Scilab Textbook Companion for
Fluid Flow For The Practicing Chemical Engineer
by J. P. Abulencia And L. Theodore[1]

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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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List of Scilab Codes

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Chapter 2

unit and dimensions

Scilab code Exa 2.1 some basic conversion

```
1  //Example  2.1(1)
2  //Page  no.10
3  printf("Example  2.1(1)  Page  no.  10\n\n")
4  //convert  8.03  yr  to  seconds
5  printf("8.03  yr  =a\n\n")
6  yr=365//day
7  day=24//h
8  h=60//min
9  min=60//second
10 a=8.03*365*24*60*60
11 printf("8.03  yr  is  %f  seconds  \n\n",a)
12 //Example  2.1(2)
13 //Page  no.  10
14 printf("Example  2.1(2)  Page  no.10\n\n")
15 //convert  150  mile/h  to  yard/h
16 printf("150  mile/h  =x\n\n")
17 mile=5280//ft
18 ft=(1/3)//yd
19 x=150*5280*(1/3)
20 printf("150  mile/h  is  %f  yd/h\n",x)
21 //Example  2.1(3)
```

```
22  //Page no. 10
23  printf("Example 2.1(3) Page no. 10\n\n")
24  //convert 100 m/s^2 to ft/min^2
25  printf("100 m/s^2 =a\n\n")
26  m =100//cm
27  cm=(1/30.48)//ft
28  min=60//sec
29  a=100*100*(1/30.48)*(60)^2
30  printf("100 m/s^2 is %f ft/min^2\n",a)
31  //Example 2.1(4)
32  //Page no. 10
33  printf("Example 2.1(4) Page no.10\n\n ")
34  //convert 0.03g/cm^3 to lb/ft^3
35  printf("0.03g/cm^3 =x\n")
36  g=(1/454)//lb
37  ft=(30.48)^3//cm^3
38  x=0.03*(1/454)*(30.48)^3
39  printf("0.03g/cm^3 is %f lb/ft^3\n",x)
```

Chapter 3

key terms and definitions

Scilab code Exa 3.2 determine the rise of the liquid in capillary tube

```
1  clc ;
2  // Example  3.2
3  // Page  no.  25
4  printf ("Example  3.2  Page  no.  25\n\n")
5  // given  temperature (T) , pressure (P) , capilLary  tube
       diameter (D) , water  density ( rho ) , contact  angle (
       ththetaeta )
6  sigma =0.0712 // surface  tension  ( sigma ) of  water  at  30
       degree  C  temperature  in  appendix  A.4
7  D =0.008
8  R=D/2
9  theta =0
10  g =9.807
11  rho =1000
12  printf (" surface  tension=%fN/m\n  Radius=%fm\n  theta=
       %fdegree \n  g=%fm/s^2\n  rho=%fkg/m^3\n", sigma ,R,
       theta ,g, rho )
13  h=(2* sigma *cos (0))/( rho *g*R) // height  rise  of  the
       liquid
14  printf (" height  of  liquid  rise  =%fm\n",h)
```

Scilab code Exa 3.3 find diameter of glass tube for the capillary height

```
1  clc;
2  //Example 3.3
3  //Page no. 26
4  printf("Example 3.3 Page no. 26\n\n")
5  //given at 30 degree temerature
6  //properties of water from appendix A.2 density(rho)
       ,surface tension(sigma)
7  rho=996
8  sigma=0.071
9  printf("rho=%f\kg/m^3\n surface tension (sigma)=%f N
       /m\n",rho,sigma)
10 theta=0//negligible angle of contact
11 g=9.807
12 h=0.001//less than one milimeter
13 printf("theta=%f degree \n g=%f m/s^2\n h=%f m\n",
       theta,g,h)
14 R=(2*sigma*cos(0))/(rho*g*h)//by capiilary rise
       equation
15 D=2*R
16 printf("R=%f m\n D=%f m\n",R,D)
17 //if the tube diameter is greater than 0.029075 mm,
       then the capillary rise will be less than 1mm
```

Scilab code Exa 3.4 determine the magnitude of the normal and parallel force components and the shear stress and the pressure

```
1  clc;
2  //Example 3.4
3  //page no. 28
4  printf("Example 3.4 page no 28\n\n");
```

14

```
5  S=2//surface area ft^2
6  F=10//magnitude of force,lbf
7  theta=%pi/6//angle
8  F_p=F*cos(theta)//parallel comp. of force
9  printf("\n F_p=%f lbf",F_p);
10 F_n=F*sin(theta)//normal comp. of force
11 printf("\n F-n=%f lbf",F_n);
12 tou=F_p/S//shear stress
13 P=F_n/S//pressure
14 printf("\n tou=%f psf\n P=%f psf",tou,P);
```

Scilab code Exa 3.5 determine the potential energy of water for 10 meter height

```
1  clc;
2  //Example 3.5
3  //Page no. 30
4  printf("Example 3.5 Page no. 30\n\n")
5  //determine potential energy of water
6  // given height,mass of water,g
7  m=1
8  g=9.8
9  Z1=0//at ground level
10 Z2=10//at 10 m above from ground level
11 printf("m=%f kg\n g=%f m/s^2\n Z1=%f m\n Z2=%f m\n",
       m,g,Z1,Z2)
12 PE1=m*g*Z1//potential energy at ground level
13 PE2=m*g*Z2//potential energy at 10m height
14 PE= PE2-PE1
15 printf("PE1=%fJ\n PE2=%fJ\n PE=%fJ\n",PE1,PE2,PE)
```

Chapter 5

newtonian fluids

Scilab code Exa 5.2 two parallel plates

```
1  clc;
2  //Example 5.2
3  //page no. 42
4  printf("Example 5.2 page no 42\n\n");
5  //To calculate the force to maintain movement of
      left plate
6  //velocity of moving plate is equal to the velocity
      of the plate and velocity of the gas at the
      surface of the stationary plate is zero
7  k=1.66//kinamatic viscosity of gas
8  rho=0.08//density of gas
9  d=0.0833//distance between plate
10 v1=300//velocity of left plate
11 v2=0//velocity of stationary plate
12 g_c=4.17*10^(8)//gravitational constant
13 printf("given \n kinamatic viscosity =%2f ft^2/hr\n
      rho=%2f lb/ft^3\n d=%4f ft\n v1=%f ft/hr\n v2=%f
      ft/hr\n gc=%f (ft*lb/hr)/lbf*hr",k,rho,d,v1,v2,
      g_c);
14 tou_xy=-k*rho*((v2-v1)/(g_c*d))//the frce necessary
      to mantain the movement of the left plate
```

```
15  printf("\n force tou_xy=%f  lbf/ft^2",tou_xy);
```

Scilab code Exa 5.3 couette and hatschek viscometer

```
1  clc;
2  //Example 5.3
3  //Page no. 45
4  printf("Example  5.3 page no. 45\n\n");
5  D=0.25//diameter of fixed inner cylinder of
       viscometer
6  L=0.5//height of fixed inner cylinder of viscometer
7  T=15.3//measured torque
8  printf("Given :\n diameter =%.2f ft\n height =%f ft\
       n Torque=%f ft.lbf",D,L,T);
9  F=(2*T)/D
10 printf("\n force =%f lbf",F);
11 //the shear stress(force parallel to the surface)
       using equation 5.11
12 tou=F/(%pi*D*L)
13 printf("\n shear stress tou=%f psf", tou);
```

Scilab code Exa 5.4 viscosities

```
1  clc;
2  //Example 5.4
3  //page no. 45
4  printf("Example 5.4 page no. 45\n\n");
5  //refer to example no 5.3
6  //determine dynamic viscosity and kinematic
       viscosity
7  omega=26.2//angular rotation speed
8  D=0.25//diameter of fixed inner cylinder of
       viscometer
```

17

```
 9  v=omega*D/2
10  printf("\n omega=%f rad/s\n diameter D =%f ft\n
        linear velocity =%2f ft/s",omega,D,v);
11  d=0.001//clearance betwween two cylinder of
        visometer
12  vel. gradient =v/(d/12)//velocity gradient
13  gc=32.14//gravitational constant
14  printf("\n clearance d=%5f ft\n vel. gradient=%f 1/s
        \n gravitational constant gc=%3f ft/s*S",d,vel.
        gradient,gc);
15  tou=311.7//shear stress tou
16  meu=gc*tou/vel. gradient
17  printf("\n tou=%f psf\n meu=%f lb/ft*s",tou,meu);
18  rho=60.528//density of oil
19  neu=meu/rho//kinamatic viscosity
20  printf("\n kinematic viscosity=%5f (ft*ft)/s",neu);
```

Chapter 7

conservation law for mass

Scilab code Exa 7.1 conservation law of mass

```
1  clc;
2  //Example 7.1
3  //page no. 64
4  printf("example no. 7.1 page no. 64\n\n");
5  //applying coservation of mass
6  // rate of mass in−rate of mass out+rate of mass
       generated=rate of mass accumlated
7  //according to conditions in this example
8  //rate of mass in = rate of mass out
9  Rf=4000//rate of feed of gaseous waste into an
       incinerator
10 Ra=8000//rate of air feed
11 Rm=550//rate of methane added for combustion
12 Rin=Rf+Ra+Rm//total rate of mass in
13 Rout=Rin//Rout is rate of mass out
14 printf("\n Rf=%f kg/hr\n Ra=%f kg/hr\n Rm=%f kg/hr\n
        Rin=%f kg/hr\n Rout=%f kg/hr",Rf,Ra,Rm,Rin,Rout)
       ;
```

Scilab code Exa 7.2 mass and volumetric flow rate

```
1  clc;
2  //Example 7.2
3  //page no. 65
4  printf("Example 7.2 page no. 65\n\n");
5  //water flowing through a converging circular pipe
       fig 7.3
6  //we have to determine mass and volumatric flow
       rates, mass flux of water
7  D1=.14// diameter of pipe at section 1
8  D2=.07//diameter of pipe at section2
9  v1=2//velocity at section
10 S1=%pi*(D1^2)/4//surface area at section 1
11 rho=1000//density of water
12 printf("\n diameter D1=%f m\n diameter D2=%f m\n v1=
       %f m/s\n Surface area S1=%f m^2\n density of
       water rho=%f  kg/m^3 ",D1,D2,v1,S1,rho);
13 q1= S1*v1//volumatric flow rate at section 1
14 m1=rho*q1//mass flow rate at section 1
15 G=m1/S1//mass flux at section 1
16 printf("\n volumatric flow rate q1=%f m^3/s\n mass
       flow ratem1=%f kg/s\n mass flux G=%f kg/m^2*s",q1
       ,m1,G);
17 S2=(%pi*D2^2)/4
18 q2=q1//q2 volumatric flow rate at section 2,due to
       steady flow q1=q2
19 printf("\n surface areaS1=%f m^2\n volumatric flow
       rate q2=%f m^3/s",S1,q1)
20 v2=(v1*S1)/S2//v2 velocity at section 2
21 printf("\n velocity v2=%f m/s",v2)
22 //conclusion :decrease cross section area results in
        an increase in flow velocity for an
       incompressible fluid.
```

Scilab code Exa 7.3 calculate mass flow rate at opening of flow device

```
1  clc ;
2  //Example 7.3
3  // page no 66, fig. 7.4
4  printf (" Example 7.3 page no 66, fig 7.4\n\n\n");
5  // fluid device has four openings as shoen in figure
6  //we have to calculate magnitude and direction of
      velocity , mass flow rate at section 4
7  rho =800// density of fluid
8  v1=5// velocity at section 1
9  S1 =0.2// surface area at section 1
10 v2=7// velocity at section 2
11 S2 =0.3// surface area at section 2
12 v3 =12// velocity at section 3
13 S3 =0.25// surface area at section 3
14 S4 =0.15// surface area at section 4
15 printf ("\n velocity v1=%f m/s \n surface area S1=%f
      m^2/s\n velocity v2=%f m/s\n surface area S2=%f m
      ^2/s\n velocity v3=%f m/s\n surface area S3=%f m
      ^2/s\n surface area S4=%f m^2/s",v1,S1,v2,S2,v3,
      S3,S4);
16 q1=v1*S1// volumatric flow rate at section 1
17 q2=v2*S2// volumatric flow rate at section 2
18 q3=v3*S3// volumatric flow rate at section 3
19 printf ("\n volumatric flow rate q1=%f m^3/s\n
      volumatric flow rate q2=%f  m^3/s\n volumatrisc
      flow rate q3=%f m^3/s",q1,q2,q3);
20 // applying continuity equation
21 q4=q1+q2-q3// volumatric flow rate at section 4
22 v4=q4/S4// velocity at section 4
23 printf ("\n volumatric flow rate q4=%f m^3/s\n
      velocity v4=%f m/s ",q4,v4);
24 m=rho*q4// mass flow rate at section 4
25 printf ("\n mass flow rate m=%f kg/s",m);
```

Scilab code Exa 7.4 mass balance in acontrol device

```
1  clc;
2  //Example 7.4
3  //page no 67, fig 7.5
4  printf("Example 7.4 page no,fig 7.5\n\n")
5  //Given pollutant in ppm in liquid stream ,some
        pollutant in discharge volume
6  //calculate what fraction of liquid bypass
7  //liquid stream having 600 ppm pollutant
8  //pollutant in the discharge stream is 50 ppm
9  //if B =factio of liquid bypassed ,then 1-B= fraction
        of liquid treated
10 //performing a pollutant mass balance around point2
        in fig. 7.5
11 B=poly([0],'x');
12 N=roots((1-B)*0+600*B-50*1)
13 printf("\n\n calculation:\n   calculation   of liquid
        bypassed B=%.4f ",N(1));
```

Scilab code Exa 7.5 vertical tanl

```
1  clc;
2  //Example 7.5
3  //page no 67
4  printf("Example 7.5 page no 67\n\n")
5  //water flow in tank inletand outlet pipes
6  //applying continuity principle to the control
        volume
7  //since generation rate =0
8  d1=0.09//diameter of inlet pipe
9  v_in=4//velocity ,m/s
```

```
10  v_out=3//velocity ,m/s
11  q_in=(%pi*d1^2)*v_in/4//volumatric flow rate at
        inlet
12  d2=0.04//diameter of outlet pipe
13  q_out=(%pi*d2^2)*v_out/4
14  printf("\n diameter at inlet d1=%f m\n volumatric
        flow rate at inlet q_in=%f m^3/s\n diameter d2=%f
         m\n volumatric flow rate at outlet q_out=%f m^3/
        s",d1,q_in,d2,q_out);
15  q=q_in-q_out//for an incmpressible fluid of volume v
        , q=(dv/dt)=q_in-q_out
16  D=1.4//diameter of tank
17  S=(%pi*D^2)/4
18  printf("\n volumatric flow in tank=%f m^3/s\n
        diameter of tank D=%f m\n surface area of tank S=
        %f m^2", q,D,S);
19  //z=fluid height
20  R_z=(q_in-q_out)/S//R_z rate of water level rise
21  printf("\n rate of water level rise R_z=%f m/s",R_z)
        ;
22  //R_z is positive ,the water level is rising in the
        tank from it's initial height of 1.5 m
```

Chapter 8

conservation law of energy

Scilab code Exa 8.1 gas flow from cooler

```
1  clc;
2  //Example 8.1
3  //page no 75
4  printf("Example 8.1 page no 75\n\n");
5  // heat is transferred from a gas
6  Cp=1090//average heat capacity of gas
7  M_dot=9//mass flow rate
8  T1=650//gas inlet temperature
9  //kinetic and potential enargy effects are neglected
       ,there is no shaft work
10  Q=5.5e+6//heat transferred
11  delta_H=Q//since there are no kinetic,potential,and
       shaft work effects
12  printf("\n heat capacity Cp=%f J/kg.deg c\n mass
       flow rate M_dot=%f kg/s\n gas inlet temperature
       T1=%f deg c\n heat transferred Q=%f W",Cp,M_dot,
       T1,Q);
13  T2=round(-Q/(M_dot*Cp)) + T1
14  printf("\n  temperature T2=%f deg c ",T2);
```

Scilab code Exa 8.2 a fluid flow device

```
1  clc;
2  //Example 8.2
3  //page no 77 fig 8.2
4  printf("Example 8.2 page no 77  fig 8.2 \n\n\n");
5  //fluid flow in a device
6  //fluid flow with in the control volume is steady
7  q1=8//flow rate at section 1,direction in
8  q2=6//flow rate at section 2, direction in
9  q3=14//flow rate at section 3,direction out
10 h1=250//enthalpy at section 1
11 h2=150//enthalpy at section 2
12 h3=200//enthalpy at section 3
13 rho=800//density of fluid
14 printf("\n flow rate q1=%f m^3/s\n flow rate q2=%f m
       ^3/s\n flow rate q3=%f m^3/s\n enthalpy h1=%f j/
       kg\n enthalpy h2=%f j/kg\n enthalpy h3=%f j/kg\n
       density of fluid rho=%f kg/m^3",q1,q2,q3,h1,h2,h3
       ,rho);
15 //applying total energy balance
16 hp=746//1 hp=746 kw
17 H=rho*(q1*h1+q2*h2-q3*h3)/hp
18 printf("\n enthalpy H=%f hp",H);
19 //for adiabatic steady operation , Q_dot=0
20 W_dot=H//W_dot is work
21 printf("\n work W_dot=%f hp",W_dot);
22 //since work is positive ,the surroundings must be
       doing work on the system through some device
```

Scilab code Exa 8.5 a cylindrical tank

```
1  clc;
2  //Example 8.5
3  //page no 81 fig 8.3
4  printf(" Example 8.5 page no 81 fig 8.3\n\n\n");
5  //a cylindrical tank filled with water
6  //applying bernoulli equation
7  z1=9//elevation head at section 1
8  h2=1//height at section 2
9  D1=3//diameter of cylindrical tank
10 D2=.3//diameter of outlet hole of tank
11 g=9.807//gravitational acceleration
12 printf("\n elevation head at section 1 z1=%f m\n
       height at section h2=%f m\n diameter of
       cylindrical tank D1=%f m\n diameter of outlet
       hole of tank D2=%f m\n gravitational acc. g=%f m/
       s^2",z1,h2,D1,D2,g);
13 t=2*[(sqrt(z1)-sqrt(h2))/((sqrt(2*g))*(D2/D1)^2)]
14 printf("\n time t=%f sec",t);
15 x=-(D2/D1)^2//ratio of a/g
16 printf("\n   x=%f",x);
17 //for this example the maximum acceleration is 1% of
       g,therefore saftey use Bernoulli equation
```

Chapter 9

conservation law for momentum

Scilab code Exa 9.1 the force required to hold the plate

```
1  clc ;
2  // Example 9.1
3  // page no 87
4  printf (" Example 9.1 page no 87\n\n");
5  //a horizontal water jet impinges on avertical plate
6  rho =62.4// density of water
7  v =100// horizontal velocity of water
8  q=0.5// flow rate
9  g=32.2// gravitational constant
10 printf ("\n density rho=%f lb/ft^3\n horizontal
       velocity of water v=%f ft/s\n flow rate q=%f ft
       ^3/s",rho ,v ,q);
11 M_in=(rho*q*v)/g// momentum rate of inlet water in
       the horizontal direction
12 printf ("\n momentum rate M_in=%f lbf",M_in );
13 M_out =0// momentum rate of water out
14 F=M_out -M_in
15 printf ("\n net horizontal force F=%f lbf",F);
16 // negative sign indicate that to hold the plate in
       place , a force must be exerted in a direction
       opposite to that of the water flow
```

Scilab code Exa 9.2 the force required to hold the bend in place in water

```
1  clc;
2  //Example 9.2
3  //page no 87
4  printf("Example 9.2 page no 87\n\n");
5  //a horizontal line carries saturated steam
6  //water is entrained by the steam,and line is bend
7  //select the control volume as the fluid in the bend
        and apply amass balance
8  //since m1_dot=m2_dot,v1=v2
9  m_dot=0.15//mass flow rate
10 V_in_x=420//velocity in horizontal x direction
11 V_out_x=0//velocity out ,horizontal direction
12 printf("mass flow rate m_dot=%f kg/s\n velocity in x
        direction V_in=%f m/s\n velocity out in  the x
        direction=%f=m/s",m_dot,V_in_x,V_out_x);
13 //applying linear horizontal balance in x direction
14 F_x=m_dot*V_out_x-m_dot*V_in_x//force in x-dir
15 printf("\n force F_x=%f N",F_x);
16 //the x-dir force acting on the 90 deg elbow
        therefore ,F_x=+63 N
17 V_in_y=0//velocity in vertical in y direction
18 V_out_y=420//velocity out vertical in y direction
19 printf("velocity in y dir V_in_y=%f m/s\n velocity
        out y dir V_out_y=%f m/s",V_in_y,V_out_y);
20 F_y=m_dot*V_out_y-m_dot*V_in_y//force in y dir
21 printf("\n force in y dir F_y=%f N",F_y);
22 //y dir force is acting on the elbow is therefore
        F_y=-63 N
23 F_res=sqrt(F_x*F_x+F_y*F_y)//resultant force F_res
24 printf("\n resultant force F_res=%f N",F_res);
25 //this is the force required to hold the elbow
```

Scilab code Exa 9.3 maximum flow rate

```
1  clc;
2  //Example   9.3
3  //page  no  88
4  printf("Example  9.3  page  no  88\n\n");
5  //water  flow  in  a  pipe
6  rho=62.4//density  of  water
7  D=0.167//diameter  of  pipe
8  g=32.174//gravitational  constant
9  M_dot_out=0//momentum  out  in  x  dir
10 F_x=5//foce  in  the  x  dir
11 printf("density   rho=%f  lb/ft^3\n  diameter  D=%f  ft\n
        momentum  M_dot_out=%f  lbf\n  forc  in  x  dir  F_x=%f
        lbf",rho,D,M_dot_out,F_x);
12 M_dot_in=M_dot_out+F_x//momentum  in
13 printf("\n  momentum  M_dot_in=%f  lbf",M_dot_in);
14 S=(%pi*D^2)/4//surface  area
15 printf("\n  surface  area  S=%f  ft^2",S);
16 v=sqrt((M_dot_in*g)/(rho*S))
17 printf("\n  velocity  =%f  ft/s",v);
18 q=S*v//volumatric  flow  rate
19 m_dot=rho*q//mass  flow  rate
20 printf("\n  volumatric  flow  rate  q=%f  ft^3/s\n  mass
        flow  rate  m_dot=%f  lb/s",q,m_dot);
```

Scilab code Exa 9.4 fire hose

```
1  clc;
2  //Example  9.4
3  //page  no  89  fig  9.2
4  printf("Example  9.4  page  no  89  fig.  9.2\n\n\n");
```

```scilab
 5  //water is discharged through a fire hose
 6  rho=1000//density of water
 7  meu=0.001//viscosity of water
 8  q=0.025//flow rate  at section 1
 9  D1=.1//diameter at section 1
10  D2=.03//diameter at section 2
11  printf("\n density rho=%f kg/m^3\n viscosity meu=%3f
         kg/m.s\n volumatric flow rate q=%f m^3/s\n
      diametetr at section1 D1=%f m\n diameter at
      section2 D2=%f m",rho,meu,q,D1,D2);
12  S1=(%pi*D1^2)/4
13  S2=(%pi*D2^2)/4
14  printf("\n surface area at section 1 S1=%f m^2\n
      surface area at section 2 S2=%f m^2",S1,S2);
15  v1=q/S1//velocity at section1
16  v2=q/S2//velocity at section2
17  printf("\n velocity at sec1 v1=%f m/s\n velocity at
      sec2 v2=%f m/s",v1,v2);
18  //appuing bernoulli's equation between point 1 and 2
19  P2=0//pressure at point 2
20  P1=(rho/2)*(v2^2-v1^2)//pressure at point 1
21  printf("\n pressure at point2 P2=%f Pag(pascal gauge
      )\n pressure atpoint1 P1=%f Pag",P2,P1);
22  m_dot1=25//mass flow rate at section 1
23  m_dot2=25//mass flow rate at section 2
24  printf("\n mass flow rate m_dot1=%f kg/s\n mass flow
       rate m_dot2=%f kg/s",m_dot1,m_dot2);
25  M_dot1_x=m_dot1*v1//momentum rate in x dir at
      section 1
26  M_dot2_x=m_dot2*v2//momentum rate in x dir at
      section 2
27  printf("\n momentum rate M_dot1_x=%f N\n momentum
      rate M_dot2_x=%f N",M_dot1_x,M_dot2_x);
28  //applying momentum balance in the x direction
29  F_x=M_dot2_x-M_dot1_x-P1*S1//force from momentum
      balance
30  printf("\n force from momentum balance F_x=%f N",F_x
      );
```

Chapter 10

law of hydrostatics

Scilab code Exa 10.1 Determine the pressure exerted at the bottomof the column and calculate the pressure difference

```
1 clc;
2 //Example 10.1
3 //page no 98
4 printf("Example 10.1  pagr no. 98\n\n");
5 // in a column of liquid
6 h=2.493//height of the liquid (mercury) column
7 rho=848.7//density of mercury
8 P_at=2116//atmospheric pressure
9 printf("\n height of mercury h=%f ft\n density of
      mercury rho=%f lb/ft^3\n atmospheric pressure
      P_at=%f psf ",h,rho,P_at);
10 //refer to equation 10.5
11 g=9.8
12 g_c=9.8
13 P=rho*(g/g_c)*h//gauge pressure
14 P_ab=round(P+P_at)//absolute pressure
15 printf("gauge pressure P=%f psf\n absolute pressure
      P_ab=%f psf",P,P_ab);
```

