Scilab Textbook Companion for Mechanics Of Fluid by B. S. Massey And A. J. Ward-Smith[1]

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Book Description

Title: Mechanics Of Fluid

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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

Fundamental Concepts

Scilab code Exa 1.1 1

```
clc
p=2*10^5; // Pa
T=300; // K
R=287; // J/(kg.K)
V=3; // m^3

rho=p/(R*T);
disp("(a) The density of air = ")
disp(rho)
disp("kg/m^3")

m=rho*V;
disp("(b) Its mass =")
disp(m)
disp("m^3")
```

Scilab code Exa 1.2 2

```
clc
M_C=12;
M_N=14;
M_O=16;
R=8314; // J/(kg.K)

M_CO=M_C+M_O;
R_CO=R/M_CO;

M_CO2=M_C+2*M_O;
R_CO2=R/M_CO2;

M_NO=M_N+M_O;
R_NO=R/M_NO;

M_N2O=2*M_N+M_O;
R_N2O=R/M_N2O;

disp("Gas constant for CO = ")
disp(R_CO)
disp("J/(kg.K)")

disp("Gas constant for CO2 = ")
disp(R_CO2)
disp("J/(kg.K)")

disp("Gas constant for NO = ")
disp(R_NO)
disp("J/(kg.K)")

disp("Gas constant for N2O = ")
disp(R_N2O)
disp("J/(kg.K)")
```

Scilab code Exa 1.3 3

```
clc
d=0.004; // m
rho=1000; // kg/m^3
v=3; // m/s
meu=10^(-3); // khm(m.s)

Re=rho*v*d/meu;
disp("Reynolds number =")
disp(Re)
disp("The Reynolds number is well in excess of 4000,
    so the flow is turbulent.")
```

Chapter 2

Fluid Statics

Scilab code Exa 2.1 1

```
clc
d=1.5; // m
m=1.2; // kg
rate=0.0065; // K/m
R=287; // J/(kg.K)
T_0=288.15; // K
p_0=101*10^3; // Pa
g=9.81; // m/s^2

rho=m/(%pi*d^3/6);
rho_0=p_0/R/T_0;

// log(rho/rho_0)=(g/R*rate - 1)*log((T_0-rate*z)/
    T_0)

z=1/rate*(T_0-T_0*exp(log(rho/rho_0)/(g/R/rate-1)));

disp("The height above sea level to which the ballon
     will rise = ")
disp(z)
disp("m")
```

```

printf("The height above sea level to which the ballon will rise = %f m", z)
```

Scilab code Exa 2.2 2

```
clc
d=2; // m
a=1; // radius in m
rho=880; // density of oil in kg/m^3
g=9.81; // m/s^2
rho_w=1000; // density of water in kg/m^3

C_0=4*a/3/%pi; // centroid of the upper semicircle
h1=a-C_0; // distance of the centroid from the top

P1=rho*g*h1; // Pressure of the oil at this point
F1=P1*%pi*a^2/2; // Force exerted by the oil on the upper half of the wall

cp1=a^4*(%pi/8-8/(9*%pi)); // (AK^2)_C

cp2=cp1/(%pi*a^2/2*h1); // Centre of Pressure below the centroid

cp0=cp2+h1; // Centre of Pressure below the top

P_w=(rho*g*a)+(rho_w*g*C_0);
F_w=P_w*%pi*a^2/2;

h2=C_0+rho/rho_w;
cp2_w=cp1/(%pi*a^2/2*h2);
cp0_w=a+C_0+cp2_w; // below the top of cylinder

F_total=F1+F_w;
```

```
// F1*cp0 + F_w*cp0_w = F_total*x

x=(F1*cp0 + F_w*cp0_w)/F_total;

disp("Total force =")
disp(F_total)
disp("N")

disp("Distance of line of action of total force from
    top of cylinder =")
disp(x)
disp("m")
```

Scilab code Exa 2.3 3

```
clc

rho=1000; // kg/m^3
g=9.81; // m/s^2
r=4; // m
h=2; // m
l=5; // m
theta=%pi/6;

A=h*l;

F_h=rho*g*h*A; // Horizontal force

C0=(2^2/(12*2))+2; // distance of line of action
   below the free surface

AB=4-4*cos(theta);

F_v=rho*g*l*(AB*1+%pi*r^2*theta/(2*%pi)-1/2*h*r*cos(
```

```
    theta));
BC=0.237; // m

F_net=sqrt(F_h^2+F_v^2);

phi=atand(F_v/F_h);

disp("Net force =")
disp(F_net)
disp("N")

disp("Angle between net force and horizontal =")
disp(phi)
disp("degrees")
```

