Scilab Textbook Companion for Problems In Fluid Flow by D. J. Brasch And D. Whyman[1]

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Book Description

Title: Problems In Fluid Flow

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

Contents

List of Scilab Codes

Chapter 1

Pipe Flow of Liquids

Scilab code Exa 1.1.1 laminar turnulent pipe flow and Reynolds number

```


//exapple 1.1
clc; funcprot(0);
// Initialization of Variable
//part1
mu=6.3/100;//viscosity
rho=1170;//density
d=.3;//diameter of pipe
b=0.142;//conversion factor
pi=3.14;
//calculation
Q=150000*b/24/3600//flow rate
u=Q/pi/d^2*4//flow speed
Re=rho*u*d/mu
if   Re>4000   then
    disp(Re,"the system is in turbulent motion as
        reynolds no is greater than 4000:");
elseif Re<2100 then
    disp(Re,"the system is in laminar motion" );
else
```

```
    disp(Re, "the system is in transition motion");
end
//part 2
mu=5.29/1000;
d=0.06;
G=0.32;//mass flow rate
Re= 4*G/pi/d/mu;
if   Re>4000   then
    disp(Re,"the system is in turbulent motion as
       reynolds no is greater than 4000:");
elseif Re<2100 then
    disp(Re,"the system is in laminar motion as Re
       is less than 2100" );
else
    disp(Re, "the system is in transition motion");
end
```

Scilab code Exa 1.1.2 conditions in pipeline while liquid passes in steady motion through it

```


//exapple 1.2
clc; funcprot(0);
// Initialization of Variable
G=21.2;//mass flow rate
rho=1120;//density
d=0.075;//diameter
l=50;
g=9.81;
pi=3.14;
delz=24/100;//head difference
//calculation
delP=delz*rho*g;//differece of pressure
u=4*G/pi/d^2/rho;
```

```
phi=delP/rho*d/l/u^2/4*50;
disp(phi,"The Stanton-Pannel friction factor per
   unit of length:");
R=phi*rho*u^2;
disp(R , "shear stress exerted by liquid on the pipe
    wall in (N/m^2):");
F=pi*d*l*R;
disp(F , "Total shear force exerted on the pipe in (
   N):");
Re=(.0396/phi)^4;//reynold's no.
mu=rho*u*d/Re;
disp(mu , "viscosity of liquid in (kg/m/s):")
```

Scilab code Exa 1.1.3 laminar flow and Hagen Poiseuille equation

```


//exapple 1.3
clc; funcprot(0);
// Initialization of Variable
pi=3.14;
g=9.81;
d=0.00125;
Re=2100;
l=0.035;
rhoc=779;//density of cyclohexane
rhow=999;//density of water
muc=1.02/1000;//viscosity of cyclo hexane
//calculation
u=Re*muc/rhoc/d;//speed
Q=pi*d^2*u/4;//volumetric flow rate
delP=32*muc*u*l/d^2;//pressure difference
delz=delP/(rhow-rhoc)/g;
disp(delz*100 , "the difference between the rise
   levels of manometer in (cm):")
```

Scilab code Exa 1.1.4 velocity distribution in fluid in laminar motion in pipe

```


//exapple 1.4
clc; funcprot(0);
// Initialization of Variable
d=0.05;
l=12;
per=100-2;
pi=3.1428
//calculation
s=sqrt(per/100/4*d^2);//radius of core of pure
    material
V=pi*d^2/4*l/(2*(1-(2*s)^2/d^2));
disp(V, "The volume of pure material so that 2%
    technical material appears at the end in (m^3):")
```

Scilab code Exa 1.1.5 comparison of laminar and turbulent flow

```


//exapple 1.5
clc; funcprot(0);
// Initialization of Variable
//part 1
a=1/2*(1-1/sqrt(2));
disp(a*100, "The percent value of d for which where
    pitot tube is kept show average velocity in
    streamline flow in (%):");
```

```
//part 2
a=(49/60)^7/2;
disp(a*100, "The percent value of d for which where
   pitot tube is kept show average velocity in
   turbulent flow in (%):");
//part 3
//on equating coefficient of r
y=a*2;//y=a/100*2*r
s=1-y;//s=r-y
//on equating coeff. of 1/4/mu*del(P)/del(l)
E=(1-s^2-.5)/.5;
disp(E , "The erreor shown by pitot tube at new
   position if value of streamlined flow flow was to
    be obtained in (%) :");
disp("The - sign indicates that it will display
   reduced velocity than what actually is");
```

Scilab code Exa 1.1.6 power required for pumping local pressure in pipeline and the effects on both of an increase in pipe roughness

```


//exapple 1.6
clc; funcprot(0);
// Initialization of Variable
rhon=1068;//density of nitric acid
mun=1.06/1000//viscosity of nitric acid
g=9.81;
l=278;
d=0.032;
alpha=1;
h2=57.4;//height to be raised
h1=5;//height from which to be raised
e=.0035/1000;//roughness
G=2.35//mass flow rate
```

```
//calculations
//part 1
u=4*G/rhon/pi/d^2;
Re=rhon*d*u/mun;
rr=e/d;//relative roughness
//Reading's from Moody's Chart
phi=.00225;//friction coeff.
W=u^2/2+g*(h2-h1)+4*phi*l*u^2/d;//The work done/kg of fluid flow in J/kg
V=abs(W)*G;
disp(abs(V)/1000, "The Power required to pump acid in kW :");
//part 2
P2=-u^2*rhon/2+g*(h1)*rhon+abs(W+2)*rhon;;
disp(P2/1000,"The gauge pressure at pump outlet when piping is new in (kPa)" );
//part 3
e=.05/1000;
Re=rhon*d*u/mun;
rr=e/d;
//Reading's from Moody's Chart
phi=0.0029;
W=u^2/2+g*(h2-h1)+4*phi*l*u^2/d;
Vnew=abs(W)*G;
Pi=(Vnew-V)/V*100;
disp(Pi , "The increase in power required to transfer in old pipe in (%):");
//part 4
P2=-u^2*rhon/2+g*(h1)*rhon+abs(W+2)*rhon;
disp(P2/1000,"The gauge pressure at pump outlet when piping is old in (kPa)" );
```

Scilab code Exa 1.1.7 power required for pumping when pipe system contains resistances to flow

```
//exapple 1.7
clc; funcprot(0);
// Initialization of Variable
rho=990;
mu=5.88/10000;
g=9.81;
pi=3.14;
temp=46+273
e=1.8/10000//absolute roughness
Q=4800/1000/3600;
l=155;
h=10.5;
d=0.038;
delh=1.54//head loss at heat exchanger
effi=0.6//efficiency
//calculations
//part 1
u=Q*4/pi/d^2;
Re=rho*d*u/mu;
rr=e/d;//relative roughness
//from moody's diagram
phi=0.0038//friction factor
alpha=1//constant
leff=l+h+200*d+90*d;
Phe=g*delh//pressure head lost at heat exchanger
W=u^2/2/alpha+Phe+g*h+4*phi*leff*u^2/d;//work done
    by pump
G=Q*rho;//mass flow rate
P=W*G;//power required by pump
Pd=P/effi//power required to drive pump
disp(Pd/1000,"power required to drive pump in (kW)")
    ;
//part 2
P2=(-u^2/2/alpha+W)*rho;
disp(P2/1000,"The gauge pressure in (kPa):")
```

Scilab code Exa 1.1.8 fluid flow rate and use of friction and chart

```
//exapple 1.8
clc; funcprot(0);
// Initialization of Variable
rho=908;
mu=3.9/100;
g=9.81;
pi=3.14;
d=0.105;
l=87;
h=16.8;
e=0.046/1000;//absolute roughness
//calculations
//part1
P=-rho*g*h;//change in pressure
a=-P*rho*d^3/4/l/mu^2//a=phi*Re^2
//using graph given in book(appendix)
Re=8000;
u=mu*Re/rho/d;
Q=u*pi*d^2/4;
disp(Q,"Volumetric flow rate initial (m^3/s):");
//part 2
W=320;
Pd=W*rho;//pressure drop by pump
P=P-Pd;
a=-P*rho*d^3/4/l/mu^2//a=phi*Re^2
//using graph given in book(appendix)
Re=15000;
u=mu*Re/rho/d;
Q=u*pi*d^2/4;
disp(Q,"Volumetric flow rate final(part 2) (m^3/s):"
```

```
);
```

Scilab code Exa 1.1.9 time taken to drain a tank

```


//exapple 1.9
clc; funcprot(0);
// Initialization of Variable
rho=1000;
mu=1.25/1000;
g=9.81;
pi=3.14
d1=0.28;//diameter of tank
d2=0.0042;//diameter of pipe
l=0.52;//length of pipe
rr=1.2/1000/d;//relative roughness
phid=0.00475;
disp(phid,"It is derived from tyhe graph giben in
    appedix and can be seen is arying b/w 0.0047 &
    0.0048 dependent on D which varies from 0.25 to
    0.45")
//calculations
function[a]=intregrate()
    s=0;
    for i=1:1000
        D=linspace(0.25,0.45,1000);
        y=sqrt(((pi*d1^2/pi/d2^2)^2-1)/2/9.81+(4*
            phid*l*(pi*d1^2/pi/d2^2)^2)/d2/9.81)
            *((0.52+D(i))^-0.5)*2/10000;
        s=s+y;

    end
    a=s;
endfunction
```

```
b=intregrate();
disp(b,"Time required to water level to fall in the
   tank in (s):");
```

Scilab code Exa 1.1.10 minimum pipe diameter to obtain a given fluid flow

```


//exapple 1.10
clc; funcprot(0);
// Initialization of Variable
rho=1000;
mu=1.42/1000;
g=9.81;
pi=3.14;
l=485;
h=4.5
e=8.2/100000;
Q=1500*4.545/1000/3600;
disp("assume d as 6cm");
d=0.06;
u=4*Q/pi/d^2;
Re=rho*d*u/mu;
rr=e/d;//relative roughness
//using moody's chart
phi=0.0033//friction coeff.
d=(64*phi*l*Q^2/pi^2/g/h)^0.2;
disp(d*100, "The calculated d after (1st iteration
   which is close to what we assume so we do not do
   any more iteration) in(cm) ")
```

Chapter 2

pipe flow of gasses and gas liquid mixtures

Scilab code Exa 2.1.1 gas flow through pipe line when compressibility must be considered

```


//exapple 2.1
clc; funcprot(0);
// Initialization of Variable
pi=3.1428;
mmm=16.04/1000;//molar mass of methane
mV=22.414/1000;//molar volume
R=8.314;
mu=1.08/10^5;
r=4.2/100;//radius
rr=0.026/2/r;//relative roughness
Pfinal=560*1000;
tfinal=273+24;
l=68.5;
m=2.35;//mass flow rate
//calculation
A=pi*r^2;
```

```
A=round(A*10^5)/10^5;
rho=mmm/mV;
rho24=mmm*Pfinal*273/mV/101.3/tfinal;//density at
    24'C
u=m/rho24/A;
Re=u*rho24*2*r/mu;
//from graph
phi=0.0032;
//for solving using fsolve we copy numerical value
    of constant terms
//using back calculation
//as pressure maintained should be more than Pfinal
    so guessed value is Pfinal;
function[y]=eqn(x)
    y=m^2/A^2*log(x/Pfinal)+(Pfinal^2-x^2)/2/R/
        tfinal*mmm+4*phi*l/2/r*m^2/A^2;
endfunction
[x,v,info]=fsolve(560*10^3,eqn);
disp(x/1000,"pressure maintained at compressor in (
    kN/m^2):");
```