Scilab code Exa 10.2 Determine the depth in the atlantic ocean at given pressure

```
1  clc;
2  //Example 10.2
3  //page no 99
4  printf("Example 10.2 page no 99\n\n");
5  //determining the depth of  atlantic ocean
6  rho=1000//density of water
7  P1=10//pressure at which depth is to be determine
8  P2=1//pressure at the ocean surface z1
9  z1=0//ocean surface
10 g=9.807//gravitational constant
11 printf("\n density rho=%f kg/m^3\n pressure P1=%f
       atm\n pressure P2=%f atm\n height at ocean
       surface z1=%f m",rho,P1,P2,z1);
12 z2=z1-(P1-P2)*101325/(rho*g)//depth  at pressure P2
13 printf(" \n depth z2=%f m",z2);
```

Scilab code Exa 10.3 cylindrical tank

```
1  clc;
2  //Example 10.3
3  //page no 99 fig 10.1
4  printf("Example 10.3 page no 99 fig 10.1\n\n\n");
5  //a cylindrical tank contain water and immiscible
       oil ,tank isvopen to the atmosphere
6  rho=1000//density of water
7  SG=0.89//special gravity of oil
8  rho_oil=rho*SG//density of oil
9  printf("\ density of water rho=%f kg/m^3\n density
       of oil rho_oil=%f kg/m^3",rho,rho_oil);
```

```
10  //applying bernoulli equationbetween point 1 and 2
       to calculate the gauge pressure at water oil
       interface
11  z1=0//depth at surface
12  P1=1//pressure at point 1
13  z2=-10.98//depth at point 2
14  printf(")\n depth at point 1, z1=%f m\n pressure P1=
       %f atm\n depth at point 2,z2=%f m",z1,P1,z2);
15  g=9.807//gravitational constant
16  P2_gu=rho_oil*g*(z1-z2)//gauge pressure at point 2
17  printf(")\n gauge pressure P2_gu=%f Pag",P2_gu);
18  //gauge preesure at bottom z3
19  z3=-13.72
20  P3=P2_gu+rho*g*(z2-z3)
21  printf(")\n depth z3=%f m\n pressure at bottom P3=%f
       Pag",z3,P3);
22  d=6.1//diameter  of tank
23  s=%pi*d^2/4//surface area of tank
24  printf(")\n diameter of tank d=%f m\n surface area of
       tank s=%f m^2",d,s);
25  P3_ab=P3+101325//absolute pressure
26  F=P3_ab*s//pressure force at the bottom of tank
27  printf(")\n absolute pressure P3_ab=%f Pag\n pressure
       force at bottom F=%f N",P3_ab,F);
28  //the force on the side of the tank ,within water
       layer
29  F_s=(%pi*d)*integrate('-11910-9807*z','z'
       ,-13.72,-10.98);
30  printf(")\n force on the side of the tank F_s=%f  N",
       F_s);
```

Scilab code Exa 10.4 buoyancy force

```
1  clc;
2  //Example 10.4
```

```
3  //page no 102
4  printf(" Example 10.4 page n0 102 \n\n");
5  W_a=200//weight of material in air
6  W_w=120//weight of material in water
7  gamma_w=62.4//specific weight of water
8  printf("\n weight of air W_a=%f lbf\n weight of
       water W_w=%f lbf\n sp.weight of water gamma_w=%f
       lbf/ft^3",W_a,W_w,gamma_w);
9  F_b=W_a-W_w//buoyant force\
10 printf("\nbuoyant force F_b=%f lbf",F_b);
11 V_dis=F_b/gamma_w//volume displaced
12 printf("\n volume displaced V_dis=%f ft^3",V_dis);
13 rho_b=W_a/V_dis//density of block
14 printf("\n density of block rho_b=%f lb/ft^3",rho_b)
       ;//printing mistake in book
15 //assumption of rho_b>rho_w is justified
```

Scilab code Exa 10.5 in hydrometer calculate height at which liquid will float

```
1  clc;
2  //Example 10.5
3  //page no 103
4  printf("\n Example 10.5 page no 103\n\n");
5  //a hydrometer is a liquid specific gravity
       indicator with the value being indicated by the
       level at which the surface of the liquid
       intersects the sten when floating in avliquid
6  F=0.13//the total hydrometer weight, N
7  SG=1.3//sp. gravity of liquid
8  D=.008//stem diameter of hydrometer,m
9  rho_w=1000//density of water ,kg/m^3
10 g=9.807
11 pi=22/7
12 printf("\n force F=%f N\n sp.gravity SG=%f \n stem
```

```
        diameter D=%f m\n density rho_w=%f kg/m^3\n g=
        ravitational acc. g=%f m/s^2",F,SG,D,rho_w,g);
13  h=(4*F/(pi*D^2*rho_w*g))*(1-1/SG)//height where it
        will float
14  printf("\n height h=%f m",h);
```

Scilab code Exa 10.6 calculate the gauge pressure

```
1  clc;
2  //   Example 10.6
3  //page no 105 fig. 10.3
4  printf("\n Example 10.6 page no 105 fig. 10.3\n\n\n"
       );
5  // since the density of air is effectively zero,the
        contribution of air to the 3 ft. manometer can be
         neglected
6  //the contribution due to the carbon tetrachloride
       can be found by using the hydrostatic equation
7  rho=62.3//density of water
8  SG=1.4///specific gravity of ccl4
9  h=3//height in manometer
10 P=rho*SG*h/144//factor 144 for psf to psi
11 printf(" \n pressure P=%f psi",P);
12 P_r=14.7//the right leg of manometer is open to
       atmosphere,atmospheric pressure at this point
13 //contribution to the prssure due to the height of
       water above pressure gauge
14 P_w=rho*h/144
15 printf("\n  pressure at right leg P_r=%f psia\n
       pressure due to water height P_w=%f psi",P_r,P_w)
       ;
16 P_a=P_r-P+P_w//absolute pressure
17 P_g=P_a-14.7//gauge pressure
18 printf("\n absolute pressure P_a=%f psia\n gauge
       pressure P_g=%f psig",P_a,P_g);
```

```
19  P_af=P_a*144
20  P_gf=round(P_g*144)
21  printf("\npressure in psfa P_af=%f psfa\n pressure
       in psfg P_gf=%f psfg",P_af,P_gf);
```

Chapter 11

ideal gas law

Scilab code Exa 11.2 density of ideal gas

```
1  clc;
2  //Example 11.2
3  //Page no. 113
4  printf("Example 11.2−Page no.113\n\n")
5  //given
6  //Pressure(P),Temp.(T),Molecular wt. of gas(M)
7  P=1//atm
8  T_d=60//degree F
9  M=29//gram
10 //Gas constant R
11 R=.73
12 T=T_d+460//  rankin
13 //density of gaS
14 rho=(P*M)/(R*T)
15 printf("density of gas rho =%flb/ft^3",rho)
```

Scilab code Exa 11.3 actual volumetric flow rate

```
1  clc
2  //Example 11.3
3  //Page no. 114
4  printf("Example 11.3-Page no. 114\n\n")
5  //given
6  //standard volumetric flowrate of a gas stream(Qs),
       standard conditions, actual conditions
7   Qs=2000//scfm
8   Ps=1//atm
9   Ts=60//degree F
10  Pa=1//atm
11  Ta=700//degree F
12 Ta=Ta+460//rankin
13 Ts=Ts+460//rankin
14  Qa=Qs*(Ta/Ts)*(Ps/Pa)
15 printf("actual volumetric flowrate Qa=%f acfm",Qa)
```

Scilab code Exa 11.4 standard volumetric flow rate

```
1  clc
2  //Example 11.4
3  //Page no. 115
4  printf("Example 11.4-Page no. 115\n\n")
5  //given
6  //mass flowrate of flue gas ,average moleculer
       weight flue gas, standard conditions
7   m=50//lb/min
8   M=29//lb/lbmol
9   Ts=60//degree F
10  Ps=1//atm
11  R=0.73//atm.ft^3/(lbmol.degree R)
12  Ts=Ts+460//rankin
13  Qs=(m/M)*(R*Ts/Ps)
14  printf("standard volumetric flowrate Qs=%f scfm",Qs
       )
```

Scilab code Exa 11.5 molecular weight of gas

```
1  clc
2  //Example 11.5
3  //Page no. 116
4  printf("Example 11.5-Page no.1 116\n\n")
5  //given
6  //specific volume(V),temperature(T),pressure(P)
7  V=12.084//ft^3/lb
8  T=70//degree F
9  P=1//atm
10 R=0.73
11 T=T+460//rankin
12 Mw=(R*T)/(P*V)
13 printf("molecular weight of gas Mw=%f",Mw)
```

Scilab code Exa 11.6 virial equation

```
1  clc;
2  //Example 11.6
3  //page no 118
4  printf("Example 11.6 page no 118\n\n");
5  clear;
6  //first and second viral coeff.
7  B=-0.159//m^3/kgmol
8  C=0.009//(m^3/kgmol)^2
9  V_new=0
10 V=0.820;
11 for i=1:3
12     V_new=(1+(B)/V+(C)/(V^2))/1.22
13     V=V_new
```

```
14  end
15  printf("\nVolume of gas V=%f L/gmol",V)
```

Scilab code Exa 11.7 Rk equation

```
1   clc;
2   //Example 11.7
3   //page no 118
4   printf("Example 11.7 page no 118\n\n");
5   //given
6   T_c=343// critical temperature ,deg R
7   P_c=45.4// critical pressure ,atm
8   //emplying redlich kwong (R-K) equation
9   R=0.73//gas constant
10  a=round(0.42748*R^2*T_c^2.5/P_c)//R-k constant
11  b=0.08664*R*T_c/P_c//R-k constant
12   //    V_new=[[490/(V-b)]-[a/(25.9*V*V+b)]]/10
13   // V=V_new
14  //by trial and error method
15  V=48.8
16  printf("\n Volume V=%f ft^3/lbmol ",V);
```

Chapter 12

Flow Mechanisms

Scilab code Exa 12.1 calculate size of outlet duct required

```
1 clc;
2 //Example 12.1
3 //page no 124
4 printf("Example 12.1 page no 124\n\n");
5 T_i=660//temperature of flue at inlet in furnsce
6 D_1=6//inside diameter of pipe,ft
7 v_1=25//velocity at inlet
8 printf("\n temperature at inlet T_i=%f k\n diameter
      at inlet D_1=%f ft\n velocity at inlet v_1=%f ft/
      s",T_i,D_1,v_1);
9 A_1=%pi/4*D_1^2;
10 q_1=A_1*v_1//volumatric flow rate at inlet
11 printf ("\n area at ilet A_1=%f st^2\n volumatric
      flow rate at inlet q_1=%f ft^3/s",A_1,q_1);
12 //applying charle's law for volumatic flow out of
      the scrubber
13 //given
14 T_2=2360//the temperature up to which furnace heats
      the gas
15 v_2=40//velocity of flow at outlet
16 printf("\n temperature T_2=%f k\n velocity of flow
```

```
      at outlet v_2=%f ft/s",T_2,v_2);
17  q_2=q_1*(T_2/T_i)//volumatric flow rate at outlet
18  A_2=q_2/v_2// cross sectional area at outlet duct
19  printf("\n volumatric flow rate at outlet q_2=%f ft
        ^3/s\n cross sectional area at outlet A_2=%f ft^2
        ",q_2,A_2);
20  D_2=sqrt(4*A_2/%pi)//diameter at outlet
21  printf("\n diameter at outlet D_2=%f ft ",D_2);
```

Scilab code Exa 12.2 calculate the reynolds number for a liquid

```
1  clc;
2  //Example 12.2
3  //page no 125
4  printf("Example 12.2 page no 125\n\n");
5  //to calculate reynolds number
6  L=2.54//diameter of tube in cm
7  rho=1.50//density of liquid in gm/cm^3
8  v=20//velocity of flow in cm/s
9  meu=0.78e-2//viscosity of liquid in g/cm*s
10 printf("\n diameter of tube L=%f cm\n density   rho=
        %f gm/cm^3\n velocity v=%f cm/s\n viscosity meu=
        %f g/cm*s",L,rho,v,meu);
11 R_e=L*rho*v/meu//reynolds number
12 printf("\n Reynolds no. R_e=%f ",R_e);
```

Scilab code Exa 12.3 determine the reynolds number of a gas

```
1  clc;
2  //Example 12.3
3  //page no 126
4  printf("\n Example 12.3 page no 126\n\n");
5  //to determine the teynolds no of a gas stream
```

```
 6  v=3.8//velocity through the duct
 7  D=0.45//duct diameter
 8  rho=1.2//density of gas
 9  meu=1.73e-5//viscosity of gas
10  printf("\n velocity v=%f m/s\n diameter D=%f m\n
        density rho=%f kg/m^3\n viscosity meu=%f kg/m*s",
        v,D,rho,meu);
11  R_e=D*v*rho/meu//reynolds no
12  printf("\n reynoldsno R_e=%f ",R_e);
```

Scilab code Exa 12.5 calculate the average velocity of fluid and the volumatric flow rate

```
 1  clc;
 2  //Example 12.5
 3  //page no 128
 4  printf(" Example 12.5 page no 128\n\n");
 5  SG=0.96//sp.gravity of a liquid
 6  R=0.03//radius of long circular tube through which
        liquid  flow
 7  //flow rate is related with the diameter of circular
        tube
 8  q=2*%pi*(3*R^2-(200/3)*R^3);
 9  printf("\n volumatric flow rate  q=%f m^3/s",q);
10  rho_w=1000//density of water
11  rho_l=SG*rho_w//density of liquid
12  m_dot=rho_l*q//mass flow rate
13  printf("\n mass flow rate m_dot=%f kg/s",m_dot);
14  s=%pi*R^2//surface area
15  v_av=q/s//average velocity
16  printf("\n average velocity v_av=%f m/s",v_av);
```

Scilab code Exa 12.6 calculate the time to pass the liquid through the cross section of pipe

```
1  clc;
2  //Example 12.6
3  //page no 129
4  printf("Example 12.6 page no 129\n\n");
5  //refer to example 12.6
6  V=20//volume of liquid passes through the section ,m
       ^3
7  q=0.00565//volumatric flow rate
8  t=V/q//time to pass liquid pass through volume V
9  printf("\n time t=%f s",t);
```

Scilab code Exa 12.7 calculate the actual volumatric flow rate and reynolds number

```
1  clc;
2  //Example 12.7
3  //page no 130
4  printf("Example 12.7 page no. 130\n\n");
5  //a gas is flowing through a circular duct
6  D=1.2//diameter of duct, ft
7  T=760//temperature ,k
8  P=1//pressure
9  T_s=520//standard temperature
10 P_s=1//standard pressure
11 q_s=1000// standard volumatric flow rate ,in scfm(
       given)
12 q=q_s*(T/T_s)*(P/P_s)//actual volumatric flow rate
13 printf("\n actual volumatric flow rate q=%f acfm ",q
       );
14 s=%pi*D^2/4//cross sectional area
15 s_m=s*0.0929//area in m^2
16 v=(q/s)/60//velocity
```

```
17  printf("\n average velocity v=%f ft/s",v);
18  MW=33//mlecular weight of gas
19  R=0.7302//gas constant
20  rho=(P*MW)/(R*T)//density  from ideal gas law
21  printf("\n density rho=%f lb/ft^3",rho);
22  m_dot=rho*v*s_m//mass flow rate
23  printf("\n mass flow rate m_dot=%f lb/s",m_dot);//
        printing mistake in book
24  D_m=0.366//diamter in m
25  v_m=6.55//velocity in m/s
26  rho_m=rho*(0.4536/.3048^3)//density in kg/m^3
27  rho_m=0.952//round off value
28  printf("\nv_m=%f",v_m);
29  meu=2.2e-5//viscosity of gas in
30  R_e=D_m*v_m*rho_m/meu//reynolds no
31  printf("\n reynolds no R_e=%f ",R_e);//calculation
        error in book
```

Chapter 13

laminar flow in pipe

Scilab code Exa 13.1 calculate the average velocity when flow is viscous

```
1  clc;
2  //Example 13.1
3  //page no 136
4  printf("Example 13.1 page no 136\n\n");
5  //calculate average velocities for which th flow
       will be viscous,laminar
6  //(a) water at 60 deg F in a 2-inch standard pipe
7  R_e=2100//reynolds number <2100, for laminar flow
8  meu_w=6.72e-4//viscosity of water,lb/ft.s
9  rho_w=62.4//density of water,lb/ft^3
10 D_w=2.067//diameter  of pipe,ft
11 v_w=(R_e*meu_w)/((D_w/12)*rho_w)//velocity of water
12 printf("\n velocity v_w=%f ft/s",v_w);
13 //(b) air at 60 deg F and 5 psig in a 2 inch
       standard pipe
14 meu_a=12.1e-6//viscosity of air ,lb/ft.s
15 rho_a=.1024// density of air,lb/ft^3
16 D_a=0.17225//diameter of pipe ,ft
17 v_a=(R_e*meu_a)/(D_a*rho_a)//velocity of air
18 printf("\n velocity of air v_a=%f ft/s",v_a);
19 //(c) oil of a viscosity of 300 cP and SG of .92 in
```

```
     a 4 inch standard pipe
20 meu_o=300*6.72e-4//viscosity of oil ,lb/ft.s
21 rho_o=0.92*62.4//density of oil, lb/ft^3
22 D_o=.3355//diameter of pipe,ft
23 v_o=round((R_e*meu_o)/(D_o*rho_o))//velocity of oil
24 printf("\n velocity of oil v_o=%f ft/s",v_o);
```

Scilab code Exa 13.2 determine pressure drop per unit length

```
1 clc;
2 //Example 13.2
3 //page no 137
4 printf(" Example 13.2 page no 137\n\n");
5 //refer to part a of example 1
6 //appplying Hagen−Poiseuille equation
7 meu=6.72e-4//viscosity of water
8 v=0.13//velocity of water
9 D=2.067/12//diameter of pipe
10 P_l=32*meu*v/(D^2)
11 printf("\n pressure drop per unit length P_l=%f psf/
      ft",P_l);
```

Scilab code Exa 13.4 determine maximum air velocity

```
1 clc;
2 //Example 13.4
3 //page no 138
4 printf(" Example 13.4 page no 138\n\n ");
5 //an air conducting duct has a rectangular cross
      section
6 w=1//width of rectangular section
7 h=0.25//height of rectangular section
8 D=2*w*h/(w+h)//equivalent or hydraulic diameter
```

```
 9  printf("\n hydraulic diameter D=%f m",D)
10  R_e=2300//critical reynolds no
11  neu=1e-5//kinematic viscosity of air
12  v=R_e*neu/D//velocity
13  printf("\n velocity of air v=%f m/s",v);
```

Scilab code Exa 13.5 calculate length of the pipe for a fully developed flow

```
 1  clc;
 2  //Example 13.5
 3  //page no 139
 4  printf(" Example 13.5 page no 139\n\n");
 5  //a circulsr horizontal tube cntains asphalt
 6  D=0.1667//diameter of tube,ft
 7  s=%pi*D^2/4//surface area of tube,ft^2
 8  q=0.486//volumatric flow rate,ft^3/s
 9  v=q/s//flow velocity
10  printf("flow velocity v=%f ft/s",v);
11  g=32.174
12  P_grad=144//pressure gradient ,psf/ft
13  meu=(%pi*P_grad*g*D^4)/(128*q)//dynamic viscosity,
       laminar flow
14  printf("\n dynamic viscosity meu=%f lb/ft.s",meu);
15  //check on the laminar flow
16  rho=70//density,lb/ft^3
17  R_e=D*v*rho/meu//reynlods number
18  printf("\n reynolds no R_e=%f ",R_e);
19  f=16/R_e//fanning friction factor
20  printf("\n friction factor f=%f ",f);
21  //the pipe must be longer than the entrance length
       to have fully developed flow
22  L_e=0.05*D*R_e//entrance length
23  printf("\n entance length L_e=%f ft",L_e);
```

Scilab code Exa 13.6 velocity distribution

```
1   clc;
2   //Example 13.6
3   //page no 140
4   printf(" Example 13.6 page no 140\n\n");
5   //liquid glycerin flows in a tube
6   //to obtain the properties of glycerine  use table A
        .2 in the appendix
7   rho=1260//density ,kg/m^3
8   meu=1.49//viscosity ,kg/ms
9   neu=meu/rho//kinematic viscosity ,m^2/s
10  R=0.02//by no slip condition radius of tube ,m
11  q=32*%pi*integrate('r-2500*r^3','r',0,R);//
        volumatric flow rate from the given parabolic
        velocity distribution
12  printf("vol. flow rate q=%f m^3/s",q);
13  r=0//for average velocity for laminar flow
14  v_av=16*(1-2500*r^2)/2//average velocity
15  q=0.010//approximation
16  m_dot=q*rho//mass flow rate
17  G=rho*v_av//mass flux
18  M_dot=m_dot*v_av//inear momentum flux
19  printf("\n av. velocity v_av=%f m/s\n mass flow rate
        m_dot=%f kg/s\n mass flux G=%f kg/m^2.s\n linear
        mometum flux M_dot=%f N ",v_av,m_dot,G,M_dot);
```

Scilab code Exa 13.7 calculate the reynolds no of the flow

```
1   clc;
2   //Example 13.7
3   //page no 142
```

```
 4  printf("Example 13.7 page no 142\n\n");
 5  //refer to example 13.6
 6  rho=1260//density , kg/m^3
 7  v=8//flow velocity ,m^2/s
 8  D=0.02//diameter ,m
 9  meu=1.49//viscosity
10  R_e=rho*v*D/meu//reynolds no
11  printf("\n reynolds no R_e=%f ",R_e);
12  V=14000//volume in gallons of glycerine pass through
        a cross section of tube
13  q=159.6//flow rate
14  t=V/q//time
15  printf("\n time t=%f min",t);
```

Chapter 14

TURBULENT FLOW IN PIPES

Scilab code Exa 14.1 calculate the reynolds no

```scilab
1  clc ;
2  // Example  14.1
3  // page  no  148
4  printf ("Example  14.1  page  no  148\n\n");
5  // a  liquid  flow  through  a  tube
6  meu =0.78 e -2// viscosity  of  liquid ,g/cm*s
7  rho =1.50// density ,g/cm^3
8  D =2.54// diameter ,cm
9  v =20// flow  velocity
10 R_e =D*v*rho/meu// reynolds  no
11 printf ("\n  Reynolds  no  R_e=%f ",R_e);
```

Scilab code Exa 14.2 Detemine the minimum velocity at which turblence will appear

```scilab
1  clc ;
```

```
2  //Example 14.2
3  //page no 148
4  printf("Example 14.2 page no 148\n\n");
5  //a fluid is moving through a cylinder in laminar
       flow
6  meu=6.9216e-4//viscosity of fluid,lb/ft*s
7  rho=62.4//density,lb/ft^3
8  D=1/12//diameter,ft
9  R_e=2100//reynolds no
10 v=R_e*meu/(D*rho)//minimum velocity at which
       turbulance will appear
11 printf("\n velocity v=%f ft/s",v);
```

Scilab code Exa 14.3 predict the friction factor by different equation

```
1  clc;
2  //Example 14.3
3  //page no 152
4  printf("Example 14.3 page no 152\n\n");
5  //calculate the friction factor by using different
       equation's
6  R_e=14080//reynolds no
7  K_r=0.004//relative roughness
8  //(a) by PAT proposed equation
9  f_a=0.0015+[8*(R_e)^0.30]^-1
10 printf("\n fanning friction factor f_a=%f ",f_a);
11 //equation for 5000<R_e>50000
12 f_b1=0.0786/(R_e)^0.25
13 printf("\n friction factor f_b1=%f ",f_b1);
14 // equation for 30000<R_e>1000000
15 f_b2=0.046/(R_e)^0.20
16 printf("\n friction factor f_b2=%f ",f_b2);
17 // equation for the completely turbulent region
18 f_c=1/[4*(1.14-2*log10(K_r))^2]
19 printf("\n friction factor f_c=%f ",f_c);
```

```
20  //equation given by jain
21  f_d=1/[2.28-4*log10(K_r+21.25/(R_e^.9))]^2
22  printf("\n friction factor f_d=%f ",f_d);
23  f_e=0.0085 //from figur 14.2
24  printf("\n friction factor f_e=%f",f_e);
25  f_av=(f_a+f_b1+f_b2+f_c+f_d+f_e)/6
26  printf("\n average friction f_av=%f ",f_av);
```

Scilab code Exa 14.4 Calculate the equivalent diameter

```
1  clc;
2  //Example 14.4
3  //page no 154
4  printf("Example 14.4 page no 154\n\n");
5  //for turbulent fluid flow in across section
6  //(a) for a rectangle
7  w=2//width of a rectangle ,in
8  h=10//height of rectangle ,in
9  S_a=h*w//cross sectional area
10 P_a=2*h+2*w//perimeter of rectangle
11 D_eq_a=4*S_a/P_a//equivalent diameter
12 printf("\n equivalent diameter D_eq_a=%f in",D_eq_a)
        ;
13 //(b) for an annulus
14 d_o=10//outer diameter of annulus
15 d_i=8//inner diameter
16 S_b=%pi*(d_o^2-d_i^2)/4//cross sectional area
17 P_b=%pi*(d_o-d_i)//perimeter
18 D_eq_b=(4*S_b)/(P_b)//eq. diameter
19 printf("\n equivalent diameter D_eq_b=%f cm",D_eq_b)
        ;
20 //(c) for an half- full circle
21 d_c=10//diameter of circle
22 S_c=%pi*d_c^2/8// cross sectional area
23 P_c=%pi*d_c/2//perimeter
```

```
24  D_eq_c=4*S_c/P_c//eq.  diameter
25  printf("\n  equivalent  diameter  D_eq_c=%f  cm",D_eq_c)
       ;
```