Scilab code Exa 2.4 4

```
clc

m=10; // kg
M=80; // kg
H=1.5; // m
rho=1026; // kg/m^3
g=9.81; // m/s^2
d=1; // m

// m*H + M*H/2 =(M+m)(OG)

OG=(m*H + M*H/2)/(M+m);

// For vertical equilibrium, buoyancy = weight
h=(M+m)/(rho*%pi/4*d^2);

BM=(%pi*d^4/64)/(%pi*d^2*h/4);
OB=h/2;
```

```
GM=OB+BM-OG;

disp("GM =")
disp(GM)
disp("m")

disp("Since this is negative (i.e. M is below G) buoy is unstable.")
```

Scilab code Exa 2.5 5

```
clc
m=10; // kg
M=80; // kg
OG=0.8333; // m
rho=1026; // kg/m^3
g=9.81; // m/s^2
d=1; // m
W=(m+M)*g;

// W(OG) = (W + F)(OB + BM) = rho*g*%pi/4*d^2*h1*(h1/2+d^2/(16*h1))

h1=sqrt(2*(W*OG/(rho*g*%pi/4*d^2) - d^2/16));

F=rho*g*%pi/4*d^2*h1 - W;

disp("Least vertical downward force =")
disp(F)
disp("N")

disp("Depth of immersion =")
disp(h1)
disp("m")
```

Scilab code Exa 2.6 6

```
clc

a=5; // m/s^2
s=0.5; // m
phi=atand(1/4); // degrees
g=9.81; // m/s^2
rho=880; // kg/m^3

a_x=a*cosd(phi); // Horizontal component of
    acceleration
a_z=a*sind(phi); // Vertical component of
    acceleration

theta=atand(a_x/(a_z+g)); // b=tan(theta)

d=(tand(phi)+tand(theta))/(1-tand(phi)*tand(theta));

c=s*d;

V=s*(s^2-s*c/2);

disp("(a) Volume left in the tank =")
disp(V*1000)
disp("L")

P=rho*g*s*cosd(phi);
disp("(b)Pressure at the lowest corners of the tank
    =")
disp(P)
disp("Pa")
```

Chapter 3

The Principles Governing Fluids in Motion

Scilab code Exa 3.2 2

```
clc

u_A=1.35; // m/s
d_A=0.225; // m
d_B=0.150; // m
d_C=0.150; // m
d=5.6; //m
friction=2.5; // kW
power_req=12.7; // kW

rho=1000; // kg/m^3
rho_m=13560; // kg/m^3

g=9.81; // m/s^2

pC=35000; // Pa
pA=rho_m*g*(-d_B);

Area_A=%pi*d_A^2/4;
```

```
Area_B=%pi*d_B^2/4;
Area_C=%pi*d_C^2/4;

u_B=u_A*(Area_A/Area_B);
u_C=u_A*(Area_A/Area_C);

// Energy_added_by_pump/time = (Mass/time)*((pC-pA)/
   rho+(u_C^2-u_A^2)/2+g*(zC-zA))

Energy_added = Area_A*u_A*(pC-pA+rho/2*(u_C^2-u_A^2)
   +rho*g*d)/1000+friction;

Efficiency=Energy_added/power_req*100;

disp("Overall efficiency of the pump =")
disp(Efficiency)
disp("%")
```

Scilab code Exa 3.3 3

```
clc

d_jet = 0.0086; // m
d_orifice = 0.011; // m
x = 2; // m
y = 0.6; // m
h = 1.75; // m
g = 9.81; // m/s^2

A2 = %pi/4*d_orifice^2;

Cc = (d_jet/d_orifice)^2; // Coefficient of
   Contraction

Cv = x/2/sqrt(y*h); // Coefficient of velocity
```

```
Cd = Cv*Cc; // Coefficient of Discharge

Q = Cd*A2*sqrt(2*g*h);

disp("Rate of discharge = ")
disp(Q)
disp("m^3/s")
```

Scilab code Exa 3.4 4

```
clc

Cd=0.97;
d1=0.28; // m
d2=0.14; // m

g=9.81; // m/s^2
d=0.05; // difference in mercury level in metre
rho=1000; // kg/m^3
rho_m=13600; // kg/m^3

A1=%pi/4*d1^2;
A2=%pi/4*d2^2;

p_diff=(rho_m-rho)*g*d;
h=p_diff/rho/g;

Q=Cd*A1*((2*g*h)/((A1/A2)^2-1))^(1/2);

disp("Flow rate = ")
disp(Q)
disp("m^3/s")
```