Scilab code Exa 2.1.2 flow of ideal gas at maximum velocity under isothermal and adiabatic condition

```


//exapple 2.2
clc; funcprot(0);
// Initialization of Variable
M=28.8/1000;
mu=1.73/10^5;
gamm=1.402;
P1=107.6*10^3;
V=22.414/1000;
R=8.314;
```

```
temp=285;
d=4/1000;
rr=0.0008;
phi=0.00285;
//calculation
//constant term of equation
//part1
a=1-8*phi*l/d;//constant term in deff
deff('y=f(x)','y=log(x^2)-x^2+2.938');
[x,v,info]=fsolve(1,f);
z=1/x;
z=round(z*1000)/1000;
disp(z,"ratio of Pw/P1");
//part2
Pw=z*P1;
nuw=V*P1*temp/Pw/M/273;
Uw=sqrt(nuw*Pw);
disp(Uw,"maximum velocity in (m/s):")
//part3
Gw=pi*d^2/4*Pw/Uw;
disp(Gw,"maximum mass flow rate in(kg/s):");
//part4
G=2.173/1000;
J=G*Uw^2/2;
disp(J,"heat taken up to maintain isothermal
    codition(J/s):");
//part5
nu2=2.79;//found from graph
nu1=R*temp/M/P1;
P2=P1*(nu1/nu2)^gamm;
disp(P2/P1,"crtical pressure ratio in adiabatic
    condition:");
//part6
Uw=sqrt(gamm*P2*nu2);
disp(Uw,"velocity at adiabatic condition in (m/s):")
    ;
//part7
Gw=pi*d^2/4*Uw/nu2;
```

```
disp(Gw,"mass flow rate at adiabatic condition in (
    kg/s):");
//part8
//polynomial in T of the form ax^2+bx+c=0;
c=gamm/(gamm-1)*P1*nu1+.5*Gw^2/pi^2/d^4*16*nu1^2;
b=gamm/(gamm-1)*R/M;
a=.5*Gw^2/pi^2/d^4*16*(R/M/P2)^2;
y=poly([-c b a],'x','coeff');
T2=roots(y);
disp(T2(2)-273,"temperature of discharging gas in (
    Celcius)");
```

Scilab code Exa 2.1.3 flow of a non ideal gas at maximum velocity under adiabatic condition

```


//exapple 2.3
clc; funcprot(0);
// Initialization of Variable
//1 refer to initial condition
R=8.314;
P1=550*10^3;
T1=273+350;
M=18/1000;
d=2.4/100;
pi=3.1428;
A=pi*d^2/4;
gamm=1.33;
roughness=0.096/1000/d;
l=0.85;
phi=0.0035//assumed value of friction factor
//calculation
nu1=R*T1/M/P1;
Pw=0.4*P1;//estimation
```

```
nuw=(P1/Pw)^0.75*nu1;
enthalpy=3167*1000;
Gw=sqrt(enthalpy*A^2/(gamm*nuw^2/(gamm-1)-nu1^2/2-
   nuw^2/2));
function[y]=eqn(x)
 y=log(x/nu1)+(gamm-1)/gamm*(enthalpy/2*(A/Gw)^2*(1/
    x^2-1/nu1^2)+0.25*(nu1^2/x^2-1)-.5*log(x/nu1))
    +4*phi*l/d;
endfunction
deff('y=f(x)','eqn');
[x,v,info]=fsolve(0.2,eqn);

if x~=nuw then
    disp("we again have to estimate Pw/P1");
    disp("new estimate assumed as 0.45")
    Pw=0.45*P1;//new estimation
    nuw=(P1/Pw)^0.75*nu1;
// & we equalise nu2 to nuw
nu2=nuw;
Gw=sqrt(enthalpy*A^2/(gamm*nuw^2/(gamm-1)-nu1^2/2-
   nuw^2/2));
printf("mass flow rate of steam through pipe (kg/s):
    %.2f",Gw);
//part 2
disp(Pw/1000,"pressure of pipe at downstream end in
   (kPa):");

else
    disp("our estimation is correct");

end
//part3
enthalpyw=2888.7*1000;//estimated from steam table
Tw=sqrt((enthalpy-enthalpyw+.5*Gw^2/A^2*nu1^2)*2*A
   ^2/Gw^2/R^2*M^2*Pw^2);
disp(Tw-273,"temperature of steam emerging from pipe
    in (Celcius):")
```

Scilab code Exa 2.1.4 venting of gas from pressure vessel

```


//exapple 2.4
clc; funcprot(0);
// Initialization of Variable
M=28.05/1000;
gamm=1.23;
R=8.314;
atm=101.3*1000;
P1=3*atm;
//calculation
//part1
P2=P1*(2/(gamm+1))^(gamm/(gamm-1));
disp(P2/1000,"pressure at nozzle throat (kPa):")
//part2
temp=273+50;
nu1=R*temp/P1/M;
G=18;//mass flow rate
nu2=nu1*(P2/P1)^(-1/gamm);
A=G^2*nu2^2*(gamm-1)/(2*gamm*P1*nu1*(1-(P2/P1)^((
    gamm-1)/gamm)));
d=sqrt(4*sqrt(A)/pi);
disp(d*100,"diameter required at nozzle throat in (
    cm)")
//part3
vel=sqrt(2*gamm*P1*nu1/(gamm-1)*(1-(P2/P1)^((gamm-1)
    /gamm)));
disp(vel,"sonic velocity at throat in(m/s):");
```

Scilab code Exa 2.1.5 gas flow measurement with veturimeter

```
//exapple 2.5
clc; funcprot(0);
// Initialization of Variable
T=273+15;
rho=999;
rhom=13559;//density of mercury
g=9.81;
P2=764.3/1000*rhom*g;
R=8.314;
M=16.04/1000;
d=4.5/1000;
A=pi*d^2/4;
G=0.75/1000;//mass flow rate
delP=(1-exp(R*T*G^2/2/P2^2/M/A^2))*P2;
h=-delP/rho/g;
disp(h*100,"height of manometer in (cm)")
```

Scilab code Exa 2.1.6 pressure drop required for flow of a gas liquid mixture through pipe

```
//exapple 2.6
clc; funcprot(0);
// Initialization of Variable
rhol=931;
mu=1.55/10000;//viscosity of water
Vsp=0.6057;//specific volume
T=273+133;
mug=1.38/100000;//viscosity of steam
P=300*1000;
d=0.075;
Gg=0.05;//mass flow gas phase
```

```
Gl=1.5;//mass flow liquid phase
A=pi*d^2/4;
//calculation
rhog=1/Vsp;
rhog=round(rhog*1000)/1000;
velg=Gg/A/rhog;
velg=round(velg*100)/100;
Reg=rhog*velg*d/mug;
//using chart
phig=0.00245;//friction factor gas phase
l=1;
delPg=4*phig*velg^2*rhog/d;
//consider liquid phase
vell=Gl/A/rho;
Rel=rho*vell*d/mu;
if Rel>4000 & Reg>4000 then
    disp("both liquid phase and solid phase in
       turbulent motion");
    //from chart
end
PHIg=5;
delP=PHIg^2*delPg;
disp(delP,"required pressure drop per unit length in
    (Pa)")
```

Chapter 3

velocity boundary layers

Scilab code Exa 3.1.1 streamline flow over a flat plate

```


//exapple 3.1
clc; funcprot(0);
// Initialization of Variable
rho=998;
mu=1.002/1000;
x=48/100;
u=19.6/100;
x1=30/100;
b=2.6;
//calculation
//part1
disp("fluid in boundary layer would be entirely in
   streamline motion ");
Re=rho*x*u/mu;
printf("reynolds no is %.2e",Re);
//part 2
Re1=rho*x1*u/mu;
delta=x1*4.64*Re1^-.5;
disp(delta*1000,"boundary layer width in (mm):");
```

```
//part3
y=0.5*delta;//middle of boundary layer
ux=3/2*u*y/delta-.5*u*(y/delta)^3;
disp(ux*100,"velocity of water in (cm/s):");
//part4
R=0.323*rho*u^2*Re1^-0.5;
disp(R,"shear stress at 30cm in (N/m^2):");
//part5
Rms=0.646*rho*u^2*Re^-0.5;
disp(Rms,"mean shear stress experienced over whole
   plate in (N/m^2)");
//part6
F=Rms*x*b;
disp(F,"total force experienced by the plate in (N)"
   )
```

Scilab code Exa 3.1.2 turbulent flow over a plate

```


//exapple 3.2
clc; funcprot(0);
// Initialization of Variable
P=102.7*1000;
M=28.8/1000;
R=8.314;
temp=273+18;
Recrit=10^5;
u=18.4;
b=4.7;//width
x=1.3;
mu=1.827/100000;
//calculation
//part1
rho=P*M/R/temp;
```

```
xcrit=Recrit*mu/rho/u;
a=1-xcrit/1.65;
disp(a*100,"% of surface over which turbulent
   boundary layer exist is :");
//part2
Rex=rho*u*x/mu;
thik=0.375*Rex^-.2*x;
disp(thik*100,"thickness of boundary layer in (cm):"
   );
y=0.5*thik;
ux=u*(y/thik)^(1/7);
disp(ux,"velocity of air at mid point is (m/s):")
//part4
lthik=74.6*Rex^-.9*x;
disp(lthik*1000,"thickness of laminar boundary layer
    in (mm):");
//part5
ub=u*(lthik/thik)^(1/7);
disp(ub,"velocity at outer edge of laminar sublayer
   in (m/s):");
//part6
R=0.0286*rho*u^2*Rex^-0.2;
disp(R,"shearforce expericienced in (N/m^2):");
//part7
x1=1.65;//length of plate
Rex1=rho*u*x1/mu;
Rms=0.0358*rho*u^2*Rex1^-0.2;
disp(Rms,"mean shearforce in (N/m^2):");
//part8
F=x1*Rms*b;
disp(F,"total drag force expericienced by the plate
   is (N):");
```

Scilab code Exa 3.1.3 streamline and turbulent flow through and equations of universal velocity profile

```
//exapple 3.3
clc; funcprot(0);
// Initialization of Variable
Q=37.6/1000000;
d=3.2/100;
mu=1.002/1000;
rho=998;
pi=3.14;
//calculation
//part1
u=4*Q/pi/d^2;
Re=rho*u*d/mu;
disp(Re,"pipe flow reynolds no :");
disp("Water will be in streamline motion in the pipe");
//part2
a=-8*u/d;
disp(a,"velocity gradient at the pipe wall is (s^-1) :");
//part3
Ro=-mu*a;
printf("Sherastress at pipe wall is (N/m^2) %.2e",Ro);
//part4
Q=2.10/1000;
u=4*Q/pi/d^2;
u=round(u*1000)/1000;
disp(u,"new av. fluid velocity is (m/s):");
Re=rho*u*d/mu;
phi=0.0396*Re^-0.25;//friction factor
phi=round(phi*10^5)/10^5;
delb=5*d*Re^-1*phi^-.5;
disp(delb*10^6,"thickness of laminar sublayer in (10^-6m):");
//part5
y=30*d/phi^0.5/Re;//thickness
```

```
tbl=y-delb;
disp(tbl*1000,"thickness of buffer layer in (mm):");
//part6
A=pi*d^2/4;//cross sectional area of pipe
dc=d-2*y;//dia of turbulent core
Ac=pi*dc^2/4;
p=(1-A/Ac)*100;
disp(p,"percentage of pipe-s core occupied by
    turbulent core is (%):");
//part7
uplus=5;//from reference
ux=uplus*u*phi^0.5;
disp(ux,"velocity where sublayer and buffer layer
    meet is (m/s):");
//part8
yplus=30;//from reference
ux2=u*phi^0.5*(2.5*log(yplus)+5.5);
disp(ux2,"velocity where turbulent core and buffer
    layer meet is (m/s):");
//part9
us=u/0.81;
disp(us,"fluid velocity along the pipe axis (m/s):")
    ;
//part10
Ro=phi*rho*u^2;
disp(Ro,"shearstress at pipe wall (N/m^2):");
```

