate of heat transfer in the
   radiator from the hot water to the air is")
15 Ai=n*pi*Di*L; // [m^2]
16 del_T1=Th_in-Tc_out; // [degree Celcius]
17 del_T2=Th_out-Tc_in; // [degree Celcius]
18 del_T_lm=(del_T1-del_T2)/log(del_T1/del_T2); // [
   degree Celcius]
19 disp("degree Celcius",del_T_lm,"The log mean
   temperature difference for the counter flow
   arrangement is")
20 F=0.97; //Correction Factor for this situation
21 Ui=Q/(Ai*F*del_T_lm); // [W/m^2.degree Celcius]
22 disp("W/m^2.degree Celcius",round(Ui),"the overall
   heat transfer coefficient is")
```

Scilab code Exa 11.7 ab137

```
1 clear;
2 clc;
3
4 //Example11.6[Cooling of Water in an Automotive
   Radiator]
5 //Given:-
6 m=0.6; //Mass Flow rate of water[kg/s]
7 Th_in=90, Th_out=65, Tc_in=20, Tc_out=40; // [degree
   Celcius]
8 Di=0.005; // [m]
9 L=0.65; // [m]
10 n=40; //No of tubes
11 Cp=4195; // [J/kg.degree Celcius]
12 //Solution:-
13 Q=m*Cp*(Th_in-Th_out); // [W]
14 disp("W",Q,"The rate of heat transfer in the
   radiator from the hot water to the air is")
15 Ai=n*pi*Di*L; // [m^2]
16 del_T1=Th_in-Tc_out; // [degree Celcius]
17 del_T2=Th_out-Tc_in; // [degree Celcius]
18 del_T_lm=(del_T1-del_T2)/log(del_T1/del_T2); // [
   degree Celcius]
19 disp("degree Celcius",del_T_lm,"The log mean
   temperature difference for the counter flow
   arrangement is")
20 F=0.97; //Correction Factor for this situation
21 Ui=Q/(Ai*F*del_T_lm); // [W/m^2.degree Celcius]
22 disp("W/m^2.degree Celcius",round(Ui),"the overall
   heat transfer coefficient is")
```

Scilab code Exa 11.8 ab138

```
1 clear;
```

```

2  clc;
3
4  //Example11.8[Using the Effectiveness – NTU Method]
5  //Given:–
6  mc=1.2,mh=2;//Mass Flow rate of water and geothermal
    fluid [kg/s]
7  U=640;//Overall Heat transfer Coefficient [W/m^2.
    degree Celcius]
8  Di=0.015;// [m]
9  Tc_out=80,Tc_in=20;//Outlet and Inlet temp of water [
    degree Celcius]
10 Th_in=160;//Inlet temp of geothermal fluid [degree
    Celcius]
11 Cp_c=4.18,Cp_h=4.31;//Specific Heats of water and
    geothermal fluid [kJ/kg.degree Celcius]
12 //Solution:–
13 Ch=mh*Cp_h;// [kW/degree Celcius]
14 Cc=mc*Cp_c;// [kW/degree Celcius]
15 if (Ch>Cc) then,
16     Cmin=Cc;
17     c=Cmin/Ch;
18 else
19     Cmin=Ch;
20     c=Cmin/Cc;
21 end
22 Q_max=Cmin*(Th_in-Tc_in);// [kW]
23 disp("kW",Q_max,"The maximum heat transfer rate is")
24 Q_ac=mc*Cp_c*(Tc_out-Tc_in);// [kW]
25 e=Q_ac/Q_max;
26 disp(e,"The effectiveness of the heat exchanger is")
27 NTU=(1/(c-1))*log((e-1)/(e*c-1));
28 disp(NTU,"The NTU of this counter flow heat
    exchanger is")
29 As=NTU*Cmin*1000/U;// [m^2]
30 disp("m^2",As,"The heat transfer surface area is")
31 L=As/(%pi*Di);// [m]
32 disp("m",round(L),"The length of the tube is")

```

Scilab code Exa 11.9 ab139

```
1 clear;
2 clc;
3
4 //Example11.9[ Cooling Hot Oil by Water in Multipass
   Heat Exchanger]
5 //Given:-
6 Cp_c=4.18,Cp_h=2.13;//Specific Heats of water and
   oil [kJ/kg]
7 mc=0.2,mh=0.3;//Mass Flow rate of oil and water [kg/
   s]
8 Th_in=150,Tc_in=20;//[degree Celcius]
9 n=8;//No of tubes
10 D=0.014;//[m]
11 L=5;//[m]
12 U=310;//Overall Heat transfer Coefficient [W/m^2.
   degree Celcius]
13 //Solution:-
14 Ch=mh*Cp_h;// [kW/degree Celcius]
15 Cc=mc*Cp_c;// [kW/degree Celcius]
16 if (Ch>Cc) then,
17     Cmin=Cc;
18     c=Cmin/Ch;
19 else
20     Cmin=Ch;
21     c=Cmin/Cc;
22 end
23 Q_max=Cmin*(Th_in-Tc_in);// [kW]
24 disp("kW",Q_max,"The maximum heat transfer rate is")
25 As=n*pi*D*L;// [m^2]
26 disp("m^2",As,"Heat transfer Surface Area is")
27 NTU=U*As/Cmin;
28 disp(NTU,"The NTU of this heat exchanger is")
```

```

29 e=0.47; //Determined from fig 11.26(c) using value of
    NTU and c
30 Q=e*Q_max; // [kW]
31 Tc_out=Tc_in+(Q/Cc); // [degree Celcius]
32 Th_out=Th_in-(Q/Ch); // [degree Celcius]
33 disp("degree Celcius",Tc_out,"to", "degree Celcius",
    Tc_in,"The temperature of cooling water will rise
    from")
34 disp("degree Celcius",Th_out,"to", "degree Celcius",
    Th_in,"as it cools the hot oil from")

```

Scilab code Exa 11.10 ab140

```

1 clear;
2 clc;
3
4 //Example11.10[Installing a Heat Exchanger to Save
    Energy and Money]
5 //Given:-
6 Cp=4.18; // [kJ/kg.degree Celcius]
7 Th_in=80,Tc_in=15; // Inlet temperatures of hot and
    cold water [degree Celcius]
8 m=15/60; // [kg/s]
9 e=0.75; // Effectiveness
10 t=24*365; // Operating Hours [hours/year]
11 neta=0.8; // Efficiency
12 cost=1.10; // [$/therm]
13 //Solution:-
14 Q_max=m*Cp*(Th_in-Tc_in); // [kJ/kg.degree Celcius]
15 disp("kJ/kg.degree Celcius",Q_max,"Maximun Heat
    recover is")
16 Q=e*Q_max; // [kJ/s]
17 E_saved=Q*t*3600; // [kJ/year]
18 disp("kJ/year",E_saved,"The energy saved during an
    entire year will be")

```