Scilab code Exa 3.5 5

```
clc

Cd=0.62;
g=9.81; // m/s^2
d=0.1; // m
d0=0.06; // m
d1=0.12; // m

rho=1000; // kg/m^3
rho_m=13600; // kg/m^3
rho_f=0.86*10^3; //kg/m^3

A0=%pi/4*d0^2;
A1=%pi/4*d1^2;

p_diff=(rho_m-rho_f)*g*d;

h=p_diff/rho_f/g;

Q=Cd*A0*((2*g*h)/(1-(A0/A1)^2))^(1/2);

m=rho_f*Q;

disp("Mass flow rate = ")
disp(m)
disp("kg/s")
```

Scilab code Exa 3.6 6

```
clc
```

```
Cd=0.61;
g=9.81; // m/s^2
b=0.6; // m
H=0.155; // mQ
A=0.26; // m^2
u1=0.254; // m/s

Q=2/3*Cd*sqrt(2*g*b*(H)^3/2);

velo=Q/A;

H1=H+u1^2/(2*g);

Q1=2/3*Cd*sqrt(2*g*b*(H1)^3/2);

disp("Discharge =")
disp(Q1)
disp("m^3/s")
```

Chapter 4

The Momentum Equation

Scilab code Exa 4.1 1

```
clc

rho=1000; // kg/m^3
u1=36; // m/s
u2=30; // m/s
d=0.05; // m
theta=60; // degrees

A=%pi/4*d^2;

Q=A*u1;

F_x=rho*Q*(u2*cosd(theta) - u1);
F_y=rho*Q*u2*sind(theta);

F=sqrt(F_x^2+F_y^2);
phi=atand(F_y/F_x);

disp("The Hydrodynamic force on the vane =")
disp(F)
disp("N")
```

```
printf("This resultant force acts at angle of %f to
    the x-direction", phi)
```

Scilab code Exa 4.2 2

```
clc

Q1=0.45; // m^3/s
Q2=0.425; // m^3/s
d1=0.6; // m
d2=0.3; // m
p1=1.4*10^5; // Pa
rho=1000; // kg/m^3
theta=45; // degrees

A1=%pi/4*d1^2;
A2=%pi/4*d2^2;

u1=Q1/A1;
u2=Q2/A2;

p2=p1+rho/2*(u1^2-u2^2);

F_x=rho*Q2*(u2*cosd(theta)-u1)-p1*A1+p2*A2*cosd(
    theta)
F_y=rho*Q2*(u2*sind(theta)-0)+p2*A2*sind(theta);

F=sqrt(F_x^2+F_y^2);
phi=atand(F_y/F_x);

disp("The net horizontal force exerted by the water
    onthe bend =")
disp(F)
disp("N")
```

```
printf("This resultant force acts at angle of %f to
   the x-direction", phi)
```

Scilab code Exa 4.3 3

```
clc

rho=1.2; // kg/m^3
d=12; // m
u1=20; // m/s
u4=8; // m/s

A=%pi/4*d^2
F=rho*A*(u1+u4)/2*(u1-u4);

disp("(b) The thrust on the turbine = ")
disp(F)
disp("N")

P=rho*A*(u1+u4)/2*(u1^2/2-u4^2/2);
disp("Power generated by the turbine =")
disp(P)
disp("W")
```

Chapter 5

Physical Similarity ans Dimensional Analysis

Scilab code Exa 5.3 3

```
clc

u_p=10; // m/s
scale=1/25;  // l_m/l_p
L=125; // m
meu=1.235*10^(-6); // m^2/s
meu_p=1.188*10^(-6); // m^2/s
rho_p=1025; // kg/m^3
rho_m=1000; // kg/m^3
A=3500; // wetted surface in m^2

u_m=u_p*sqrt(scale);

d=L*scale;
Re=d*u_m/meu; // Reynolds no.
C_F=0.075/(log10(Re)-2)^2; // Skin friction
    coefficient

res_skin=rho_m/2*u_m^2*(A*scale^2)*C_F;
```

```
res_tot=54.2; // N

F_resid_m=res_tot-res_skin;

F_resid_p=F_resid_m*rho_p/rho_m/scale^3;

Re_p=u_p*L/meu_p;

C_F_p=0.075/(log10(Re_p)-2)^2+0.0004;
C_F_pnew=1.45*C_F_p;

res_friction=rho_p/2*u_p^2*A*C_F_pnew;

Resistance=F_resid_p+res_friction;
disp("The total resistance of the prototype =")
disp(Resistance)
disp("N")
```

Scilab code Exa 5.4 4

```
clc

A=0.88; // ratio of A2 and A1
C_D=0.85; // ratio of C_D2 to C_D1
P=1.20; // ratio of P2 to P1
V1=11; // m/s

V2=V1*(P/A/C_D)^(1/3);
disp("Maximum speed of the redesigned torpedo =")
disp(V2)
disp("m/s")
```