Chapter 4

Flow Measurement

Scilab code Exa 4.1.1 use of pitot tube to measure flow rate

```


//exapple 4.1
clc; funcprot(0);
// Initialization of Variable
rho=998;
rhom=1.354*10^4;//density of mercury
M=2.83/100;
mu=1.001/1000;
mun=1.182/10^5;//vicosity of natural gas
R=8.314;
g=9.81;
h=28.6/100;
d=54/100;
//part1
nu=1/rho;
delP=h*g*(rhom-rho);
umax=sqrt(2*nu*delP);
umax=round(umax*10)/10;
disp(umax,"maximum fluid velocity in (m/s)");
Re=umax*d*rho/mu;
```

```
printf("reynold no. is %.2e",Re);
//using chart
u=0.81*umax;
G=rho*pi*d^2/4*u;
disp(G,"mass flow rate in (kg/s):");
disp(G/rho,"Volumetric flow rate in (m^3/s):");
//part2
P1=689*1000;//initial pressure
T=273+21;
nu1=R*T/M/P1;
nu1=round(nu1*10000)/10000;
rhog=1/nu1;//density of gas
h=17.4/100;
P2=P1+h*(rho-rhog)*g;
P2=round(P2/100)*100;
umax2=sqrt(2*P1*nu1*log(P2/P1));
disp(umax2,"maximum fluid velocity in (m/s)");
Re=rhog*umax2*d/mun;
printf("reynold no. is %.3e",Re);
//from table
u=0.81*umax2;
Q=pi*d^2/4*u;
disp(Q,"volumetric flow rate is (m^3/s):");
disp(Q*rhog,"mass flow rate  in (kg/s):")
```

Scilab code Exa 4.1.2 use of pitot tube to measure flow of gas

```
//exapple 4.2
clc; funcprot(0);
// Initialization of Variable
rd=[0 1 2.5 5 10 15 17.5]/100;//radial distance from pipe
dlv=[0 0.2 0.36 0.54 0.81 0.98 1]/100;//differnce in
```

```
    liquid levels
r=[.175 .165 .150 .125 .075 .025 0];//
g=9.81;
R=8.314;
rho=999;
temp=289;
P1=148*1000;
M=7.09/100;
pi=3.12
rhoCl2=P1*M/R/temp;//density of Cl2
nuCl2=1/rhoCl2;//specific volume of Cl2
function[y]=P2(x);
    y=P1+x*(rho-rhoCl2)*g;
endfunction
for i=1:7
    y=P2(dlv(i));
    u(i)=sqrt(2*P1*nuCl2*log(y/P1));
    a(i)=u(i)*r(i);
end
clf();
plot(r,a);
xtitle("","r (m)","u*r (m^2/s)");
s=0;
for i=1:6//integration of the plotted graph
    s=abs((r(i)-r(i+1))*.5*(a(i)+a(1+1)))+s;
end
s=s-0.01;
Q=2*pi*s;
disp(Q,"volumetric flow rate (m^3/s):");
disp(Q*rhoCl2,"mass flow rate of chlorine gas (kg/s)
   ")
```

Scilab code Exa 4.1.3 use of orifice and manometer to measure flow

```
//exapple 4.3
clc; funcprot(0);
// Initialization of Variable
pi=3.14;
Cd=0.61;
rho=999;
rhoo=877;//density of oil
g=9.81;
h=75/100;
d=12.4/100;//dia of orifice
d1=15/100;//inside diameter
nuo=1/rhoo;//specific volume of oil
//calculation
//part1
delP=h*(rho-rhoo)*g;
A=pi*d^2/4;
G=Cd*A/nuo*sqrt(2*nuo*delP/(1-(d/d1)^4));
disp(G,"mass flow rate in (kg/s)")
//part2
h=(1+0.5)*d1;
delP=rhoo/2*(G*nuo/Cd/A)^2*(1-(d/d1)^4)+h*rhoo*g;
disp(delP,"pressuer differnce between tapping points
    ");
delh=(delP-h*rhoo*g)/(rho-rhoo)/g;
disp(delh,"difference in water levels in manometer i
    (cm)")
```

Scilab code Exa 4.1.4 determination of orifice size for flow measurement and pressure drop produced by orifice and venturi meters

```
//exapple 4.4
clc; funcprot(0);
```

```
// Initialization of Variable
rhom=1.356*10^4;//density mercury
rhon=1266;//density NaOH
Cd=0.61;
g=9.81;
Cdv=0.98;//coeff. of discharge of venturimeter
Cdo=Cd;//coeff. of discharge of orificemeter
d=6.5/100;
pi=3.14;
A=pi*d^2/4;
Q=16.5/1000;
h=0.2;//head differnce
//calculation
//part1
delP=g*h*(rhom-rhon);
G=rhon*Q;
nun=1/rhon;//specific volume of NaOH
Ao=G*nun/Cd*sqrt(1/(2*nun*delP+(G*nun/Cd/A)^2));//
    area of orifice
d0=sqrt(4*Ao/pi)
disp(d0*100,"diameter of orifice in (cm):");
//part2
a=(Cdv/Cdo)^2;
disp(a,"ratio of pressure drop ")
```

Scilab code Exa 4.1.5 use of rotatometer for flow measurement

```


//exapple 4.5
clc; funcprot(0);
// Initialization of Variable
M=3.995/100;
g=9.81;
R=8.314;
```

```
Cd=0.94;
temp=289;
df=9.5/1000;//diameter of float
Af=pi*df^2/4;//area of float
P=115*10^3;
V=0.92/10^6;
rhoc=3778;//density of ceramic
//calculation
rho=P*M/R/temp;
nu=1/rho;
P=V*(rhoc-rho)*g/Af;
disp(P,"pressure drop over the float in (Pa):");
//part2
x=.15/25*(25-7.6);
L=df*100+2*x;
L=L/100;
A1=pi*L^2/4;
A0=A1-Af;
G=Cd*A0*sqrt(2*rho*P/(1-(A0/A1)^2));
printf("mass flow rate in (kg/s) is %.3e",G);
Q=G/rho;
disp(Q,"Volumetric flow rate in (m^3/s):")
```

Scilab code Exa 4.1.6 mass of float required to measure fluid rate in rotatometer

```


//exapple 4.6
clc; funcprot(0);
// Initialization of Variable
rho=999;
rhos=8020;//density of steel
g=9.81;
pi=3.14;
```

```
df=14.2/1000;//dia of float
Af=pi*df^2/4;//area of float
Cd=0.97;
nu=1/rho;
Q=4/1000/60;
G=Q*rho;
//calculation
x=0.5*(18.8-df*1000)/280*(280-70);
L=df*1000+2*x;
L=L/1000;
A1=pi*L^2/4;
A0=A1-Af;
Vf=Af/g/(rhos-rho)/2/nu*(G*nu/Cd/A0)^2*(1-(A0/A1)^2)
    ;
m=Vf*rhos;
disp(m*1000,"mass of float equired in (g):")
```

Chapter 5

Flow measurement in open channel

Scilab code Exa 5.1.1 use of manning and chezy formulae

```


//exapple 5.1
clc; funcprot(0);
// Initialization of Variable
rho=999.7;
g=9.81;
mu=1.308/1000;
s=1/6950;
b=0.65;
h=32.6/100;
n=0.016;
//calculation
//part1
A=b*h;
P=b+2*h;
m=A/P;
u=s^.5*m^(2/3)/n;
Q=A*u
```

```
disp(Q,"volumetric flow rate (m^3/s):");
C=u/m^0.5/s^0.5;
disp(C,"chezy coefficient (m^0.5/s):");
a=-m*rho*g*s/mu;//delu/dely
disp(a,"velocity gradient in the channel (s^-1):")
```

Scilab code Exa 5.1.2 stream depth in trapezoid channel

```


//exapple 5.2
clc; funcprot(0);
// Initialization of Variable
Q=0.885;
pi=3.1428;
s=1/960;
s=round(s*1000000)/1000000;
b=1.36;
n=0.014;
theta=55*pi/180;
//calculation
function[y]=flow(x);
    a=(x*(b+x/tan(theta)))/(b+2*x/sin(theta));
    y=a^(2/3)*s^(1/2)*(x*(b+x/tan(theta)))/n-Q;
endfunction
x=fsolve(0.1,flow);
disp(x,"depth of water in (m):")
```

Scilab code Exa 5.1.3 optimum base angle of a Vshaped channel Slope of a channel

```


```

```
//exapple 5.3
clc; funcprot(0);
// Initialization of Variable
n=0.011;
h=0.12;
Q=25/10000;
//calculation
deff('y=f(x)','y=1/x^2-1');
x=fsolve(0.1,f);
theta=2*atan(x);
A=h*2*h/tan(theta/2)/2;
P=2*h*sqrt(2);
s=Q^2*n^2*P^(4/3)/A^(10/3);
disp(s,"the slope of channel in (radians):")
```

Scilab code Exa 5.1.4 stream depth and maximum velocity and flow rate in a pipe

```


//exapple 5.4
clc; funcprot(0);
// Initialization of Variable
//part1
//maximizing eqution in theta & get a function
function[y]=theta(x)
    y=(x-.5*sin(2*x))/2/x^2-(1-cos(2*x))/2/x;
endfunction
x=fsolve(2.2,theta);
x=round(x*1000)/1000;
a=(1-cos(x))/2;
printf("velocity will be maximum when stream depth in times of diameter is %.3f",a);
//part2
//maximizing eqution in theta & get a function
```

```
function[y]=theta2(x)
    y=3*(x-.5*sin(2*x))^2*(1-cos(2*x))/2/x-(x-.5*sin
        (2*x))^3/2/x^2 ;
endfunction
x1=fsolve(2.2,theta2);
x1=round(x1*1000)/1000;
a=(1-cos(x1))/2;
disp("")
printf("vlumetric flow will be maximum when stream
    depth in times of diameter is %.3f",a);
//part3
r=1;
A=1*x-0.5*sin(2*x);
s=0.35*3.14/180;
P=2*x*r;
C=78.6;
u=C*(A/P)^0.5*s^0.5;
disp(u,"maximum velocity of obtained fluid (m/s):");
//part4
disp(x1,"maximum flow rate obtained at angle in (
    radians):")
```

Scilab code Exa 5.1.5 flow measurement with sharp crested weir

```


//exapple 5.5
clc; funcprot(0);
// Initialization of Variable
g=9.81;
h=28/100;
Cd=0.62;
B=46/100;
Q=0.355;
n=2;//from francis formula
```

```
//calcualtion
//part1
u=sqrt(2*g*h);
disp(u,"velocity of fluid (m/s):");
//part2a
H=(3*Q/2/Cd/B/(2*g)^0.5)^(2/3);
disp(H,"fluid depth over weir in (m):");
//part2b
//using francis formula
function[y]=root(x)
    y=Q-1.84*(B-0.1*n*x)*x^1.5;
endfunction
x=fsolve(0.2,root);
disp(x,"fluid depth over weir in if SI units uesd in (m):");
//part3
H=18.5/100;
Q=22/1000;
a=15*Q/8/Cd/(2*g)^0.5/H^2.5;
theta=2*atan(a);
disp(theta*180/3.14,"base angle of the notch of weir (degrees)")
```

Scilab code Exa 5.1.6 equation of specific energy and analysis of tranquil and shooting flow

```


//exapple 5.6
clc; funcprot(0);
// Initialization of Variable
Q=0.675;
B=1.65;
D=19.5/100;
g=9.81;
```

```
//caculation
u=Q/B/D;
u=round(u*1000)/1000;
E=D+u^2/2/g;
y=poly([8.53/1000 0 -E 1],'x','coeff');
x=roots(y);
disp(x(1),"alternative depth in (m)");
disp("It is shooting flow");
Dc=2/3*E;
Qmax=B*(g*Dc^3)^0.5;
disp(Qmax,"maximum volumetric flow (m^3/s)");
Fr=u/sqrt(g*D);
disp(Fr,"Froude no.");
a=(E-D)/E;
disp(a*100,"% of kinetic energy in initial system");
b=(E-x(1))/E;
disp(b*100,"% of kinetic energy in final system");
```