```
19 F_saved=(E_saved/neta)*(1/105500);//[therms]
20 disp("therms/year",F_saved,"Fuel savings will be")
21 M_saved=F_saved*cost;/>[$/year]
22 disp("per year",M_saved,"The amount of money saved
    is $")
```

Chapter 12

Fundamentals of Thermal Radiation

Scilab code Exa 12.1 ab141

```
1 clear;
2 clc;
3
4 //Example12.1[Radiation Emission from a Black Ball]
5 //Given:-
6 T=800;//Temperature of suspended ball [K]
7 D=0.2;//Diameter [m]
8 C1=3.74177*10^8;//[(micrometer^4)/m^2]
9 C2=1.43878*10^4;//[micrometer.K]
10 lambda=3;//[micrometer]
11 //Solution (a):-
12 Eb=(5.67*10^(-8))*(T^4);//[W/m^2]
13 disp("of energy in the form of energy in the form of
      electromagnetic radiation per second per m^2",
      kJ",Eb/1000,"The ball emits")
14 //Solution(b):-
15 As=%pi*(D^2);//[m^2]
16 disp("m^2",As,"The total Surface area of the ball is
      ")
```



```

17 del_t=5*60; //[seconds]
18 Q_rad=Eb*As*del_t; //[J]
19 disp("kJ",Q_rad/1000,"The total amount of radiation
    energy emitted from the entire ball is")
20 //Solution (c)
21 Eb_lambda=C1/((lambda^5)*((exp(C2/(lambda*T)))-1));
    //[W/m^2.micrometer]
22 disp("W/m^2.micrometer",round(Eb_lambda),"The
    spectral blackbody emissive power")

```

Scilab code Exa 12.2 ab142

```

1 clear;
2 clc;
3
4 //Example12.2[Emission of Radiation from a Lightbulb
    ]
5 //Given:-
6 T=2500; //Temp of the filament [K]
7 lambda1=0.4,lambda2=0.76; //Visible ranfe [micrometer]
8 f1=0.000321,f2=0.053035; //The black body radiation
    functions corresponding to lamda1*T and lambda2*T
9 //Solution:-
10 f3=f2-f1;
11 disp(f3,"Fraction of radiation emitted between the
    two given wavelengths is")
12 lambda_max=2897.8/T; //[micrometer]
13 disp("micron",lambda_max,"The wavelength at which
    the emission of radiation from the filament peaks
    is")

```

Scilab code Exa 12.3 ab143

```

1 clear;
2 clc;
3
4 //Example12.3[Radiation Incident on a small surface]
5 //Given:–
6 A1=3*10^(-4); // [m^2]
7 T1=600; // [k]
8 A2=5*10^(-4); // [m^2]
9 theta1=%pi*55/180,theta2=%pi*40/180; // [Radian]
10 r=0.75; // [m]
11 //Solution:–
12 w_2_1=(A2*cos(theta2))/(r^2); // [Steradian]
13 disp("sr",w_2_1,"The solid angle subtended by a2
    when viewed from A1 is")
14 I1=(5.67*10^(-8))*(T1^4)/(%pi); // [W/m^2.sr]
15 disp("W/m^2.sr",I1,"The Intensity of radiation
    emitted by A1 is")
16 Q1_2=I1*(A1*cos(theta1))*w_2_1; // [W]
17 disp("W",Q1_2," is ", "Steradian",w_2_1," through the
    solid angle", "radians",theta1,"The rate of
    radiation energy emitted by A1 in the direction
    of")

```

Scilab code Exa 12.4 ab144

```

1 clear;
2 clc;
3
4 //Example12.4[Emissivity of a surface and emissive
    Power]
5 e1=0.3; //For 0<= lambda <= 3micron
6 e2=0.8; //3micron<=lambda<=7micron
7 e3=0.1; //7micron<=lamda<infinity
8 lambda1=3,lambda2=7; // [micron]
9 T=800; // [K]

```

```

10 //Solution:-
11 p=lambda1*T;// [micron.K]
12 q=lambda2*T;// [micron.K]
13 //Hence blackbody radiation functions are
14 f1=0.140256;
15 f2=0.701046;
16 f0_1=f1-0;
17 f2_inf=1-f2;
18 e_T=e1*f1+e2*(f2-f1)+e3*(1-f2);
19 disp(e_T,"Average emissivity of the surface is")
20 E=e_T*(5.67*10^(-8))*(T^4);// [W/m^2]
21 disp("W/m^2",E,"The Emissive Power of the surface is
    ")

```

Scilab code Exa 12.5 ab145

```

1 clear;
2 clc;
3
4 //Example12.6[ Selective Absorber and Reflective
    Surfaces]
5 //Given:-
6 G_D=400,G_d=300;// Direct and diffuse components of
    solar radiation [W/m^2]
7 Ts=320,T_sky=260;// [K]
8 theta=20*%pi/180
9 //Solution:-
10 G_solar=(G_D*cos(theta))+G_d
11 //(a)
12 ab_a=0.9,e_a=0.9;//Grey absorber surface
13 q_net_rad_a=ab_a*G_solar+e_a*(5.67*10^(-8))*((T_sky
    ^4)-(Ts^4));// [W/m^2]
14 disp("W/m^2",round(q_net_rad_a),"(a) The net
    radiation heat transfer is")
15 //(b)

```

```

16 ab_b=0.1,e_b=0.1; //Grey reflector surface
17 q_net_rad_b=ab_b*G_solar+e_b*(5.67*10^(-8))*((T_sky
    ^4)-(Ts^4)); // [W/m^2]
18 disp("W/m^2",round(q_net_rad_b),"The net radiation
    heat transfer is")
19 //(c)
20 ab_c=0.9,e_c=0.1; //Selective Absorber surface
21
22 q_net_rad_c=ab_c*G_solar+e_c*(5.67*10^(-8))*((T_sky
    ^4)-(Ts^4)); // [W/m^2]
23 disp("W/m^2",round(q_net_rad_c),"The net radiation
    heat transfer is")
24 //(d)
25 ab_d=0.1,e_d=0.9; //Selective reflector surface
26 q_net_rad_d=ab_d*G_solar+e_d*(5.67*10^(-8))*((T_sky
    ^4)-(Ts^4)); // [W/m^2]
27 disp("W/m^2",round(q_net_rad_d),"The net radiation
    heat transfer is")

```

Scilab code Exa 12.6 ab146