Chapter 6

Laminar Flow Between Solid Boundaries

Scilab code Exa 6.1 1

```
clc

RD=0.83;
rho_w=1000; // density of water in kg/m^3
v=2.3; // m/s
d=0.012; // m
u=0.08; // dynamic viscocity in kg/m/s

rho_oil=RD*rho_w;

Re=rho_oil*v*d/u;
disp("(a) Reynolds number =")
disp(Re)

v_max=2*v;
disp("(b)Maximum velocity =")
disp(v_max)
disp("m/s")

```

```
Q=%pi/4*d^2*v;
disp("(c)Volumetric flow rate =")
disp(Q)
disp("m^3/s")

p=-128*Q*u/%pi/d^4;
disp("Pressure gradient along the pipe = ")
disp(p)
disp("Pa/m")
```

Scilab code Exa 6.2 2

```
clc
c=0.001; // m
p1=15*10^3; // Pa
u=0.6; // kg/m/s
R=6; // ratio of R2/R1

Q=%pi*c^3*p1/(6*u*log(R));
disp("(b)Rate at which oil must be supplied =")
disp(Q)
disp("m^3/s")
```

Scilab code Exa 6.3 3

```
clc

F=6*10^3; // Pa
b=0.12; // m

f=F*b;

disp("(a) The load the pad will support =")
```

```
disp(f)
disp("N/m")

dp=12*10^3; // N/m^2
dx=0.12; // m
c=0.00018; // m
u=0.5; // kg/m/s
V=5; // m/s

q=(dp/dx)*c^3/12/u + V*c/2;
disp("(b) The rate at which oil must be supplied =")
disp(q)
disp("m^2/s")
```

Scilab code Exa 6.4 4

```
clc

d_p=0.05; // diameter of piston in m
d_c=0.0504; // diameter of cylinder in m
SG=0.87;
rho_w=1000; // kg/m^3
v=10^-4; // m^2/s
dp=1.4*10^6; // Pa
l=0.13; // m

c=(d_c-d_p)/2; // clearance

u=SG*rho_w*v; // Dynamice viscocity

Vp=dp*c^3/(6*u*l*(d_p/2+c));
disp("Velocity of the dashpot =")
disp(Vp)
disp("m/s")
```

Scilab code Exa 6.5 5

```
clc

disp("(a)the dynamic and kinematic viscosities of
   the oil")

d=0.00475; // m
g=9.81; // m/s^2
rho_s=1151; // kg/m^3
rho=880; // kg/m^3
u=0.006; // m/s

F=%pi/6*d^3*g*(rho_s-rho);

rat_d=0.25; // ratio of d/D
rat_F=1.8; // ratio of F/Fo

dynamic=F/(1.8*3*%pi*u*d);

kinematic=dynamic/rho;

disp("Dynamic viscosity = ")
disp(dynamic)
disp("kg/m/s")

disp("Kinematic viscosity =")
disp(kinematic)
disp("m^2/s")

disp("(b) Reynolds number of sphere =")

Re=rho*u*d/dynamic;
disp("Reynolds number =")
```

```
disp(Re)
```

Scilab code Exa 6.6 6

```
clc

D=0.120; // m
h=0.08; // m
c=0.001; // m
t=0.01875; // m
rev=65; // revolutions per min
T=4*10^-3; // N.m

K1=%pi*h/4/c;
K2=%pi/32/t;

u=T/(rev*2*%pi/60)/(K1*D^3+K2*D^4);
disp("viscosity of the liquid =")
disp(u)
disp("Pa.s")
```

Scilab code Exa 6.7 7

```
clc

V=10; // m/s
h1=0.0005; // m
h2=0.00025; // m
L=0.1; // m
b=0.1; // m
RD=0.87;
u=2*10^-4; // m^2/s
rho_w=1000; // kg/m^3
```

```

H=h1/h2;

Q=V/2*(1+H^2)/(1+H^3)*b*h1;
disp("(b) Volumetric flow rate of oil =")
disp(Q)
disp("m^3/s")

F=V/2*(1-(1+H^2)/(1+H^3))*12*RD*rho_w*u/h1^2*L^2/4*b
    ;
disp("The load supported by the bearing =")
disp(F)
disp("N")
```

Chapter 7

Flow and Losses in Pipes and Fittings

Scilab code Exa 7.1 1

```
clc

Q=50*10^-3; // m^3/s
d=0.15; // m
l=300; // m
v=1.14*10^-6; // m^2/s
g=9.81; // m/s^2

// For galvanised steel
k=0.00015; // m
t=0.001; // ratio of k to d ; (k/d)
f=0.00515;

A1=%pi/4*d^2;

u=Q/A1;
Re=u*d/v;

h_f=4*f*l*u^2/d/(2*g);
```

```
disp("Head lost to friction =")
disp(h_f)
disp("m")
```