Scilab code Exa 14.5 pipe diameter and velocity

```
 1  clc;
 2  //Exampkle  14.5
 3  //page  no  157
 4  printf("Example  14.5  page  no  157\n\n");
 5  //air  is  transported  through  a  circular  conduit
 6  MW=28.9//molecular  weight  of  air
 7  R=10.73//gas  constant
 8  T=500//temperature
 9  P=14.75//pressure,psia
10  //applying  ideal  gas  law  for  density
11  rho=P*MW/(R*T)//density
12  rho=0.08//after  round  off
13  meu=3.54e-7//viscosity  of  air  at  40  degF
14  //assume  flow  is  laminar
15  q=8.33//flow  rate  ,ft^3/s
16  L=800//length  of  pipe,ft
17  P_1=.1//pressure  at  starting  point
18  P_2=.01//pressure  at  delivery  point
19  D=[(128*meu*L*q)/(%pi*(P_1-P_2)*144)]^(1/4)//
        diameter
20  printf("\n  pipe  diameter  D=%f  ft",D);
21  //check  the  flow  type
22  meu=1.14e-5
23  R_e1=4*q*rho/(%pi*D*meu)//reynolds  no
24  //printf("\n  reynolds  no  R_e=%f  ",R_e);
25  //from  R_e  we  can  conclude  that  laminar  flow  is  not
        valid
26  P_drop=12.96//pressure  drop  P_1-P2  in  psf
27  f=0.005//fanning  friction  factor
```

```
28  g_c =32.174
29  D=(32*rho*f*L*q^2/(g_c*%pi^2*P_drop))^(0.2)//diamter
        from new assumption
30  //strat the second iteration with the newly
        calculated D
31  k=0.00006/12//roughness factor
32  K_r=k/D//relative roughness
33  C_f =1.321224
34  R_e_n=4*q*rho/(%pi*D*meu)//new reynolds no
35  //printf("\n new reynolds no R_e=%f ",R_e);
36  f_n=0.0045//new fanning friction factor
37  D=[((8*rho*f_n*L*q^2)/(g_c*%pi^2*P_drop))^(0.2)]*C_f
        //final calculated diameter because last diameter
        is same with this
38  printf("\nD=%f ",D);
39  //iteration may now be terminated
40  S=%pi*(D^2)/4//cross sectional area of pipe
41  v=q/S//flow velocity
42  printf("\n flow velocity v=%f ft/s",v);//printing
        mistake in book in the value of meu in the
        formula of D is first time that's why this
        deviation in answer
```

Scilab code Exa 14.6 determine the tube diameter and velocity

```
1  clc;
2  //Example 14.6
3  //page no 159
4  printf("Example 14.6 page no. 159\n\n");
5  //ethyl alcohol is pumped through a horizontal tube
6  rho=789//density .kg/m^3
7  meu=1.1e-3//viscosity ,kg/m-s
8  k=1.5e-6//roughness ,m
9  L=60//length of tube ,m
10 q=2.778e-3//flow rate
```

```
11  g=9.807
12  h_f=30//friction loss
13  A=(L*q^2)/(g*h_f)
14  A=1.574e-7
15  //D=0.66*[[(k^1.25)*(A^4.75)+meu*(A^5.2)/(q*rho)
        ]^.04]
16  D=0.0377
17  //calculate velocity of alcohol in the tube
18  S=3.14*(D)^2/4//surface area
19  v=q/S//velocity
20  v=3.93//velocity
21  neu=1.395e-6//dynamic viscosity
22  R_e=D*v/neu//reynolds no
23  printf("\n R_e=%f ",R_e);//printing mistake in book
24  printf("\n since R_e is more than 4000 flow is
        turbulent");
```

Scilab code Exa 14.7 kerosene flow in pipe

```
1  clc;
2  //Exanmple 14.7
3  //page no 160
4  printf("Example 14.7 page no 160\n\n");
5  //kerosene flow ina lng ,smooth ,horizontal pipe
6  rho=820//density ,kg/m^3
7  D=0.0493//iside diameter of pipe by appendix A.5,m
8  R_e=60000
9  meu=0.0016//viscosity ,kg/m.s
10 v=(R_e*meu)/(D*rho)// flow average velocity
11 printf("\n average velocity v=%f m/s",v);
12 S=(%pi/4)*D^2//cross sectional area
13 printf("\n S=%f ",S);
14 q=v/S//flow rate
15 printf("\n flow rate q=%f m^3/s",q);//printing
        mistake in book
```

```
16  m_dot=rho*q//mass flow rate
17  printf("\n mass flow rate m_dot=%f kg/s",m_dot);//
        printing mistake in book in the value of v
18  n=7//seventh power apply
19  v_max=v/(2*n^2/((n+1)*(2*n+1)))//maximum velocity
20  printf("\n v_max=%f m/s",v_max);
21  //check the assumptioon of fully developed flow
22  R_e=60000//reynolds no
23  L_c=4.4*R_e^(1/6)*D//critical length
24  printf("\n length L_c=%f m",L_c);
25  //since L_c <L th eassumption is valid
```

Scilab code Exa 14.8 determine the fanning friction factor and friction loss and the pressure drop

```
1   clc;
2   //Example 14.8
3   //page no 161
4   printf("\n Example 14.8 page no 161\n\n");
5   //refer to example no 14.7
6   rho=860//density
7   R_e=60000//reynolds no
8   f=.046/R_e^.2//fanning friction factor
9   printf("\n fanning friction factor f=%f ",f);
10  L=9//length of tube
11  v=2.38//velocity
12  D=.0493//diameter of tube
13  g=9.807
14  h_f=4*f*(L*v^2)/(D*2*g)//friction loss
15  printf("\n h_f friction loss=%f m ",h_f);
16  //applying  bernoulli equation
17  P_drop=rho*g*h_f//pressure drop in pa
18  P_drop_a=P_drop/10^5//pressure drop in atm
19  printf("\n P_drop_a =%f atm",P_drop_a);
```

Scilab code Exa 14.9 calculate the force required to hold the pipe in place

```
1  clc;
2  //Example 14.9
3  //page no 161
4  printf(" Example 14.9 page no 161\n\n");
5  //refer to example 14.7
6  D=0.0493//diameter of tuube
7  S=%pi*D^2/4//cross sectional area\
8  P=8685//pressure
9  F=P*S//force required to hold the pipe,direction is
       opposite the flow
10 printf("\n Force required to hold pipe F=%f N",F);
```

Scilab code Exa 14.10 turbulent flow through a pipe

```
1  clc;
2  //Example 14.10
3  //page no 163
4  printf("Example 14.10 page no 163\n\n");
5  //a fluid is moving in the turbulent flw through a
       pipe
6  // a hot wire anemometer is inserted to measure the
       local velocity at a given point P in the system
7  //following readings were recorded at equal time
       interval
8  //instantaneous velocities at subsequent time
       interval
9  vz=[43.4,42.1,42,40.8,38.5,37,37.5,38,39,41.7]
10 vz_bar=0;
11 n=10;
12 i = 0;
```

```
13  sums =0;
14  for i = 1:10
15      sums = sums + vz ( i ) ;
16  end
17  vz_bar = sums / n ;
18  printf ( "\n vz_bar=%f" , vz_bar );
19  sigma =0;
20  for i =1:10
21      sigma = sigma +( vz ( i ) - vz_bar )^2;
22      vz_sqr = sigma /10;
23  end
24  printf ( "\n vz_sqr=%f" , vz_sqr )
25  I = sqrt ( vz_sqr ) / vz_bar // intensity of turbulance
26  printf ( "\n intensity of turbulance I=%f " , I );
```

Scilab code Exa 14.11 calculate the volumatric flow rate in different condition

```
1  clc ;
2  // Example 14.11
3  // page no 164
4  printf ( " Example 14.11 page no 164\n\n" );
5  // a fluid is flowing through a pipe
6  D=2// inside diameter of pipe , in
7  v_max =30// maximum velocity , ft / min
8  A=(%pi /4) *( D /12) ^2// cross sectional area
9  //(a) for laminar flow
10 v_a =(1/2) * v_max // average velocity
11 q_a = v_a * A // volumatric flow rate
12 printf ( "\n flow rate q_a=%f ft^3/min" , q_a );
13 //(b) for plug flow
14 v_b = v_max // average velocity
15 q_b = v_b * A // volumatric flow rate
16 printf ( " \nflow rate q_b=%f ft^3/min" , q_b );
17 //(c) for turbulent flow
```

```
18  v_c =(49/60) * v_max //average velocity
19  q_c = v_c * A //volumatric flow rate
20  printf("\n flow rate q_c=%f ft^3/min",q_c);
```

Chapter 15

compressible and sonic flow

Scilab code Exa 15.2 nitrogen gas

```
1  clc;
2  //Example 15.2
3  //page no 169
4  printf(" Example 15.2 page no 169\n\n");
5  //nitrogen gas is flowing in a duct,neglect
       compressibility effects
6  T=293//temperature,k
7  R=8314.4//gas constant
8  k=1.4//for nitrogen
9  M=28//molecular weight of nitrogen
10 c=sqrt(k*R*T/M)//speed of sound in nitrogen
11 printf("\n speed of sound on nitrogen c=%f m/s",c);
12 v=82//flow velocity
13 M_a=v/c//mach no.
14 printf("\n mach no. M_a=%f ",M_a);
```

Scilab code Exa 15.3 propane flow through a pipe

```
1  clc;
2  //Example 15.3
3  //page no 170
4  printf("Example 15.3 page no 170\n\n");
5  //propane is flowing in a tube
6  k=1.3//degree of freedom for propane
7  T=290//temperature ,k
8  M=44//mol. weight
9  R=8314.4//gas constant
10 c=sqrt((k*R*T)/M)//speed of sound in propane
11 printf("\n speed of sound in propane c=%f m/s",c);
12 v=43//average velocity
13 M_a=v/c//mach no.
14 printf("\n M_a mach no=%f ",M_a);
15 //mach no is< 0.3,that's why flow is incompressible
16 rho=6.39//density ,kg/m^3
17 meu=8e-6//viscosity ,m^2/s
18 D=0.0254//inside diameter of tube
19 R_e=D*rho*v/meu//reynolds no.
20 printf("\n reynolds no R_e=%f ",R_e);
21 //because R_e is >4000,flow is turbulent
```

Scilab code Exa 15.6 pressure drop in the flow of natural gas

```
1  clc;
2  //Example 15.6
3  //page no 173
4  printf("Example 15.6 page no 173\n\n");
5  //methane is flowing through a horizontal steel pipe
6  m_dot=10//mass flow rate , lb/s
7  D=1//diameter of pipe ,ft
8  G=m_dot/((%pi/4)*D^2)//mass velocity flux
9  P=89.7//inlet pressure
10 T=530//temprature ,k
11 MW=16//mol. weight
```

```
12  R=10.73//gas constant
13  //applying eq 15.7
14  rho=P*MW/(R*T)//density
15  f=0.008//friction factor
16  L=15840//length of pipe,ft
17  g_c=32.2//gravitational constant
18  P_drop=(2*f*L*(G^2))/(g_c*rho*D)//pressure drop
19  P1=89.7//inlet pressure,psia
20  P2=P1-(P_drop/144)
21  P2=54.7//corrected value
22  P_drop=P1-P2//updated value of P_drop
23  printf("\n pressure drop P_drop=%f psia",P_drop);
```

Scilab code Exa 15.7 reynolds number

```
1  clc;
2  //Example 15.7
3  //page no 174
4  printf("Example 15.7 page no 174\n\n");
5  //refr to example 15.6
6  D=1//diameter of pipe
7  G=12.7//mass velocity flux
8  meu=7.39e-6//viscosity,lb/ft.s
9  R_e=(D*G)/(meu)//reynolds no
10 printf("\n reynolds no R_e=%f ",R_e);
```

Scilab code Exa 15.8 pressure drop across the line

```
1  clc;
2  //Example 15.8
3  //page no 174
4  printf("Example no page no 174\n\n");
5  //air flowing through a steel pipe
```

```
6  P_1=2.7// pressure ,atm
7  T=288// temperature ,k
8  v=30// velocity at the entrance of the pipe ,m/s
9  Mw=29//mol. weight of air
10 V=22.4// standard volume
11 T_s=273// st. temp
12 P_s=1// st. pressure
13 rho=(Mw*P_1*T_s)/(V*T*P_s)// density
14 printf("\ density rho =%f kg/m^3",rho);
15 G=v*rho//mass veocity flux
16 printf("\n G mass velocity flux =%f kg/m^2.s",G);
17 f=0.004// friction factor
18 D=0.085// diameter ,m
19 L=65// length of pipe ,m
20 // gravitational constant
21 P_2=P_1-2*f*L*G^2/(rho*D*101325)// pressure drop
      across the line
22 // factor 101325 for atm
23 printf("\n pressure drop P__2=%f atm",P_2);
24 P_drop=P_1-P_2// pressure drop
25 printf("\n P_drop pressure=%f atm",P_drop);
```

Scilab code Exa 15.9 friction factor

```
1  clc;
2  //Example 15.9
3  //page no 175
4  printf(" Example 15.9 page no 175\n\n");
5  // refer to Example 15.9
6  meu=1.74e-5// viscosity ,kg/m.s
7  D=0.085// diameter of pipe
8  G=99.3//mass velocity flux
9  R_e=D*G/meu// reynolds no.
10 printf("\n reynolds no R_e=%f ",R_e);
```

Chapter 16

two phase flow

Scilab code Exa 16.2 pressure drop

```
1  clc;
2  //Example 16.2
3  //page no 183
4  printf(" Example 16.2 page no 183\n\n");
5  //cal. pressure drop if the flow for both phases is
       turbulent
6  //a. since the flow is tt and 1<X<10 ,apply
       equatuion 16.16b to obtain Y_g
7  X=1.66
8  Y_g=5.80+6.7143*X+6.9643*X^2-0.75*X^3
9  printf("\n Y_g=%f ",Y_g);
10 //the value of Y_g is an excellent agreement with
       the values provided by lockhart and Martinelli
11 //then pressure drop is
12 P_drop_g=2.71
13 P_drop_t=Y_g*P_drop_g
14 printf("\n P_drop_t=%f psf/100 ft",P_drop_t);
15 //b. applying eq. 16.17b to generate Y_l
16 Y_l=18.219*X^-.8192
17 printf("\n Y_l =%f ",Y_l);
18 //pressure drop from eq. 16.2
```

```
19 P_drop_l =7.50
20 P_drop = Y_l * P_drop_l
21 printf("\n P_drop=%f psf/100 ft",P_drop);
```

Scilab code Exa 16.3 pressure drop

```
1  clc;
2  //Example 16.3
3  //page no 185
4  printf(" Example 16.3 page no 185\n\n");
5  //if the flow for the gas phase is turbulent and the
         liquid phase is viscous
6  //cal. pressure drop total
7  X=1.66//from ex. 16.1
8  Y_G_tv =20-21.81*X+16.357*X^2-1.8333*X^3
9  printf("\n Y_G_tv=%f ",Y_G_tv);
10 //pressure drop from eq 16.1
11 P_drop_g=2.71
12 P_drop_a = Y_G_tv * P_drop_g
13 printf("\n pressure drop P_drop_a=%f psf/100 ft",
       P_drop_a);
14 //b. applying eq 16.20b to generate Y_l
15 Y_l_tv =11.702*X^-0.7334
16 printf("\n Y_l_tv=%f ",Y_l_tv);
17 //pressure drop from equation 16.2
18 P_drop_l =7.50
19 P_drop_b = Y_l_tv * P_drop_l
20 printf("\n P_drop_b=%f psf/100 f",P_drop_b);
```

Scilab code Exa 16.4 laminar flow in both phase

```
1  clc;
2  //Example 16.4
```

```
 3  // page no 187
 4  printf (" Example  16.4  page  no  187\n\n");
 5  // if  flow  for  both  phases  is  laminar  then  cal
        pressure  drop  total
 6  //a.  apply  eq.  16.22b  to  obtain  Y_G
 7  X=1.66
 8  Y_G=10-10.405*X+8.6786*X^2-0.9167*X^3
 9  printf ("\n  Y_G=%f  ",Y_G);
10  // pressure  drop  from  eq  16.1
11  P_drop_g=2.71
12  P_drop=Y_G*P_drop_g
13  printf ("\n  pressure  drop  P_drop=%f  psf/100  ft",
        P_drop);
14  //b.  apply  eq  16.23b  to  generate  Y_l
15  Y_l=6.4699*X^-0.556
16  printf ("\n  Y_l  =%f  ",Y_l);
17  // pressure  drop  from  eq.  16.2
18  P_drop_l=7.50
19  P_drop_b=Y_l*P_drop_l
20  printf ("\n  pressure  drop  P_drop_b=%f  psf/100  ft",
        P_drop_b);
```

Scilab code Exa 16.6 flow regime

```
 1  clc ;
 2  // Example  16.6
 3  // page  no  191
 4  printf ("\n  Example  16.6  page  no  191\n\n");
 5  //a  mixture  of  air(a)  and  kerosene(k)  are  flowing  in
        a  horizontal  pipe
 6  rho_a=0.075// density  of  airlb/ft^3
 7  meu_a=1.24e-5// viscosity  of  air  ,lb/ft.s
 8  q_a=5.3125// flow  rate  ft^3/s
 9  rho_k=52.1// density  of  kerosene ,lb/ft^3
10  meu_k=0.00168// viscosity  lof  kerosene ,lb/ft.s
```

```scilab
11  q_k=1.790//flow  rate  ft^3/s
12  D=.19167//diameter  of  pipe  ,ft
13  S=(%pi/4)*D^2//cross  sectional  area ,ft^2
14  printf("\n  S=%f  ",S);
15  //superficial  velocity  of  each  phase  can  be  obtained
        by  applying  either  eq,  16.7  and  16.8
16  v_a=q_a/(S*60)//for  air
17  v_k=q_k/(S*60)//for  kerosene
18  printf("\n  velocity  v_a =%f  ft/s\n  velocity  v_k=%f
      ft/s",v_a,v_k);
19  R_e_a=D*rho_a*v_a/meu_a//reynolds  no.  of  Air
20  R_e_k=D*rho_k*v_k/meu_k//reynolds  no.  of  kerosene
21  printf("\n  R_e_a=%f\nR_e_k=%f  ",R_e_a,R_e_k);
```

Chapter 17

prime movers

Scilab code Exa 17.1 fan law

```
1  clc;
2  //Example 17.1
3  //page no 201
4  printf("Example 17.1 page no 201\n\n");
5  //fan are operating for transporting gas
6  //two fans fan(a)and fan(b)
7  D_a=46//diameter of blade of fan (a)
8  rpm_a=1575//operating speed of fan(a)
9  D_b=42//diameter of blade of fan(b)
10 rpm_b=1625//operating speed of fan(b)
11 h_p_a=47.5//power requirement of fan (a)
12 h_p_b=(rpm_b^3/rpm_a^3)*(D_b/D_a)^5*h_p_a//power
        requirement of fan(b)
13 printf("\n power requirement h_p_b=%f bhp",h_p_b);
```

Scilab code Exa 17.2 fan operating

```
1  clc;
```

```
2  //Example 17.2
3  //page no 201
4  printf("Example 17.2 page no 201\n\n");
5  rpm=1694//speed of fan
6  q=12200//flow rate of q_a
7  rpm_n=2100//new speed of fan
8  q_n=q*(rpm_n/rpm)//new flow rate
9  printf("\nnew flow rate q_n=%f acfm",q_n);
10 //applyingeq 17.5
11 P=5//pressure  ,in
12 P_n=P*(rpm_n^2/rpm^2)//new pressure
13 printf("\nnew pressureP_n=%f in H20",P_n);
14 //required power is calculated using eq. 17.6
15 hp=9.25//power at 1694 speed
16 hp_n=hp*(rpm_n^3/rpm^3)//new power required
17 printf("\n new powerhp_n=%f bhp",hp_n);
```

Scilab code Exa 17.3 gas stream

```
1  clc;
2  //Example 17.3
3  //page no. 201
4  printf("\Example 17.3 page no 201\n\n");
5  // a gas stream in a process
6  P_l_m=4.4// minor pressure loss for duct work,valves
       etc,in
7  P_l_mz=6.4//major pressure loss due to pieces of
      equipment ,in
8  P_drop=P_l_m+P_l_mz//total pressure drop
9  printf("\n total pressure P_drop=%f in H20",P_drop);
10 //applying eq 17.7
11 q=6500//flow rate ,acfm
12 neta=0.63//overall fan-motor effficiency
13 bhp=1.575e-4*q*P_drop/neta//brake horse power
      required
```

```
14  //1.575e−5 is aconversion factor for horse power
15  printf(”\n brake horse power bhp=%f bhp”,bhp);
```

Scilab code Exa 17.4 pump in opeation

```
1   clc ;
2   //Example 17.4
3   //page no 208
4   printf(” Example 17.4 page no 208\n\n”);
5   //a pump is in process
6   //given: parabolic pump pressure flow
7   //P=a−b*q^2  equation
8   //a and  b calculate from conditions
9   a=25
10  b=5
11  //then equation becomes P=25−5*q^2
12  //pressure at 1m^3/s  flow rate
13  q=1//flow rate ,m^3/s
14  P=a-b*q^2//pressure
15  printf(”\n pressure P=%f kpa”,P);
```

Scilab code Exa 17.6 centrifugal pump

```
1   clc ;
2   //Example 17.6
3   //page no 214
4   printf(”\n Example 17.6 page no. 214\n\n”);
5   //the total head developed by a centrifugal pump is
        given by a equation
6   //hc=42−0.0047*q^2
7   //the pump is to be used in a water flow system in
        which the pump head in feet of water is given by
        eq .
```

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```
8  //hp=12+0.0198*q^2
9  //for cal. flow rate hc=hp
10 q=35//from condition hc=hp,gpm
11  hc=42-0.0047*q^2//total head
12  printf("\n total head hc=%f ft of water",hc);
13 rho=62.40//density
14 q_c=0.078//flow rate in cfs unit
15 m_dot=rho*q_c//mass flow rate
16 printf("\n m_dot mass flow rate =%f lb/s",m_dot);
17 W_dot=m_dot*hc//fluid power requirement can be
       calculated
18 printf("\n fluid power requirement W_dot=%f lbf.ft/s
       ",W_dot);
19 neta=.6//efficiency
20 W_dot_hp=.32//fluid power requirement in hp
21 bhp=W_dot_hp/neta//brake horse power
22 printf("\n brake horse power bhp=%f bhp",bhp);
```

Scilab code Exa 17.8 power requirement

```
1  clc;
2  //Example 17.8
3  //page no 216
4  printf(" Example 17.8 page no 216\n\n");
5  //compressed air is to be employed in the nozzle
6  T1=520//temperature
7  P2=40//pressure
8  P1=14.7//atmosphric pressure
9  gamma=1.3//degree of freedom
10 R=1.987//gas constant
11 W_s=-(gamma*R*T1/(gamma-1))*[(P2/P1)^((gamma-1)/
       gamma)-1]//compreesd energy requirement
12 printf("\n energy requirement W_s=%f btu/lbmol of
       air",W_s);
13 hp=W_s*(7.5/29)*778//power
```

```
14  printf("\n power hp=%f ft .lbf/min",hp);
```

Chapter 18

valves and fittings

Scilab code Exa 18.1 sudden expansion

```
1  clc;
2  //Example 18.1
3  //page no 225
4  printf("\n Example 18.1 page no 225\n\n");
5  //there is a sudden expansion in which the diameter
      D1 doubls to D2,D2=2D1
6  //if D1=1 then D2=2
7  D1=1//diameter D1
8  D2=2//diameter D2
9  K_se=[1-(D1/D2)^2]^2// coefficent of sudden
      expansion
10 printf("\n K_se coeff. of sudden expansion=%f ",K_se
      );
```

Scilab code Exa 18.2 equivalent length

```
1  clc;
2  //Example 18.2
```

```
3  //page no 227
4  printf("\n Example 18.2 page no 227\n\n");
5  //cal. equivalent length of pipe that would cause
       the same head los  for gate and globe valve
       located in piping
6  D=3//diameter  of pipe,in
7  L_gate=7//L/D ratio for fully open gate valve
8  L_globe=300//L/D ratio for globe valve
9  L_eq_gate=L_gate*D//equivalent length for gate valve
10 printf("\n L_eq_gate=%f in",L_eq_gate);
11 L_eq_globe=L_globe*D//equivalent length for globe
       valve
12 printf("\n L_eq_globe=%f in ",L_eq_globe);
```

Scilab code Exa 18.3 pressure drop in a pipe

```
1  clc;
2  //Example 18.3
3  //page no 227
4  printf("\n Example 18.3 page no 227\n\n");
5  // water is flowing at room temperature
6  rho=62.4//density  of water,lb/ft^3
7  meu=6.72e-4//viscosity of water,lb/ft.s
8  D=0.03125//diameter of pipe
9  v=10//velocity
10 R_e=D*v*rho/meu//reynolds no.
11 printf("\n reynolds no R_e=%f ",R_e);
12 f=0.0015+0.125/R_e^.30//equation for friction factor
13 printf("\n friction factor f=%f ",f);
14 L=30//length of pipe
15 gc=32.2//gravitational constant
16 P_drop=2*f*rho*v^2*L/(D*gc)//pressure drop
17 printf("\n pressure drop P_drop=%f lbf/ft^2 ",P_drop
       );
```

Scilab code Exa 18.4 frictional fitting

```
1  clc ;
2  //Example 18.4
3  //page no 229
4  printf (" \n Example 18.4 pageno 229\n\n");
5  //refer to example 18.3
6  //applying eq 18.4 for friction loss by globe valve
7  K_f =22// coeff of expansion loss
8  v =10// velocity
9  gc =32.2// ravitational constant
10 h_f = K_f * v^2/(2* gc )// friction loss due to globe valve
11 printf (" \n friction loss due to globe valve h_f=%f
       ft . lbf / lb ",h_f );
```

Scilab code Exa 18.5 total pressure drop

```
1  clc ;
2  //Example 18.5
3  //page no 230
4  printf (" Example 18.5 page no. 230\n\n");
5  //refer to example no. 18.3 and 18.4
6  P_drop =34.16// pressure drop , ft
7  h_f =43// friction loss due to fitting
8  rho =62.4// density , lb / ft ^3
9  P_d_t =( P_drop + h_f )* rho // total pressure drop
10 printf (" \n total pressure drop P_d_t=%f lbf / ft ^2" ,
       P_d_t );
```

Scilab code Exa 18.6 volumetric flow rate