Scilab code Exa 5.1.7 alternate depth of stream gradient of mild and steep slope

```


//exapple 5.7
clc; funcprot(0);
// Initialization of Variable
G=338;//mass flow rate
rho=998;
q=G/rho;
E=0.48;
n=0.015;
g=9.81;
B=0.4;
y=poly([5.85/1000 0 -E 1],'x','coeff');
x=roots(y);
```

```
disp(x(1),x(2),"alternate depths (m):");
s=(G*n/rho/x(2)/(B*x(2)/(B+2*x(2)))^(2/3))^2
disp(s,"slode when depth is 12.9cm");
s=(G*n/rho/x(1)/(B*x(1)/(B+2*x(1)))^(2/3))^2
disp(s,"slode when depth is 45.1cm");
```

Scilab code Exa 5.1.8 critical flw condition

```


//exapple 5.8
clc; funcprot(0);
// Initialization of Variable
pi=3.14;
theta=pi/3;
h=1/tan(theta);
B=0.845;
E=0.375;
g=9.81;
//calculation
//part1
//deducing a polynomial(quadratic) in Dc
a=5*h;
b=3*B-4*h*E;
c=-2*E*B;
y=poly([c b a],'x','coeff');
x=roots(y);
disp(x(2),"critical depth in (m):");
//part2
Ac=x(2)*(B+x(2)*tan(theta/2));
Btc=B+x(2)*tan(theta/2)*2;
Dcbar=Ac/Btc;
uc=sqrt(g*Dcbar);
disp(uc,"critical velocity (m/s):");
//part3
```

```
Qc=Ac*uc;
disp(Qc,"Critical volumetric flow (m^3/s):");
```

Scilab code Exa 5.1.9 flow measurement with broad crested weir

```


//exapple 5.9
clc; funcprot(0);
// Initialization of Variable
B2=1.60;//breadth at 2
D2=(1-0.047)*1.27;//depth at 2
g=9.81;
B1=2.95;//breadth at 1
D1=1.27;//depth at 1
Z=0;
//calculation
Q=B2*D2*(2*g*(D1-D2-Z)/(1-(B2*D2/B1/D1)^2))^0.5;
disp(Q,"volumetric flow rate over flat topped weir
    over rectangular section in non uniform width(m
    ^3/s)");
//next part
B2=12.8;
D1=2.58;
Z=1.25;
Q=1.705*B2*(D1-Z)^1.5;
disp(Q,"volumetric flow rate over flat topped weir
    over rectangular section in uniform width (m^3/s)
    :")
```

Scilab code Exa 5.1.10 gradually varied flow behind a weir

```

```

```
//exapple 5.10
clc; funcprot(0);
// Initialization of Variable
pi=3.14;
n=0.022;
B=5.75;
s=0.15*pi/180;
Q=16.8;
function[y]=normal(x)
    y=Q-B*x/n*(B*x/(B+2*x))^(2/3)*s^0.5;
endfunction
x=fsolve(1.33,normal);
disp(x,"Normal depth in (m):");
Dc=(Q^2/g/B^2)^(1/3);
disp(Dc,"Critical depth in (m):");
delD=.1;
D=1.55:.1:2.35
su=0;
for i=1:9
    delL=delD/s*(1-(Dc/D(i))^3)/(1-(x/D(i))^3.33);
    su=su+delL
end
disp(su,"distance in (m) from upstream to that place
   :")
```

Scilab code Exa 5.1.11 analysis of hydraulic jump

```


//exapple 5.11
clc; funcprot(0);
// Initialization of Variable
g=9.81;
q=1.49;
```

```
pi=3.14;
//calculation
//part1
Dc=(q^2/g)^.333;
disp(Dc,"critical depth in (m):");
//part2
n=0.021;
su=1.85*pi/180;//slope upstream
sd=0.035*pi/180;//slope downstream
Dnu=(n*q/sqrt(su))^(3/5);
Dnu=round(Dnu*1000)/1000;
disp(Dnu,"normal depth upstream in (m):");
Dnd=(n*q/sqrt(sd))^(3/5);
disp(Dnd,"normal depth downstream in (m):");
//part3
D2u=-0.5*Dnu*(1-sqrt(1+8*q^2/g/Dnu^3));
D2u=round(D2u*1000)/1000;
disp(D2u,"conjugate depth for upstream in (m):");
D1d=-0.5*Dnd*(1-sqrt(1+8*q^2/g/Dnd^3));
disp(D1d,"conjugate depth for downstream in (m):");
//part4
//accurate method
delD=.022;
D=0.987:.022:1.141
dis=0;
for i=1:8
    delL=delD/su*(1-(Dc/D(i))^3)/(1-(Dnu/D(i))^3.33)
        ;
    dis=dis+delL
end
disp(dis,"distance in (m) of occurence of jump by
    accurate method:");
//not so accurate one
E1=D2u+q^2/2/g/D2u^2;
E2=Dnd+q^2/2/g/Dnd^2;
E2=round(E2*1000)/1000;
E1=round(E1*1000)/1000;
ahm=(D2u+Dnd)/2;//av. hydraulic mean
```

```
afv=.5*(q/D2u+q/Dnd);//av. fluid velocity
i=(afv*0.021/ahm^(2/3))^2;
l=(E2-E1)/(su-i+0.0002);
disp(l,"distance in (m) of occurence of jump by not
    so accurate method:")
//part5
rho=998;
Eu=Dnu++q^2/2/g/Dnu^2;
Eu=round(Eu*1000)/1000;
P=rho*g*q*(Eu-E1);
disp(P/1000,"power loss in hydraulic jump per unit
    width in (kW):")
```

Chapter 6

pumping of liquids

Scilab code Exa 6.1.1 cavitation and its avoidance in suction pipes

```

//example 6.1
clc; funcprot(0);
//exapple 6.1
// Initialization of Variable
atp=100.2*1000;
g=9.81;
rho_w=996;
rho_toluene=867;
vap_pre_toluene=4.535*1000;
viscosity_toluene=5.26/10000;
//calculation
m=(atp-vap_pre_toluene)/rho_toluene/g;
disp(m,"Max. height of toluene supported by atm.
    pressure (in m):");
//part(1)
hopw=0.650;//head of pump in terms of water
hopt=hopw*rho_w/rho_toluene;//head of pump in terms
    of toluene
Q=1.8*10^-3;//flow in m^3/s
d=2.3*10^-2;//diameter of pipe
```

```
pi=3.14127;
//u=4*Q/pi/d^2
//substituting this for reynolds no.
Re=4*Q*rho_toluene/pi/d/viscosity_toluene;//reynolds
    no.
disp(Re ,"reynolds no :");
phi=0.0396*Re^-0.25;
//since both LHS and RHS are function of x(max. ht.
   ab. toluene)
//we define a new variable to solve the eqn
//y=(atp/rho_toluene/g)-(vap_pre_toluene/rho_toluene
   /g)-(4*phi*16*Q^2*x/pi^2/d^5/g)-hopt;
//y=x
//these are two equations
b=[0;((atp/rho_toluene/g)-(vap_pre_toluene/
   rho_toluene/g)-hopt)];
A=[1 -1;1 4*phi*16*Q^2/pi^2/d^5/g];
x=A\b;
disp(x(2,1), "the maximum height above toulene in
   the tank the pump can be located without risk
   while flow rate is 1.80dm^3/s (in m):");
//solution of part(2)
l=9//length
u=sqrt(((atp/rho_toluene/g)-(vap_pre_toluene/
   rho_toluene/g)-hopt-l)*d*g/4/phi/l);//fluid
   velocity in pipes
Q=pi*d^2*u/4;
disp(Q,"Maximum delivery rate if pump is located 9m
   above toluene tank(in m^3/s)")
//solution of part(3)
//clubing d together we get
Q=1.8/1000;
a=(atp/rho_toluene/g)-(vap_pre_toluene/rho_toluene/g
   )-hopt-l;
b=a*pi^2*g/4/9/16/Q^2/0.0396/(4*Q*rho_toluene/pi/
   viscosity_toluene)^-0.25;
d=(1/b)^(1/4.75);
disp(d , "minimum smooth diameter of suction pipe
```

```
which will have flow rate as (1.8 dm^3/s) for pump kept at 9 m high (in m):");
```

Scilab code Exa 6.1.2 specific speed of a centrifugal pump

```

//example 6.2
clc; funcprot(0);
//exapple 6.2
// Initialization of Variable
Q1=24.8/1000;//flow in pump 1
d1=11.8/100;//diameter of impeller 1
H1=14.7//head of pump 1
N1=1450//frequency of motor 1
Q2=48/1000//flow in pump 2
//calculation
H2=1.15*H1;//head of pump 2
specific_speed=N1*Q1^0.5/H1^0.75;
N2=specific_speed*H2^0.75/Q2^0.5;//frequency of motor 2
disp(N2 ,"frequency of motor 2 in rpm");
d2=sqrt(N2^2*H1/H2/N1^2/d1^2);
disp(1/d2 , "diametr of impeller 2 (in m)");
```

Scilab code Exa 6.1.3 theoritical and effective characteristic of centrifugal pump flow rate

```

//example 6.3
clc; funcprot(0);
clf()
//exapple 6.3
// Initialization of Variable
```

```
Q=[0 0.01 0.02 0.03 0.04 0.05];//discharge
effi_hyd=[65.4 71 71.9 67.7 57.5 39.2];
effi_over=[0 36.1 56.0 61.0 54.1 37.0];
H_sys=[0 0 0 0 0 0]
d=0.114;//diameter of pipe
d_o=0.096;//diameter of impeller
h=8.75;//elevation
g=9.81;//acc. of gravity
rho=999;//denisity of water
l=60;//length of pipe
theta=0.611;//angle in radians
B=0.0125;//width of blades
pi=3.1412
mu=1.109/1000;//viscosity of water
omega=2*pi*1750/60;
// calculation
 for i=1:6
     if i==1 then
     H_sys(i)=h;
 else

    H_sys(i)=h+8*Q(i)^2/pi^2/d^4/g*(1+8*l*0.0396/d
       *(4*rho*Q(i)/pi/d/mu)^-0.25);
end,
end;
H_theor=omega^2*d_o^2/g-omega*Q/2/pi/g/B/tan(theta);
//disp(H_sys"head of system (in m)");
//disp(H_theor);
for i=1:6
    H_eff(i)=effi_hyd(i)*H_theor(i)/100;
end
//disp(H_eff);
plot(Q,effi_hyd, 'r--d');
plot(Q,effi_over, 'g');
plot(Q,H_eff,'k');
plot(Q,H_theor);
plot(Q,H_sys ,'c-');
title('system characteritics');
```

```
ylabel('Head(m)or  Efficiency(%)');
xlabel('volumetric  flow  rate(m^3/s)');
//calculation  of  power
//at  intersecting  point  using  datatrip  b/w  H_sys  &
    H_eff
Q=0.0336
effi_over=59.9
H_eff=13.10
P=H_eff*rho*g*Q/effi_over/10;
disp(P ,"Power  required  to  pump  fluid  at  this  rate(
    in  KW):")
```

Scilab code Exa 6.1.4 flow rate when cetrifugal pumps operate singly and in parallel

```


clc; funcprot(0);
clf()
//exapple  6.4
//  Initialization  of  Variable
//each  is  increased  by  five  units  to  make  each
    compatible  for  graph  plotting
Q=[0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09
    0.1];//flow  rate
HeffA=[20.63 19.99 17.80 14.46 10.33 5.71 0 0 0 0 0
    ];//Heff  of  pump  A
HeffB=[18 17 14.95 11.90 8.10 3.90 0 0 0 0 0];//Heff
    of  pump  B
alpha=1;
h=10.4;
d=0.14;
l=98;
pi=3.1412;
g=9.81;
```

```
rho=999;
for i=1:11
     if i==1 then
     H_sys(i)=h;
 else

    H_sys(i)=h+8*Q(i)^2/pi^2/d^4/g*(1+8*l*0.0396/d*(4*rho*Q(i)/pi/d/mu)^-0.25);
end,
end;
//H_sys is head of the system
disp(H_sys, "the head of system in terms of height of water :");
plot(Q,H_sys,'r--d');
plot(Q,HeffA ,'-c');
plot(Q,HeffB);
//at intersecting point using datatrip b/w H_sys & H_effA
disp(0.03339,"the flow rate at which H_sys takes over HeffA");
```