Scilab code Exa 7.2 2

```
clc

k=0.00025; // m
d=0.1; // m
l=120; // m
h_f=5; // m
g=9.81; // m/s^2
v=10^-5; // m^2/s

f=0.0079042;

u=sqrt(h_f*d*(2*g)/(4*f*l));
Re=u*d/v;

Q=u*%pi/4*d^2;
disp("Rate =")
disp(Q)
disp("m^3/s")
```

Scilab code Exa 7.3 3

```
clc

h_f=9; // m
l=180; // m
Q=85*10^-3; // m^3/s
f=0.00475;
```

```
k=0.00015; // m
v=1.14*10^-6; // m^2/s
g=9.81; // m/s^2

d=(4*f*l*Q^2/h_f/(%pi/4)^2/(2*g))^(1/5);
Re=(Q/(%pi*d^2/4))*d/v;

disp("The size of galvanized steel pipe = ")
disp(d)
disp("m")
```

Scilab code Exa 7.4 4

```
clc

// D1=(5*b1/3/a)^(1/8)
// D2=(5*b1/3/a)^(1/8)

// But b2=2.5*b1
// Therefore D2=(2.5)^(1/8)*D1

D1=600; // mm

D2=(2.5)^(1/8)*D1;

disp("Revised estimate of the optimum pipe diameter
   =")
disp(D2)
disp("mm")
```

Scilab code Exa 7.5 5

```
clc
```

```
disp("(a) Feed is at the end of the main")
Q0=4.5*10^-3; // m^3/s
d=0.1; // m
l=4.5*10^3; // m
g=9.81; // m/s^2
f=0.006;
rho=1000; // kg/m^3

u0=Q0/(%pi/4*d^2);
h_f=4*f*u0^2*l/3/(d*2*g);

dp=h_f*rho*g;
disp("Pressure difference =")
disp(dp)
disp("N/m^2")

disp("(b) Feed is at the centre of the main")

Q0_b=Q0/2;
u0_b=u0/2;
l_b=l/2;

dp_b=(u0_b/u0)^2*(l_b/l)*dp;
disp("Pressure difference =")
disp(dp_b)
disp("N/m^2")
```

Scilab code Exa 7.6 6

```
clc

d1=3; // m
d2=2; // m
f=0.007;
```

```
l=75; // m
d=0.05; // m
g=9.81; // m/s^2
h1=1.8; // m

A1=%pi/4*d1^2;
A2=%pi/4*d2^2;

// dh/dt=dz1/dr*(1+A1/A2)
// Q=-A1*dz1/dt = -4/13*A1*dh/dt

// u=(Q/2)^2/(%pi/4*d^2)
// h=(4*f*l/d + 1.5)*u^2/2g = 1.438*10^5*Q^2

// t=integrate('-1/(1+A1/A2)*A1*(1.438*10^5/h)^(1/2)','h',h1,H)

// By integrating , we get
H=(h1^(1/2)-(900/2/824.7))^2;
h=h1-H;
dz1=1/(1+A1/A2)*h;

disp("The change in the level in larger tank =")
disp(dz1)
disp("m")
```

Chapter 8

Boundary Layers Wakes and Other Shear Layers

Scilab code Exa 8.1 1

```
clc

delta=0.6; // mm

delta1=delta/3;

theta=2/15*delta;

disp("Displacement thickness =")
disp(delta1)
disp("mm")

disp("Momentum thickness =")
disp(theta)
disp("mm")
```

Scilab code Exa 8.3 3

```
clc

disp("(a) To determine the values of a1 & a2")

// To determine the values of a1 & a2 following
   conditions must be satisfied

// Condition I - When n=0, u/um=0
// Condition II - When n=1, u/um=a1+a2=1
// Condition III - When n=1, d(u/um)/dn = a1+2a2=0

// By  satisfying these conditions , we have
// a1+a2=1;
// a1+2a2=0;

A=[1,1;1,2];
B=[1;0];
X=inv(A)*B;

a1=X(1);
a2=X(2);

disp("a1=")
disp(a1)
disp("a2=")
disp(a2)

disp("(b)Evaluate the constants A and B")

// A = integrate('(1-f(n))*f(n)','n',0,1)

A=integrate('(1-(2*n-n^2))*(2*n-n^2)','n',0,1)
disp("A =")
disp(A)

// B = differentiation of (2*n-n^2) at n=0, we get
```

```
B=2;

disp("B =")
disp(B)
```

Scilab code Exa 8.4 4

```
clc

v=1.5*10^(-5); // m^2/s
Re_t=5*10^5;
x_t=1.2; // m
rho=1.21; // kg/m^3

u_m=v*Re_t/x_t;

disp("(a) the velocity of the airstream =")
disp(u_m)
disp("m/s")

theta=0.646*x_t/sqrt(Re_t);

F=rho*u_m^2*theta;

D_F=2*F*x_t;

disp("(b) the frictional drag of the plate, D_F =")
disp(D_F)
disp("N")
```