```
1  clc;
2  //Example 18.6
3  //page no 230
4  printf("Example 18.6 page no 230\n\n");
5  k=0.00085//relative roughness of pipe ,ft
6  D=0.833//diameter  of pipe,ft
7  f=0.005//we assume fanning friction factor
        ,0.004-0.005,select upper limit
8  K=0.45//entrance loss coefficient is estimated from
        eq. 18.10 and 18.11
9  L=5000//length of pipe,ft
10 h_f=4*f*(L/D)//the friction head loss in terms of
        the line velocity
11 printf("\n h_f=%f ",h_f);//printing mistake in book
        12 instead of 120
12 //applying bernoulli equation between points 1 and 2
         to calculate v2
13 h_s=0//no shaft head
14 v1=0//large tank
15 //because both locations open to the atmosphere,P1=
        P2=0 psig
16 h=260//height from point 1 to 2
17 V2_h=sqrt(h/(1+h_f+K))//total velocity head at point
         2
18 g=32.174
19 V2=V2_h*2*g
20 V2=11.75
21 neu=1.0825e-5//viscosity
22 R_e=D*(V2)/neu//reynolds number
23 printf("\n reynolds number R_e=%f ",R_e);//printing
        mistake in book due to value of h_f
24 q=V2*(%pi*(D^2)/4)//volumatric flow rate
25 printf("\n vol. flow rate q=%f ft^3/s",q);//printing
         mistake in book due to value of h_f
```

Scilab code Exa 18.7 friction loss

```
1  clc;
2  //Example 18.7
3  //page no 232
4  printf("Example 18.7 page no 232\n\n")
5  //two large water reservoirs are connected by a
       pipe
6  D=0.0779//diameter of pipe (m), by appendix A.5 for
       3 inch schdule 40 pipe
7  k=0.046*1e-3//roughness of pipe
8  K_r=k/D//relative roughness
9  printf("\n relative roughness K_r=%f ",K_r);
10 q=0.0126//flow rate of water m^3/s,
11 S=(%pi/4)*D^2//cross sectional area of pipe
12 v=q/S//flow velocity of water
13 printf("\n flow velocity v=%f m/s",v);
14 neu=1e-6//viscosity of water
15 R_e=v*D/neu//reynolds no
16 printf("\n reynolds no R_e=%f ",R_e);
17 //from R_e and relative roughness K_r ,obtain
       friction factor
18 f=0.00345
19 L=2000*.3048//length of pipe ,m
20 h_f=4*f*(L/D)*(v^2/2)
21 printf("\n head loss h_f=%f J/kg",h_f);
22 //apply bernoulli equation between station 1 and 2.
       Note that P1=P2=1 atm,v1=v2,z1=z2
23 //P_drop/rho + V^2/2g + z =  h_s - h_f
24 //whera h_s is the major friction loss
25 //above equation reduces to h_s=h_f
26 h_s=h_f//h_s is major friction loss
27 printf("\n major friction losses h_s=%f J/kg",h_s);
```

Scilab code Exa 18.8 pressure rise in pump

```scilab
1  clc;
2  //Example 18.8
3  //page no 233
4  printf("\n Example 18.8 page no 233\n\n");
5  //refer to example no 18.7
6  rho=1000//density
7  g=9.807//gravitational acc.
8  h_f=38.39//head loss
9  P_rise=rho*g*h_f//pressure rise across the pump
10 P_rise=475000//in book by mistake this value instead
       original value
11 q=0.0126//flow rate from example 18.7
12 W_dot=q*P_rise//ideal pumping requirement(the fluid
      power)
13 printf("\n W_dot fluid power=%f kw",W_dot);//
      printing mistake in book in putting value of
      P_rise
```

Chapter 19

flow measurement

Scilab code Exa 19.1 air pressure in the oil tank

```
1  clc;
2  //Example 19.1
3  //page no. 246
4  printf("Example 19.1 page no 246\n\n");
5  //we have to find pressure at different point in a
       oil tank
6  //apply manometer equation between point 1 and 2
7  //since rho1=rho2,z1=z2
8  //it gives P1=P2
9  //applying manometer equation between points 2 and 3
10 rho_oil=0.8*1000//density of oil
11 //since rho3=rho_oil=rho2
12 rho3=rho_oil
13 z_32=.4//height difference between point 2 and 3
14 g=9.807//grav. acc.
15 P7=0//pressure at point 7,on gauge basis
16 z_76=0.8//height difference between point 6 and 7
17 rho_hg=13600//density of mercury
18 P6=P7 + rho_hg*g*z_76//pressure at point 6
19 P5=P6//pressure at point 5
20 rho_air=1.2//density of air
```

```
21  z_54=1//height difference between point 5 and 4
22  P4=P5 + rho_air*g*z_54//pressure at point 4
23  P3=P4//pressure at point 3
24  P2=P3 + rho_oil*g*z_32//pressure at point 2
25  P1=P2//air pressure in the oil tank
26  printf("\n pressure P1=%f Pag",P1);
```

Scilab code Exa 19.2 pitot tube

```
1  clc;
2  //Example 19.2
3  //page no 250
4  printf("Example 19.2 page no 250\n\n");
5  //pitot tube is located at the center line of a
       horizontal pipe transporting air
6  rho=0.075//density of gas ,lb/ft^2
7  h=0.0166667//height difference ,ft
8  g=32.2//gravitational acc. lb/ft^2
9  rho_m=62.4//density of medium which is air
10 v=sqrt(2*g*h*(rho_m-rho)/rho)//velocity
11 printf("\n velocity v=%f ft/s",v);
12 v_max=v//because at that point where the reading was
        taken is the centerline
13 printf("\n maximum veocity v_max=%f ft/s",v_max);
14 //since the flowing fluid is air at a high velocity
       the flow has a high probability of being
       turbilent .from chapter 14,assume
15 //v_av/v_max=0.815
16 v_av=v_max*0.815
17 printf("\n average velocity v_av=%f ft/s",v_av);
```

Scilab code Exa 19.3 mass flow rate

```
1  clc;
2  //Example 19.3
3  //page no 251
4  printf("Example 19.3 page no 251\n\n");
5  //refer to example 19.3
6  S=0.785//cross sectional area,ft^2
7  v_av=24.4//average velocity,ft/s
8  q=v_av*S*60//flow rate,factor 60 for minute
9  printf("\n flow rate q=%f ft^3 min",q);
10 rho=0.075//density
11 m_dot=q*rho*60//mass flow rate
12 printf("\n m_dot mass flow rate=%f lb/hr",m_dot);
```

Scilab code Exa 19.4 volumatric flow rate

```
1  clc;
2  //Example 19.4
3  //page no 251
4  printf("Example 19.4 page no\n\n")
5  //water flow ina circular pipe,a pitot tube is used
        to measure the water velocity
6  h=0.07//manometer height,m
7  rho=1000//density of water,kg/m^3
8  rho_m=13600//density of mercury,kg/m^3
9  g=9.807
10 v=sqrt(2*g*h*(rho_m-rho)/rho)
11 printf("\n water velocity v=%f m/s ",v);
12 D=0.0779//pipe inside diameter,by using table A.5 in
        the appendix for a 3 inch schedule 40 pipe
13 S=(%pi/4)*D^2
14 printf("/n cross sectional area S=%f m^2",S);
15 q=v*S//flow rate
16 printf("\n flow rate q=%f m^3/s",q);
17 meu=0.001//viscosity of water,kg/m.s
18 R_e=rho*v*D/meu//reynolds number
```

```
19 printf("\n reynolds no R_e=%f ",R_e);
```

Scilab code Exa 19.5 venturimeter

```
1  clc;
2  //Example 19.5
3  //page no 254
4  printf("Example 19.5 page no 254\n\n");
5  //a venturi meter has gasoline flowing through it.
6  h=0.035//height of venturi meter
7  D1=0.06//upsteeam diameter,m
8  D2=0.02//throat diameter,m
9  rho_m=13600//density of mercury
10 rho=680//density of gasoline
11 g=9.807
12 v2=sqrt((2*g*h*(rho_m-rho)/rho)/1-D2^4/D1^4)//
       velocity of gasoline at the the throat
13 printf("\n velocity at throat v2=%f m/s",v2);
14 q=(%pi/4)*D2^2*v2//flow rate
15 printf("\n flow rate q =%f m^3/s",q);
16 P1=101325//upstream pressure,Pa
17 P2=P1-g*h*(rho_m-rho)//pressure at throat P2
18 printf("\n pressure P2=%f Pa",P2);
19 P_d=P1-P2//pressure difference
20 P_l=.1*P_d//pressure loss is 10 %
21 printf("\n pressure loss P_l=%f Pa",P_l);
22 W_l=q*P_l//power loss
23 printf("\n power loss W_l=%f W",W_l);
```

Scilab code Exa 19.6 flow rate

```
1  clc;
2  //Example 19.6
```

```
3  //page no. 255
4  printf("\n Example 19.6 page no. 255\n\n");
5  //refer to example 19.5
6  //if gasoline has vapor pressure of 50000Pa ,we have
       to calculate flow rate at whhich cavitation to
       occur
7  P1=101325//upstream pressure ,Pa
8  P2=50000//given vapor pressure ,Pa
9  D1=0.06//upstream diameter ,m
10 D2=0.02//throat diameter ,m
11 rho=680//density of gasoline
12 v2=sqrt((2*(P1-P2))/rho*(1-D2^4/D1^4))//velocity
13 printf("\n velocity v2=%f m/s",v2);
14 q=(%pi/4)*D2^2*v2//flow rate
15 printf("\n flow rate q=%f m^3/s",q);
```

Scilab code Exa 19.7 orifice meter

```
1  clc;
2  //Example 19.7
3  //page no 258
4  printf("Example 19.7 page no 258\n\n");
5  //an  orifice meter is equipped with flange top is
       installed to measure the flow rate of air in a
       circular duct
6  D1=0.25//diameter of circular duct ,m
7  D2=0.19//orifice diamter ,m
8  v2=4/(%pi*D2^2)//velocity through orifice
9  printf("\n velocity through orifice v2=%f m/s",v2);
10 C_o=1// assuming orifice discharge coefficient
11 rho=1.23//density of air ,kg/m^3
12 P=rho*v2^2*[1-(D2^4/D1^4)]/2//pressure
13 printf("\n pressure P=%f Pa",P);
14 meu=1.8e-5// absolute viscosity
15 R_e=rho*v2*D2/(meu)//reynolds no.
```

```
16  printf("\n Reynolds no. R_e=%f ",R_e);
17  C_ac=0.62//actual discharge cefficient ,from fig.19.8
18  P_ac=P/(C_ac)^2//actual pressure drop
19  P_rec=14*(D2/D1) + 80*((D2/D1)^2)//equation for
        percentage pressure recovery
20  P_loss=100-P_rec//precentage pressure loss
21  P_l=round((P_loss/100)*P_ac)//actual pressure  drop
        after recovery
22  printf("\n actual pressure drop P_l=%f Pa",P_l);
```

Scilab code Exa 19.9 orifice pressure drop

```
1  clc;
2  //Example 19.9
3  //page no 259
4  printf("\n Example 19.9 page no 259\n\n");
5  //air at ambient condition is flowing in a pipe
6  rho=0.075//density of air ,lb/ft^3
7  m_dot=0.5//mass flow rate ,lb/s
8  q=m_dot/rho//volumatric flow rate
9  printf("\n volumatric flow rate q=%f ft^3/s",q);
```

Chapter 20

ventilation

Scilab code Exa 20.2 diluent volumetric flow rate

```scilab
1  clc;
2  //Example 20.2
3  //page no 269
4  printf("\n Example 20.2 page no 269\n\n");
5  //ventilation required in an indoor work area where
      a toluene containing adhesive in a nanotechnology
       process is used.
6  //equation for estimate the dilution air
      requirement
7  C_a=80e-6//concentration of toluene
8  q=3/8//volumatric flow rate , gal/h
9  v=0.4//adhesive contains 4 volume % toluene
10 S_g=0.87//specific gravity
11 printf("\n C_a concentration of toluene=%f \n q
      volumatric flow rate q=%f gal/h \n S_g specific
      gravity=%f ",C_a,q,S_g);
12 //mass flow rate of toluene
13 m_dot_tol=q*v*S_g*(8.34)//factor 8.34 for lb
14 printf("\n mass flow rate m_dot-tol=%f lb/h",
      m_dot_tol);
15 m_dot_g=m_dot_tol*(454/60)//unit conversion of mass
```

```
          flow rate in g/min
16  printf(")\n mass flow rate in g/min m_dot_g=%f g/min"
        ,m_dot_g);
17  M_w=92//molecular weight of toluene
18  n_dot_tol=m_dot_g/M_w//no. of gm moles of toluene/
        min
19  printf(")\n no. of moles n_dot_tol=%f gmol/min",
        n_dot_tol);
20  //resultant toluene vapor volumatric flow rate q_tol
          is directly calculated from th eidal gas law
21  //applying ideal gas law
22  R=0.08206//gas constant
23  P=1//standard pressure
24  T=293//standard temperature
25  printf(")\n R gas constant=%f atm.L/(gmol.K)\n T
        temperature=%f K\n P pressure =%f atm",R,T,P);
26  q_tol=n_dot_tol*R*T/P//toluene vapor volumatric flow
          rate
27  printf(")\n toluene vapor vol. flow rate q_tol=%f L/
        min",q_tol);
28  q_tol=2.15//round off value
29  //the required diluent volumatric flow rtae
30  K=5//dimensionless mixing factor
31  q_dil=K*q_tol/(C_a)//diluent vol. flow rate
32  printf(")\n diluent vol. flow rate q_dil=%f L/min",
        q_dil);
```

Scilab code Exa 20.3 limiting reactant

```
1  clc;
2  //Example 20.3
3  //page no 270
4  printf("Example 20.3 page no 270 \n\n");
5  // a certain poorly ventilated room chemical stroage
        room has a ceiling fan
```

```
6  //inside this room bottle of iron(3) sulfide sits
      next to a bottle sulfuric acid  containg 1 lb
      H2SO4 in water
7  // an earthquake sends the botlles on the shelf
      crashing to the floor where bottles break and
      their contant mix and react to form iron(3)
      sulfate and hydrogen sulfide
8  //we have to calculate maximum H2S concentration
      that could be reached in the room
9  Mw_Fe2S3=208//mol. weight of Fe2S3
10 Mw_H2SO4=98//mol. weight of H2SO4
11 Mw_H2S=34//mol. weight of H2S
12 Mw_air=29//mol. weight of air
13 //balancing chemical reaction
14 // from the stiochiometric of the reaction ,sulfuric
       acid is the limiting reagent
15 // 0.030 lbmol of Fe2S3 is required to react with
      0.010 lbmol of H2SO4\
16 v_r=1600//volume of room,ft^3
17 n_H2SO4=0.010// lbmol of H2SO4
18 Stoi_c_H2SO4=3//stoichiometric coeff. of H2SO4
19 Stoi_c_H2S=3//stoichiometric coeff. of H2S
20 n_H2S=n_H2SO4*(Stoi_c_H2S/Stoi_c_H2SO4)//lbmol of
      H2S
21 printf("\n lbmol of H2S n_H2S=%f lbmol",n_H2S);
22 m_H2S=n_H2S*Mw_H2S//conversion of moles into mass of
       H2S
23 printf("\n mass of H2S m_H2S=%f lb",m_H2S);
24 //at 32 degF and i atm pressure an ideal gas
      occupies 359 ft^3 volume then,at 51 deg F
      occupies
25 T_r=51//temperature of air in the room
26 T_st=32//standard temperature
27 v_st=359//standard volume
28 printf("\n stand. temperature T_st=%f F\n
      temperature of air in room T_r=%f F\n stand.
      volume v_st=%f ft^3",T_st,T_r,v_st);
29 V_a=v_st*(460+T_r)/(460+T_st)//volume of air
```

```
30  printf("\n volume of air at 51deg F V_a=%f ft^3",V_a
      );
31  //the final concentration of H2S in the room in ppm
      C_H2S
32  C_H2S=m_H2S*(V_a/Mw_air)*1e+6/(v_r)
33  printf("\n conc. of H2S in ppm C_H2S=%f ppm",C_H2S);
```

Scilab code Exa 20.4 vinyl chloride application

```
1   clc;
2   //Example 20.4
3   //Page no 271
4   printf("Example 20.4 page no 271\n\n");
5   //vinyl chloride application
6   //calculation of density by using ideal gas law
7   Mw=78//molecular weight of vinyl chloride
8   R=82.06//gas constant ,cm^3.atm/mol.K
9   T=298//temperature ,K
10  P=1//pressure  ,atm
11  rho=P*Mw/(R*T)//density of vinyl chloride
12  printf("\n rho density of vinyl chloride=%f g/cm^3",
      rho);
13  //given
14  m_dot=10//mass flow rate ,g/min
15  q=m_dot/rho//volumatric flow rate
16  printf("\n vol. flow rate q=%f cm^3/min",q);
17  q_acfm=0.1107//vol flow rate in acfm
18  //cal. the air flow rate in acfm q_air required to
      meet the 1.0 ppm constraint with the equation
19  q_air=q_acfm/1e-6
20  printf("\n vol.flow rate q_air=%f acfm",q_air);
21  S_factor=10//correct for mixing by employing a
      saftey factor
22  //apply saftey factor to calculate the actual air
      flow rate for dilution ventilation
```

```
23  q_dil=S_factor*q_air
24  printf("\n air flow rate for dilution q_dil=%f acfm"
        ,q_dil);
25  //now consider the local exhaust ventilation by
        first calculating the face area
26  H=30//height of hood,in
27  W=25//width of hood,in
28  S=H*W/144//surface area of hood ,ft^2
29  //the air flow rate in acfm q_air,exh required for a
        face velocity of 100 ft/min is then
30  v=100//face velocity,ft/min
31  q_exh=round(S*v)
32  printf("\n air flow rate q_exh=%f acfm",q_exh);
```

Scilab code Exa 20.7 ventilation flow rate

```
1   clc;
2   //Example 20.7
3   //page no 276
4   printf("\n Example 20.7 page no 276\n\n");
5   //refer to illustrative Example 20.5
6   //(1)
7   //we have to calculate minimum air ventilation flow
        rate into the room containing 10 ng/m^3 of a
        toxic chemical
8   //ng means nanograms
9   rV=250//chemical generated in the laboratory,ng/min
10  c_o=10//room containg toxic chemical of 10ng/m^3
11  c=35//limit of chemical concentration,ng/m^3
12  //applicable modal in this case
13  //q_o(c_o-c) + rV  =V*dc/dt
14  //substituting gives
15  q_o=(-rV)/(c_o-c)//minimum air ventilation flow rate
16  printf("\n q_o min. air ventilation flow rate=%f m
        ^3/min",q_o);
```

Scilab code Exa 20.8 ventilation air

```
1  clc;
2  //Example 20.8 page no 277
3  printf(" Example 20.8 page no 277\n\n");
4  //refer to example no 20.5 and 20.7
5  V=142//volume of room,m^3
6  q=12.1// flow rate of air,m^3/min
7  tou=V/q//time ,min
8  r=30//rate of generation of chemical,ng/min
9  k=r/V//ng/(m^3.min)
10 c_i=85//intial concentration in laboratory ,ng/m^3
11 c_o=10//given concentration in room
12 c=20.7//final concentration in room
13 //by using  trial and error mthod we get
14 function y=f(t)
15    y=c_i*(exp(-t/tou))+ (c_o+k*tou)*(1-exp(-t/tou)) -
          c
16 endfunction
17 t=fsolve(30,f);
18 //by using trail and error method we get
19 t=29
20 printf("\n t=%f min ",t);
```

Chapter 21

academic application

Scilab code Exa 21.7 reynolds number

```scilab
1  clc ;
2  //Example  21.7
3  //Page  no  284
4  printf (" Example  21.7  page  no  284\n\n");
5  //  water  is  flowing  through  a  3/8  in  schedule  40
       brass  pipe
6  D=0.0411//diameter  of  pipe , ft
7  S=0.00133//cross  section  area  of  pipe , ft ^2
8  meu=6.598e-4//viscosity  of  water  from  table  A.4  in
       the  appendix , lb / ft . s
9  rho=62.4//density , lb / ft ^3
10 q_gpm=2//vol.flow  rate
11 q=q_gpm *0.00228//volumatric  flow  rate  in  ft ^3 s
12 v=q/S//velocity  of  fluid
13 printf ("\n  veloctiy  of  fluid  v=%f  ft / s",v );
14 R_e=D*v*rho/meu//reynolds  no.
15 printf ("\n  reynolds  no  R_e=%f  ",R_e );
```

Scilab code Exa 21.8 reynolds number

```
1  clc;
2  //Example 21.8
3  //page no 285
4  printf("Example 21.8 page no 285\n\n");
5  //water flowing through a pipe
6  rho=62.4//density of water,lb/ft^3
7  meu=6.72e-4//viscosity of water,lb/ft.s
8  q_1gpm=1.5//vol. flow rate in gpm
9  q_2gpm=6//vol. flow rate in gpm
10 D_1=0.493//internal diameter of 3/8 in schdule pipe
11 v11=(0.409*q_1gpm)/(D_1^2)//flow velocity for an 3/8
        in pipe with 1.5 gpm flow rate
12 v12=(0.409*q_2gpm)/(D_1^2)//flow velocity for an 3/8
        pipe with 6 gpm flow
13 R_e11=D_1*v11*rho/meu//reynolds no for case 11
14 R_e12=D_1*v12*rho/meu//reynolds no for case 12
15 printf("\n reynolds no R_e11=%f\n reynolds no R_e12=
      %f  ",R_e11,R_e12);//printing mistake in book
16 D_2=0.622//internal diameter of  1/2 in schdule pipe
17 v21=(0.409*q_1gpm)/D_2^2//flow velocity for 1/2 pipe
        with 1.5 gpm
18 v22=(0.409*q_2gpm)/D_2^2//flow velocity for 1/2 pipe
        with 6 gpm
19 R_e21=D_2*v21*rho/meu//reynolds no for case 21
20 R_e22=D_2*v22*rho/meu//reynolds no foe case 22
21 printf("\n reynolds no R_e21=%f\n reynolds no R_e22=
      %f",R_e21,R_e22);
22 //printing mistake in value of R_e
```

Scilab code Exa 21.9 pressure drop

```
1  clc;
2  //Example 21.9 page no 286
3  printf("Example no 21.9 page no 286\n\n");
4  //water is flowing in a vertical pipe
```

```
5  //assume constant velocity
6  P_drop=-4.5//pressure drop from bottom to top
7  rho=62.4 //density of water
8  z2=15//height of pipe
9  z1=0//bottom level
10 //applying bernoulli equation
11 h_f=(P_drop/rho)+(z2-z1)//frictional loss
12 printf("\n frictional loss h_f=%f ft.lbf/lb ",h_f)
```

Scilab code Exa 21.10 centrifugal pump

```
1  clc;
2  //Example 21.10
3  //page no 286
4  printf("Example 21.10 page no 286\n\n");
5  //a centrifugal pump is needed to transport water
       from sea level to 10000 feet above sea level
6  //using bernoulli equation
7  //neglectiing kinetic energy effects and frictional
       losses
8  P1=14.7//atmospheric pressure at sea level,psi
9  P2=10.2//atmospheric pressure at 10000 feet,psi
10 z1=0//at sea level,ft
11 z2=10000//height above sea level,ft
12 rho=62.4//density of water
13 g=32.2//gravitational acc.
14 g_c=32.2//gravitational constant
15 h_s=((P2-P1)*144/(rho)  + (z2-z1)*(g/g_c))//work
       deliverd by the pump to the water,in ft.lbf/lb
16 h_s=9990//ft.lbf/lb
17 h_sf=h_s*50//in ft.lbf
18 printf("\n work h_sf=%f ft.lbf/s",h_sf);
19 //actual pump work is calculated by dividing the
       above terms by the frictional afficiency
20 neta=0.65//frictional efficiency
```

```
21  W_p=round((h_sf/550)/neta)//actual work
22  printf("\n actual work W_p=%f hp",W_p);
```

Scilab code Exa 21.12 friction loss

```
1  clc;
2  //Example 21.12
3  //page no 288
4  printf("Example 21.12 page no 288\n\n");
5  //refer to illustrative Example 21.4
6  // if the pipe contains two globe valves and one
       straight through tee,what is the friction loss
7  K_f_globe=6
8  K_f_tee=0.4
9  v=2.53// flow velocity
10 g_c=32.2
11 f=5/4//friction factor
12 L=144//lenth of pipe
13 D=62.4//diameter
14 h_f=4*f*(L/D) + (2*K_f_globe + K_f_tee)*(v^2/(2*g_c)
       )
15 printf("\n frictional loss h_f=%f ft.lbf/lb",h_f);
```

Scilab code Exa 21.13 pitot tube

```
1  clc;
2  //Example 21.13
3  //page no 289 figure 21.1
4  printf("Example 21.13 page no 289 fig 21.1  \n\n\n")
       ;
5  //a pitot tube is inserted in acircular pipe  to
       measure the flow velocity
```

```
6  // the tube is inserted so that it points upstream
       into the flow and the pressure sensed by thre
       probeis the stagnation pressure
7  //the change in elevation between the tip of the
       pitot and the wall pressure tap is negligible
8  //the flowing fluid is soyabean oil at 20 deg C and
       the fluid in manometer tube is mercury
9  //point 2 is a stagnation point ,P2>P1 and the
       manometer fluid should be higher on th eleft side
       (h<0)
10 rho_m=13600// density of mercury ,kg/m^3
11 h=0.04//height of mercury ,
12 rho=919//density of oil kg/m^3
13 g=9.804
14 D=0.055// diameter of pipe ,m
15 meu=0.04// viscosity of oil ,kg.m.s
16 v=sqrt(2*g*h*((rho_m/rho)-1))//flow velocity
17 printf("\n flow velocity v=%f m/s",v);
18 // assuming uniform velocity
19 S=(%pi/4)*D^2
20 m_dot=rho*v*S//mass flow rate
21 R_e=(D*v*rho)/meu//reynolds no
22 printf("\n reynolds no R_e=%f ",R_e);
23 printf("\n mass flow rate m_dot=%f kg/s",m_dot);
```

Scilab code Exa 21.14 flow rate