Scilab code Exa 6.1.5 pumping with a reciprocating pump

```

//example 6.5
clc; funcprot(0);
//exapple 6.5
// Initialization of Variable
rho=1000;
dc=.15;
l=7.8;
g=9.81;
pi=3.1428;
atp=105.4*1000;
vap_pre=10.85*1000;
```

```
sl=.22;
dp=0.045;
h=4.6;
//("x(t)=sl/2*cos(2*pi*N*t)"  "the function of
    displcement");
//"since we have to maximize the acceleration double
    derivate the terms");
//since double derivation have the term cos(kt)
//finding it maxima
t=linspace(0,5,100);
k=1;
function[m,v]= maximacheckerforcosine()
h=0.00001;
a=0.00;
for i=1:400
    if (cos(a+h)-cos(a-h))/2*h==0 & cos(i-1)>0 then
break;
else
    a=0.01+a;
end
break;
end
m=i-1;
v=cos(i-1);
endfunction;
[a, b]= maximacheckerforcosine();
disp(a,"time t when the acceleration will be maximum
    (s)");
//double derivative will result in a square of value
    of N
//lets consider its coefficient all will be devoid
    of N^2
k=sl/2*(2*pi)^2//accn max of piston
kp=k*1/4*pi*dc^2/1*4/pi/dp^2;//accn coeff. ofsuction
    pipe
f=1/4*pi*dp^2*l*rho*kp;//force exerted by piston
p=f/1*4/pi/dp^2;//pressure exerted by piston
//calculation
```

```
o=atp-h*rho*g-vap_pre;
//constant term of quadratic eqn
y=poly([o 0 -p],'N', 'coeff')
a=roots(y);
disp(abs(a(1,1)),"Maximum frequency of oscillation
    if cavitation o be avoided(in Hz)");
```

Scilab code Exa 6.1.6 pumping with a air lift pump

```

//example 6.6
clc; funcprot(0);
//exapple 6.6
// Initialization of Variable
rhos=1830;//density of acid
atp=104.2*1000;//atmospheric pressure
temp=11+273;//temp in kelvin
M=28.8/1000;//molar mass of air
R=8.314;//universal gas constant
g=9.81;//acceleration of gravity
pi=3.14;
d=2.45;//diameter of tank
l=10.5;//length of tank
h_s=1.65;//height of surface of acid from below
effi=0.93//efficiency
//calculation
mliq=pi*d^2*l*rhos/4;
h_atm=atp/rhos/g;//height conversion of atp
h_r=4.3-1.65;//height difference
mair=g*h_r*mliq*M/(effi*R*temp*log(h_atm/(h_atm+h_s)
    ));//mass of air
disp(mair,"mass of air required to lift the
    sulphuric acid tank");
disp("The negative sign indicates air is expanding &
     work done is magnitude of value in kg:");
```

```
m=abs(mair/mliq);
disp(m, "The mass of air required for per kilo of
    acid transferred:");
```

Chapter 7

Flow Through Packed Beds

Scilab code Exa 7.1.1 determination of particle size and specific surface area for a sample of powder

```


//exapple 7.1
clc; funcprot(0);
// Initialization of Variable
mu=1.83/1000;
rhom=1.355*10000;//density mercury
K=5;
g=9.81;
d=2.5/100;
pi=3.14;
thik=2.73/100;
rho=3100;//density of particles
Q=250/(12*60+54)/10^6;
//calculation
A=pi*d^2/4;
Vb=A*thik;//volume of bed
Vp=25.4/rho/1000;//volume of particles
e=1-Vp/Vb;
u=Q/A;
```

```
delP=12.5/100*rhom*g;
S=sqrt(e^3*delP/K/u/thik/mu/(1-e)^2);
S=round(S/1000)*1000;
d=6/S;
disp(d*10^6,"average particle diameter in (x10^-6m)"
   );
A=pi*d^2/1000/(4/3*pi*d^3/8*rho);
disp(A*10^4,"surface area per gram of cement (cm^2):
   ")
```

Scilab code Exa 7.1.2 rate of flow through packed bed

```


//exapple 7.2
clc; funcprot(0);
// Initialization of Variable
mu=2.5/1000;
rho=897;
g=9.81;
pi=3.1414;
K=5.1;
l=6.35/1000;
d=l;
hei=24.5+0.65;
len=24.5;
dc=2.65;//dia of column
thik=0.76/1000;
Vs=pi*d^2/4*l-pi*l/4*(d-2*thik)^2;//volume of each
   ring
n=3.023*10^6;
e=1-Vs*n;
e=round(e*1000)/1000;
Surfacearea=pi*d*l+2*pi*d^2/4+pi*(d-2*thik)*l-2*pi*(
   d-2*thik)^2/4;
```

```
S=Surfacearea/Vs;
S=round(S);
delP=hei*g*rho;
delP=round(delP/100)*100;
u=e^3*delP/K/S^2/mu/(1-e)^2/len;
Q=pi*dc^2/4*u;
disp(Q,"initial volumetric flow rate in (m^3/s):")
```

Scilab code Exa 7.1.3 determination of pressure drop to drive fluid through a packed bed of raschig rings then of similar size spheres and the determination of total area of surface presented with two types of packing

```


//exapple 7.3
clc; funcprot(0);
// Initialization of Variable
dr=2;//dia of column
mu=2.02/10^5;
rho=998;
K=5.1;
g=9.81;
Q=10000/3600;
l=50.8/1000;
d=l;
n=5790;
len=18;
thik=6.35/1000;
pi=3.1414;
//part1
//calculation
CA=pi*dr^2/4;//cross sectional area
u=Q/CA;
Vs=pi*d^2/4*l-pi*l/4*(d-2*thik)^2;//volume of each
    ring
```

```
e=1-Vs*n;
Surfacearea=pi*d*l+2*pi*d^2/4+pi*(d-2*thik)*l-2*pi*(
   d-2*thik)^2/4;
S=Surfacearea/Vs;
S=round(S*10)/10;
delP=K*S^2/e^3*mu*len*u*(1-e)^2;
delh=delP/rho/g;
disp(delh*100,"pressure drop in terms of (cm of H20)
   ")
```

Chapter 8

Filtration

Scilab code Exa 8.1.1 constant rate of filtration in a plate and frame filter process

```


//exapple 8.1
clc; funcprot(0);
// Initialization of Variable
//part1
a=78/1000;//dV/dt
rho=998;//density of water
rhoc=2230;//density of china clay
rhod=1324;//density of cowdung cake
mu=1.003/1000;
P2=3.23*1000;//pressure after 2 min.
P5=6.53*1000;//pressure after 5 min.
t=30*60;
b=[P2;P5];
A=[a^2*120 a;a^2*300 a];
x=A\b;
P=x(1,1)*a^2*t+x(2,1)*a;
disp(P/1000,"pressure drop at t=30min in (kN/m^2):")
//part2
```

```
J=0.0278;//mass fraction
l=1.25;
b1=0.7;
A1=l*b1*17*2;//area of filtering
V=a*30*60;//volume of filterate
e=1-rhod/rhoc;
nu=J*rho/((1-J)*(1-e)*rhoc-J*e*rho);
l1=nu*V/A1;
disp(l1,"the thickness of filtercake formed after 30
    min in (m):")
//part3
r=x(1,1)/mu/nu*A1^2;
L=x(2,1)*A1/r/mu;
disp(L,"thickness of cake required in (m):");
//part 4
S=sqrt(r*e^3/5/(1-e)^2);
d=6/S;
disp(d*10^6,"average particle diameter in(10^-6m):")
```

Scilab code Exa 8.1.2 Constant rate and pressure drop filteration

```


//exapple 8.2
clc; funcprot(0);
// Initialization of Variable
P1=5.34*1000;//pressure after 3 min.
P2=9.31*1000;//pressure after 8 min.
a=240/1000000;//dV/dt
P3=15*10^3;//final pressure
//calculation
b=[P1;P2];
A=[a^2*180 a;a^2*480 a];
x=A\b;
//part1
```

```
t=(P3-x(2,1)*a)/x(1,1)/a^2;
disp(t,"time at which the required pressure drop have taken place in (s):");
//part 2
V1=a*t;
disp(V1,"volume of filterate in (m^3):");
//part 3
V2=0.75;
t2=t+x(1,1)/2/P3*(V2^2-V1^2)+x(2,1)/P3*(V2-V1);
disp(t2,"the time required to collect 750dm^3 of filterate in (s):");
//part 4
P4=12*10^3;
a=P4/(x(1,1)*V2+x(2,1));
t=10/1000/a;
disp(t,"time required to pass 10dm^3 volume in (s):")
```

Scilab code Exa 8.1.3 determination of characteristic of filtration system

```


//exapple 8.3
clc; funcprot(0);
// Initialization of Variable
a=16/1000;//dV/dt
J=0.0876;//mass fraction
rho=999;//density of water
rhoc=3470;//density of slurry
mu=1.12/1000;
rhos=1922;//density of dry filter cake
t1=3*60;
t2=8*60;
V1=33.8/1000;//volume at t1
V2=33.8/1000+23.25/1000;//volume at t2
```

```
P=12*1000;//pressure difference
Ap=70^2/10000*2*9;
As=650/10000;
//calculation
b=[t1;t2]
A=[V1^2/2/P V1/P;V2^2/2/P V2/P];
x=A\b;
K1p=x(1,1)*As^2/Ap^2;
K2p=x(2,1)*As/Ap;
P2=15*1000;//final pressure drop
t=(P2-K2p*a)/K1p/a^2;//time for filterate
V=a*t;//volume of filterate
e=1-rhos/rhoc;
nu=J*rho/((1-J)*(1-e)*rhoc-J*e*rho);
l=(11-1)/200;
Vf=Ap*l/nu;
tf=t+K1p/2/P2*(Vf^2-V^2)+K2p/P2*(Vf-V);
r=K1p/mu/nu*Ap^2;
L=K2p*Ap/r/mu;
disp(L,"the thickness of filter which has resistance
    equal to resistance of filter medium in (m):")
```

Scilab code Exa 8.1.4 constant pressure drop filtration of suspension which gives rise to a compressible filter cake

```


//exapple 8.4
clc; funcprot(0);
// Initialization of Variable
t1=3*60;//time 3min
t2=12*60;//time 12min
t3=5*60;//time 5min
P=45*1000;//pressure at t1&t2
P2=85*1000;//pres. at t3
```

```
a=1.86;//area
mu=1.29/1000;
c=11.8;
V1=5.21/1000;//volume at t1
V2=17.84/1000;//volume at t2
V3=10.57/1000;//volume at t3
//calculation
b=[t1;t2];
A=[mu*c/2/a^2/P*V1^2 V1/P;mu*c/2/a^2/P*V2^2 V2/P];
x=A\b;
r45=x(1,1);
r85=(t3-x(2,1)*V3/P2)*2*a^2*P2/V3^2/mu/c;
n=log(r45/r85)/log(45/85);
rbar=r45/(1-n)/(45*1000)^n;
r78=rbar*(1-n)*(78*1000)^n;
//part1
//polynomial in V as a1x^2+bx+c1=0
c1=90*60;//time at 90
Pt=78*1000;//Pt=pressure at time t=90
r78=round(r78/10^12)*10^12;
a1=r78*mu/a^2/Pt*c/2;
b=x(2,1)/Pt;
y=poly([-c1 b a1],'V1','coeff');
V1=roots(y);
disp(V1(2),"Volume at P=90kPa in (m^3):");
//part2
Pt=45*1000;
c1=90*60;
a1=r45*mu/a^2/Pt*c/2;
b=x(2,1)/Pt;
y=poly([-c1 b a1],'V1','coeff');
V1=roots(y);
disp(V1(2),"Volume at p=45kPa in (m^3):");
```