```

1 clear;
2 clc;
3
4 //Example12.6[Installing Reflective Films on Windows
    ]
5 //Given:-
6 A_glazing=40; // [m^2]
7 SHGC_wof=0.766,SHGC_wf=0.261; // [kWh/year]
8 unit_c_e=0.08; // [$/kWh]
9 unit_c_f=0.5; // [$/therm]
10 COP=2.5,neta=0.80;
11 //Solution:-
12 //For the months of June,July,August and Sepetember
13 Q_summer=5.31*30+4.31*31+3.93*31+3.28*30; // [kWh/year]

```

```

]
14 //For the months oct ,Nov,Dec ,Jan ,Feb ,Mar ,Apr
15 Q_winter
    =2.80*31+1.84*30+1.54*31+1.86*31+2.66*28+3.43*31+4.00*30;
    // [kWh/year]
16 c_l_d=Q_summer*A_glazing*(SHGC_wof-SHGC_wf); // [kWh/
    year]
17 disp("kWh/year",c_l_d,"The decrease in the annual
    cooling load is")
18 h_l_i=Q_winter*A_glazing*(SHGC_wof-SHGC_wf); // [kWh/
    year]
19 disp("kWh/year",h_l_i,"The increase in annual
    heating load is")
20 d_c_c=c_l_d*(unit_c_e)/COP; //[$/year]
21 i_h_c=h_l_i*(unit_c_f/29.31)/neta; //[$/year]
22 disp("per year",i_h_c,"and $",d_c_c,"The
    corresponding decrease in cooling costs and the
    increase in heating costs are $")
23 Cost_s=d_c_c-i_h_c; //[$/year]
24 disp("per year",Cost_s,"The net annual cost savings
    due to the reflective film is $")
25 I_cost=20*A_glazing; //[$]
26 disp(I_cost,"The implementation Cost of installing
    films is $")
27 pp=I_cost/Cost_s; // [years]
28 disp("years",pp,"Payback Period is")

```

Chapter 13

Radiation Heat Transfer

Scilab code Exa 13.1 ab151

```
1 clear;
2 clc;
3
4 //Example13.1[View Factors Associated with two
   Concentric Spheres]
5 //Solution:-
6 //The outer surface of the smaller sphere and inner
   surface of the larger sphere form a two surface
   enclosure
7 N=2;
8 disp("View Factors",N^2,"This enclosure involves ")
9 x=(1/2)*N*(N-1);
10 disp("view factor directly",x,"W need to determine
   only")
11 F11=0;
12 F12=1;
13 disp("The Two view Factors")
14 disp(F11,"Since no radiation leaving surface 1
   strikes itself..... F11=")
15 disp(F12,"Since all radiation leaving surface 1
   strikes surface 2    F12=")
```

```
16 disp("F12= ((r1/r2)^2)")
17 disp("F22= 1-((r1/r2)^2)")
18 disp("where r1 and r2 are radius of surface 1 and
      surface 2")
```

Scilab code Exa 13.2 ab152

```
1 clear;
2 clc;
3
4 //Example13.2[Fraction of Radiation Leaving through
      an Opening]
5 //Given:-
6 r1=0.1;//Radius of enclosure[m]
7 L=0.1;//Length of Enclosure[m]
8 r2=0.05,r3=0.08;//Inner and outer radii of the ring[
      m]
9 //Solution:-
10 //Using Chart in Fig 13.7
11 F12=0.11;
12 F13=0.28;
13 F1_ring=F13-F12;
14 disp(F1_ring,"The fraction of the radiation leaving
      the base cylinder enclosure that escapes through
      coaxial ring opening at its top surface is")
```

Scilab code Exa 13.3 ab153

```
1 clear;
2 clc;
3
4 //Example13.3[View Factors Associated with a
      Tetragon]
```

```

5 //Given:-
6 //A pyramid with square base and it's sides being
   isoceles triangle
7 //Solution:=
8 F11=0;//Since base is a flat surface
9 //F12=F13=F14=F15=x
10 x=(1-F11)/4;
11 disp("of total radiation",x,"Each side pf the four
   surfaces of the pyramid recieves")

```

Scilab code Exa 13.5 ab155

```

1 clear;
2 clc;
3
4 //Example13.5[The Crossed-Strings Method for View
   Factors]
5 a=12,b=5;//With od long parallel plates[cm]
6 c=6;//Distance between the plates
7 L1=a,L2=b,L3=c;
8 L4=sqrt((7^2)+(6^2));
9 L5=sqrt((5^2)+(6^2));
10 L6=sqrt((12^2)+(6^2));
11 F12_1=((L5+L6)-(L3+L4))/(2*L1);
12 F13=(L1+L3-L6)/(2*L1);
13 F14=(L1+L4+L5)/(2*L1);
14 F12_2=1-F13-F14;
15 disp(F12_1,"Therefore from two different methods
   F12_1=F12_2=",F13,"F13=",F14,"F14=")

```

Scilab code Exa 13.6 ab156

```

1 clear;

```



```

2  clc;
3
4  //Example13.6[Radiation Heat Transfer in a Black
    Furnace]
5  //Given:-
6  F12=0.2;
7  A=5*5;//Area of 1 surface of cube[m^2]
8  Tb=800,Tt=1500,Ts=500;//Temperature of base top and
    the side surfaces of the furbace[K]
9  //Solution:-
10 F11=0;
11 Q11=0;
12 F13=1-F11-F12;
13 Q13=A*F13*(5.67*10^(-8))*((Tb^4)-(Ts^4));// [kW]
14 disp("kW",round(Q13/1000),"The net rate of heat
    transfer from surfacel to surface3 is")
15 Q12=A*F12*(5.67*10^(-8))*((Tb^4)-(Tt^4));// [kW]
16 disp("kW",round(Q12/1000),"The net rate of radiation
    heat transfer from siurface1 to surface2 is")
17 Q1=Q11+Q12+Q13;// [kW]
18 disp("kW",round(Q1/1000),"Rhe net radiation heat
    transfer from the base surface is")

```

Scilab code Exa 13.7 ab157