```
1  clc;
2  //Example 21.14
3  //page no 290
4  printf("Example 21.14 page no 290\n\n");
5  //given: a 50 ft pipe with flowing water ,we have to
       determine the flow rate if there is an expansion
       from 3/8 inch to 1/8 inch and immediatly back to
       3/8n inch with an overall pressure loss no
```

```
        greater  than  2 lbf / ft ^2
 6  // from  table  A.5  in  the  appendix
 7  S1 =0.00133// cross  sectional  area  of  3/8  inch  pipe , ft
        ^2
 8  S2 =0.00211// cross  sectional  area  of  1/2  inch  pipe , ft
        ^2
 9  K_e =(1- S1/S2)^2// expansion  constant
10  K_c =0.4*(1- S2/S1)^2// contraction  constant
11  L=50// length  of  pipe
12  D=0.03125// diameter  of  pipe
13  v=1.93// velocity  , ft/s
14  f=0.01124// friction  factor  from  table  21.3 , for
        velocity  estimated  to  be  1.93  ft/s
15  g_c =32.2
16  h_f =(4*f*L/D   + K_e + K_c)*(v^2*g_c)// frictional
        loss
17  printf("\n  frictional  loss  h_f=%f  ft.lbf/lb  ",h_f);
```

Scilab code Exa 21.16 pressure drop

```
 1  clc ;
 2  // Example  21.16
 3  // page  no  291
 4  printf("Example  21.16  page  no  291\n\n");
 5  // water  flows  in  a  concrete  pipe
 6  v_p =0.02//  flow  velocity  ,m/s
 7  D_p =1.5// diameter  of  pipe
 8  L_p =20// length  of  pipe ,m
 9  rho_p =1000// density  of  water , kg/m^3
10  meu_p =0.001// viscosity  of  water , kg/m.s
11  K_p =0.003// roughnes  factor  ,m
12  // this  prototype  is  to  be  modeled  in  a  lab  using  a
        1/3o  th  scale  pipe
13  D_m=D_p/30//D_m  is  diameter  of  modeled  pipe
14  L_m=L_p*(D_m/D_p)// length  of  modeled  pipe
```

```
15  K_m=K_p*(D_m/D_p)//roughness factor for modeled pipe
16  //the fluid in the model is caster oil
17  rho_m=961.3//densiy of oil, kg/m^3
18  meu_m=0.0721//viscosity of oil,kg/m.s
19  //since R_e = (rho_m*v_m*D_m)/meu_m  =  (rho_p*v_p*
        D_p)/meu_p
20  v_m = (rho_p*v_p*D_p*meu_m)/(rho_m*D_m*meu_p)// flow
         velcity in molded pipe
21  printf("\n flow velocity v_m=%f m/s",v_m);
22  //pressure drop in prototype
23  P_drop_m=1e+5//pressure drop in model
24  P_drop_p=(P_drop_m*rho_p*(v_p)^2)/(rho_m*(v_m)^2)//
        pressure drop in prototype
25  printf("\n pressure drop in prototype P_drop_p=%f Pa
        ",P_drop_p);
```

Chapter 22

industrial application

Scilab code Exa 22.4 centrifugal pump

```
1  clc;
2  //Example 22.4
3  //page no 298
4  printf("Example 22.4 page no 298\n\n");
5  //a centrifugal pump operating at 1800 rpm ,we have
       to find the impeller diameter needed to develop a
        head of 200 ft
6  h=200//height,ft
7  g=32.2//gravitational acc. ft/s^2
8  v=sqrt(2*g*h)//velocity needed to develop a head of
       200 ft
9  printf("\n velocity v=%f ft/s",v);
10 N=1800//pump operating at this rotational speed,in
       rpm
11 c=v*60/N//the number of feet that the impeller
       travels in one rotations
12 //this c represents the circumference of the
       impeller  since it is equal to one rotation
13 printf("\n circumference c=%f ft/rotation",c);
14 D=c/%pi//diameter of the impeller
15 printf("\n diameter D=%f ft",D);
```

Scilab code Exa 22.5 total energy required

```
1  clc;
2  //Example 22.5
3  //page no 299
4  printf("Example 22.5 page no 299\n\n");
5  //water for a processing plant is required to be
       stored in a reservoir
6  //assume the properties of water at 20 deg C are
7  rho=998//density ,kg/m^3
8  meu=0.001//viscosity ,N.s/m^2
9  L=120//length of pipe ,m
10 D=0.15//diameter  of pipe ,m
11 S=(%pi/4)*D^2//cross sectional area of pipe
12 //given:
13 q=1.2/60//volumetric flow rate ,m^3/s
14 v=q/S//flow velocity ,m/s
15 R_e=D*v*rho/meu//reynolds no
16 printf("\n reynolds no R_e=%f ",R_e);
17 //from value of R_e ,flow is clearly turbulent
18 k=0.0005//roughness factor for galvanized iron
19 K_r=k/D//relative roughness
20 f=0.0053//fricion factor from fig. 14.2
21 h_f=4*f*(L/D)*(v^2/2)//friction loss of energy
22 printf("\n h_f frictional  loss=%f J ",h_f);
23 //for right elbows (from table 18.1),the estimated
       value of resistance coff. K for one regular 90
       deg elbows is 0.5
24 K=4//resstance coeff.
25 V_h=v^2/2//velociy head
26 e_l=K*V_h//the total loss from the elbows
27 printf("\n e_l total elbow loss=%f J/kg",e_l);
28 //the energy to move 1 kg of water against a head of
       22m of water is
```

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```
29  z=22//height ,m
30  g=9.81//grav. acc ,m/s^2
31  PE=z*g
32  printf("\n potential energy PE=%f J/kg",PE);
33  TE = h_f + e_l  + PE//total requirement per kg
34  printf("\n total energy TE=%f J/kg",TE);
35  W_dot_s= TE*q*rho//theoretical power requirement
36  printf("\n theoritical power W_dot_s=%f J/s",W_dot_s
        );
37  h=TE/g//head equivalent to the energy requirement
38  printf("\n equivalent head h=%f m ",h);
```

Scilab code Exa 22.6 reynolds number and head

```
1  clc;
2  //Example 22.6
3  //page no 301
4  printf("Example 22.6 page no 301\n\n");
5  //oil is flowing through a standard 3/2 inch steel
        pipe containing a 1 inch square edged orifice
6  v_gal=400//orifice velocity of oil in gal/hr
7  v_o=400*144/(0.785*3600*7.48)//orifice velocity in
        ft/hr
8  D_o=1/12//diameter of orifice
9  rho=0.87*62.4//density of oil
10 meu=20.6*0.000672//viscosity of oil
11 R_e=D_o*v_o*rho/meu
12 printf("\n reynolds no =%f ",R_e);
13 D_r=0.62//ratio of orifice plate to pipe
        diametersD_o/D1 = 1/1.61
14 C_d=0.76//discharge coeff. fro fig 19.8
15 g=32.2//grav. acc. ft/s^2
16 h=(v_o^2/(2*g*(C_d)^2))*(1-D_r^4)//height of oil in
        gauge reading
17 printf("\n gauge reading h=%f ft ",h);
```

Scilab code Exa 22.7 mass flow rate

```
1  clc;
2  //Example 22.7
3  //page no 302
4  printf("Example 22.7 page no 302\n\n ");
5  //natural gas consisting of essentially pure methane
       flows through a long straight standard 10 inch
      steel pipe into which is inserted a square edged
      orifice 2.50 inches in diameter ,with pressure
      taps ,each 5 inch from the orifice plate
6  //manometer is attached across the orifice reads
      1.60 in H20
7  D_o=2.50//diameter of orifice
8  D_1=10.15//diameter of plate
9  D_r=D_o/D_1//ratio of diameters
10 //assuming the reynolds no R_e in the orifice to be
      over 30,000
11 C_o=0.61//coeff. of discharge from R_e value
12 g=32.2//garv. acc ft/s^2
13 rho_m=62.4//density of medium (water)
14 rho=0.054//density of methane gas,lb/ft^3
15 h=1.60//manometer reading height,in
16 meu=12*0.011*0.000672//viscosity
17 v_o= C_o*sqrt((2*g*h*rho_m)/(12*rho))// orifice
      velocity
18 printf("\n orifice veloctiy v_o=%f ft/s",v_o);
19 R_e_o=D_o*v_o*rho/meu//reynolds no in the orifice
20 printf("\n R_e_o reynolds no =%f ",R_e_o);
21 //from R_e_o value C_o=0.61 is permissible
22 m_dot=round(v_o*(%pi/4)*(D_o^2)*rho*(3600/144))//
      mass flow rate
23 printf("\n mass flow rate m_dot=%f lb/hr",m_dot);
```

Scilab code Exa 22.8 gradual contraction

```
1  clc;
2  //Example 22.8
3  //page no 303
4  printf("Example 22.8 page no 303\n\n");
5  //refer to fig 22.1
6  D1=.1//upstream diameter(at station 1),m
7  D2=.06//downstream diameter(station 2),m
8  S2=(%pi/4)*D2^2//cross sectional area at point 2
9  rho=1.22//density of air  from ideal gas law
10 rho_m=827//density of medium,kg.m^3
11 g=9.8//gravitational acc.
12 h=0.08//manometer head,m
13 //from bernoulli equation
14 v2=sqrt(2*g*h*((rho_m/rho)-1))//velocity at point 2
15 v1=v2*(D2/D1)^2//velocity at point 1
16 q=v2*S2//volumatric flow rate
17 printf("\n vol.flow rate q=%f m^3/s",q);
18 //calculation of mach number from equation 15.1
19 T=293//temperature in k
20 c=20*sqrt(T)//speed of light at this temperature,m/s
21 M_a=v2/c//mach no.
22 printf("\n mach no. M_a =%f ",M_a);
23 //noting that M_a=0.095 < 0.3 , we can conclude that
        flow is incompressible//given
24 P1=130000 //absolute pressure at point 1,pa
25 //by using bernoulli eq for P2
26 P2=P1-rho*v2^2*(1-(D2/D1)^4)/2//pressure at point 2
27 printf("\n pressure at point 2=%f Pa",P2);
```

Scilab code Exa 22.9 friction loss in the conduit

```
1  clc;
2  //Example 22.9
3  //page no 305
4  printf("\n Example 22.9 page no 305\n\n");
5  //water is flowing from an elevated reservoir
        through a conduit to a turbine at a lower level
        and out of the turbine through a similar conduit
6  //refer to fig 22.2
7  //since the diameter of the conduit is the same at
        location 1 and 2 ,kinetic energy effects can be
        neglected and bernoulli eq. takes the form
8  //P/rho  + z(g/g_c)  -h_s + h_f  = 0
9  P1=30///pressure at point 1,psia
10 z1=300//height of point 1,ft
11 P2=18//pressure at point 2,psia
12 z2=-10//height of point 2,ft
13 rho=62.4//density
14 m_dot=3600//mass flow rate ,tons/hr
15 W_dot =1000//output at the shaft of turbine ,hp
16 neta=0.9//efficiency of turbine
17 h_s=W_dot*550*3600/(neta*m_dot*2000)//
18 printf("\n h_s =%f ft.lbf/lb",h_s);
19 //put this value in bernoulli eq.
20 h_f=(P2-P1)*144/rho + (z2-z1) -h_s//frictional loss
21 printf("\n frictional loss h_f=%f ft.lbf/lb",h_f)
```

Scilab code Exa 22.10 discharge and NPSH

```
1  clc;
2  //Example 22.10
3  //page no 306
4  printf("\n Example 22.10 page no 306\n\n");
5  //benzene is pumped from a large tank to a delivery
        station
6  //refer fig 22.3
```

```
 7  q=0.003//vol. flow rate,m^3/s
 8  //tank is at atmosphric pressure
 9  D=0.03//diameter of suction and discharge line,m
10  v_2=q/((%pi/4)*D^2)//discharge velocity,m/s
11  //since all diameters are same likewise velocities
        are same
12  v_3=v_2
13  g=9.807//grav. acc.
14  D_h=(v_3^2)/(2*g)//dynamic head
15  printf("\n dynamic head D_h=%f m",D_h);
16  z1=0//height at point 1,tank level
17  z2=1.8//height at point 3
18  //applying bernoulli's eq. between the top of the
        tank(open to theatomsphere)and the inlet to the
        pump(station3)
19  rho=865//density of benzene,kg/m^3
20  P3=101325-(z2+D_h)*(rho*g)//ptressure at point 3
21  printf("\n pressure at point 3 P3=%f Pa",P3);
22  P_v=26200//vapor pressure of benzene,Pa
23  NPSH = (P3 - P_v)/(rho*g) + D_h
24  printf("\n  NPSH=%f m",NPSH)
25  //the manufacturer NPSH is 8 m, which is greater
        than the calculated NPSH  of 7.06m,therfore, the
        suction point of pump must be lowered
26  //calculation of new pressure
27  NPSH_m=8//NPSH by manufacturer
28  P3_n_ab=8*(rho*g)-D_h*(rho*g) + P_v
29  printf("\n new pressure at point 3 P3_n_ab=%f Pa
        absolute",P3_n_ab);
30  P3_n_bz=-1.77//pressure in terms of benzene height,m
31  z3=-P3_n_bz -D_h//desired height of point 3
32  printf("\n height z3=%f m",z3);
```

Scilab code Exa 22.11 pump requirement in hp

```scilab
1  clc ;
2  // Example 22.11
3  // page no 308
4  printf ( " Example 22.11 page no 308\n\n" ) ;
5  // a storage tank on top of a building pumps 60 deg F
        water through an open pipe to it from a
       reservoir
6  q =1.36 // vol . flow rate , ft ^3/ s
7  D =0.333 // diameter of pipe , ft
8  S=%pi/4* D ^2 // cross sectional area , ft ^2
9  v2=q/S // flow velocity , ft /s
10 rho =62.37 // density of water , lb / ft ^3
11 meu =1.129*6.72 e -4 // viscosity of water
12 R_e = D * v2 * rho / meu // reynolds no .
13 printf ( "\n reynolds no . R_e=%f" , R_e ) ;
14 // from R_e we can conclude that flow is turbulent
15 k =0.0018 // roughness factor
16 K_r = k / D // relative roughness
17 f =0.0046 // friction factor
18 L =525 // length of pipe , ft
19 g_c =32.174 // grav . acc
20 h_fp =(4* f * L * v2 ^2) /( D *2* g_c ) // frictional loss due to
       the length of pipe
21 printf ( "\n frictional loss h_fp=%f ft . lbf / lb " , h_fp ) ;
22 // friction due to the fitings from table 18.1
23 K_ff_gate =2*0.11 // loss coeff . due to gates
24 K_ff_elbows =5*0.64 // loss coeff . due to elbows
25 // friction due to the sudden contraction is obtained
        from eq . 18.10 .
26 // note that D1/ D2 =0 , since the upstream diameter is
       singnificantly larger than the downward diameter
27 K_c =0.42 // coeff . of sudden contraction
28 K_e =1 // coeff . of sudden expansion
29 K_s = K_ff_gate + K_ff_elbows + K_e + K_c // sum of loss
       coeff .
30 h_f = K_s * v2 ^2/(2* g_c ) // friction losses due to fitting
       , expansion , contraction
31 h_f_total = h_fp + h_f // total frictional losses
```

```
32  printf("\n total frictional loss h_f_total=%f ft.lbf
       /lb",h_f_total);
33  v1=0
34  P_drop=0//pressure drop
35  z1=0//reservoir water level
36  z2=200//height of reservoir
37  W_s=(v2^2-v1^2)/(2*g_c)  + (z2-z1)  + h_f_total//
       power requirement
38  m_dot=q*rho//mass flow rate,lb/s
39  neta=0.6//efficiency of pump
40  W_dot_s=m_dot*W_s/(550*neta)//actual horsepower
       requirement
41  printf("\n W_dot_s=%f hp",W_dot_s);
```

Scilab code Exa 22.12 friction loss

```
1  clc;
2  //Example 22.12
3  //Page no 311
4  printf("Example 22.12 page no 311\n\n")
5  //turpentine is being moved  from a large storage
       tank to a blender through a 700 ft pipeline
6  rho=62.4//density
7  SG=0.872//specific gravity of terpentine
8  rho_t=SG*rho//density of turpentine
9  v=12.67//av. velocity of the turpentine in the line,
       ft/s
10 z1=20//height of top surface in the storage tank
       above floor level,ft
11 z2=90//height of discharge end of pipe,ft
12 neta=0.74//efficiency of pump
13 W_s=401.9//average energy delivered by pump,ft/lbf/
       lb
14 g_c=32.174//grav.acc
15 L=700//length of pipeline
```

```
16  //from bernoulli eq.
17  h_f= neta*W_s - v^2/(2*g_c) - (z2-z1)//frictional
        loss   if there is no pressure drop
18  printf("\n frictional loss h_f =%f ft.lbf/lb",h_f);
19  k_c=0.4//coeff. of contraction
20  k_e=0.9//coeff. of expansion
21  k_f=0.2//coeff. of bends and valve
22  //making equation (1) from the friction coeff. due to
        fittings between f and D,f=0.0293*D
23  //making another equation (2) from Reynolds number in
        terms D ,R_e=582250*D
24  //from trial and error method we get D
25  D=0.184//diameter
26  S=%pi*D^2/4//cross sectional area
27  S=0.0266
28  q=v*S//volumetric flow rate
29  printf("\n q=%f ft^3/s ",q);
30  m_dot=rho_t*q//mass flow rate
31  bhp =m_dot*W_s/(550*neta)//brake horse power
32  printf("\n brake horse power bhp=%f hp",bhp);
```

Scilab code Exa 22.13 friction loss and friction power loss per unit length of pipe

```
1  clc;
2  //Example 22.13
3  //page no 313
4  printf("Example 22.13 page no 313\n\n");
5  //hydrogen flows through a horizontal pipe
6  //properties of hydrogen at 20 deg C from table A.3
        in the appendix
7  rho=0.0838//density of hydrogen ,kg/m^3
8  meu=9.05e-6//viscosity ,kg/m.s
9  D=0.08//diameter of pipe ,m
10 L=1//unit length of pipe ,m
```

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```
11  q=0.0004//vol. flow rate ,m^3/s
12  S=.000503//cross sectional area
13  v=q/S//flow velocity ,m/s
14  m_dot=rho*q//mass flow rate ,kg/s
15  R_e=(D*v*rho/meu)//reynolds no.
16  printf("\n R_e reynolds no=%f ",R_e);
17  //since R_e is 593<2100, flow is laminar
18  //since the tube is horizontal z1=z2,calculation of
        pressure gradient(P/L)
19  P_grad= 128*meu*q/(%pi*D^4)//pressure gradient
20  printf("\n Pressure gradient P_grad=%f Pa/m",P_grad)
21  v_max=2*v//m/s
22  //calculation of fanning friction factor
23  //since the flow is laminar
24  f=16/R_e//fanning friction factor
25  printf("\n fanning friction factor f=%f ",f);
26  f_d=4*f//darcy friction factor
27  printf("\n darcy friction factor f_d=%f ",f_d);
28  g=9.807//grav. acc.
29  h_f=f_d*(L/D)*(v^2/(2*g))//friction loss
30  printf("\n friction loss h_f=%f m",h_f);
31  W_f = m_dot*g*h_f//friction power loss
32  printf("\n friction power loss W_f=%f W",W_f);
```

Scilab code Exa 22.14 average velocity of gasoline

```
1  clc;
2  //Example 22.14
3  //page no 315
4  printf("\Example 22.14 page no 315\n\n");
5  //gasoline is pump through a horizontal cast iron
        pipe
6  L=30//length of pipe
7  D=0.2//diameter of pipe ,m
8  S=(%pi/4)*D^2//cross sectional area
```

```
 9  q=0.3//vol. flow rate ,m^3/s
10  v=q/S//flow velocity ,m/s
11  rho=680//density of gasoline ,kg/m^3
12  meu=2.92e-4//viscosity of gasoline ,kg/m.s
13  R_e=D*v*rho/meu//reynolds no.
14  printf("\n reynolds no R_e=%f ",R_e);
15  //since R_e is >4000 flow is turbulent
16  k=0.00026//roughness factor from table 14.1 for cast
        iron ,m
17  K_r=k/D//relative roughness
18  f=0.00525//fanning friction factor from fig 14.2
19  //Note that the flow corresponds to complete
        turbulence in the rough pipe
20  g=9.807//gravitational acceleration
21  //h_f=4*f*(L/D)*(v^2/(2*g))//head loss
22  h_f=14.647
23  //applying bernoulli equation to the fluid in the
        pipe
24  //in this case the pipe is horizontal (z1=z2) with
        constant diameter (v1=v2) and no shaft head (h_s
        =0)
25  //first convert the friction head to a pressure
        difference
26  P_diff=rho*g*h_f//pressure difference
27  P_diff= 97.68*10^3//after round off
28  W_s_id=q*P_diff//ideal shaft work
29  printf("\n ideal shaft work W_s_id=%f W ",W_s_id);
30  neta=0.8//efficiency of pump
31  W_s_ac=W_s_id/neta//actual shaft work
32  printf("\n actual shaft work W_s_ac=%f W",W_s_ac);
33  f_s=0.009//friction factor smooth
34  f_r=0.021//friction factor roughnes
35  k=f_r/f_s
36  f_inc=100*(k-1)//percentage increment in f due to
        roughness
37  printf("\n f_inc=%f ",f_inc);
```

Scilab code Exa 22.15 average velocity of the benzene

```scilab
1  clc;
2  //Example 22.15
3  //page no 316
4  printf("\n Example 22.15 page no 316\n\n")
5  //liquid benzene flows through a smooth horizontal
       iron pipe
6  D=2.3//diameter of pipe ,m
7  L=146.304//length of pipe ,m
8  S=(%pi/4)*D^2//cross sectional area ,m^2
9  q=4000//vol. flow rate ,gal/min
10 v=q/(S*264.17*60)//flow velocity
11 printf("\n flow velocity v=%f m/s",v);
12 rho=899//density of benzene
13 meu=0.0008//viscosity of benzene ,kg/m.s
14 R_e = D*v*rho/meu//reynolds no
15 printf("\n reynolds no R_e=%f ",R_e);
16 //since the reynolds number falls in the turbulent
       regime ,determine the fanning friction factor from
        fig. 14.2
17 f=0.0032//fanning friction factor
18 // calculation of pressure drop with the assumption
       of no height and velocity change , and no pump
       work
19 //since only frictional losses are to be considered
20 //applying eq. 14.3
21 P_drop = 4*f*(L/D)*(v^2/2)*rho//pressure drop
22 printf("\n pressure drop P_drop=%f Pa",P_drop);
23 W_dot_f=q*P_drop/(264.17*60)//friction power loss
24 printf("\n friction power loss W_dot_f=%f W",W_dot_f
       );
```

Scilab code Exa 22.16 steam flow rate

```
1  clc;
2  //Example 22.16
3  //page no 317
4  printf(" \n Example 22.16 page no 317\n\n");
5  //a power plant employs steam to generate power
6  //adiabatic conditions
7  z1=0//steam vertical position at inlet,ft
8  z2=-20//steam vertical position at outlet,ft
9  v1=120//steam velocity at inlet,ft/s
10 v2=330//steam velocity at outlet,ft/s
11 H1=1505.4//steam enthalpy at inlet
12 H2=940//steam enthalpy at outlet
13 Q=0//for adiabatic conditions
14 g_c=32.174//grav .acc
15 //applying energy equation
16 W_s=-(z2/778) - v2^2/(2*g_c*778) - H2  +z1 + v1
       ^2/(2*g_c*778) + H1//work extracted from system
17 printf(" \n work extracted from the system W_s=%f Btu
       /lb ",W_s);
18 m_dot=450000//mass flow rate ,lb/h
19 W_dot_s=m_dot*W_s//total power generated by the
       turbine
20 printf(" \n W_dot_s =%f Btu/h",W_dot_s);//approx
       calculation in book
21 W_hp=W_dot_s*3.927e-4//power generated in horsepower
       hp
22 printf(" \n power generated W_hp=%f hp",W_hp);//
       approx calculation in book
```

Chapter 23

particle dynamics

Scilab code Exa 23.1 aerodynamic diameter

```
1  clc;
2  //Example 23.1 page no 323
3  printf("Example 23.1 page no 323\n\n");
4  //calculation of aerodynamic diameter for the
       following particles
5  d_es=1.4//equivalent dia of solid sphere,micrometer
6  sg_s=2//specific gravity of solid sphere
7  d_eh=2.8//equivalent diameter of hollow sphere,
       mirometer
8  sg_h=0.51//specific gravity of hollow sphere
9  d_pa1=d_es*sqrt(sg_s)//aerodynamic dia for solid
       sphere
10 d_pa2=round(d_eh*sqrt(sg_h))//aerodynamic dia for
       hollow sphere
11 printf("\n d_pa1=%f micron\nd_pa2=%f micron",d_pa1,
       d_pa2);
```

Scilab code Exa 23.2 aerodynamic diameter

```
1  clc;
2  //Example 23.2 page no 323
3  printf("Example 23.2 page no 323\n\n");
4  //calculation of aerodynamic diameter of irregular
       saped sphere
5  d_e=1.3//eq. diameter ,micron
6  sg=2.35
7  d_pa=d_e*sqrt(sg)//aerodynamic diameter
8  printf("\n aerodynamic diameter d_pa=%f micron",d_pa
       );
```

Scilab code Exa 23.3 cunningham correction factor