Scilab code Exa 8.1.5 filtration on a rotatory drum filter

```
//exapple 8.4
clc; funcprot(0);
// Initialization of Variable
t=60*0.3/0.5;//time of 1 revollution
d=34/1000000;
S=6/d;
e=0.415;
J=0.154;
P=34.8*1000;
mu=1.17/1000;
L=2.35/1000;
rho=999;//density of water
rhos=4430;//density of barium carbonate
//calculation
//part1
nu=J*rho/((1-J)*(1-e)*rhos-J*e*rho);
r=5*S^2*(1-e)^2/e^3;
//quadratic in l
//in the form of ax^2+bx+c=0
c=-t;
b=r*mu*L/nu/P;
a=r*mu/2/nu/P;
y=poly([c b a],'l','coeff');
l=roots(y);
disp(l(2),"thickness of filter cake in (m):");
//part2
d=1.2;
l1=2.6;
pi=3.1428;
u=pi*d*0.5/60;
Q=u*l1*l(2);
mnet=Q*(1-e)*rhos+Q*e*rho;
disp(mnet,"rate at which wet cake will be scrapped
   in (kg/s):");
//part3
md=Q*(1-e)*rhos;//rate at which solid scrapped from
```

```
   the drum
r=md/0.154;
disp(r*3600,"rate of which slurry is treated is (kg/
   h):")
```

Scilab code Exa 8.1.6 filtration of centrifugal filter

```


//exapple 8.6
clc; funcprot(0);
// Initialization of Variable
mu=0.224;
rho=1328;
K=5;
b=3*.5;//radius
h=2.5;
pi=3.1428;
x=2.1*.5;
rhos=1581;//density of sucrose
e=0.435;//void ratio
J=0.097;//mass fraction
m=3500;//mass flowing
a=85/10^6;//side length
L=48/1000;//thickness
omega=2*pi*325/60;
//calculation
bi=b^2-m/pi/h/(1-e)/rhos;//inner radius
bi=sqrt(bi);
bi=round(bi*1000)/1000;
nu=J*rho/((1-J)*(1-e)*rhos-J*e*rho);
S=6/a;
r=5*S^2*(1-e)^2/e^3;
t=((b^2-bi^2)*(1+2*L/b)+2*bi^2*log(bi/b))/(2*nu*rho*
   omega^2/r/mu*(b^2-x^2));
```

```
disp(t,"time taken to collect sucrose crystal in (s)
   :");
//part2
vl=pi*(b^2-bi^2)*h*e;
vs=pi*(b^2-bi^2)*h/nu-vl;
disp(vs,"volume of liquid separated as filterate i (
   m^3):");
```

Chapter 9

Forces on bodies Immersed in fluids

Scilab code Exa 9.1.1 drag forces and coefficient

```


//exapple 9.1
clc; funcprot(0);
// Initialization of Variable
rho=1.2;
mu=1.85/100000;
pi=3.1428;
d=3;
v=50*1000/3600;
//calculation part 1
Re=d*rho*v/mu;
//from chart of drag coeff. vs Re
Cd=0.2;//coeff. of drag
Ad=pi*d^2/4;//projected area
Fd=Ad*Cd*rho*v^2/2;
disp(Fd , "The drag force on sphere in N");
//part 2
v=2;
```

```
l=0.25;
Re=l*v*rho/mu;
zi=4*pi*(l^3*3/4/pi)^(2/3)/6/l^2;//sphericity
//using graph
Cd=2;
Ad=l^2;
Fd=Ad*Cd*rho*v^2/2;
disp(Fd , "The drag force on cube in N");
```

Scilab code Exa 9.1.2 lift force and lift coefficient

```


//exapple 9.2
clc; funcprot(0);
// Initialization of Variable
rho=1.2;
mu=1.85/100000;
pi=3.1428;
g=9.81;
d=1.38;
t=0.1;//thickness
v=30*1000/3600;
T=26.2;//Tension
m=0.51//mass
theta=60*pi/180;
//calculation
Fd=T*cos(theta);
disp(Fd,"Drag force in N:");
A=pi*d^2/4;
Ad=A*cos(theta);//area component to drag
Cd=2*Fd/Ad/rho/v^2;//coeff of drag
disp(Cd , "The drag coefficient:")
Fg=m*g;//force of gravity
Fb=rho*pi*d^2/4*t*g;//buoyant force
```

```
Fl=Fg-Fb+T*sin(theta);
disp(Fl , "The lift force in N :");
Al=A*sin(theta);
Cl=2*Fl/Al/rho/v^2;
disp(Cl ,"The coefficient of lift:")
```

Scilab code Exa 9.1.3 Particle diameter and terminal settling velocity

```


//exapple 9.3
clc; funcprot(0);
// Initialization of Variable
rhog=1200;//density of glycerol
mu=1.45;
pi=3.1428;
g=9.81;
rhos=2280;//density of sphere
v=0.04;//terminal velocity;
a=2*mu*g*(rhos-rhog)/v^3/3/rhog^2;//a=Cd/2/Re
//using graph of Cd/2/Re vs Re
Re=0.32;
d=Re*mu/v/rhog;
disp(d , "Diameter of sphere in (m):");
```

Scilab code Exa 9.1.4 terminal settling velocity of sphere

```


//exapple 9.4
clc; funcprot(0);
// Initialization of Variable
rhoa=1.218;//density of air
```

```
mu=1.73/100000;
pi=3.1428;
g=9.81;
rhop=2280;//density of polythene
d=0.0034;//diameter
a=4*d^3*(rhop-rhoa)*rhoa*g/3/mu^2;//a=Cd*Re^2
//using graph of Cd*Re^2 vs Re
Re=2200;
v=Re*mu/d/rhog;
disp(v , "The terminal vrlocity in (m/s)");
```

Scilab code Exa 9.1.5 effect of shape on drag force

```


//exapple 9.2
clc; funcprot(0);
// Initialization of Variable
pi=3.1428;
rho=825;
mu=1.21;
g=9.81;
l=0.02;
de=0.02;//dia exterior
di=0.012;//dia interior
//calculation
//part 1
zi=pi*(6*(pi*de^2/4-pi*di^2/4)*l/pi)^(2/3)/(pi*l*(di
   +de)+2*pi*(de^2/4-di^2/4));
disp(zi, "sphericity of Raschig ring is:");
//part 2
u=0.04;
ds=0.003//diameter of each sphere
zi=pi*(6*pi*ds^3/pi)^(2/3)/6/pi/ds^2;//sphericity
disp(zi, "sphericity of given object is:");
```

```
Ap=4*ds^2-4*3/4*(ds^2-pi*ds^2/4);//projected area
dp=sqrt(4*Ap/pi);//projected dia
Re=dp*u*rho/mu;
disp(Re, "Reynolds no. for the object:");
//using graph b/w Re and zi and Cd
Cd=105;//coeff. of drag
Fd=Ap*Cd*u^2*rho/2;
disp(Fd,"The drag force on object in (N):")
```

Scilab code Exa 9.1.6 estimation of hindered settling velocity

```


//exapple 9.6
clc; funcprot(0);
// Initialization of Variable
rho=998;//density of water
mu=1.25/1000;//viscosity of water
w=100;//mass of water
pi=3.1428;
g=9.81;
rhog=2280;//density of glass
wg=60;//mass of glass
d=45*10^-6;//diameter of glass sphere
//claculation
rhom=(w+wg)/(w/rho+wg/rhog);//density of mixure
e=w/rho/(w/rho+wg/rhog);//volume fraction of watter
//using charts
zi=exp(-4.19*(1-e));

K=d*(g*rho*(rhog-rho)*zi^2/mu^2)^(1/3);//stoke's law
    coeff.
disp(K);
if K<3.3 then
    disp("settling occurs in stoke-s law range");
```

```
    U=g*d^2*e*zi*(rhog-rhom)/18/mu;
    disp(U,"settling velocity in m/s:")
else
    disp("settling does not occurs in stoke-s law
       range");
end
```

Scilab code Exa 9.1.7 acceleration of settling particle in gravitational feild

```


//exapple 9.7
clc; funcprot(0);
// Initialization of Variable
rhog=1200;//density of glycerol
mu=1.45;//viscosity of glycerol
pi=3.1428;
g=9.81;
rhos=2280;//density of sphere
d=8/1000;
s=0;
uf=0.8*0.026;
//calculation
function[a]=intre()
    u=linspace(0,uf,1000);
    for i=1:1000
        y=((pi/6*d^3*rhos*g-pi*d^3/6*rhog*g-0.5*pi*d
           ^2/4*24*mu/d/rhog*rhog*u(i))/pi*6/d^3/
           rhos)^(-1)*uf/1000;
        s=s+y;
    end
    a=s;
endfunction
[t]=intre();
disp(t,"Time taken by particle to reach 80% of its
```

```
velocity in (s):");
```

Chapter 10

Sedimentation and Clssification

Scilab code Exa 10.1.1 determination of settling velocity from a single batch sedimentation

```


//example 10.1
clc; funcprot(0);
clf()
//exapple 10.1
// Initialization of Variable
t=[0 0.5 1 2 3 4 5 6 7 8 9 10];//time
h=[1.10 1.03 .96 .82 .68 .54 .42 .35 .31 .28 .27
    .27];
Cl=[0 0 0 0 0 0 0 0 0 0 0];
m=0.05;
V=1/1000;//volume
//calculations
Co=m/V;//concentration at t=0
v(1)=(h(1)-h(2))/(t(2)-t(1));
Cl(1)=Co;
for i=2:11

        v(i)=(h(i-1)-h(i+1))/(t(i+1)-t(i-1));//slope
```

```
        or settling velocity
    Cl(i)=Co*h(1)/(h(i)+v(i)*t(i));


end
plot(t,h,'r--d');
clf();
plot(Cl,v,'r->');
xtitle("Concentration vs Settling veocity" , "
    Concentration(kg/m^3)" , "Settling velocity (m/h)
    ");
```

Scilab code Exa 10.1.2 Minimum area required for a continuous thickener

```


//example 10.2
clc; funcprot(0);
clf()
//exapple 10.2
// Initialization of Variable
t=[0 0.5 1 2 3 4 5 6 7 8 9 10];//time
h=[1.10 1.03 .96 .82 .68 .54 .42 .35 .31 .28 .27
    .27];
Cl=50:5:100;
U=[19.53 17.71 16.20 14.92 13.82 12.87 12.04 11.31
    10.65 9.55];//mass ratio of liquid to solid
v=[0.139 0.115 0.098 0.083 0.071 0.062 0.055 0.049
    0.043 0.034];//terminal velocity
//above value taken from graph given with ques.
C=130;//conc. of solids
Q=0.06;//slurry rate
Cmax=130//maximum solid conc.
rhos=2300;//density of solid
rho=998;//density of water
```

```
V=rho*(1/C-1/rhos);
F=Q*Cl(1)*3600;
for i=1:10
A(i)=F*(U(i)-V)/rho/v(i);
end
plot(v,A,'r-');
xtitle("","Settling Velocity(m/h)", "Area(m^2)")
//maxima finding using datatraveller in the graph
disp(A,"the area for each settling velocity");
disp("1005 m^2 is the maximum area found out from
    the plot");
Qu=Q-F/3600/Cmax;
disp(Qu, "Volumetric flow rate of clarified water in
     (m^3/s):")
```