```

1  clear;
2  clc;
3
4  //Example13.7[Radiation Heat Transfer between
    Parallel Plates]
5  //Given:-
6  T1=800,T2=500;//Temp of parallel plates [K]
7  e1=0.2,e2=0.7;//Emissivities
8  //Solution:-
9  q12=(5.67*10^(-8))*((T1^4)-(T2^4))/((1/e1)+(1/e2)-1)

```

```

;
10 disp("is transferred from plate 1 to plate 2 by
    radiation per unit surface area of either plate",
    "W", round(q12), "The net heat at the rate of")

```

Scilab code Exa 13.8 ab158

```

1 clear;
2 clc;
3
4 //Example13.8[Radiation Heat Transfer in Cylindrical
    Furnace]
5 //Given:-
6 ro=1,H=1;//Radius amd height of cylinder [m]
7 e1=0.8,e2=0.4;//Emissivities
8 T1=700,T2=500;//Top and base temperatures of furnace
    [K]
9 T3=400;//Side durface temperature [K]
10 F11=0,F12=0.38;
11 //Solution:-
12 A1=%pi*(ro^2);// [m^2]
13 A2=A1;// [m^2]
14 A3=2*%pi*ro*H;// [m^2]
15 F13=1-F11-F12;
16 F21=F12;//Top and Bottom are symmetric
17 F31=F13*(A1/A3);
18 F23=F13;
19 F32=F31;
20 function [i]=rad(J)
21     i(1)=J(1)+(((1-e1)/e1)*((F12*(J(1)-(J(2))))+(F13
        *((J(1))-(J(3))))))-((T1^4)*(5.67*10^(-8)));
22     i(2)=J(2)+(((1-e2)/e2)*((F21*(J(2)-J(1)))+(F23*(
        J(2)-J(3))))))-((T2^4)*(5.67*10^(-8)));
23     i(3)=J(3)-((T3^4)*(5.67*10^(-8)));
24     def(' [i]=rad(J) ', [' i_1=J(1)+(((1-e1)/e1)*((F12

```

```

        *(J(1)-(J(2))))+(F13*((J(1))-(J(3)))))) -((T1
        ^4)*(5.67*10^(-8)))', 'i_2=J(2)+(((1-e2)/e2)
        *((F21*(J(2)-J(1)))+(F23*(J(2)-J(3)))) -((T2
        ^4)*(5.67*10^(-8)))', 'i_3=J(3)-((T3^4)
        *(5.67*10^(-8)))']])
25 disp(J(3),J(2),J(1))
26 Q1=A1*((F12*(J(1)-J(2)))+(F13*(J(1)-J(3)))); // [kW
    ]
27 Q2=A2*((F21*(J(2)-J(1)))+(F13*(J(2)-J(3)))); // [kW
    ]
28 Q3=A3*((F31*(J(3)-J(1)))+(F32*(J(3)-J(2)))); // [kW
    ]
29 disp("kW",Q3/1000,Q2/1000,Q1/1000,"The net rates
    of radiation heat transfer at the three
    surfaces are")

```

Scilab code Exa 13.9 ab159

```

1 clear;
2 clc;
3
4 //Example13.9[Radiation Heat Transfer in a
    Triangular Furnace]
5 //Given:-
6 A1=1,A2=1,A3=1; //Area of each side [m^2]
7 T1=600,T2=1000; // [K]
8 e=0.7;
9 F12=0.5,F13=0.5,F23=0.5; //Symmetry
10 //Solution:-
11 Eb1=5.67*10^(-8)*(T1^4); // [W/m^2]
12 Eb2=5.67*10^(-8)*(T2^4); // [W/m^2]
13 Q=(Eb2-Eb1)/(((1-e)/(A1*e))+(((A1*F12)+(1/((1/(A1*
    F13)))+(1/(A2*F23))))))^(-1)); // [kW]
14 disp("kW",round(Q/1000),"Heat at the rate of")
15 disp("must be supplied to the heated surface per

```

unit length of the duct to maintain steady operation in the furnace”)

Scilab code Exa 13.10 ab160

```
1 clear;
2 clc;
3
4 //Example13.10[Heat Transfer through a Tubular Solar
   Collector]
5 k=0.02588; // [W/m.degree Celcius]
6 Pr1=0.7282, Pr2=0.7255; // Prandtl no
7 nu1=1.608*(10^(-5)), nu2=1.702*10^(-5); // [m^2/s]
8 T1=20, T2=40; // [degree Celcius]
9 Tavg=((T1+T2)/2)+273; // [K]
10 Do=0.1, L=1; // Dimensions of glass tube [m]
11 Di=0.05; // Inner diameter of tube [m]
12 Q_glass=30; // Rate of heat transfer from the outer
   surface of the glass cover [W]
13 g=9.81; // [m^2/s]
14 eo=0.9, ei=0.95; // Emissivity
15 //Solution:-
16 Ao=%pi*Do*L; // Heat transfer surface area of the
   glass cover [m^2]
17 disp(Ao, Tavg)
18 Ra_Do=g*Tavg*(T2-T1)*(Do^3)*Pr1/(nu1);
19 disp(Ra_Do, "The Rayleigh number is")
20 Nu=((0.6+((0.387*(Ra_Do^(1/6))))/(1+((0.559/Pr1)
   ^((9/16))))^(8/27))))^2);
21 disp(Nu, "The nusselt number is")
22 ho=k*Nu/Do; // [W/m^2.degree Celcius]
23 Qo_conv=ho*Ao*(T2-T1); // [W]
24 Qo_rad=eo*5.67*10^(-8)*Ao*((T2+273)^4)-((T1+273)^4)
   ); // [W]
25 Qo_total=Qo_conv+Qo_rad; // [W]
```

```

26 disp("W",Qo_total,"The total rate of heat loss from
    the glass cover %.2 f")
27 Lc=(Do-Di)/2;//The characteristic length
28 Ai=%pi*Di*L;//[m^2]
29 //Assuming
30 T_tube=54,T_cover=26;//Temperature of tube and glass
    cover [degree Celcius]
31 T_avg=((T_tube+T_cover)/2)+273;// [K]
32 Ra_L=g*T_avg*(T_tube-T_cover)*(Lc^3)*Pr2/(nu2);
33 disp(Ra_L,"The Rayleigh number in this case is")
34 F_cyl=((log(Do/Di))^4)/((Lc^3)*(((Di^(-3/5)))+(Do
    ^(-3/5)))^5));
35 k_eff=0.386*k*((Pr2/(0.861+Pr2))^(1/4))*((F_cyl*Ra_L
    )^(1/4));
36 disp("W/m. degree Celcius",k_eff,"The effective
    thermal conductivity is")
37 QL_conv=2*%pi*k_eff*(T_tube-T_cover)/(log(Do/Di));
38 disp("W",QL_conv,"The rate of heat transfer between
    the cylinders by convection is")
39 QL_rad=((5.67*10^(-8))*Ai*(((T_tube+273)^4)-((
    T_cover+273)^4)))/((1/ei)+(((1-eo)/eo)*(Di/Do)));
40 disp("W",QL_rad,"The radiation rate of heat transfer
    is")
41 QL_total=QL_conv+QL_rad;// [W]
42 disp("W",QL_total,"The total rate of heat loss from
    the glass cover is")

```

Scilab code Exa 13.11 ab161