```
1  clc;
2  //Example 23.3 page no 335
3  printf("Example 23.3 page no 335\n\n");
4  //calculation of cunningham correction factor
5  dp=0.4//particle diameter
6  lemda=6.53e-2
7  A=1.257 + 0.40*exp(-1.10*dp/(2*lemda))
8  C= 1 + 2*A*lemda/dp//cunningham correction factor(
       CCF)
9  printf("CCF C=%f ",C);
```

Scilab code Exa 23.4 particle terminal velocity

```
1  clc;
2  //Example 23.4
3  //page no 336
4  printf("Example 23.4 page no 336\n\n");
5  //three different diameter sized fly ash particls
       settle through air
```

```
6  //we have to calculate the particle terminal
      velocity and determine how far each will fall in
      30 seconds
7  //assume the particles are speherical
8  SG=2.31//specific gravity of fly ash
9  rho_w=62.4//density of water
10 rho_p=SG*rho_w//density of particles
11 //properties of air
12 R=0.7302//gas constant
13 T=698//temperature,R
14 P=1//pressure ,atm
15 Mw=29//mol. wt of air
16 rho_a=P*Mw/(R*T)//density of air,lb/ft^3
17 meu=1.41e-5//viscosity of air,lb/ft.s
18 g=32.174//grav. acc
19 D1=0.4//diameter of particle 1,microns
20 D2=40//diameter of particle 2,microns
21 D3=400//diameter of particle 3,microns
22 K1=(D1/(25400*12))*(g*rho_p*rho_a/(meu^2))^(1/3)//
      dimensionless constant for particle 1
23 K2=(D2/(25400*12))*(g*rho_p*rho_a/(meu^2))^(1/3)//
      dimensionless constant for particle 2
24 K3=(D3/(25400*12))*(g*rho_p*rho_a/(meu^2))^(1/3)//
      dimensionless constant for particle 3
25 printf("\n dimensionless constant K1=%f \n K2=%f \n
      K3=%f ",K1,K2,K3);
26 //first we determine which fluid particle dynamic
      law applies for the above values of K
27 //for particle 1,strokes law applies
28 //for particle 2,strokes law applies
29 //for particle 3,intermediate law applies
30 //terminal settling velocity for each particle
31 v1=(D1/(25400*12))^2*g*rho_p/(18*meu)
32 printf("\n terminal settling velocity for particle 1
       v1=%f ft/s",v1);
33 v2=(D2/(25400*12))^2*g*rho_p/(18*meu)
34 printf("\n terminal settling velocity v2=%f ft/s",v2
      );
```

```
35  v3=(D3/(25400*12))^1.14*0.153*g^0.71*rho_p^0.71/(
       rho_a^0.29*meu^0.43)
36  printf("\n terminal settling velocity v3=%f ft/s ",
       v3);
37  //calculation of how far x,the fly ash particles
       will fall in 30 seconds
38  t=30//time,sec
39  x2=v2*t//distance travel by 2 particle
40  x3=v3*t//distance travel by 3 particle
41  printf("\n distance by 2 particle x2=%f ft\n
       distance by 3 particle x3=%f ft",x2,x3);
42  //for 1 particle K1 and v1 value are without the CCF
       .With the correction factor lemda=6.53e-8,gives
43  lemda=6.53e-8//correction factor
44  y=-1.10*(D1/(25400*12))/(2*lemda)
45  A =1.257 + 0.40*exp(y)
46  C=1 + 2*A*lemda/(D1/(25400*12))//cunningham
       correction factor(ccf)
47  //now equation 23.36 can be employed
48  v1_corrected=v1*C//corrected velocity of 1 particle
49  x1=v1_corrected*t//distance travel by 1 particle
50  printf("\n distance travel by 1 particle x1=%f ft",
       x1);
```

Scilab code Exa 23.5 size of fly ash particle

```
1  clc;
2  //Example 23.5
3  //page no 338
4  printf("\n Example 23.5 page no 338\n\n");
5  //refer to example 23.5
6  //we have to calculate size of a flyash particle
       that will settle with a velocity of 1.384 ft/s
7  SG=2.31//specific gravity of fly ash
8  rho_w=62.4//density of water
```

```
9  rho_p=SG*rho_w//density of particles
10 //properties of air
11 R=0.7302//gas constant
12 T=698//temperature,R
13 P=1//pressure ,atm
14 Mw=29//mol. wt of air
15 rho_a=P*Mw/(R*T)//density of air,lb/ft^3
16 meu=1.41e-5//viscosity of air,lb/ft.s
17 g=32.174//grav. acc
18 v=1.384//velocity at which particle settle down,ft/s
19 W= v^3*rho_a^2/(g*rho_p*meu)//dimensionless constant
20 printf("\n dimensionless constant W=%f ",W);
21 //since W < 0.2222 stokes' law applies
22 D_p=sqrt(18*meu*v/(g*rho_p))//diameter of particle
23 printf("\n diameter of particle D_p=%f ft",D_p);
```

Scilab code Exa 23.7 average height of soap particles

```
1  clc;
2  //Example 23.7
3  //page no 340
4  printf("\n Example 23.7 page no 340\n\n");
5  // In a plant manufacturing ivory soap detergent
       explodes one windy day
6  //we have to calculate the distance from the plant
       where the soap particles will start to deposit
       and where they will cease to deposit
7  //the smallest particle wll travel the greatest
       distance while the largest will travel the least
       distance
8  //for the minimumdistance ,we use largest particle
9  D_l=3.28e-3//largest diameter,ft
10 g=32.174//grav. acc.
11 SG=0.8//specific gravity of soap particle
12 rho_w=62.4
```

```
13  rho_p=SG*rho_w//density of particle
14  rho_a=0.0752//density of given atmosphere,lb/ft^3
15  meu=1.18e-5//viscosity
16  K_l = D_l*(g*(rho_p-rho_a)*rho_p/(meu^2))^(1/3)//
        dimensionless constant
17  printf("\n dimensionless constant K_l=%f ",K_l);
18  //value of K indicates the intermediate range
        applies
19  //the settling velocity is given by
20  v_l=0.153*g^0.71*D_l^1.14*rho_p^0.71/(meu^0.43*rho_a
        ^0.29)
21  printf("\n settling velocity v_l=%f ft/s",v_l);
22  H=400//vertical height blowen by particle,ft
23  t_l=H/v_l//descent time
24  v_w=20//wind velocity in miles/h
25  L=t_l*v_w*(5280/3600)//horizontal distance travelled
         by particles
26  printf("\n descent time t_l=%f second\n horizontal
        distance L=%f ft",t_l,L);
27  //for the minimum distance we use smallest particle
28  D_s=6.89e-6//diameter of smallest particle,ft
29  K_s=D_s*(g*(rho_p-rho_a)*rho_a/(meu^2))^(1/3)
30  printf("\n dimensionless constant K_s=%f ",K_s);
31  //velocity is in the stokes regime and is given by
32  v_s=g*D_s^2*rho_p/(18*meu)
33  printf("\n settling velocity v_s=%f ft/s",v_s);
34  t_s=H/v_s//descent time
35  L_s=t_s*v_w*(5280/3600)//horizontal distance
        travelled
36  printf("\n descent time t_s=%f s\nhorizontal
        distance travelled by smallest particle L_s=%f ft
        ",t_s,L_s);
37  m=100*2000//mass of particles
38  V_act=m/rho_p//actual volume of particles
39  e=0.5//void fraction
40  V_b=V_act/e//bulk volume
41  printf("\ actual volume V_act=%f ft^3\nbulk volume
        V_b=%f ",V_act,V_b);
```

```
42 L_d=L_s-L//length of drop area
43 printf("\n L_d=%f ",L_d);
44 W=100//width ,ft
45 A_d=L_d*W//deposition area
46 H_d=V_b/A_d//deposition height
47 printf("\n deposition height H_d=%f ft",H_d);
48 //deposition height can be ,at bestt, described asa
       sprinkling
```

Scilab code Exa 23.8 reynolds number and terminal velocity

```
1 clc;
2 //Example 23.8
3 //page no 342
4 printf("Example 23.8 page no 342\n\n");
5 //a small sphere is observed to fall through caster
      oil
6 v_t=0.042//terminal velocity of particle
7 meu_f=0.9//viscosity of oil
8 rho_f=970//density of oil
9 g=9.807//grav. acc.
10 D_p=0.006//diameter of particle
11 rho_p=(18*meu_f*v_t)/(g*D_p^2) + rho_f
12 printf("\n density of particle rho_p=%f kg/m^3",
      rho_p);
13 neu_f=9.28e-4//dynamic viscosity of fluid
14 R_e=D_p*v_t/neu_f//reynolds no
15 printf("\n reynolds no R_e=%f ",R_e);
16 //since R_e < 0.3
17 //calculation of the settling criterion factor ,K
18 K=D_p*(g*rho_f*(rho_p-rho_f)/(meu_f^2))^(1/3)//the
      settling criterion factor
19 printf("\n K=%f ",K);
20 //since K <3.3, stokes law applies
21 //the drag coeff. C_d
```

```
22  C_d =24/ R_e
23  printf (" \n drag coeff C_d=%f ",C_d);
24  F_d =3*%pi * meu_f * D_p * v_t // drag force
25  printf (" \n drag force F_d=%f N",F_d);
26  F_b =(%pi /6) * D_p ^3* rho_f *g // buoyancy force
27  printf (" \n buoyancy force F_b=%f N",F_b);
28  // Consider the case when same sphere is dropped in
        water
29  rho_w =1000 // density of water , kg /m^3
30  meu_w =0.001 // viscosity of water , kg /m. s
31  // the particle will move faster because of the lower
        viscosity of water , stokes law will almost
        definietly not apply
32  K_w = D_p *( g * rho_w *( rho_p - rho_w )/( meu_w ^2)) ^(1/3) // the
        settling criterion factor
33  printf (" \n k_w settling factor =%f ",K_w);
34  // since K_w = 158 > 43.6 , the flow is in the Newton 's
        law regime
35  // employ eq. 23.31 but include the ( buoyant ) density
        ratio factor
36  v_t_w =1.75* sqrt (( rho_p - rho_w )/( rho_w )*g* D_p ) //
        terminal velocity
37  printf (" \n terminal velocity in water v_t_w=%f m/s",
        v_t_w );
```

Scilab code Exa 23.9 drag force

```
1  clc ;
2  // Example 23.9
3  // page no 344
4  printf (" Example 23.9 page no 344\n\n");
5  // the bottom of a ship , moving in water
6  rho =1000 // density of water
7  v =12 // velocity of boat ,m/s
8  L =20 // length ,m
```

```
 9  W=5//width ,m
10  meu=1e-3//viscosity
11  R_e=rho*v*L/meu//reynolds no
12  printf("Reynolds no R_e=%f ",R_e);
13  //from reynolds no  flow is turbulent
14  C_d=0.031/(R_e^(1/7))//coeff. discharge\
15  printf("\ncoeff. discharge C_d=%f ",C_d);
16  //calculation of the drag on area LW
17  F_d=(1/2)*C_d*rho*v^2*L*W//drag force
18  printf("\n drag force F_d=%f N",F_d);
```

Chapter 24

sedimentation centrifugation and flotation

Scilab code Exa 24.1 terminal velocity and effective viscosity

```
1  clc;
2  //Example 24.1
3  //page no 350
4  printf("Example 24.1 page no 350\n\n");
5  //glass sphere are settling in water at 20 deg C
6  //the slurry contains 60 wt% solids
7  // start by assuming a basis of 100 kg of slurry
8  m_f=40//mass of fluid,kg
9  rho_f=998//density of water,kg/m^3
10 V_f=m_f/rho_f//volume of the fluid,m^3
11 m_s=60//mass of solid,kg
12 rho_p=2467//density of glass,kg/m^3
13 V_s=m_s/rho_p//volume of glass,m^3
14 V = V_f + V_s//total volume,m^3
15 v_frac_f = V_f/V//volume fraction for the fluid
       particles
16 printf("\n volume fraction fluid particles v_frac_f
       =%f ",v_frac_f);
17 v_frac_p=1-v_frac_f//volume fraction for the glass
```

```
                particles
18  printf("\n volume fraction for the glass particles
        v_frac_p=%f  ",v_frac_p);
19  rho_m=round(v_frac_f*rho_f  + v_frac_p*rho_p)//bulk
        density of slurry
20  printf("\n bulk density of slurry rho_m=%f kg/m^3 ",
        rho_m);
21  b=10^(1.82*(1-v_frac_f))//dimensionless correction
        factor
22  g=9.807//gravitational acc.,m/s^2
23  D_p=0.0001554//diameter of particle ,m
24  meu_f=0.001//viscosity of fluid
25  v_t = g*D_p^2*(rho_p-rho_f)*v_frac_f^2/(18*meu_f*b)
        //terminal velocity
26  printf("\n terminal velocity v_t=%f m/s",v_t);
27  meu_m = meu_f*b//effective mixture viscosity
28  printf("\n effective mixture viscosity meu_m=%f kg/m
        .s",meu_m);
```

Scilab code Exa 24.2 reynolds number

```
1  clc;
2  //Example 24.2
3  //page no 352
4  printf("Example 24.2 page no 352\n\n");
5  //refer to example 24.1
6  m_f=40//mass of fluid ,kg
7  rho_f=998//density of water ,kg/m^3
8  V_f=m_f/rho_f//volume of the fluid ,m^3
9  m_s=60//mass of solid ,kg
10 rho_p=2467//density of glass ,kg/m^3
11 V_s=m_s/rho_p//volume of glass ,m^3
12 V = V_f + V_s//total volume ,m^3
13 v_frac_f = V_f/V//volume fraction for the fluid
        particles
```

```scilab
14 printf("\n volume fraction fluid particles v_frac_f
       =%f ",v_frac_f);
15 v_frac_p=1-v_frac_f//volume fraction for the glass
        particles
16 printf("\n volume fraction for the glass particles
       v_frac_p=%f ",v_frac_p);
17 rho_m=round(v_frac_f*rho_f + v_frac_p*rho_p)//bulk
        density of slurry
18 printf("\n bulk density of slurry rho_m=%f kg/m^3 ",
       rho_m);
19 b=10^(1.82*(1-v_frac_f))//dimensionless correction
        factor
20 g=9.807//gravitational acc.,m/s^2
21 D_p=0.0001554//diameter of particle ,m
22 meu_f=0.001//viscosity of fluid
23 v_t = g*D_p^2*(rho_p-rho_f)*v_frac_f^2/(18*meu_f*b)
       //terminal velocity
24 printf("\n terminal velocity v_t=%f m/s",v_t);
25 meu_m = meu_f*b//effective mixture viscosity
26 printf("\n effective mixture viscosity meu_m=%f kg/m
        .s",meu_m);
27 R_e=rho_m*v_t*D_p/(meu_m*v_frac_f)//reynolds no.
28 printf("\n reynolds no R_e=%f ",R_e);
```

Scilab code Exa 2.3 minimum size of charcoal

```scilab
1 clc;
2 //Example 24.3
3 //page no  352
4 printf("Example 24.3 page no 352\n\n");
5 //classification of small speherical particles of
        charcoal with a specific gravity of 2.2
6 //the particles are falling in a vertical tower
        against a rising current of air
7 //we have to calculate the minimum size of charcoal
```

```
        that  will  settle  down  to  the  bottom  of  the  tower
 8  rho =0.075// density  of  air , lb / ft ^3
 9  meu =1.23 e -5// viscosity  of  air , lb / ft . s
10  // assume  stokes  law  to  apply
11  SG =2.2// specific  gravity  of  charcoal
12  rho_w =62.4// density  of  water
13  rho_p = SG * rho_w // density  of  charcoal
14  v =15// velocity  of  air
15  g =32.2// grav .  acc
16  D_p1 =(18* meu * v /( g * rho_p ))^0.5
17  K1 = D_p1 *( g * rho * rho_p / meu ^2)^(1/3)// settling  factor
18  printf (" \n  settling  factor  K1=%f  ",K1);
19  // from  value  of  K, stokes  law  does  not  apply
20  // therefore , assume  Intermediate  range  law  applies
21  D_p =(( v * rho ^0.29* meu ^0.43)/(0.153*( g * rho_p )^0.71))
       ^(1/1.14)
22  printf (" \n  particle  diameter= D_p=%f  ft  ",D_p);
23  K_n =( D_p / D_p1 )* K1
24  printf (" \n  final  settling  factor  K_n=%f",K_n)
25  // since  the  result  is  correct  for  the  intermediate
       range
```

Scilab code Exa 24.4 number of Gs

```
 1  clc ;
 2  // Exmple  24.4
 3  // page  no  354
 4  printf (" Example  24.4  page  no  354\n\n");
 5  //a  particle  is  spining  in  a  3  inch  ID  centrifuge
 6  r =3/12// radius  of  centrifuge , ft
 7  omega =30// rotational  speed , rad / s
 8  g =32.2
 9  G = round ( r * omega ^2/ g )
10  printf (" \n  G=%f  ",G);
```

Scilab code Exa 24.5 angular velocity

```
1  clc;
2  //Example 24.5
3  //page no 357
4  printf("Example 24.5 page no 357\n\n");
5  //a circular cylinder filled with water is rotated a
        uniform ,steady angular speed about it's central
        axis in rigid body motion
6  //since the cylinder is full the water will spill
        the moment the cylinder starts to spin ,spilling
        occur when omega > 0 rpm
7  // to determine the angular speed for 1/3 of the
        water to spill , consider the cylinder at rest
        when 1/3 of the water has already beem spilled
8  g=32.174//grav. acc
9  R = 0.25 //radius   of cylinder
10 z_st=2/3//the stationary height , ft
11 h = 2*(1-z_st)//increase in height is h/2,ft
12 omega=sqrt(4*g*(h/2)/R^2)
13 printf("\n omega =%f rad/s",omega);
```

Scilab code Exa 24.6 equatio describing pressure

```
1  clc;
2  //Example 26.6
3  //page no 392
4  printf("Example 26.6 page no 392\n\n");
5  //a bed of pulverized is to be fluidized with liquid
        oil
6  D=4//diameter of bed ,ft
7  d_p=0.00137//particle diameter ,ft
```

```
 8  rho_s =84// coal  particle  density  , lb / ft ^3
 9  rho_f =55// oil  density , lb / ft ^3
10  e_mf =0.38// void  fraction
11  L_mf =8// bed  height  at  minimum  fluidization , ft
12  P_drop =( rho_s - rho_f )*(1 - e_mf )* L_mf  + rho_f * L_mf
13  printf ("\ npressure  drop  P_drop=%f  psf ", P_drop );
```

Scilab code Exa 24.7 angular speed and film thickness

```
 1  clc ;
 2  // Example  24.7
 3  // page  no  358
 4  printf (" Example  24.7  page  no  358\n\n");
 5  // a  cylindrical  cup  open  to  the  atmosphere  is  filled
        with  liquid  to  a  height  of  7  cm
 6  // rotated  around  it 's  axis
 7  // calculation  of  an  angular  velocity  that  will  cause
        the  liquid  to  start  spilling
 8  h=0.03// height ,m
 9  R=0.03// radius ,cm
10  // applying  eq .  24.22
11  g=9.807// grav .  acc
12  omega = sqrt (2* h*g/(R^2))
13  omega =36.2// printing  mistake  in  book
14  // calculation  of  pressure  at  point  A  and  B  that  is
        P_a  and  P_b
15  z=.1// liquid  height  above  point  A  and  B,m
16  rho =1010// density  of  liquid , kg / m^3
17  P_a  =  rho *g*z
18  P_b=P_a// from  symmetry  P_a  =  P_b
19  printf ("\n  pressure  P_a=%f  Pa_gauge\n  pressure  P_b=
        %f  Pa_gauge ", P_a , P_b );
20  z_c =0.04// liquid  height  above  point  c,m
21  P_c= rho *g* z_c // pressure  at  point  c
22  printf ("\n  pressure  P_c=%f  Pa_gauge ", P_c );
```

```
23  //to  obtain  the  film  thicknes , we  have  to  find  the
        original  height
24  z_l=0.07//liquid  height  ,m
25  h_o=z_l-z_c//original  height
26  r  =  100*sqrt(2*h_o*g/(omega^2))//100  for  centimeter
27  printf("\n  r=%fcm  ",r);
28  R=3
29  t_f=R-r//thikness  of  film
30  printf("\n  thickness  film  t_f=%f m",t_f);//printing
        mistake  in  book
```

Scilab code Exa 24.8 velocity to obtain pure galena

```
1  clc;
2  //Example  24.8
3  //page  no  360
4  printf("Example  24.7  page  no  358\n\n");
5  //It  is  desired  to  separate  quartz  particles   from
        galena  particles
6  SG_q  =  2.65//specific  gravity  of  quartz  particle
7  SG_g=7.5//specific  gravity  of  galena  particles
8  rho_f=1000//density  of  water
9  rho_q=SG_q*rho_f//density  of  quartz  paticles
10  rho_g=SG_g*rho_f//density  of  galena  particle
11  //calculation  of  the  settling  veloctiy  of  the
        largest  quartz  particle  with  a  diameter
12  D_q=9e-5//diameter  of  largest  particle  of  quartz
13  g=9.807//grav.  acc
14  meu_f=0.001//viscosity  of  water
15  K_q  =  D_q*(g*(rho_q-rho_f)*rho_f/(meu_f^2))^(1/3)//
        settling  factor
16  printf("\n  settling  factor  K_q=%f  ",K_q);
17  //since  K  =2.27<3.3,stokes  flow  regime  applies  ,from
        the  equation  23.36
18  v_q=g*D_q^2*(rho_q-rho_f)/(18*meu_f)//settling
```

```
           velocity  of  thelargest  quartz  particle
19  printf("\n  settling  velocity  (quartz)  v_q=%f m/s",
       v_q);
20  //calculation  of  the  settling  velocity  of  the
        smallest  galena  partilce
21  d_g=4e-5//diameter  of  smallest  galena  particle
22  K_g = d_g*(g*(rho_g-rho_f)*rho_f/(meu_f^2))^(1/3)//
        settling  factor
23  printf("\n  settling  factor  K_g=%f ",K_g);
24  //since  K = 1.6<3.3,stokes  flow  regime  again  applies
25  v_g=g*d_g^2*(rho_g-rho_f)/(18*meu_f)//settling
        velocity  for  galena  particles
26  printf("\n  setling  velocity  v_g=%f m/s",v_g);
27  //to   obtain  pure  galena  the  upward  velociy  of  the
        water  must  be  equal  to  or  greater  than  the
        settling  veloctiy  of  the  quartz  particle
28  v_w=v_q//velocity  of  water
29  printf("\n  water  velocity  v_w=%f m/s",v_w);
```

Scilab code Exa 24.9 size range of galena particle

```
1  clc;
2  //Example  24.9
3  //page  no  361
4  printf("\n  Example  24.9  page  no  361\n\n");
5  //refer  to  illustrative  example  24.8
6  //we  have  to  determine  the  size  range  of  the  galena
        in  the  top  product
7  //to  determine  the  size  range  of  the  galena  product
        ,calculate  the  galena  particle  size  that  has  a
        settling  velocity  equal  to  water  velocity
8  //assume  stokes  law  applies
9  v_w=0.0073//velocity  of  water
10  v_q=v_w//velocity  of  quartz  particles
11  SG_q = 2.65//specific  gravity  of  quartz  particle
```

```
12  SG_g=7.5//specific gravity of galena particles
13  rho_f=1000//density of water
14  rho_q=SG_q*rho_f//density of quartz paticles
15  rho_g=SG_g*rho_f//density of galena particle
16  g=9.807//grav. acc
17  meu_f=0.001//viscosity of water
18  D = sqrt(18*meu_f*v_q/(g*(rho_g-rho_f)))
19  printf("\n diameter D =%f m",D);
20  //check on the validity of stokes law by calculating
        the K factor
21  K = D*(g*(rho_g-rho_f)*rho_f/(meu_f^2))^(1/3)//
        settling factor
22  printf("\n settling factor K=%f ",K);
23  //since K =1.82<3.3 , the flow is in the stokes law
        range
```

Scilab code Exa 24.10 maximum diameter

```
1   clc;
2   //Example 24.10
3   //page no 362
4   printf("Example 24.10 page no 362\n\n");
5   //air is being dried by bubbling through
        concentrated NaOH
6   q=4/60//flow rate of air,ft^3/min
7   D=2.5/12//diameter of tube
8   S=(%pi/4)*D^2//cross sectional area
9   v=q/S//velocity of air,ft/s
10  meu=1.23e-5//viscosity of NaOH
11  rho=0.0775//density of air
12  g=32.2//grav. acc.
13  SG=1.34//specific gravity of NaOH
14  rho_w=62.4//density of water
15  rho_p=SG*rho_w//density of NaOH
16  D_p_max = [v*(rho^0.29)*(meu^0.43)/(0.153*(g*rho_p)
```

```
        ^0.71)]^(1/1.14)//assuming that the intermediate
        range applies ,maximum diamter of particle
17  printf("\nD_p_max=%f ",D_p_max);
18  //settling factor
19  K=D_p_max*(g*rho*rho_p/(meu^2))^(1/3)
20  printf("\n settling factor K=%f ",K);
21  //tus result for D_p_max is correct
```

Chapter 25

porous media and packed beds

Scilab code Exa 25.1 effective particle diameter

```
1  clc ;
2  // Example  25.1
3  // page  no  370
4  printf ( " Example  25.1  page  no  370\n\n" ) ;
5  // calculation  of  efffective  particle  diameter  for  a
       set  of  packing
6  V =0.2 // packing  volume
7  n =100 // no .  of  particle  assume
8  V_p = V *1000/ n // the  volume  of  single  particle , mm ^2//
9  S_p =2.18 // average  surface  area  of  particle , mm ^2
10  a_p = S_p / V_p // specific  surface  area  of  particle  ,( mm )
       ^ -1
11  D_p  =  6/ a_p // effective  diameter  of  particle , mm
12  printf ( " \n  effective  partcle  diameter  D_p=%f  mm  " ,
       D_p ) ;
```

Scilab code Exa 25.2 reynolds number

133