Scilab code Exa 10.1.3 classification of materials on basis of settling velocities

```


//example 10.3
clc; funcprot(0);
//exapple 10.3
// Initialization of Variable
rho1=2600;//density lighter
rho2=5100;//density heavier
pd1=0.000015:0.000010:0.000095;//particle diameter
    lighter
pd2=0.000025:0.00001:0.000095;//particle diameter
    heavier
wp1=[0 22 35 47 59 68 75 81 100];//weight
    distribution lighter
wp2=[0 21 33.5 48 57.5 67 75 100];//weight
    distribution heavier
rho=998.6;//density water
```

```
mu=1.03/1000;//viscosity water
g=9.81;
u=0.004;//velocity of water
d=95/1000000;//paeticle diameter maximum
//calculation
//part 1
Re=d*u*rho/mu;
d1=sqrt(18*mu*u/g/(rho1-rho));
d2=sqrt(18*mu*u/g/(rho2-rho));
function[a]=inter(d,f,g,b);//interpolation linear
    for i=1:b
        if d<=f(i+1)& d>f(i)  then
            break
        else
            continue
        end
        break
    end
    a=(d-f(i))/(f(i+1)-f(i))*(g(i+1)-g(i))+g(i);
endfunction
[a]=inter(d1,pd1,wp1,9);
[b]=inter(d2,pd2,wp2,8);
v2=1/(1+5)*100-b/100*1/(1+5)*100;
v1=5/(1+5)*100-a/100*5/(1+5)*100;
pl2=(v2)/(v2+v1);
disp(pl2, "The fraction of heavy ore remained in
   bottom");
 //part 2
 rho=1500;
 mu=6.25/10000;
 a=log10(2*d^3*rho*g*(rho1-rho)*3*mu^2);//log10(Re
   ^2(R/rho/mu^2))
  //using value from chart(graph)
Re=10^0.2136;
u=Re*mu/rho/d;
d2=sqrt(18*mu*u/g/(rho1-rho));
[b]=inter(d2,pd2,wp2,8);
disp(100-b+3.5,"The percentage of heavy ore left in
```

```
   this case");
//part 3
a=0.75//% of heavy ore in overhead product
s=100*5/6/(100*5/6+0.75*100/6);
disp(s,"the fraction of light ore in overhead
   product:");
//part 4
da=pd2(1);
db=pd1(9);
rho=(da^2*rho2-db^2*rho1)/(-db^2+da^2);
  disp(rho,"The minimum density required to seperate
     2 ores in kg/m^3:")
```

Scilab code Exa 10.1.4 density variation of settling suspension

```


//example 10.4
clc; funcprot(0);
//exapple 10.4
// Initialization of Variable
rho=998;
w0=40;//density of slurry
mu=1.01/1000;
g=9.81;
rho1=2660;//density quartz
h=0.25;
t=18.5*60;
mp=[5 11.8 20.2 24.2 28.5 37.6 61.8];
d=[30.2 21.4 17.4 16.2 15.2 12.3 8.8]/1000000;
u=h/t;
d1=sqrt(18*mu*u/g/(rho1-rho));
function[a]=inter(d,f,g,b);//interpolation linear
    for i=1:b
        if d>f(i+1)& d<=f(i)  then
```

```
            break
        else
            continue
        end
        break
    end

    a=-(d-f(i+1))/(f(i)-f(i+1))*(g(i+1)-g(i))+g(i+1)
        ;
endfunction
[a]=inter(d1,d,mp,6);
phi=1-a/100;
rhot=phi*(rho1-rho)/rho1*w0+rho;
disp(rhot,"the density of suspension at depth 25cm
   in kg/m^3 is")
```

Scilab code Exa 10.1.5 determination of particle size distribution using a sedimentation method

```


//example 10.5
clc; funcprot(0);
clf()
//exapple 10.5
// Initialization of Variable
t=[0 45 135 495 1875 6900 66600 86400];//time
m=[0.1911 0.1586 0.1388 0.1109 0.0805 0.0568 0.0372
   0.0359];//mass total
rho1=3100;//density of cement
mu=1.2/1000;//viscosity of desperant liquid
rho=790;//density of desperant liquid
h=0.2;
V=10;
s=0;
```

```
d(1)=100/1000000;//assumed value
for i=1:7
    d(i+1)=sqrt(18*mu*h/g/t(i+1)/(rho1-rho));//dia
        of particles
    mc(i+1)=m(i+1)-0.2/100*V;//mass of cement
    s=s+mc(i+1);
end
mc(1)=m(1)-0.2*V/100;
s=s+mc(1);
mp(1)=100;
for i=1:7
    mp(i+1)=mc(i+1)/mc(1)*100;//mass percent below
        size
end
plot(mp,d);
xtitle("", "%undersize", "Particle Size(m)");
u=h/t(2);
Re=d(2)*u*rho/mu;
if Re<2 then
    disp("since Re<2 for 81% of particles so
        settlement occurs mainly by stoke-s law")
end
```

Scilab code Exa 10.1.6 determination of particle size distribution of a suspended solid

```


//example 10.6
clc; funcprot(0);
//exapple 10.6
clf()
// Initialization of Variable
rho=998;
rho1=2398;//density of ore
```

```
mu=1.01/1000;
g=9.81;
h=25/100;
t=[114 150 185 276 338 396 456 582 714 960];
m=[0.1429 0.2010 0.2500 0.3564 0.4208 0.4781 0.5354 0.6139 0.6563 0.7277];
for i=1:10
ms=0.0573+m(10);//total mass setteled
d(i)=sqrt(18*mu*h/g/(rho1-rho)/t(i));
P(i)=m(i)/ms*100;//mass percent of sample
end
plot(t,P);
xtitle("","Settling time (s)","mass percent in (%)");
disp(P,d,"& its percentage mass distribution respectively" ,"the particle size distribution in (m)" );
for i=2:9
        del(i)=(P(i+1)-P(i-1))/(t(i+1)-t(i-1));//slope
        W(i)=P(i)-t(i)*del(i);
        W(1)=P(1)-P(1);

end
W(10)=P(10)-t(10)*0.025;
disp("mass% and diameter(m)respectively with serial no:")
for i=4:10
    disp(i-4);
    disp("mass% is")
    disp( "for diameter in(m) of",W(i));
    disp(d(i));

end
```

Scilab code Exa 10.1.7 decanting of homogeneous suspension to obtain particle size of a given size range

```
//example 10.7
clc; funcprot(0);
//exapple 10.7
// Initialization of Variable
rho=1002;//density of disperant
rho1=2240;//density of kaolin
mu=1.01/1000;//viscosity
g=9.81;
t=600;
h2=0.2;
h1=0.4;
dg=15*10^-6;//particle size to be removed
//calculations
//part 1
d=sqrt(18*mu*h2/g/(rho1-rho)/t);
x=dg/d;
f=h2/h1*(1-x^2);//fraction separated after first
    decanting
g=f*(1-f);
disp(g,"fraction of particles separated after second
     decanting");
disp(f+g,"total fraction of particles separated
    after decanting")
//part 2
h=(1-20/40*(1-x^2))^6;
disp(h,"fraction of particles separated after sixth
    decanting");
```

Chapter 11

Fluidisation

Scilab code Exa 11.1.1 particulate and aggregative fluidisation

```


//exapple 11.1
clc; funcprot(0);
// Initialization of Variable
pi=3.1428;
d=0.3/1000;
mu=2.21/100000;
rho=106.2;//density under operating condition
u=2.1/100;
rhos=2600;//density of particles
l=3.25;
g=9.81;
dt=0.95//fluidising diameter
//part 1
//calculation
a=u^2/d/g*d*rho*u/mu*(rhos-rho)/rho*l/dt;
if a>100 then
    disp(a,"Bubbling fluidisation will occur as
        value is ")
end
```

```
//part 2
Q=2.04/100000;
rhos=2510;
rho=800;
mu=2.85/1000;
l=4.01;
dt=0.63;
d=0.1/1000;
u=Q*4/pi/dt^2;
a=u^2/d/g*d*rho*u/mu*(rhos-rho)/rho*l/dt;
if a<100*10^-4 then//compare as value of a is much less than 100
  disp(a,"fluidisation occur in smooth mode as value is:");
end
```

Scilab code Exa 11.1.2 calculation of minimum flow rates

```


//exapple 11.2
clc; funcprot(0);
// Initialization of Variable
d=50/1000000;
rhos=1850;//density of particle
rho=880;//density of hydrocarbon
mu=2.75/1000;//viscosity of hydrocarbon
e=0.45;//void fraction coeff.
g=9.81;
h=1.37;//flow depth
c=5.5/1000;//c=1/K
//calculation
//part 1
u=c*e^3*d^2*g*(rhos-rho)/mu/(1-e);
disp(u,"The superficial linear flow rate in (m/s):")
```

```
//part 2
u=d^2*g*(rhos-rho)/18/mu;
disp(u,"Terminal Settling Velocity in (m/s):");
Re=d*u*rho/mu;
if Re<2 then
    disp("Stoke law assumption is sustained with
       this velocity")
end
//part 3
P=g*(rhos-rho)*h*(1-e);
disp(P,"Pressure drop across fluidised bed in (N/m
   ^2):");
```

Scilab code Exa 11.1.3 calculation of flow rates in fluidised beds

```



//exapple 11.3
clc; funcprot(0);
// Initialization of Variable
g=9.81;
rhos=1980;//density of ore
rho=1.218;//density of air
e=0.4;
mu=1.73/10^5;
s=0;
wp=[0 .08 .20 .40 .60 .80 .90 1.00];//weight percent
d=[0.4 0.5 0.56 0.62 0.68 0.76 0.84 0.94]/1000;
//part 1
for i=1:7
    dav(i)=d(i+1)/2+d(i)/2;//average dia
    mf(i)=wp(i+1)-wp(i);//mass fraction
    a(i)=mf(i)/dav(i);
    s=s+a(i);
```

```
end
db=1/s;//d bar
//quadratic coeff. ax^2 +bx +c=0
c=-(rhos-rho)*g;
b=150*(1-e)/e^3/db^2*mu;
a=1.75*rho/e^3/db;
y=poly([c b a],'U','coeff');
U=roots(y);
disp(abs(U(2)), "the linear air flow rate in (m/s):");
//part 2
d=0.4/1000;
a=2*d^3/3/mu^2*rho*(rhos-rho)*g;
a=log10(a);
disp(a,"log10(Re^2/rho/U^2*R)=");
//using chart
Re=10^1.853;
u=Re*mu/rho/d;
disp(u, "speed required for smallest particle in (m/s):")
```

Scilab code Exa 11.1.4 estimation of vessel diameters and height for fluidisation operations

```
//exapple 11.4
clc; funcprot(0);
// Initialization of Variable
U=2.032/10^4;
pi=3.1428;
rho=852;
g=9.81;
mu=1.92/1000;
mf=125/3600;//mass flow rate
```

```
//calculation
//part 1
G=U*rho;
A=mf/G;
d=sqrt(4*A/pi);
disp(d, "the diameter of vessel will be in(m):");
//part 2
A=0.201;
e=0.43;
ms=102;//mass of solids
rhos=1500;//density of solid
L=ms/rhos/A;
Lmf=L/(1-e);
disp(Lmf , "depth of bed in (m):")
//part 3
d1=0.2/1000;
U=2*5.5/10^3*e^3*d1^2*(rhos-rho)*g/mu/(1-e);
//now euating for e
//a=e^3/(1-e)
a=U/5.5*10^3/(d1^2*(rhos-rho)*g/mu);
y=poly([-a a 0 1],'e',"coeff");
e2=roots(y);
L=Lmf*(1-e)/(1-e2(3));
disp(L,"depth of fluidised bed under operating
    condition in (m):")
```

Scilab code Exa 11.1.5 power required for pumping in fluidised beds

```


//exapple 11.5
clc; funcprot(0);
// Initialization of Variable
g=9.81;
pi=3.1428;
```

```
r=0.51;
e=0.48;//void ratio
rhos=2280;//density of glass
rho=1.204;//density of air
U=0.015;//velocity of water entering bed
L=7.32;
gam=1.4;//gamma
neta=0.7//efficiency
P4=1.013*10^5;
P1=P4;
v1=1/1.204;//volume 1
//calculation
P3=P4+g*(rhos-rho)*(1-e)*L;
P2=P3+0.1*85090;
v2=(P1*v1^gam/P2)^(1/gam);//vlume 2
W=1/neta*gam/(gam-1)*(P2*v2-P1*v1);//work done
v3=P2*v2/P3;//volume 3
M=U*pi*r^2/v3;//mass flow rate
P=M*W;
disp(P,"The power supplies to the blower in (W):");
```