```

1 clear;
2 clc;
3
4 //Example13.11[Radiation Shields]
5 //given:-
6 e=0.1;//Emissivity of aluminium sheet

```

```

7 T1=800,T2=500; //Temperatures of two parallel plates [
  K]
8 e1=0.2,e2=0.7; //Emissivities of plates
9 //So9lution:-
10 q12=((5.67*10^(-8))*((T1^4)-(T2^4)))/((1/e1)+(1/e2)
  -1+(1/e)+(1/e)-1); // [W/m^2]
11 disp("W/m^2",round(q12),"Radiation Heat Transfer")

```

Scilab code Exa 13.12 ab162

```

1 clear;
2 clc;
3
4 //Example13.12[Radiation Effect on Temperature
  Measurements]
5 //Given:-
6 Tw=400,Tth=650; //Temperature of duct wall and hota
  air flowing in it [K]
7 e=0.6; //emissivity
8 h=80; //Heat transfer coefficient [W/m^2.K]
9 //Solution:-
10 Tf=Tth+((e*5.67*10^(-8))*((Tth^4)-(Tw^4)))/h); // [K]
11 disp("K",round(Tf),"The temperature of actual air is
  ")

```

Scilab code Exa 13.13 ab163

```

1 clear;
2 clc;
3
4 //Example13.13[Effective Emissivity of Combustion
  Gases]

```

```

5 d=5,H=5;//Diameter and height of cylindrical furnace
   [m]
6 T=1200;//Temp of gases [K]
7 P=2;//Pressure [atm]
8 yN2=0.8,yH2O=0.08,yO2=0.07,yCO2=0.05;//Volumetric
   Composition
9 //Solution:-
10 Pc=yCO2*P;// [atm]
11 Pw=yH2O*P;// [atm]
12 disp("atm",Pw,"and","atm",Pc,"The partial pressures
   of CO2 and H2O are")
13 L=0.6*d;// [m]
14 x=Pc*L,y=Pw*L;// [m.atm]
15 ec_1=0.16,ew_1=0.23;//Emissivity of CO2 and H2O at 1
   atm pressure
16 Cc=1.1,Cw=1.4;//Pressure Correction Factors are
17 del_e=0.048;//Emissivity correction factor at T=1200
   K
18 e_g=Cc*ec_1+Cw*ew_1-del_e;
19 disp(e_g,"The effectivity of the combustion gases is
   ")

```

Scilab code Exa 13.14 ab164

```

1 clear;
2 clc;
3
4 //Example13.14[Radiation Heat Transfer in a
   Cylindrical Furnace]
5 //Given:-
6 Ts=600;//Wall Temperature [K]
7 d=5,H=5;//Diameter and Height of cylindrical furnace
8 Tg=1200, eg=0.45;//Average gas temperature and
   average emissivity of the combustion gases
9 Pc=0.10,L=3,Pw=0.16;//From Previous examples

```

```

10 //Solution:-
11 x=Pc*L*Ts/Tg; //[m. atm]
12 y=Pw*L*Ts/Tg; //[m. atm]
13 ec_1=0.11,ew_1=0.25; //Emissivities of CO2 and H2O
    corresponding to 600K and 1atm
14 Cc=1.1,Cw=1.4; //Correction Factors
15 a_c=Cc*((Tg/Ts)^(0.65))*(ec_1);
16 a_w=Cw*((Tg/Ts)^(0.45))*ew_1;
17 disp(a_w,"and",a_c,"The absorptivities of CO2 and
    H2O are")
18 del_a=0.027;
19 a_g=a_c+a_w-del_a;
20 disp(a_g,"The absorptivity of the combustion gases
    is")
21 As=(%pi*d*H)+(pi*(d^2)/2); //[m^2]
22 disp("m^2",round(As),"the surface area of the
    cylindrical surface is")
23 Q_net=round(As)*(5.67*10^(-8))*((eg*(Tg^4))-(a_g*(Ts
    ^4)));
24 disp("W",Q_net,"The net rate of radiation heat
    transfer from the combustion gases to walls of
    the furnace is")

```

Scilab code Exa 13.15 ab165

```

1 clear;
2 clc;
3
4 //Example13.15[Effect of Clothing on Thermal Comfort
    ]
5 h_rad=4.7,h_conv=4.0; //The radiation and convection
    heat transfer coefficient [W/m^2.degree Celcius]
6 R_clo=0.6*0.155; //Thermal resistance of clothing [m
    ^2.degree Celcius/W]
7 T_skin=33,T_amb=22; //Skin and Ambient temperature [

```



```

    degree Celcius]
8 As=1.8;//Surface area of an average man
9 //Solution:-
10 h_comb=h_conv+h_rad;//combined heat transfer
    coefficient [W/m^2.degree Celcius]
11 Q_sen_clo=As*(T_skin-T_amb)/(R_clo+(1/h_comb));//[W]
12 disp("W",Q_sen_clo,"The sensible heat loss from this
    person when clothed is")
13 //On removing the clothes
14 //R_clo=0 Clothing resistance on removing clothes
15 //Setting both heat transfer rates equal to
    determine new ambient air temperature
16 T_amb_new=T_skin-(Q_sen_clo*(1/h_comb)/As)//[degree
    Celcius]
17 disp("degree Celcius",T_amb_new,"The ambient
    temperature now is")

```

Chapter 14

Mass Transfer

Scilab code Exa 14.1 ab171