```
1  clc;
2  //Example 25.2
3  //page no 371
4  printf("Example 25.2 page no 371\n\n");
5  //refer to example 25.1
6  V=0.2//packing volume
7  n=100//no. of particle assume
8  V_p=V*1000/n//the volume of single particle ,mm^2//
9  S_p=2.18//average surface area of particle ,mm^2
10 a_p=S_p/V_p//specific surface area of particle ,(mm)
        ^-1
11 D_p = 6/a_p//effective diameter of particle ,mm
12 D_p=5.50//round off value for accurate answer
13 rho=0.235//density of fluid ,g/cm^3
14 meu=2e-4//viscosity ,g/cm.s
15 v=10//interstitial velocity ,cm
16 R_e=round((D_p/v)*rho*v/meu)//reynolds no
17 printf("\n Reynolds no R_e=%f ",R_e);
18 //from R_e value we can conclude that the flow of
        fluid would be in the turbulent region
```

Scilab code Exa 25.3 particle specific surface and effective diameter

```
1  clc;
2  //Example 25.3
3  //page no 372
4  printf("Example 25.3 page no 372\n\n");
5  //air flows across a packed bed
6  d_p=1.5//diamter of cylinderical particles ,cm
7  h=2.5//height ,cm
8  V_p=%pi*d_p^2*h/(4)//volume of the cylinderical
        particles
9  S_p=%pi*d_p*h + 2*(%pi*d_p^2/4)//cylinderical
        particle surface area ,cm^2
10 a_p=S_p/V_p//particle specific surface
```

```
11 printf("\n particle specific surface a_p =%f cm^-1 "
      ,a_p);
12 d_p_e=6/a_p//effective particle diameter
13 printf("\n effective particle diameter d_p_e=%f cm",
      d_p_e);
```

Scilab code Exa 25.4 specific surface and effective particle diameter

```
1 clc;
2 //Example 25.4
3 //page no 373
4 printf("\nExample 25.4 page no 373\n\n");
5 //a absorber bed consists of cube particles
6 L=3/4//edge length of particle
7 V_p=L^3//volume of particle
8 S_p=6*L^2//surface area of particle
9 a_p=6*L^2/L^3//specific particle surface area
10 printf("\n specific particle surface area a_p=%f in
      ^-1",a_p);
11 d_p_e = L//effective particle diameter = edge length
12 printf("\n effective particle diameter d_p_e=%f in",
      d_p_e)
```

Scilab code Exa 25.5 a catalyst tower

```
1 clc;
2 //Example 25.5
3 //page no 373
4 printf("Example 25.5 page no 373\n\n");
5 //gas(propane) flows through a catalyst tower
6 Mw=44.1//molecular weight
7 P=4320//pressre at the bottom of the catalyst bed,
      psf
```

```
8   R=10.73//gas constant
9   T=960//temperature, Rankine
10  rho=P*Mw/(R*T*144)//density of propane
11  L=50//height of bed, ft
12  D=20//diameter of bed, ft
13  V=%pi*D^2*L/4//bed volume
14  theta=10//contact time, s
15  e=0.4//bed porosity
16  q=V*e/theta//volumetric flow rate
17  v_s=4*q/(%pi*D^2)//superficial velocity
18  printf("\n superficial velocity v_s=%f ft/s",v_s);
19  v_i=v_s/e//interstitial velocity
20  printf("\n interstitial velocity v_i=%f ft/s",v_i);
21  rho_s=77.28//ultimate density(spheres )
22  rho_b=(1-e)*rho_s//bulk density
23  printf("\n bulk density rho_b=%f lb/ft^3",rho_b);
24  d_p=0.0833//diameter of particles
25  a_p=6/d_p//specific surface area
26  printf("\n specific surface area a_p=%f ft^-1",a_p);
27  a_b=a_p*(1-e)//bed specific surface
28  printf("\n bed specific surface a_b=%f ft^-1",a_b)
```

Scilab code Exa 25.6 hydraulic radius and hydraulic diameter

```
1   clc;
2   //Example 25.6
3   //page no 375
4   printf("Example 25.6 page no 375\n\n");
5   //refer to example 25.5
6   d_p=0.0833//diameter of particles, ft
7   e=0.4//bed porosity
8   D_h=2/3*(e/(1-e))*d_p//hydraulic diameter
9   r_h=D_h/4//hydrulic radius
10  printf("\n hydraulic diameter D_h=%f ft\n hydrulic
        radius r_h=%f ft",D_h,r_h);
```

Chapter 26

fluidization

Scilab code Exa 26.2 water softner unit

```
1  clc ;
2  //Example 26.2
3  //page no 382
4  printf ("Example 26.2 page no 384\n\n");
5  //a water softner unit consists of a large diameter
      tank ,the bottom of tank is connected to a
      vertical ion exchange pipe
6  h_f =1.25// total fluid height
7  h_l = h_f
8  g=32.174// grav. acc
9  e =0.25// bed porosity
10 d_p =0.00417// ion exchange resin particle diameter ,ft
11 L=1// pipe length , ft
12 //assume turbulent flow ,apply burke purmer equation
13 v_s =sqrt (g*h_f*e^3*d_p /(1.75*(1 -e)*L))// superficial
      velocity
14 printf ("\n superficial velocity v_s=%f ft/s",v_s);
15 meu =6.76 e -4// absolute viscosity of water
16 rho =62.4// density of water
17 //check for turbulent flow
18 R_e = d_p*v_s*rho /((1 -e)*meu)
```

```
19  printf("\n R_e=%f",R_e);
20  //since reynold no is low the calculation is not
        valid
21  //assume laminar flow and use Blake−Kozeny equation
        26.9
22  v_s_t=rho*g*h_f*e^3*d_p^2/(150*meu*((1-e)^2)*L)//
        superficial velocity
23  printf("\n superficial velocity v_s_t=%f ft/s",v_s_t
        );
24   //check the porous medium reynolds no
25   R_e_t=v_s_t*d_p*rho/((1-e)*meu)
26   printf("\n reynolds no R_e_t=%f ",R_e_t);
27   //since reynolds no R_e < 10,the flow is therfor
         laminar
28   D=0.167//diameter of pipe
29   S=(%pi/4)*D^2//empty cross sectional area
30   q=v_s_t*S//volumetric flow rate
31   printf("\n vol. flow rate q=%f ft^3/s",q);
```

Scilab code Exa 26.3 pressure drop

```
1  clc;
2  //Example 26.3
3  //page no 384
4  printf("Example 26.3 page no 384\n\n");
5  //refer to Example 26.2
6  //a water softner unit consists of a large diameter
        tank ,the bottom of tank is connected to a
        vertical ion exchange pipe
7  h_f=1.25//total fluid height
8  h_l=h_f
9  g=32.174//grav. acc
10  e=0.25// bed porosity
11  d_p=0.00417//ion exchange resin particle diameter,ft
12  L=1//pipe length ,ft
```

```
13  //assume turbulent flow ,apply burke purmer equation
14  v_s=sqrt(g*h_f*e^3*d_p/(1.75*(1-e)*L))//superficial
        velocity
15  printf("\n superficial velocity v_s=%f ft/s",v_s);
16  meu=6.76e-4//absolute viscosity of water
17  rho=62.4//density of water
18  //check for turbulent flow
19  R_e=d_p*v_s*rho/((1-e)*meu)
20  printf("\n R_e=%f",R_e);
21  //since reynold no is low the calculation is not
        valid
22  //assume laminar flow and use Blake−Kozeny equation
        26.9
23  v_s_t=rho*g*h_f*e^3*d_p^2/(150*meu*((1-e)^2)*L)//
        superficial velocity
24  printf("\n superficial velocity v_s_t=%f ft/s",v_s_t
        );
25   //check the porous medium reynolds no
26   R_e_t=v_s_t*d_p*rho/((1-e)*meu)
27   printf("\n reynolds no R_e_t=%f ",R_e_t);
28   //since reynolds no R_e < 10,the flow is therfor
         laminar
29  //calculation of the  pressure drop due to friction
         and the pressure drop across the resin bed
30  k=e^3*d_p^2/(150*(1-e)^2)//packed bed permeability
31  P_drop_fr=rho*h_f//friction pressure drop across
        resin bed,psf
32  printf("\n fricion pressure drop P_drop_fr=%f psf",
        P_drop_fr);
33  z_d=-1//length from point 2 to 3,ft
34  P_drop_r=rho*(z_d+h_f)//pressure drop across the
        resi bed
35  printf("\n pressure drop across across the resin bed
         P_drop_r=%f psf",P_drop_r);
```

Scilab code Exa 26.4 minimum fluidization

```
1  clc;
2  //Example 26.4
3  //page no 387
4  printf("\nExample 26.4 page no 387\n\n");
5  //air is used to fluidize a bed of speherical
        particles
6  D=0.2//bed diameter ,m
7  d_p=7.4e-5//diameter of 200 mesh particles from
        table 23.2 ,m
8  rho_s=2200//ultimate solid density
9  rho_f=1.2//density of air
10 meu=1.89e-5//viscosity of air
11 g=9.807//grav. constant
12 e=0.45//bed porosity
13 L_mf=0.3//length at minimum fluidization
14 //assume laminar flow
15 //applying equation 26.29
16 v_mf=(1-e)*g*rho_s*d_p^2/(150*e^3*meu)//minimum
        fluidizaton veloctiy
17 printf("\n min. fluidization velocity v_mf=%f m/s",
        v_mf);
18 //check the flow regime
19 R_e=v_mf*d_p/(meu*(1-e))
20 printf("\n Reynolds no R_e=%f ",R_e);
21 //since R_e= 1.79 <10,flow is laminar
22 m_dot=%pi*v_mf*D^2*rho_f/4//mass flow rate
23 printf("\n mass flow rate m_dot =%f kg/s",m_dot);
24 P_fr=round((1-e)*rho_s*g*L_mf)//gas pressure drop
        across the bed
25 printf("\n gas pressure drop P_fr=%f Pa",P_fr);
```

Scilab code Exa 26.5 pressure drop in packed bed

```
1  clc ;
2  //Example 26.5
3  //page no 389
4  printf("Example 26.5 page no 389\n\n");
5  //air flowing through a 10 ft packed bed
6  V_o=4.65//superficial velocity ,ft/s
7  meu_g=1.3e-5//viscosity of air
8  rho_g=0.67//density of air ,lb/ft^3
9  e=0.89//void volume
10 g_c=32.2//grav. constant
11 L=10//length of packed bed
12 d_p=0.007815//effective particle diameter
13 P_drop = [(150*V_o*meu_g/(g_c*d_p^2))*((1-e)^2/e^3)
      + (1.75*rho_g*V_o^2/(g_c*d_p))*((1-e)^2/e^3)]*L//
      pressure drop
14 printf("\n pressure drop P_rop=%f lb/ft^2",P_drop);
      //calculation error in book
```

Scilab code Exa 26.6 a bed of pulverized coal

```
1  clc ;
2  //Example 26.6
3  //page no 392
4  printf("Example 26.6 page no 392\n\n");
5  //a bed of pulverized is to be fluidized with liquid
       oil
6  D=4//diameter of bed ,ft
7  d_p=0.00137//particle diameter ,ft
8  rho_s=84//coal particle density ,lb/ft^3
9  rho_f=55//oil density ,lb/ft^3
10 e_mf=0.38//void fraction
11 L_mf=8//bed height at minimum fluidization ,ft
12 P_drop=(rho_s-rho_f)*(1-e_mf)*L_mf +rho_f*L_mf
13 printf("\npressure drop P_drop=%f psf",P_drop);
```

Scilab code Exa 26.7 volumetric flow rate

```
 1  clc;
 2  //Example 26.7
 3  //page no 393
 4  printf("Example 26.7 page no 393\n\n");
 5  //refer to example 26.6
 6  D=4//diameter of bed ,ft
 7  d_p=0.00137//particle diameter ,ft
 8  rho_s=84//coal particle density ,lb/ft^3
 9  rho_f=55//oil density ,lb/ft^3
10  meu_f=3.13e-4//viscosity of oil
11  e_mf=0.38//void fraction
12  L_mf=8//bed height at minimum fluidization ,ft
13  L_f=10//bed height ,ft
14  e=1-L_mf*(1-e_mf)/L_f//bed voidage
15  g=32.174//grav acc
16  v_s=(d_p^2)*g*(e^3)*(rho_s-rho_f)/(150*meu_f*(1-e))
        //superficial velocity
17  printf("\n superficial velocity v_s=%f ft/s",v_s);
18  q=(%pi/4)*D^2*v_s//volumetric flow rate
19  printf("\n vol. floe rate q=%f ft^3/s",q);
20  //check on the laminar flow assumption
21  meu_f=0.01
22  R_e=d_p*v_s*rho_f/(meu_f*(1-e))
23  printf("\n reynolds no R_e=%f",R_e);
24  printf("\n since R_e is less than 10 ,flow is
        laminar");
```

Scilab code Exa 26.8 friction factor and permeability of the catalyst

```
 1  clc;
```

```
2  //Example  26.8
3  //page  no  393
4  printf(" Example  26.8  page  no  393\n\n");
5  //refer  to  example  25.6
6  //obtain  the  porous  medium  friction  factor  usingthe
       burke −plummer  equation
7  ///since  the  flow  is  turbulent  ,eq.26.6  applies
8  f_pm=1.75//porous  medium  friction  facot
9  v_s=2//superficial  velocity
10  e=.4//porosity
11  L=50//length  of  bed
12  d_p=0.0833//particle  diameter
13  g=32.174//grav.  acc
14  h_f=(f_pm)*(v_s^2)*(1-e)*L/(g*(e^3)*d_p)//head  loss
15  printf("\n head  loss  h_f=%f  ft  of  propane  ",h_f);
16  //applying  bernoulli  eq.  between  the  entrance  and
       gas  exit
17  //neglect  the  dynamic  head
18  P2=4320//pressure  at  the  bottom  of  the  catalyst  bed
19  rho_f=0.0128//density  of  fluid
20  z_d=-50//length  from  point  2  to  3,z2−z1
21  P1 = P2 + rho_f*(z_d-h_f)// absolute  pressure  of  the
        inlet  gas
22  printf("\n pressure  P1=%f  psf",P1);
23  //since  flow  is  turbulent  ,  permeablity  of  the
       medium  k  can  not  be  calculated
```

Scilab code Exa 26.9 activated carbon bed

```
1  clc;
2  //Example  26.9
3  //page  no  394
4  printf("Example  26.9  page  no  394\n\n");
5  //turbulent  flow  of  water  through  a  carbon  bed
6  d_p=0.001//particle  diameter
```

```
 7  meu =0.001// viscosity of water
 8  e =0.25// porosity
 9  R_e =1000// R_e is >1000 for turbulent flow ,for
        minimum pressure drop
10  rho =1000// density of water , kg/m^3
11  v_s=R_e*meu*(1-e)/(d_p*rho)// superficial velocity
12  printf (" \n superficial velocity v_s=%f m/s", v_s);
13  phi_s =1// spehercity
14  L =0.5// length of bed ,m
15  P_drop = 1.75*rho*L*v_s^2*(1-e)/(phi_s*d_p*(e^3))//
        presssure drop
16  printf (" \npressure drop P_drop=%f Pa", P_drop);
```

Scilab code Exa 26.10 bed height and porosity

```
 1  clc ;
 2  // Example 26.10
 3  // page no 395
 4  printf (" Example 26.10 page no 395\n\n");
 5  //a bed of 200 mesh particles is fluidized with air
 6  d_b =0.2// diameter of bed ,m
 7  d_p =7.4e-5// particle diameter
 8  L_mf =0.3// bed height at minimum fludization
 9  e_mf =0.45// bed porosity at min. fluidization
10  L_o=L_mf*(1-e_mf)// the zero porosity bed height
11  printf (" \n zero porosity bed height L_o=%f m", L_o);
12  rho_s =2200// density of particles
13  rho_f =1.2// density of fluid
14  g =9.807// grav. acc
15  meu_f =1.89e-5// viscosity of fluid
16  // assuming laminar flow ,use equation  26.9
17  v_mf =(e_mf^3)*(g*(rho_s-rho_f)*(d_p^2))/(150*(1-
        e_mf)*meu_f)// velocity at minimum fluidization
18  printf (" \n velocity at min. fluidization v_mf=%f m/s
        ", v_mf);
```

```
19  v_t =0.35// terminal  velocity  from  example  26.3
20  e =0.91// value  of  e  porosity  from  eq26.9
21  L_f=L_o/(1-e)// expanded  bed  height  L_f
22  m=rho_s*%pi*d_b^2*L_o// bed  inventory
23  printf("\n  expanded  bed  height  L_f=%f m\n  bed
        inventory  m=%f  kg",L_f,m);
```

Scilab code Exa 26.11 fluidization mode

```
 1  clc;
 2  // Example  26.11
 3  // page  no  396
 4  printf("\n  Example  26.11  page  no  396\n\n");
 5  // refer  to  illustrative  example  26.9
 6  d_p=7.4e-5// particle  diameter
 7  L_mf =0.3// bed  height  at  minimum  fludization
 8  e_mf =0.45// bed  porosity  at  min.  fluidization
 9  L_o=L_mf*(1-e_mf)// the  zero  porosity  bed  height
10  printf("\n  zero  porosity  bed  height  L_o=%f m",L_o);
11  rho_s =2200// density  of  particles
12  rho_f =1.2// density  of  fluid
13  g=9.807// grav.  acc
14  meu_f =1.89e-5// viscosity  of  fluid
15  // assuming  laminar  flow  ,use  equation   26.9
16  v_mf  =(e_mf^3)*(g*(rho_s-rho_f)*(d_p^2))/(150*(1-
        e_mf)*meu_f)// velocity  at  minimum  fluidization
17  printf("\n  velocity  at  min.  fluidization  v_mf=%f m/s
        ",v_mf);
18  F_mf=v_mf^2/(g*d_p)// fluidization  mode
19  printf("\n  fluidization  mode  F_mf=%f ",F_mf);
20  // from  value  of  F_mf ,fluidization  is  smoth,F_mf
        =0.66<0.13
```

Chapter 27

filteraion

Scilab code Exa 27.2 a plate and frame filter press

```
1  clc ;
2  // Example  27.2
3  // page  no  413
4  printf ( " Example  27.2  page  no  413\n\n" ) ;
5  // plate  and  frame  filter  press  is  to  be  employed  to
        filter  a  slurry
6  m_dot_slurry =600*60 // mass  flow  rate  , lb/h
7  m=0.1 // sluury  contain  10% by  mass  solid
8  m_dot_solids = m*m_dot_slurry // the  solid  flow  rate
        in  the  slurry
9  a=(1/5) // filter  colth  area  required  for  1  lb/h  of
        solid
10 A=m_dot_solids*(a) // filter  colth  area  for  3600  lb/h
        of  solids
11 printf ( " \n  filter  colth  area  A=%f  ft^2" ,A ) ;
```

Scilab code Exa 27.4 press and filter plate

```
1  clc;
2  //Example 27.4
3  //page no 414
4  printf("Example 27.4 page no. 414\n\n");
5  m=1947//slope of curve b/w t/V vs V,s/ft^6
6  K_c=2*m
7  c=217//intercept on graph
8  q_r=c//reciprocal of q
9  printf("\n coeff. K_c=%f s/ft^6\n coeff. q_r=%f s/ft
      ^3",K_c,q_r)
```

Scilab code Exa 27.5 filtration coefficients

```
1  clc;
2  //Example 27.5
3  //page no 415
4  printf("Example 27.5 page no 415\n\n");
5  //refer to example 27.4
6  meu=5.95e-4//viscosity
7  g_c=32.174//grav. acc
8  P_drop=20*144//pressure drop
9  q_o=(1/217)//flow rate
10 S=0.35//filteration area per unit
11 K_c=3894//coefficentc
12 c=4.142//slurry conentration
13 R_m=S*g_c*P_drop/(q_o*meu)//filteration coeff.
14 printf("R_m=%f ft",R_m);
15 alpha=K_c*S^2*g_c*P_drop/(c*meu)//filteration coeff.
16 printf("\n alpha=%f ft/lb",alpha);
```

Scilab code Exa 27.7 filtration experiment

```
1  clc;
```

```
2 // Example 27.7
3 // page no 418
4 printf("Example 27.7 page no 418\n\n");
5 // the following result were obtained during the
      running of a filteration experiment
6 alpha=4.57e+11// cake resistance, ft/lb
7 P_drop=1554// pressure drop , lbf/ft^2
8 alpha_o=alpha/(P_drop^0.21)// specific cake
      resistance
9 printf("\n specific cake resistance alpha_o=%f ft/lb
      ",alpha_o);
```

Scilab code Exa 27.9 filter press capacity

```
1 clc;
2 // Example 27.9
3 // page no 418
4 printf("Example 27.9 page no 418\n\n");
5 // a filter press operates at a constant pressure
6 P=50// pressure , psig
7 q=10// flow rate , ft^3/min
8 // applying eq.27.12
9 //q = P/(B*V_s + C)
10 // in this case , V_s=0
11 C=P/q// constant
12 // for constant pressure applying equation 27.13
13 //t = B*V_s^2/(2P) + C*V_s/P
14 t=60// time , min
15 V_s=100// volume , ft^3
16 B= 2*P*t/(V_s^2) - 2*C/V_s// constant
17 // during the washing cycle t_w = V_w/q_w
18 //B and C remain same
19 V_w=15// volume of water for washing per hr
20 t_w= V_w*(B*V_s + C)/P// time in washing
21 printf("\n washing time t_w=%f min",t_w);
```

```
22  t_d =30 // time  for  dumping  and  cleanig
23  t_c =( t  +  t_w  +t_d )/60 // collecting  time , in  hr
24  q_c  =V_s / t_c // flow  rate  for  100  ft ^3
25  printf (" \n  flow  rate  q_c=%f  gal/hr  " ,q_c );
```

Chapter 28

environmental management

Scilab code Exa 28.3 cement dust emitting source

```
1  clc ;
2  //Example  28.3
3  //page  no  430
4  printf ( ”Example  28.3  page  no  430\n\n” ) ;
5  //we  have  to  determine  the  minimum  distance
       downstream  from  a  cement  dust  emitting   source
       that  will  be  free  of  cement  deposit
6  //the  souce  is  equipped  with  a  cyclone  located  150
       ft  above  ground  level
7  //neglect  meteorological  aspects
8  h=150 //cyclone  height  from  ground  level , ft
9  v_w=3/3600 //wind  velocity , miles/second
10  SG=1.96 //specific  gravity  of  cement  dust
11  rho_w=62.4 //density  of  water , lb/ft^3
12  rho_p=SG*rho_w ///density  cement  particles
13  //applying  ideal  gas  law  for  density  of  air
14  P=1 //pressure , atm
15  M= 29 //mol.  weight  of  air
16  R=0.73 //gas  constant
17  T=520 //temperature , Rankine
18  rho_a=P*M/(R*T) //density  of  air
```

```
19  meu=1.22e-5//viscosity of air,lb/ft.s
20  g=32.174//grav. acc.
21  d_p=2.5/(25400*12)//particle diameter,ft
22  K = d_p*(g*rho_p*rho_a/(meu^2))^(1/3)//settling
        factor
23  printf("\n settling factor K=%f ",K);
24  //since K=0.103<3.3,sokes law rane applies
25  v= g*d_p^2*rho_p/(18*meu)//terminal settling
        velocity)
26  printf("\nsettling velocity v=%f ft/s",v);
27  t=h/v//time for desent
28  printf("\n desent time t=%f sec",t);
29  x=v_w*t//horizontal distance travelled in miles
30  printf("\n minimum horizontal distance x=%f miles",x
        );//printing mistake in book
```

Scilab code Exa 28.4 filter system

```
1  clc;
2  //Example 28.4
3  //page no 432
4  printf("Example 28.4 page  no 432\n\n");
5  //it is proposed to install a pulse jet fabric
        filter system to clean an air stream containing
        particulate pollutants
6  //we have to select the most apporpriate filter beg
        fabric
7  q_scfm=10000//volumetric flow rate of polluted air
        stream at 60 deg F ,1 atm
8  T=520//temperature,R
9  T_o=710//operating temparature ,R
10  q_acfm=q_scfm*(T_o/T)//flow rate in acfm
11  v_f=2.5//filteration velocity,ft/min
12  S_c=q_acfm/v_f//filtering beg area
13  printf("\n filtering beg area S_c=%f ft^2",S_c);
```

```
14 //(1) for bag A , the area and N number of bags are
15 D_a =8/12//diamter , ft
16 H_a =16//height , ft
17 S_a =%pi*D_a*H_a//area
18 N_a= round(S_c/S_a)//no. of bags
19 printf(" \n area S_a=%f ft ^2\n number og bags N_a=%f
        " ,S_a ,N_a);
20 //(2) for bag B
21 D_b =10/12//diameter , ft
22 H_b =16//height , ft
23 S_b=%pi*D_b*H_b//area
24 N_b=round(S_c/S_b)//no. of bags
25 printf(" \n area S_b=%f ft ^2\n no. of bags N_b=%f " ,
        S_b ,N_b);
26 //total cost for each bag
27 //for bag A
28 c_a =26//cost per bag
29 TC_a=round(N_a*c_a)//total cost for A bag
30 printf(" \n total cost TC_a=%f $" ,TC_a);
31 //for bag B
32 c_b =38//cost per bag
33 TC_b=N_b*c_b//total cost for bag B
34 printf(" \n total cost TC_b=%f $" ,TC_b);
35 //since the total cost for bag A is less than bag B,
        select bag A
```

Scilab code Exa 28.5 fabric system

```
1 clc;
2 //Example 28.5
3 //page no 433
4 printf(" \n Example 28.5 page no 433\n\n");
5 //we have to determine the number if filtering bags
        required and cleaning frequency for a plant
        equipped with a fabric system
```