Scilab code Exa 8.5 5

```
clc
```

```

u_m = 50; // m/s or 180 km/h
v=1.5*10^(-5); // m^2/s
l=100; // m
rho=1.2; // kg/m^3
b=8.3; // m

delta = 0.37*(v/u_m)^(1/5)*l^(4/5);

disp("(a) the boundary layer thickness at the rear
    of the train =")
disp(delta)
disp("m")

Re_l = u_m*l/v;
C_F=0.074*(Re_l)^(-1/5);
F=0.037*rho*u_m^2*l*Re_l^(-1/5);

D_F = F*b;

disp("(b) the frictional drag acting on the train,
    D_F =")
disp(D_F)
disp("N")

P=D_F*u_m;
disp("(c) the power required to overcome the
    frictional drag =")
disp(P/1000)
disp("kW")
```

Scilab code Exa 8.6 6

```
clc

```

```
Re_t=5*10^5;
Re_l=5*10^6;

r1=Re_t/Re_l; // r1=x_t/l
r2=1-36.9*(1/Re_t)^(3/8); // r2=x_0/x_t

r=r1*r2; // r=x_0/l;

disp("(a) the proportion of the plate occupied by
   the laminar boundary layer =")
disp(r*100)
disp("%")

C_F = 0.074/Re_l^(1/5)*(1-r)^(4/5);
disp("(b) the skin friction coefficient CF evaluated
    at the trailing edge =")
disp(C_F)
```

Chapter 9

The Flow of an Inviscid Fluid

Scilab code Exa 9.2 2

```
clc

// p_a-p_b=-1/2*rho*C^2*(1/R_A^2-1/R_B^2)

rho_w=1000; // kg/m^3
g=9.81; // m/s^2
h=0.0115; // m
rho=1.22; // kg/m^3
R_A=0.4; // m
R_B=0.2; // m

C=sqrt(rho_w*g*h*2/(rho*(1/R_B^2-1/R_A^2)));

m=rho*C*R_B*integrate('1/R','R', R_B, R_A);

disp("Mass flow rate =")
disp(m)
disp("kg/s")
```

Scilab code Exa 9.3 3

```
clc

// p=1/2*rho*w^2*R^2 + C


// At z=0
rho=900; // kg/m^3
g=9.81; // m/s^2
h=0.6; // m

C=rho*g*h;

// p = -rho*K^2/(2*R^2)+D
// From this we get , D = 9*w^2 + C

// At z = 0
// p = D - rho*K^2/2/R^2;
p_max=150000; // Pa

// From the above equation we obtain ,
w=135.6; // rad/s

disp("The maximum speed at which the paddles may
   rotate about their vertical axis =")
disp(w)
disp("rad/s")
```

Scilab code Exa 9.4 4

```
clc

U=40; // m/s
h=0.01; // m
```

```

m=2*U*h;
disp("(a) the strength of the line source =")
disp(m)
disp("m^2/s")

s = m/(2*%pi*U);
disp("(b) the distance s the line source is located
    behind the leading edge of the step =")
disp(s*1000)
disp("mm")

x=0; // m
y=0.005; // m

u=U + m/(2*%pi)*(x/(x^2+y^2));
v=m/(2*%pi)*(y/(x^2+y^2));
disp("Horizontal component =")
disp(u)
disp("m/s")

disp("Vertical Component =")
disp(v)
disp("m/s")
```

Scilab code Exa 9.5 5

```
clc

b=0.0375; // m
t=0.0625; // m
U=5; // m/s

m=2*%pi*U*t/atan(2*b*t/(t^2-b^2));

```

```
L=2*b*(1+m/(%pi*U*b))^(1/2);

disp("L =")
disp(L)
disp("m")
```

Scilab code Exa 9.7 7

```
clc

l1=10; // m
r1=2; // m
C_D1=0.0588;
theta1=6.5; // degrees

AR1=l1/r1; // Aspect ratio

C_L=0.914;

C_D2=C_L^2/(%pi*AR1);
theta2=atand(C_L/(%pi*AR1))

C_D3=C_D1-C_D2;
theta3=theta1-theta2;

AR2=8;

C_Di=C_L^2/(%pi*AR2);
C_D=C_Di+C_D3;

theta4=atand(C_L/(%pi*AR2));
theta=theta4+theta3;

disp("Lift coefficient =")
disp(C_L)
```

```
disp("Drag coefficient =")
disp(C_D)

disp("Effective angle of attack =")
disp(theta)
disp("degrees")
```