```
1 clear;
2 clc;
3
4 //Example14.1[Determining Mass Fractions from Mole
   Fractions]
5 //Given:-
6 yN2=0.781,yO2=0.209,yAr=0.01;//Mole fractions
7 M_N2=28,M_O2=32,M_Ar=39.9;//Molar Masses
8 //Solution:-
9 M_air=yN2*M_N2+yO2*M_O2+yAr*M_Ar;//[kg/kmol]
10 disp("kg/kmol",M_air,"The molar mass of air is")
11 w_N2=yN2*M_N2/M_air;
12 w_O2=yO2*M_O2/M_air;
13 w_Ar=yAr*M_Ar/M_air;
14 disp("respectively","percent",100*w_Ar,"and","
   percent",100*w_O2,"","percent",100*w_N2,"The
   mass fractions of N2, O2 and Ar in dry standard
   atmosphere are")
```

Scilab code Exa 14.2 ab172

```
1 clear;
2 clc;
3
4 //Example14.2[Mole Fraction of Water Vapor at the
   surface of a Lake]
5 //Given:-
6 P_vapor=1.705;//Partial Pressure of water vapor in
   the air at the lake surface is saturation
   pressure of watre at 15 degree Celcius[kPa]
7 T_lake=15;//[degree Celcius]
8 P=92;//Atmospheric pressure at lake level [kPa]
9 //Solution:-
10 y_vapor=P_vapor/P;
11 disp(y_vapor,"The mole fraction of water vapor in
   the air at the surface of lake is")
12 y_water=1-y_vapor;//Since water contains dissolved
   air
13 disp(y_water,"Mole fraction of liquid water in lake"
   )
```

Scilab code Exa 14.3 ab173

```
1 clear;
2 clc;
3
4 //Example14.3[Mole Fraction of Dissolved Air in
   Water]
5 //Given:-
6 P_vapor=1.96;//The partial presure of water vapor in
   the air at the lake surface is the saturation
   pressure of water at 17 degree Celcius
7 H=62000;//Henry's constant for air dissolved in
   water at 290K[bar]
```

```

8 P=92; //Atmospheric Pressure at lake level [kPa]
9 //Solution:-
10 P_dryair=P-P_vapor; // [kPa]
11 disp("bar",P_dryair/100,"The partial pressure of dry
    air is")
12 y_dryair=(P_dryair/100)/H;
13 disp(y_dryair,"The mole fraction of air in the water
    is")

```

Scilab code Exa 14.4 ab174

```

1 clear;
2 clc;
3
4 //Example14.4[ Diffusion of Hydrogen Gas into a
    Nickel Plate]
5 //Given:-
6 s=0.00901; //Solubility of hydrogen in nickel at 358K
    [kmol/m^3.bar]
7 P_H2=300/100; // [bar]
8 M_H2=2; //Molar Mass of hydrogen [kg/kmol]
9 //Solution:-
10 C_H2=s*P_H2; // [kmol/m^3]
11 disp("kmol/m^3",C_H2,"The molar density of hydrogen
    in the nickel at the interface is")
12 rho_H2=C_H2*M_H2; // [kg/m^3]
13 disp("kg/m^3",rho_H2,"Mass Density of hydrogen is")

```

Scilab code Exa 14.5 ab175

```

1 clear;
2 clc;
3

```

```

4 //Example14.5[Diffusion of Hydrogen through a
   Spherical Container]
5 //Given:-
6 CA1=0.087,CA2=0;//Molar concentration of hydrogen in
   the nickel at inner and outer surfaces [kmol/m^3]
7 r2=4.8/2;//Outer radius [m]
8 t=0.06;//Thickness of shell [m]
9 D_AB=1.2*(10^(-12));//Diffusion coefficient for
   hydrogen in the nickel at the specified
   temperature is [m^2/s]
10 M_H2=2;//Molar Mass of H2[kg/kmol]
11 //Solution:-
12 r1=((2*r2)-(2*t))/2;//Inner radius [m]
13 N_diff=4*pi*r1*r2*D_AB*(CA1-CA2)/(r2-r1);
14 disp("kmol/s",N_diff,"The molar flow rate of
   hydrogen through the shell by diffusion is")
15 m_diff=M_H2*N_diff;
16 disp("kg/s",m_diff,"The mass flow rate of hydrogen
   is")

```

Scilab code Exa 14.6 ab176

```

1 clear;
2 clc;
3
4 //Example14.6[Condensation and Freezing of Moisture
   in Walls]
5 Ti=20,To=-16;//Indoor and outdoor temperatures[
   degree Celcius]
6 R_wall=3.05;//Total thermal resistance of the wall[m
   ^2.degree Celcius/W]
7 A=1;//Heat transfer area [m^2]
8 R_ext=0.40;//The thermal resistance of the exterior
   part of the wall beyond the insulation [m^2.degree
   Celcius/W]

```

```

9 Rv_int=0.012+0.0004,Rv_ext=0.0138+0.019; //Indoor and
    outdoor vapor resistances [Pa.m^2.s/ng]
10 phi1=0.6,phi2=0.7; //Indoor and outdoor Relative
    Humidity
11 Psat1=2340,Psat2=151; //Indoor and outdoor saturation
    pressures [Pa]
12 //Solution:-
13 Q_wall=A*(Ti-To)/R_wall; // [W]
14 disp("W",Q_wall,"The rate of heat transfer through
    unit area of wall is")
15 T_I=To+(Q_wall*R_ext);
16 disp("degree Celcius",T_I,"The temperature of outer
    sheathing interface is")
17 P=234; //The saturation pressure of water at temp T_I
    [Pa]
18 Pv1=phi1*Psat1;
19 Pv2=phi2*Psat2;
20 disp("Pa",round(Pv2),"and","Pa",Pv1,"The vapor
    pressure at the indoor and the outdoor is")
21 mv_int=A*(Pv1-P)/Rv_int;
22 mv_ext=A*(P-Pv2)/Rv_ext;
23 disp("ng/s",mv_ext,"and","ng/s",mv_int,"The rate of
    moisture flow through the interior and exterior
    parts of the wall is")
24 mv_freezing=mv_int-mv_ext;
25 disp("ng/s",mv_freezing,"The moisture is freezing in
    the insulation at the rate of")

```

Scilab code Exa 14.7 ab177

```

1 clear;
2 clc;
3
4 //Example14.7[Hardening of Steel by the diffusion of
    carbon]

```

```

5 //Given:-
6 D_AB=4.8*10^(-10); //Diffusion coefficient of carbon
   in steel at the furnace temperature [m^2/s]
7 wA_i=0.0015; //Initial carbon concentration
8 wA_e=0.012; //Equilibrium concentration of carbon
9 wA_t=0.01; //Concentration of carbon after desired
   time
10 x=0.0005; //Diffusion distance [m]
11 //Solution:
12 a=(wA_t-wA_i)/(wA_e-wA_i);
13 //The argument whose complimentary error function
   is a=0.81 is 0.17
14 t=(x^2)/(4*D_AB*(0.17^2)); // [seconds]
15 disp("seconds", round(t), "Time taken to reach desired
   level of hardening is")

```

Scilab code Exa 14.8 ab178