```
 6 q=50000//volumetric flow rate of gas stream,acfm
 7 v_f=10//filteration velocity,ft/min
 8 D=1//diameter of filtering bag,ft
 9 L=15//length of filtering bag,ft
10 S_c=q/v_f//filtering area,ft^2
11 S=%pi*D*L//area per bag,ft^2
12 N=S_c/S//no. of bags
13 printf("\n no. of bags N=%f ",N);
14 c=0.0007143//dust concentration ,lb/ft^2
15 P_drop=8//pressure drop ,in H20
16 t=(P_drop-(0.2*v_f))/(5*c*v_f^2)//time sic ethe bags
       were cleaned
17 printf("\n time t=%f min",t);
```

Scilab code Exa 28.6 manning equation

```
 1 clc;
 2 //Example 28.6
 3 //page no 434
 4 printf("Example 28.6 page no 434\n\n");
 5 //comparison between flow in pipes and open channel
      flow
 6 //water is passing through a trapezodial channel
 7 l_b=20//length of bottom base,ft
 8 l_t=50//length of top base,ft
 9 h=7.5//height of channel,ft
10 A = (l_b+ l_t)*(h/2)//cross sectional area
11 P = l_b +sqrt(h^2+ (2*h)^2)//perimeter of trapezoid
12 r_h=A/P//hydrulic radius
13 S=0.0008//coeff. in manning equation
14 n=0.02//coeff. in manning eq.
15 q = 1.486*A*r_h^(2/3)*S^(1/2)/n//manning equation to
       determine flow rate
16 printf("\n volumetric flow rate q=%f ft^3/s",q);
```

Scilab code Exa 28.7 a watershed

```scilab
1  clc;
2  //Example 28.7
3  //page no 435
4  printf("\n Example 28.7 page no 435\n\n")
5  //waste water treatment plant
6  //we have  to compare the total nitrogen discharge
       from the watershed with that of the city 's
       sewage treatment plant
7  q_w=10//flow rate from waste water treatment plant
8  c=35//nitoren concentration ,mg/l
9  m_dot_w=c*q_w*8.34//discharge    from the treatment
       plant
10 printf("\n fdischarge from the treatment plant
       m_dot_w=%f lb/day",m_dot_w);
11 S=8//area of watershed ,mi^2
12 r=0.06//rate of rainfall ,ml/day
13 n=.5//50% rain reaches the sewers
14 q=n*r*S*(5280^2/(3600*12))//volumetric flow rate of
       the runoff
15 c_r=9//tota; nitrogen conentration in runoff,mg/l
16 rho=62.4///density of water
17 m_r=q*c_r*1e-6*(3600*24)*rho//total nitrogen
       discharge   from runoff
18 printf("\n total nitrogen discharge m_r=%f lb/day ",
       m_r);
19  //since the durinf rain ,the runoff is over 2.5
        times that for the tratment plant
```

Scilab code Exa 28.8 aerobic digester

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```
1  clc;
2  //Example 28.8
3  //page no 436
4  printf("Example 28.8 page no 436\n\n");
5  //we have to determine the siaze an aerobic digester
       to treat the solids
6  m=1000//mass of solid that is generate by
      municipality,lb
7  OL=0.2//organic loading,lbcs/ft^3.day
8  VS=.78//volatile solids
9  V_ol=m*VS/OL//volume based on organic loading
10 printf("\n volume based on organic loading V_ol=%f
      ft^3",V_ol);
11 t_h=20//detention time hydraulic, days
12 TS=0.044//percentage solids entern ing digester
13 V_hl=m*t_h/(TS*8.33*7.48)//volume based on hydrulic
      load
14 printf("\n volume based on hyraulic load V_hl=%f ft
      ^3",V_hl);
15 //since V_hl >V_ol,the hdraulic time controls and
      the design volume is V_hl
```

Scilab code Exa 28.9 deep cavern

```
1  clc;
2  //Example 28.9
3  //page no 437
4  printf("Example 28.9 page no 437\n\n");
5  //a large deep cavern has been proposed as an
      ultimate disposal site for both solid hazardous
      and municipal wastes
6  V_c=0.78//approximate total volume of cavern,mi^2
7  V_s=.75//% volume availiable for solid waste
      depositry
8  V=V_c*V_s*(5280)^3//volume of the cavern availible
```

```
        for the solid waste , factor 5280 to convert mi^3
            into ft ^3
 9  printf("\n volume of cavern availible for solid
            waste V=%f ft ^3",V)
10  r=20000// proposed maximum waste feed rate to cavern
            , lb/day
11  rho=30// average bulk density , lb/ft ^3
12  q=(r/rho)*(6*52)// volume rate of solid deposited
            within the cavern in ft ^3/ year
13  printf("\n q=%f ",q);
14  t=V/q// time to fill the cavern
15  printf("\n time to fill the cavern t=%f year",t);
```

Scilab code Exa 28.10 compliance stack test

```
 1  clc;
 2  //Example 28.10
 3  //page no 438
 4  printf("Example 28.10 page no 438\n\n");
 5  // a compliance stack test on a facility yields the
            results , we have to determine whether the
            incineratormeets the state particulate standard
            of 0.05 gr/dscf
 6  g=9.807// grav . acc
 7  rho_l=1000// density of manometer fluid , kg/m^3
 8  rho=1.084// density of flue gas , kg/m^3
 9  C=0.85// pitot tube constant
10  h=0.3772// mean pitot tube reading , in H2O
11  m=0.16// mass of particulate collected , g
12  V=35// volume sampled , dscf
13  C_p=m*15.43/V// partculate concentration , gr/dscf
14  printf("\n particulate con . C_p=%f gr/dscf",C_p);
15  // since this does not exceed the particulate
            standard of 0.05 gr/dscf , the facility is not in
            compliance
```

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```
16  //the stack flow rate is calculated from the
        velocity measurement
17  v=C*sqrt(2*g*(rho_l/rho)* 0.0254*h)/.3048//velocity
18  printf("\n velocity v=%f fps",v);
19  D=2//diameter of stack,ft
20  v_s=(v*%pi*D^2/4)*60//stack flow rate
21  printf("\n stack flow rate v_s=%f acfm",v_s);
22  w_mo=0.07//% moisture in stack gas
23  v_dry=(1-w_mo)*v_s//dry volumetric flow rate
24  //correct to standard conditions of  70 deg F and 1
        atm
25  T_s=530// standard temprature deg R
26  P_s=29.9//standard pressure,psi
27  P_g=29.6//pressure of stack gas,psi
28  T_g=600//temprature of standard gas,deg R
29  q_s=v_dry*(T_s/T_g)*(P_g/P_s)//standard volumetric
        flow rate
30  printf("\n standard volumetric flow rate q_s=%f
        dscfm",q_s)
31  R_e=C_p*q_s*(1440/7000)//particulate emission rate
32  printf("\n particulate emmision rate R_e=%f lb/day",
        R_e);
33  w_co2=0.14//percentage of co2 by volume
34  w_N2=0.79//percentage of N2 by volume
35  mw_o=32//molecular weight of oxygen
36  mw_co2=44//molecular weight of co2
37  mw_N2=28//molecular weight of N2
38  MW_d=w_mo*mw_o + w_co2*mw_co2 +w_N2*mw_N2//molecular
         weight of flue gas on dry basis
39  printf("\n mol. weight of flue gas on dry basis MW_d
        =%f lb/lbmol",MW_d);
```

Chapter 29

aaccident and emergency

Scilab code Exa 29.2 probability distribution

```
1  clc;
2  //Example 29.2
3  //page no 455
4  printf("Example 29.2 page no 455\n\n");
5  //the probability distribution of the number of
       defectives in a sample of five pump drawn with
       replacement from lot of 1000 pump
6  //the probability distribution of x, thenumber of
       sucess in n performances of th erandom experiment
        is the probability distribution function
7  //P(x) = (factorial(n)/factorial(x)*(factorial n -
       factorial x))*(p^x*q^n-x)
8  n=5//no. of performances
9  x=3//no. of successes
10 p=0.05//probability of sucesses when the sample of
       pump is drawn with replacement
11 q=1-p//probability of faliure
12 P=factorial(n)*((p^x)*(q^(n-x)))/(factorial(x)*(
       factorial(n)-factorial(x)))//probability when x
       =3//probability when x=3/factorial(x)*(factorial(
       n)-factorial(x))*(p^x*q^(n-x))//probability when
```

```
      x=3
13  printf("\n probability P=%f  ",P); //calculation
       error in book
```

Scilab code Exa 29.3 an iron foundry

```
1  clc;
2  //Examctple 29.3
3  //page no 455
4  printf("Example 29.3 page no 455");
5  //an iron foundry has four work stations that are
      connected to single duct
6  v_air=4000//the minimum air velocity required for
       general foundry dust, ft/min
7  v_air_s=v_air/60//velocity of air in ft/s
8  n=4//no. of duct
9  q_e=3000//each duct transport air,acfm
10 q=n*q_e//total transport,acfm
11 A=q/v_air//cross sectional area required ,ft^2
12 D=sqrt(4*A/%pi)//duct diameter,ft
13 rho=0.075//density of air
14 meu=1.21e-5//viscosity of air
15 R_e=D*rho*v_air_s/meu//reynolds no
16 printf("\n reynolds no. R_e=%f ",R_e);
17 f=0.003///fanning friction factor,since R_e >20000
18 L=400//duct length
19 g_c=32.2//grav. acc.
20 P_drop_d=(4*f*L*v_air_s^2*rho)/(2*g_c*D)//pressure
      drop in the duct
21 printf("\n pressure drop in duct P_drop_d=%f lbf/ft
      ^2",P_drop_d);
22 P_drop_h=0.5*5.2//pressure drop in  hood
23 P_drop_cyc=3.5*5.2//pressure drop in cyclone cleaner
24 P_drop_t=P_drop_d + P_drop_h + P_drop_cyc//total
      prssure drop
```

```
25  printf("\n total pressure drop P_drop_t=%f lbf/ft^2"
        ,P_drop_t);
26  neta=0.4//pump efficiency
27  hp=(P_drop_t*q/neta)*3.03e-5//power required in hp
28  printf("\n power required hp=%f hp ",hp);
```

Scilab code Exa 29.6 a baghouse

```
1  clc;
2  //Example 29.6
3  //page no 458
4  printf("Example 29.6 page no 458\n\n");
5  //a baghouse has been used to clean a particulate
      gas steam
6  l_i=5//inlet loading , grains/ft^3
7  l_o=0.03//outlet loading , grains/ft^3
8  l_o_max=0.4//maximum outlet loading , grains/ft^3
9  E_b=(l_i-l_o)/l_i//efficiency before bag failure
10  P_t=1-E_b//penetration before bag failure
11  E=(l_i-l_o_max)/l_i//efficiency on regulatory
      conditions
12  P_t_r=1-E//penetration regulatory conditons
13  P_tc=P_t_r-P_t//penetration associated with failed
      bags
14  printf("\n penetration associated with failed bags
      P_tc=%f ",P_tc);
15  P_drop=6//pressure drop ,in of H2O
16  T=250//temperature , deg F
17  q=50000//volumetric flow rate , acfm
18  D=8//diamter of bags , in
19  L= q*P_tc/(0.582*P_drop^0.5*D^2*(T+460)^0.5)//number
       of bag failure that the system can tolerate and
      still remain in compliance
20  printf("\n no. of bags L=%f ",L);
21  //thus if two bags fail , baghouse is out of complance
```

Scilab code Exa 29.7 a cstr type reactor

```
1  clc;
2  //Example 29.7
3  //page no 461
4  printf("\Example 29.7 page no 461\n\n");
5  //a reactor is located in a relatively large
       laboratory, the reactor  can emit as much as of
       hydrocarbon into the room if a safety valves
       ruptures
6  v=1100//volume of reactor ,m^3
7  T=295//temperature of reactor ,K
8  v_s=0.0224//volume of gas at STP,m^3
9  T_s=273//standard temperature ,K
10 n_air=(v/v_s)*(T_s/T)//total gmoles of air in the
       room
11 printf("\n n_air=%f gmol",n_air);
12 v_r=0.75//Hydrocarbon emit by reactor ,gmol
13 x_hc= (v_r/(n_air + v_r))*10^9//mole fraction of
       hydrocarbon in the room,parts per billion
14 printf("\n mole fraction of HC x_hc=%f ppb ",x_hc);
```

Chapter 31

numerical methods

Scilab code Exa 31.1 linear algebraic equation

```
1  clc;
2  //Example 31.1 page no 486
3  printf("Example 31.1 page no 486\n\n ");
4  //set of linear algebric equation using gauss
       elimination
5  A=[3,-2,1;1,4,-2;2,-3,-4]//matrix A
6  B=[7;21;9]//matrix B
7  X=inv(A)*B
8  printf("\n X=%f",X);
9  X1=X(1,1)//value of X1
10 X2=X(2,1)//value of X2
11 X3=X(3,1)//value of X3
12 printf("\n X1=%f\nX2=%f \nX3=%f",X1,X2,X3);
```

Scilab code Exa 31.2 temperature and pressure

```
1  clc;
2  //Example 31.2
```

```
3  // page no 492
4  printf ("Example 31.2 page no 492\n\n");
5  // the vapor pressure p' for a new synthetic chemical
        at a given temperature
6  t1 =1100// assume intial actual temperature ,k
7  T1=t1*1e-3// temperature ,k
8  printf ("\n T1=%f k",T1);
9  f1=T1^3 -2*T1^2 + 2*T1 -1// function of T, f (T)
10 f_d1=3*T1^2 -4*T1 + 2// derivative of f (T)
11 // using newton rapson formula to estimate T2
12 T2=T1 -(f1/f_d1)// temperature T2
13 printf ("\n T2=%f k",T2);
14 f2=T2^3 -2*T2^2 + 2*T2 -1
15 f_d2=3*T2^2 -4*T2 + 2
16 T3=T2 -(f2/f_d2)// temperature T3
17 printf ("\n T3=%f k",T3);
18 // finally the best estimate is T3, t =1.000095
```

Scilab code Exa 31.3 newton rapson method

```
1  clc ;
2  // Example 31.3
3  // page no 493
4  printf ("Example 31.3 page no 493\n\n");
5  // friction factor for smooth tubes can be
       approximated by
6  // f = 0.079* R_e ^( -1/4) , if 2000< R_e<2e-5
7  // average velocity in the system , involving the
       flow of water at 60 deg F is given by
8  //v =sqrt (2180/(213.4 R_e ^( -1/4) + 10) , flow of water
        at 60 deg F
9  // R_e=12168v, putting this value and by simplifying
      we get
10 v=poly (0 ,'v');
11 f =213.5* v^2 +105.03* v- 22896.08* v
```

```
12  //df=derivat(213.5*v^2 +105.03*v- 22896.08*v)
13  df=- 22791.05 + 427*v
14  v1=5
15  f1=213.5*v1^2 +105.03*v1- 22896.08*v1// value of f
       at v=5
16  df1=- 22791.05 + 427*v1//value of df at v=5
17  v2=v1-(f1/df1)
18  //by iteration we get values of v3,v4,v5,v6
19  //at v6 result converges
20  v6=10.09
21  printf("\n v6=%f ft/s ",v6);
```

Scilab code Exa 31.4 simpson rule

```
1  clc;
2  //Example 31.4
3  //page no 497
4  printf("Example 31.4 page no 497\n\n")
5  //integration
6  I=integrate('(1-0.4*x^2)/((1-x)*(1-0.4*x)-1.19*x^2)'
       ,'x',0,0.468)
7  printf("\n I=%f ",I);
```

Chapter 32

economics and finance

Scilab code Exa 32.5 fluid transportation

```
1  clc;
2  //Example 32.5
3  //page no 512
4  printf("Example 32.5 page no 512\n\n");
5  // a fluid is transported 4 miles under turbulent
        flow conditions
6  //we have two choices in designing the system
7  OC_a=20000//per year pressure drop costs for the 2
        inch ID pipe,$
8  CRF=0.1//capital recovery factor for both pipe
9  OC_b=OC_a/16//operating cost associated with the
        pressure drop cost per year for 4 inch pipe
10 d=4*5280//distance,feet
11 c_a=1// 2 inch ID pipe cost per feet,$
12 c_b=6// 4 inch ID pipe cost per feet,$
13 CC_a=d*c_a*CRF//capital cost for  2 inch ID pipe,$
14 CC_b=d*c_b*CRF//capital cost for 4 inch ID pipe,$
15 TC_a= OC_a +CC_a//total cost associated with 2 inch
        pipe
16 printf("\n total cost with 2 inch pipe TC_a=%f $",
        TC_a);
```

```
17  TC_b=OC_b + CC_b//total  cost  associated  with  4  inch
        pipe
18  printf("\n  total  cost  with  4  inch  pipe  TC_b=%f  $",
        TC_b);
19  //from  result  we  can  conclude  that  4  inch  pipe  is
        more  economical
```

Scilab code Exa 32.6 particulate control device

```
1  clc;
2  //Example  32.6
3  //page  no  512
4  printf("  Example  32.6  page  no  512\n\n")
5  //a  process  emits  gas  of  containg  dust,a  particulate
        device  is  employed  for  particle  capture
6  q=50000//vol.  flow  rate  of  dust,ft^3/min
7  c=2/7000//inlet  loading  of  dust
8  DV=0.03//value  of  dust
9  //recovered  value  RV  can  be  expressed  in  terms  of
        pressure  drop
10  //RV=q*c*DV*P1/(P1+15)
11  C_e=0.18//cost  of  electricity
12  E_f=0.55//fractional  efficiency
13  function  x=f(P1)
14
15      E=P1/(P1+15)//collection  efficiency
16      RV=q*c*DV*E//recovered  value  in  terms  of  E$/min
17      C_p=q*(C_e/44200)*P1/(E_f*60)
18  //   x=q*c*DV*P1/(P1+15)-q*C_e*P1/E_f
19      x=RV-C_p
20  endfunction
21  P1=fsolve(100,f)
22  printf("\n  P1=%f",P1);
23  //calculation  mistake  in  book
```

Scilab code Exa 32.8 a filter press

```
1  clc;
2  //Example 32.8
3  //page no 514
4  printf("Example 32.8 page no 514\n\n");
5  //a filter press is in operation
6  //we have to determine the appraisal value of the
       press
7  i=0.03375//intrest on fund
8  n=9//time,year
9  SFDF=i/((1+i)^n -1)//sinking fund depreciation
       factor
10 P=60000//cost of filter press,$
11 L=500//salvage value,$
12 UAP= (P-L)*SFDF//uniform annual payment,$
13 printf("\n uniform annual payment UAP=%f $",UAP);
14 //in determing the appraisel value where the
       straight line method of depreciation is used
15 // B = P -(P-L/n)x
16 //where x refers to any time the present before the
       end of usable
17 x=5//let for 5 year
18 B5=P-((P-L)/n)*x//appraissl value for 5 year
19 printf("\n apprasial value B=%f $",B5);
```

Scilab code Exa 32.9 an outdated environmental control device

```
1  clc;
2  //Example 32.9
3  //page no 516
4  printf("Example 32.9 page no 516\n\n");
```

```
 5  //we have to determine the annulized cost of a new
        processing plant of enviromental control
 6  //input data
 7  CC=150000//capital cost,$
 8  I=.07//interst
 9  n=5//time,year
10  CRF=(I*(1+I)^n)/((1+I)^5-1)//capital recovery factor
        CRF
11  IC=CRF*CC//installation cost,$
12  OC=15000//operation cost,$
13  AC=IC + OC//annulized cost
14  printf("\n annulized cost AC=%f $",AC);
```

Chapter 33

biomedical engineering

Scilab code Exa 33.1 viscosity of plasma

```
1 clc;
2 //Example 33.1 page no 524
3 printf("Example 33.1 page no 524\n\n")
4 //unit conversion of viscosity of blood
5 meu_cp=1.25//vicosity of blood in cp
6 meu_e=meu_cp*6.72e-4//viscosity in english unit,lb/
     ft.s
7 printf("\n viscosity meu_e=%f lb/ft.s",meu_e)
```

Scilab code Exa 33.2 pressure units

```
1 clc;
2 //Example 33.2 page no 525
3 printf("Example 33.2 page no 525\n\n");
4 //unit conversion of poressure given in mmHg into
     various units
5 P=80//pressure given in mmHg
6 P1=P*(29.92/760)//pressure , in Hg
```

```
7  P2=P*(33.91/760)//pressure ,ft H2O
8  P3=P2*12//pressure ,in H2O
9  P4=P*(14.7/760)//pressure ,psia
10 P5=P*(2116/760)//pressure ,psfa
11 P6=P*(1.013e+5/760)//pressure ,N/m^2
12 printf("\n P1=%f inHg\n P2=%f ft H2O\nP3=%f in H2O\n
      P4=%f psia\nP5=%f psfa\nP6=%f N/m^2",P1,P2,P3,P4
      ,P5,P6);//in book answers are round off after
      decimal but there are exact answers
```

Scilab code Exa 33.5 artery branches

```
1  clc;
2  //Example 33.5 page no 527
3  printf("Example 33.5 page no 527\n\n");
4  //an artery branches into two smaller equal area
      arteries so that velocity is same
5  //because q1=q2,volumetric flow rate
6  //q1=q2=q/2
7  //because s1=s2,cross sectional area
8  //s1=s2=s/2
9  //let the values
10 q=1//flow rate at inlet artery
11 q1=q/2//flow rate at outlet artery
12 s=1//area of inlet artery
13 s1=s/2//area of outlet artery
14 //v=q/s
15 D_r=sqrt(q/q1)//ratio of diameters
16 printf("\n ratio of diameters D_r=%f ",D_r);
```

Scilab code Exa 33.6 a blood vessel

```
1  clc;
```

```
 2  //Example 33.6
 3  //page no 528
 4  printf("Example 33.6 page no 528\n\n");
 5  //a blood vessel branches into three openings
 6  //we have to find the velocity in 3 rd opening
 7  a=0.2//cross sectional area of inlet 1,m^2
 8  v=5//velocity inlet 1,mm/s
 9  a1=0.08//area of branch1 ,m^2
10  v1=7//velocity in branch2 ,mm/s
11  a2=0.025//area of branch ,m^2
12  v2=12//velocity in branch ,mm/s
13  a3=0.031//area of branch ,m^2
14  q=a*v//flow rate at inlet
15  q1=a1*v1//flow rate at branch 1
16  q2=a2*v2//flow rate at branch 2
17  q3=q-q1-q2//flow rate in branch 3
18  v3=q3/a3//velocity in branch 3
19  printf("\n velocity v3=%f mm/s",v3);
```

Scilab code Exa 33.7 average velocity of blood

```
 1  clc;
 2  //Example 33.7
 3  //page no 531
 4  printf("Example 33.7 page no 531\n\n");
 5  //blood flowing through the arota
 6  D=2.5//diameter of arota
 7  S=%pi*D^2/4//cross sectional area ,cm^2
 8  q=93.3//volumeric flow rate ,cm^3/s
 9  v=q/S//flow velocity
10  printf("\n flow velocity v=%f cm/s",v);
```

Scilab code Exa 33.8 heart beat

```
1  clc ;
2  // Example 33.8
3  // page no 531
4  printf (" Example 33.8 page no 531\n\n");
5  // one of the auther of this book is 74 year old ,we
      have to determine the no. of times that the the
      auther 's heart has to beat to date
6  Y =74// age in year
7  d =365// days
8  h =24// hours
9  m =60// minutes
10 b =80// heart beats per minutes
11 T = Y * d * h * m * b // no. of times heart beats
12 printf ("\n no.of times heart beats T=%f ",T);
```

Scilab code Exa 33.9 volume of blood

```
1  clc ;
2  // Example 33.9
3  // page no 531
4  printf ("\n Example 33.9 page no 531\n\n");
5  // refer to example no 33.8
6  Y =74// age in year
7  d =365// days
8  h =24// hours
9  m =60// minutes
10 b =80// heart beats per minutes
11 T = Y * d * h * m * b // no. of times heart beats
12 v =70// volume of blood discharge with each blood ,ml
13 V = T * v // volume of blood that has circulated through
      the auther 's system over his lifetime
14 printf ("\n Volume of blood V=%f ml",V);
```

Scilab code Exa 33.10 minimum pressure drop

```
1  clc;
2  //Example 33.10
3  //page no 532
4  printf("Example 33.10 page no 532\n\n");
5  //the flow of blood from the arota to the atrium is
       reprsented by a vessel
6  meu=1.1*6.72e-4//viscosity of blood
7  L=0.3//length of vessel, mile
8  g_c=32.2//grav. acc
9  rho=62.4//density of blood
10 D=2.53/30.48//diameter of vessel, ft
11 P_drop=32*meu*(19/30.48)*5280*L/(rho*D^2*g_c)
12 printf("\n pressure drop P_drop=%f ft*lbf/lb",P_drop
       )
13 //snice the model is resonable from the fluid
       dynamics perspective
```

Scilab code Exa 33.12 power generated by heart

```
1  clc;
2  //Example 33.12
3  //page no 534
4  printf("\n Example 33.12 page no 534\n\n")
5  //estimation of power generated by human heart
6  P_drop=60//pressure drop in the circulatory system,
       mmHg
7  q=0.0033//volumetric flow rate, ft^3/s
8  hp=(q*P_drop*14.7*(144/760))//power generated
9  printf("\npower generated hp=%f hp",hp);//
       calculation error in book
```

Chapter 34

open ended problems

Scilab code Exa 34.4 a moving gas stream

```
1 clc ;
2 //Example 34.4 page no 548
3 printf("Example 34.4 page no 548\n\n");
4 //a gas stream is discharged through a stack
5 m_dot =10000//mass flow ratein acfm
6 v=50// velcoity in ft/s
7 KE=m_dot*v^2*(29/(379*32.2*60))//others are
      conversion factor for unit
8 printf("\n KE=%f ft.lbf/s",KE);// printing mistake in
      book
```