Scilab code Exa 11.1.6 wall effect in fluidised beds

```


//exapple 11.6
clc; funcprot(0);
// Initialization of Variable
dt=12.7/1000;
d=1.8/1000;
Q=2.306/10^6;
pi=3.1428;
//calculation
//part 1
Sc=4/dt;
```

```
S=6/d;
f=(1+0.5*Sc/S)^2;
U=Q*4/pi/dt^2;//velocity
Ua=f*U;//actual velocity
disp(Ua,"minimum fluidising velocity found using
   smaller glass column in (m/s):")
//part 2
dt=1.5;
Sc=4/dt;
f=(1+0.5*Sc/S)^2;
Ua=f*U;//actual velocity
disp(Ua,"fluidising velocity found using larger
   glass column in (m/s):")
```

Scilab code Exa 11.1.7 effect of particle size on the ratio of terminal velocity

```


//exapple 11.7
clc; funcprot(0);
// Initialization of Variable
e=0.4;//incipent to fluidisation
//calculation
//part 1
disp("for Re<500");
disp("the ratio of terminal velocity & minimmum
   fluidising velocity is");
a=3.1*1.75/e^3;
disp(sqrt(a));
//part 2
disp("for Re>500");
disp("the ratio of terminal velocity & minimmum
   fluidising velocity is");
a=150*(1-e)/18/e^3;
```

```
disp(a);
```

Chapter 12

Pneumatic Conveying

Scilab code Exa 12.1.1 flow pattern in pneumatic conveying

```


//example 12.1
clc; funcprot(0);
// Initialization of Variable
rho=1.22;
pi=3.1428;
rhos=518;
rhoav=321;
mu=1.73/10^5;
g=9.81;
d=0.65/1000;
d2=25.5/100;//dia of duct
ms=22.7/60;//mass flow rate
//calculation
e=(rhos-rhoav)/(rhos-rho);
//coeff of quadratic eqn in U
//a*x^2+b*x+c=0
c=-(1-e)*(rhos-rho)*g;
b=150*(1-e)^2*mu/d^2/e^3;
a=1.75*(1-e)*rho/d/e^3;
```

```
y=poly([c b a],'U','coeff');
U=roots(y);
Us=ms*4/pi/d2^2/rhos;//superficial speed
Ua=e/e*(U(2)/e+Us/(1-e));
disp(Ua,"the actual linear flow rate through duct in
    (m/s):")
```

Scilab code Exa 12.1.2 prediction of choking velocity and choking choking voidage in a vertical transport line

```


//example 12.2
clc; funcprot(0);
// Initialization of Variable
rho=1.22;//density of air
pi=3.1428;
rhos=910;//density of polyethene
d=3.4/1000;//dia of particles
mu=1.73/10^5;
g=9.81;
dt=3.54/100;//dia of duct
//calculation
a=2*d^3*rho*g*(rhos-rho)/3/mu^2;
disp(a,"R/rho/U^2*(Re^2)=");
//using Chart
Re=2*10^3;
U=mu*Re/d/rho;
b=U/(g*dt)^.5;
if b>0.35 then
    disp("choking can occur of this pipe system");
else
    disp("choking can not occur of this pipe system"
       );
end
```

```
//part 2
Uc=15;//actual gas velocity
e=((Uc-U)^2/2/g/dt/100+1)^(1/-4.7);
Usc=(Uc-U)*(1-e);//superficial speed of solid
Cmax=Usc*rhos*pi*dt^2/4;
disp(Cmax,"the maximum carrying capacity of
   polythene particles in (kg/s)");
```

Scilab code Exa 12.1.3 prediction of pressure drop in horizontal pneumatic transport

```


//example 12.3
clc; funcprot(0);
// Initialization of Variable
rho=1.22;//density of air
pi=3.1428;
rhos=1400;//density of coal
mu=1.73/10^5;
g=9.81;
U=25;
Ut=2.80;
l=50;
ms=1.2;//mass flow rate
mg=ms/10;//mass flow of gas
//calculation
Qs=ms/rhos;//flow of solid
Qg=mg/rho;//flow of gas
us=U-Ut;//actual linear velocity
A=Qg/U;
Us=Qs/A;//solid velocity
e=(us-Us)/us;
d=sqrt(4*A/pi);
function [y ]= fround(x,n)
```

```
// fround(x,n)
// Round the floating point numbers x to n decimal
   places
// x may be a vector or matrix// n is the integer
   number of places to round to
y=round(x*10^n)/10^n;
endfunction
[d]=fround(d,4);
Re=d*rho*U/mu;
//using moody's chart
phi=2.1/1000;//friction factor
P1=2*phi*U^2*l*rho/d*2;
f=0.05/us;
P2=2*l*f*(0.0098)*rhos*us^2/d;
P2=fround(P2/1000,1)*1000
delP=rho*e*U^2+rhos*(0.0098)*us^2+P1+P2;
//disp(delP," the pressure difference in kN/m^2 ");
printf('The Pressure value in (kN/m^2) is %.1f',delP
   /1000);
```

Scilab code Exa 12.1.4 prediction of pressure drop in vertical pneumatic transport

```


//example 12.4
clc; funcprot(0);
// Initialization of Variable
rho=1.22;//density of air
pi=3.1428;
rhos=1090;//density of steel
mu=1.73/10^5;
g=9.81;
d=14.5/100;
Qg=0.4;
```

```
Qs=5000/3600/1090;
Ut=6.5;
ar=0.046/1000;//absolute roughness
l=18.5;//length
//calculation
function [y]= fround(x,n)
// fround(x,n)
// Round the floating point numbers x to n decimal
   places
// x may be a vector or matrix// n is the integer
   number of places to round to
y=round(x*10^n)/10^n;
endfunction
Us=Qs/pi/d^2*4;//solid velocity
U=Qg/pi/d^2*4;
us=U-Ut;//actual linear velocity
e=1-Us/us;
e=fround(e,4);
Re=rho*U*d/mu;
rr=ar/d;//relative roughness
//using moody's diagram
phi=2.08/1000;
P1=2*phi*U^2*l*rho/d*2;
f=0.05/us;
P2=2*l*f*(1-e)*rhos*us^2/d;
P2=fround(P2/1000,2)*1000;
delP=rhos*(1-e)*us^2+rhos*(1-e)*g*l+P1+P2;
//disp(delP," the pressure difference in kN/m^2 ");
printf('The Pressure value in (kN/m^2) is %.2f',delP
   /1000)
```

Scilab code Exa 12.1.5 density phase flow regime for pneumatic transport

```
//example 12.5
clc; funcprot(0);
// Initialization of Variable
l=25;
pi=3.1428;
rhos=2690;//density of ore
emin=0.6;
emax=0.8;
//calculation
Pmax=rhos*(1-emin)*g*l;
disp(Pmax,"The maximum pressure drop in (N/m^2):");
Pmin=rhos*(1-emax)*g*l;
disp(Pmin,"The minimum pressure drop in (N/m^2):");
```

Chapter 13

Centrifugal Separation Operations

Scilab code Exa 13.1.1 Equations of centrifugal operations

```


//exapple 13.1
clc; funcprot(0);
// Initialization of Variable
rho=998;
g=9.81;
pi=3.1428;
omega=2*pi*1055/60;//angular rotation
r=2.55/100//radius outer
ld=1.55/100;//liq. depth
l=10.25/100;
//calculation
//part1
a=r*omega^2/g;
disp(a,"ratio of cetrifugal force & gravitational
   force is:");
//part2
ri=r-ld;//radius internal
```

```
V=pi*(r^2-ri^2)*l;
sigma=(omega^2*V)/(g*log(r/ri));
disp(sigma,"equivalent to gravity settling tank of
    crossectional area of in (m^2):")
```

Scilab code Exa 13.1.2 fluid pressure in tubular bowl centrifuge

```


//exapple 13.2
clc; funcprot(0);
// Initialization of Variable
sigma=55*10^6;//maximum stress
d=35.2/100;
rhos=8890;//density of bronze
rho=1105;//density of solution
t=80/1000;//thickness
tau=4.325/1000;
pi=3.1428;
//calculation
//part1
ri=d/2-t;//radius internal
function [y ]= fround(x,n)
// fround(x,n)
// Round the floating point numbers x to n decimal
    places
// x may be a vector or matrix// n is the integer
    number of places to round to
y=round(x*10^n)/10^n;
endfunction
omega=sqrt((sigma*tau*2/d)/(.5*rho*(d^2/4-ri^2)+rhos
    *tau*d/2));
N=60*omega/2/pi;
disp(N,"The maximum safe speed allowed in rpm:");
//part2
```

```
P=.5*rho*(d^2/4-ri^2)*omega^2;
P=fround(P/10^4,1)*10^4;
//disp(P,"the power in N/m^2:");
printf('the power in N/m^2: %3.2e\n', P);
a=rho*omega^2*d/2;
a=fround(a/10^6,1)*10^6;
//disp(a,"pressure gradient in radial direction in N
    /m^3:")
printf('pressure gradient in radial direction in N/m
    ^3: %3.2e\n', a);
```

Scilab code Exa 13.1.3 particle size determination of fine particles

```


//exapple 13.3
clc; funcprot(0);
// Initialization of Variable
rhos=1425;//density of organic pigment
rho=998;//density of water
pi=3.1428;
omega=360*2*pi/60;
mu=1.25/1000;
t=360;
r=0.165+0.01;
ro=0.165;
//calculation
d=sqrt(18*mu*log(r/ro)/t/(rhos-rho)/omega^2);
printf('the minimum diameter in organic pigment in m
    : %3.1e\n', d);
```

Scilab code Exa 13.1.4 flow rates in continuous centrifugal sedimentation

```
//exapple 13.4
clc; funcprot(0);
// Initialization of Variable
rhos=1455;//density of crystals
rho=998;//density of wliquid
g=9.81;
pi=3.1428;
mu=1.013/1000;
omega=2*pi*60000/60;
l=0.5;
d=2*10^-6;//dia of particles
r=50.5/1000;//radius
t=38.5/1000;//thickness of liquid
//calculation
ri=r-t;
V=pi*l*(r^2-ri^2);
Q=d^2*(rhos-rho)/18/mu*omega^2*V/log(r/ri);
disp(Q,"the maximum volumetric flow rate in (m^3/s):
    ")
```

Scilab code Exa 13.1.5 separation of two immiscible liquid by centrifugation

```
//exapple 13.5
clc; funcprot(0);
// Initialization of Variable
rhoc=867;//density of cream
rhom=1034;//density of skimmem milk
rm=78.2/1000;//radius of skimmed milk
rc=65.5/1000;//radius of cream
//calculation
```

```
r=sqrt((rhom*rm^2-rhoc*rc^2)/(rhom-rhoc));
disp(r,"distance of xis of rotation of cream milk
   interface in (m):")
```

Scilab code Exa 13.1.6 Cyclone Separators

```


//exapple 13.6
clc; funcprot(0);
// Initialization of Variable
rho=1.210;//density of air
mu=1.78/10^5;
g=9.81;
rhos=2655;//density of ore
pi=3.1428;
d=0.095;
dp=2*10^-6//particle diameter
dt=0.333;//dia of cyclone separator
h=1.28;
//calculation
U=dp^2*g*(rhos-rho)/18/mu;
Q=0.2*(pi*d^2/4)^2*d*g/U/pi/h/dt;
disp(Q,"volumetric flow rate in(m^3/s):")
```

Scilab code Exa 13.1.7 efficiency of cyclone separators

```


//exapple 13.6
clc; funcprot(0);
// Initialization of Variable
b=4.46*10^4;
```

```
c=1.98*10^4;
s=0;
function[a]=intregrate()
    s=0;
    for i=1:10889
        d=linspace(0,10000,10889);
        y=(1-exp(-b*d(i))*c*(1-exp(-c*d(i))))*0.69;;
        s=s+y;

    end
    a=y;
endfunction
a=intregrate();
disp(a*100,"overall efficiency of cyclone separator
   in %");
```