```

1 clear;
2 clc;
3
4 //Example14.8[Venting of Helium into the Atmosphere
   by Diffusion]
5 //Given:-
6 D_AB=7.2*10^(-5); //Diffusion coefficient of air in
   helium [m^2/s]
7 M_He=4, M_air=29; //Molar masses of helium and air [kg/
   kmol]
8 D=0.005; //Internal diameter of tube [m]
9 L=15; //Length of tube [m]
10 R1=8.314; //Universal Gas Constant [kPa.m^3/kmol.K]
11 R2=2.0769; //Universal Gas Constant [kPa.m^3/kg.K]
12 T=298; //Ambient temperature [K]
13 //Solution:-
14 A=%pi*(D^2)/4; //Flow area [m^2]

```

```

15 P_He0=1,P_HeL=0;//Pressure of helium at x=0 i.e.
    bottom of tube and at x=L i.e. at the top of the
    tube [atm]
16 N_He=D_AB*A*(P_He0-P_HeL)*(101.3)/(R1*T*L);
17 disp("kmol/s",N_He,"The molar flow rate of Helium is
    ")
18 m_He=N_He*M_He;
19 disp("kg/s",m_He,"Mass flow rate of helium is")
20 N_air=-N_He;//Equimolar counter diffusion process
21 m_air=N_air*M_air;
22 disp("kg/s",m_air,"The flow rate of air into the
    pipeline is")
23 w_air=m_air/(m_air+m_He);
24 disp("which is negligible",w_air,"Mass fraction of
    air in the helium pipeline is")
25 m_net=m_He+m_air;//[kg/s]
26 //Taking density of mixture at x=0 to be the density
    of helium as the mass fraction of air at the
    bottom is very small
27 rho=P_He0*101.325/(R2*T);//[kg/m^3]
28 V=m_net/(rho*A);//[m/s]
29 disp("m/s",V,"The average flow velocity at the
    bottom of the tube is")

```

Scilab code Exa 14.9 ab179

```

1 clear;
2 clc;
3
4 //Example14.9[Measuring Diffusion Coefficient by the
    Stefan tube]
5 //Given:-
6 D=0.03;//Diameter of tube[m]
7 P=83.5;//Atmospheric Pressure at an elevation of
    1600m[kPa]

```



```

8 T=20+273; //Ambient temperature [K]
9 R=8.314; //Universal Gas Constant [kPa.m^3/kmol.K]
10 P_vapor0=2.34; //The saturation pressure of water at
    20 degree Celcius [kPa]
11 M_vapor=18; //Molar mass of water vapor [kg/kmol]
12 x=0.4; //Distance from water surface to the open end
    of the tube [m]
13 //Solution:-
14 //water vapor is species A
15 yA0=P_vapor0/P;
16 disp(yA0,"The mole fraction of water vapor (species
    A) at the Interface is")
17 yAL=0; //mole fraction of water vapor on the top of
    the tube
18 C=P/(R*T); // [kmol/m^3]
19 A=%pi*(D^2)/4; // [m^2]
20 disp("m^2",A,"The cross sectional area of tube")
21 m_vapor=(1.23*10^(-3))/(15*24*3600); //Rate of
    evaporation [kg/s]
22 N_vapor=m_vapor/M_vapor;
23 disp("kmol/s",N_vapor,"The molar flow rate of vapor
    is")
24 D_AB=(N_vapor/A)*(x/C)/log((1-yAL)/(1-yA0));
25 disp("m^2/s",D_AB,"Binary diffusion coefficient of
    water vapor in air at 20 degree Celcius and 83.5
    kPa")

```

Scilab code Exa 14.10 ab180

```

1 clear;
2 clc;
3
4 //Example14.10[Mass Convection inside a Circular
    Pipe]
5 //Given:-

```

```

6 D=0.015; //Inner Diameter [m]
7 T=300; //Temp of air [K]
8 P=1; //Pressure of air [atm]
9 v=1.2; //Average velocity of air [m/s]
10 nu=1.58*10^(-5); //Viscosity [m^2/s]
11 //Solution:-
12 //Water is Species A and air is species B
13 D_AB=(1.87*10^(-10))*(T^2.072)/P; // [m^2/s]
14 disp("m^2/s",D_AB,"The mass diffusivity of water
    vapor in air at 300K is")
15 Re=v*D/nu;
16 disp(round(Re),"The Reynolds number for internal
    flow is")
17 if(Re<2300) then
18     disp("laminar Flow")
19     Sh=3.66; //Sherwood number equals to Nusselt
        number
20     h_mass=Sh*D_AB/D; // [m/s]
21     disp("m/s",h_mass,"The mass transfer coefficient
        is")
22 else
23     disp("Flow is not laminar")
24 end

```

Scilab code Exa 14.11 ab181

```

1 clear;
2 clc;
3
4 //Example14.11[Analogy between Heat and Mass
    Transfer]
5 //Given:-
6 //Napthalene is species A and air is species B
7 M_A=128.2; //Molar Mass of A[kg/kmol]
8 M_air=29; //Molar mass of B[kg/kmol]

```

```

 9 P=101325; //Pressure of Air [Pa]
10 T=298; //Temperature [K]
11 D_AB=0.61*10^(-5); // [m^2/s]
12 v=2; //Stream velocity [m/s]
13 rho=1.184; //Density of air [kg/m^3]
14 Cp=1007; //Specific Heat [J/kg.K]
15 a=2.141*10^(-5); //Absorptivity [m^2/s]
16 w_inf=0; //Mass fraction of naphthalene at free stream
    conditions
17 P_As=11; //Vapor Pressure of Napthalene at surface [Pa
    ]
18 mA=12*10^(-3); //Mass of naphthalene sublimated [kg]
19 delta_t=15*60; //time of sublimation [s]
20 As=0.3; //surface area of the body [m^2]
21 //Solution:-
22 w_As=(P_As/P)*(M_A/M_air);
23 disp(w_As,"Mass fraction at the surface is")
24 m_evap=mA/delta_t; // [kg/s]
25 disp("kg/s",m_evap,"The rate of evaporation of
    naphthalene is")
26 h_mass=m_evap/(rho*As*(w_As-w_inf));
27 disp("m/s",h_mass,"The mass convection coefficient
    is")
28 //Using analogy between heat and mass transfer
29 h_heat=rho*Cp*h_mass*((a/D_AB)^(2/3)); // [W/m^2.
    degree Celcius]
30 disp("W/m^2.degree Celcius",round(h_heat),"The
    average heat transfer coefficient is")

```

Scilab code Exa 14.12 ab182