Chapter 10

Flow with a Free Surface

Scilab code Exa 10.1 1

```
clc

Q=400; // m^3/s
b2=20; // m
g=9.81; // m/s^2
b1=25; // m

h2=(Q/b2/sqrt(g))^(2/3);
// Since energy is conserved
// h1 + u1^2/2g = h2 +u2^2/2g = h2 + h2/2 = 3h2/2

// h1 + 1/2*g*(Q/(b1h1))^2 = 3*h2/2;

// h1^3-5.16*h1^2+13.05 = 0;

// By solving this cubic equation

h1=4.52; // m

disp("(a) The depth of the water under the brigde =")
```

```
disp(h2)
disp("m")

disp("(b) the depth of water upstream =")
disp(h1)
disp("m")
```

Scilab code Exa 10.2 2

```
clc

w=0.04; // thickness of block in m
d=0.07; // depth of liquid in m
b=0.4; // m
g=9.81; // m/s^2

H=d-w;

Q=1.705*b*H^(3/2);

u1=Q/d/b;
h=u1^2/(2*g);

H1=H+h;

Q1=1.705*b*H1^(3/2);

disp("Rate of flow = ")
disp(Q1)
disp("m^3/s")
```

Scilab code Exa 10.3 3

```
clc

h1=0.45; // m
g=9.81; // m/s^2
b1=0.8; // m
h2=0.35; // m
b2=0.3; // m
disp("(a) the flow rate")
Q=sqrt((h1-h2)*2*g/((1/(h1*b1)^2)-(1/(h2*b2)^2)));
disp("(a) Flow rate =")
disp(Q)
disp("m^3/s")

disp("(b) the Froude number at the throat")
Fr2=Q/(sqrt(g)*b2*h2^(3/2));
disp("The Froude number at the throat =")
disp(Fr2)

disp("(c) the depth of water at the throat")

// (h1/h2)^(3) + 1/2*(b2/b1)^2 = 3/2*(h1/h2)^2

// The solution for the above eqn is as follows
// (h1/h2) = 0.5 + cos(2arcsin(b2/b1)/3)

// h1/h2=1.467

h2_new=h1/1.467;
disp("Depth of water at the throat =")
disp(h2_new)
disp("m")

disp("(d)the new flow rate")
Q=sqrt(g)*b2*h2_new^(3/2);
disp("New flow rate =")
disp(Q)
disp("m^3/s")
```

Scilab code Exa 10.4 4

```
clc

Q=8.75; // m^3/s
w=5; // m
n=0.0015;
s=1/5000;

// Q/(w*h0) = u = m^(2/3)*i^(1/2)/n = 1/0.015*(w*h0
    /(w+2*h0))^(2/3)*sqrt(s);
// Solution by trial gives h0
h0=1.8; // m

q=1.75;
g=9.81;
hc=(q^2/g)^(1/3); // critical depth

disp("Depth =")
disp(h0)
disp("m")
```

Scilab code Exa 10.5 5

```
clc

g=9.81; // m/s^2
T=5; // s
h=4; // m

// lambda=g*T^2/(2*%pi)*tanh(2*%pi*h/lambda1);
// by trial method , we get
```

```
lambda1=28.04;

lambda=g*T^2/(2*%pi)*tanh(2*%pi*h/lambda1);
disp("Wavelength =")
disp(lambda)
disp("m")
```

Scilab code Exa 10.6 6

```
clc

g=9.81; // m/s^2
T=12; // s

c=g*T/(2*%pi);

lambda=c*T;

disp("Phase velocity =")
disp(c)
disp("m/s")

disp("Wavelength =")
disp(lambda)
disp("m")
```

Scilab code Exa 10.7 7

```
clc

c=18.74; // m/s
lambda=225; // m

```

```
disp("(a)Estimate the time elapsed since the waves
   were generated in a storm occurring 800 km out to
    sea. ")

x=800*10^3; // m
cg=c/2;

t=x/cg;

disp("time elapsed =")
disp(t/3600)
disp("hours")

disp("(b)Estimate the depth at which the waves begin
    to be significantly influenced by the sea bed as
    they approach the shore.")

h1=lambda/2;

h2=lambda/(2*%pi)*atanh(0.99);

printf("The answers show that h lies in the range
   between about %f m and %f m", h2,h1)
```

Chapter 11

Compressible Flow of Gases

Scilab code Exa 11.1 1

```
clc

disp("(a) the density at plane 1")

p1=1.5*10^5; // N/m^2
R=287; // J/kg.K
T1=271; // K

rho1=p1/R/T1;
disp("Density at plane 1 =")
disp(rho1)
disp("kg/m^3")

disp("(b) the stagnation temperature")

u1=270; // m/s
cp=1005; // J/Kg.K

T0=T1+u1^2/(2*cp);
disp("The stagnation temperature =")
disp(T0)
```

```
disp("K")

disp("(c) the temperature and density at plane 2")

u2=320; // m/s
p2=1.2*10^5; // N/m^2

T2=T0-u2^2/(2*cp);
disp("Temperature = ")
disp(T2)
disp("K")

rho2=p2/(R*T2);
disp("density =")
disp(rho2)
disp("kg/m^3")
```