```

1 clear;
2 clc;
3
4 //Example14.12 [Evaporative Cooling of a Canned Drink

```

```

]
5 //Given:-
6 //Water is species A and air is species B
7 M_A=18,M_B=29;;//Molar Masses of water and air [kg/
  kmol]
8 D_AB=2.5*10^(-5);//Diffusivity of water vapor in air
  [m^2/s]
9 T_inf=30;//Ambient Temperature[degree Celcius]
10 T_avg=(20+T_inf)/2;//Average temperature
11 P=101.325;//Atmospheric Pressure[kPa]
12 //Properties of A at 20 degree Celcius
13 h_fg=2454;//[kJ/kg]
14 Pv1=2.34;//Saturation vapor pressure[kPa]
15 Pv2=4.25;//Vapor Pressure at 30 degree Celcius[kPa]
16 //Properties of air at average temperature and 1 atm
17 Cp=1.007;//[kJ/kg]
18 a=2.141*10^(-5);//[m^2/s]
19 phi=0.4;//Relative Humidity
20 //Solution:-
21 Le=a/D_AB;
22 disp(Le,"The Lewis Number is")
23 Pv_inf=phi*Pv2;//[kPa]
24 disp("kPa",Pv_inf,"The vapor pressure of air away
  from the surface is")
25 Ts=T_inf-(h_fg*M_A*(Pv1-Pv_inf)/(Cp*(Le^(2/3))*M_B*P
  ));
26 disp("degree Celcius",Ts,"The temperature of the
  drink can be lowered to")

```

Scilab code Exa 14.13 ab183

```

1 clear;
2 clc;
3
4 //Example14.13[Heat Loss from Uncovered Hot Water

```

```

    Baths]
5 //Given:-
6 Ts=50+273;//Uniform temperature of water[K]
7 T_surr=20+273;//Average temperature of surrounding
    surfaces [K]
8 T_inf=25+273;//Ambient temperature [K]
9 As=3.5*1;//Surface area of water bath[m^2]
10 p=2*(3.5+1);//Perimeter of top surface of water bath
    [m]
11 e=0.95;//Emissivity of liquid water
12 phi=0.52;//Relative Humidity
13 Rv=0.4615;//Universal Gas Constant [kPa.m^3/kg.K]
14 Ra=0.287;//Universal Gas Constant [kPa.m^3/kg.K]
15 g=9.81;//[m^2/s]
16 //solution:-
17 //(a)
18 Q_rad=e*As*(5.67*10^(-8))*((Ts^4)-(T_surr^4));
19 disp("W",round(Q_rad),"The radiation heat loss from
    the water to the surrounding surface is")
20 //(b)
21 Tavg=(Ts+T_inf)/2;//Average temperature [degree
    Celcius]
22 P=92;//Atmospheric pressure [kPa]
23 //At average temperature Tavg and Pressure P,
    Properties of dry air:-
24 k=0.02644;//[W/m.degree Celcius]
25 Pr=0.7262;//Prandtl number, independent of pressure
26 a=(2.312*10^(-5))/P;//Absorptivity [m^2/s]
27 nu=(1.849*10^(-5));//Kinematic viscosity [m^2/s]
28 //At T_surr properties of water are:-
29 h_fg=2383;//[kJ/kg]
30 Pvs=12.35;//[kPa]
31 Psat=3.17;//Saturation Pressure of water at surface
    temp[kPa]
32 //The air at surface is saturated therefore vapor
    pressure at surface is simple the saturation
    pressure of water at the surface temperature
33 Pv_inf=phi*Psat;//[kPa]

```

```

34 //At the surface
35 rho_vs=Pvs/(Rv*Ts);
36 disp("kg/m^3",rho_vs,"Density of water vapor at the
    surface is")
37 rho_as=(P-Pvs)/(Ra*Ts);
38 disp("kg/m^3",rho_as,"Density of air at the surface
    is")
39 rho_s=rho_vs+rho_as;
40 disp("kg/m^3",rho_s,"Density of mixture at the
    surface is")
41 //Away from the surface
42 rho_vinf=Pv_inf/(Rv*T_inf);
43 disp("kg/m^3",rho_vinf,"Density of vapor away from
    the surface is")
44 rho_ainf=(P-Pv_inf)/(Ra*T_inf);
45 disp("kg/m^3",rho_ainf,"Density of air away from the
    surface is")
46 rho_inf=rho_ainf+rho_vinf;
47 disp("kg/m^3",rho_inf,"The density of mixture away
    from the surface is")
48 Lc=As/p;
49 disp("m",Lc,"The characteristic length is")
50 Gr=g*(rho_inf-rho_s)*(Lc^3)/(((rho_inf+rho_s)/2)*(nu
    ^2));
51 disp(Gr,"The Grashof number is")
52 Nu=0.15*((Gr*Pr)^(1/3));
53 disp(Nu,"The Nusselt number is")
54 h_conv=Nu*k/Lc;
55 disp("W/m^2.degree Celcius",h_conv,"The convection
    heat transfer coefficient is")
56 Q_conv=h_conv*As*(Ts-T_inf);
57 disp("W",ceil(Q_conv),"The natural convection heat
    transfer rate is")
58 //(c)
59 D_AB=(1.87*10^(-10))*(Tavg^2.072)/(P/101.325);
60 disp("m^2/s",D_AB,"The mass diffusivity of water
    vapor in air at the average temperature is")
61 Sc=nu/D_AB;

```

```
62 disp(Sc,"The Schmidt Number is")
63 Sh=0.15*((Gr*Sc)^(1/3));
64 disp(Sh,"The Sherwood Number is")
65 h_mass=Sh*D_AB/Lc;
66 disp("m/s",h_mass,"The mass transfer coefficient is"
    )
67 mv=h_mass*As*(rho_vs-rho_vinf);
68 disp("kg/s",mv,"The evaporation rate is")
69 Q_evap=mv*h_fg;
70 disp("kW",Q_evap,"The rate of heat transfer by
    evaporation is")
71 Q_total=Q_rad+Q_conv+1000*Q_evap;
72 disp("W",Q_total,"The total rate of heat transfer
    from the water to the surrounding air and
    surfaces is")
```