Scilab code Exa 11.2 2

```
clc

disp("(a) the angle through which the airstream is
    deflected")

y=1.4;
R=287; // J/kg.K
T1=238; // K
u1=773; // m/s
beta1=38; // degrees
cp=1005; // J/kg.K

a1=sqrt(y*R*T1);
M1=u1/a1;

beta2=atand(tand(beta1)*((2+(y-1)*M1^2*(sind(beta1))
```

```
^2)/((y+1)*M1^2*(sind(beta1))^2)));

deflection_angle=beta1-beta2;
disp("Deflection angle =")
disp(deflection_angle)
disp("degrees")

disp("(b) the final Mach number")

u2=u1*cosd(beta1)/cosd(beta2);

T2=T1+1/(2*cp)*(u1^2-u2^2);
a2=sqrt(y*R*T2);

M2=u2/a2;

disp("Final Mach number =")
disp(M2)

disp("(c) the pressure ratio across the wave.")
ratio=T2/T1*(tand(beta1)/tand(beta2));
disp("Pressure ratio =")
disp(ratio)
```

Scilab code Exa 11.3 3

```
clc

M1=1.8;
theta1=20.73; // degrees
theta2=30.73; // degrees
M2=2.162;
p1=50; // kPa
y=1.4;

```

```
p2=p1*((1+(y-1)/2*M1^2)/(1+(y-1)/2*M2^2))^(y/(y-1));

disp("Pressure after the bend =")
disp(p2)
disp("kPa")
```

Scilab code Exa 11.4 4

```
clc

p=28*10^3; // N/m^2
y=1.4;
M1=2.4;
M2=1;
T0=291; // K
R=287; // J/kg.K

disp("(a) the pressures in the reservoir and at the
    nozzle throat")

p0=p*(1+(y-1)/2*M1^2)^(y/(y-1));
pc=p0*(1+(y-1)/2*M2^2)^(-y/(y-1));

disp("Pressure in the reservoir =")
disp(p0)
disp("N/m^2")

disp("Pressure at the nozzle throat =")
disp(pc)
disp("N/m^2")

disp("(b) the temperature and velocity of the air at
    the exit.")

T=T0*(1+(y-1)/2*M1^2)^(-1);
```

```
disp("Temperature =")
disp(T)
disp("K")

a=sqrt(y*R*T)

u=M1*a;

disp("Velocity =")
disp(u)
disp("m/s")
```

Scilab code Exa 11.5 5

```
clc

M_He=1.8;
y_He=5/3;
y_air=1.4;
p2=30; // kPa

// (A/At)=(1+(y-1)/2*M^2)^((y+1)/(y-1))/M^2*(2/(y+1)
    )^((y+1)/(y-1))

//     = (1+1/3*1.8^2)^(4)/1.8^(2)*(3/4)^(4) = 1.828
    for helium

//     = (1+0.2*M^2)^6/M^2*1/1.2^6     for air
// Hence by trial

M1=1.715;
disp("Mach number before the shock =")
disp(M1)

```

```
p1=p2/((2*y_air*M1^2-(y_air-1))/(y_air+1));

p0_1=p1*(1+(y_air-1)/2*M1^2)^(y_air/(y_air-1));

disp("Stagnation Pressure =")
disp(p0_1)
disp("kPa")
```

Scilab code Exa 11.6 6

```
clc

p0=510; // kPa
pA=500; // kPa
pB=280; // kPa
d=0.02; // m
l_max=12; // m

disp("(a) the value of the friction factor for the
    pipe")

// At A, pA/p0 = 500/510 = 0.980. From the
    Isentropic Flow Tables (Appendix 3), M_A = 0.17.
// From the Fanno Flow Tables (Appendix 3)for M_A =
    0.17 and  = 1.4, pc/pA = 0.1556 and (fl_maxP/A)
    _A = 21.37

pC=pA*0.1556;

// From the Fanno Tables at pc/pB = 0.278,M_B =
    0.302 and (fl_maxP/A)B = 5.21.
// For a circular pipe P/A=4/d
M_B=0.302;
f=(21.37-5.21)/l_max/4*d;

```

```
disp("friction factor =")
disp(f)

disp("(b) the overall length of the pipe, L, if the
    flow exhausts to atmosphere")

p=100; // kPa

// At exit, pc/p = 77.8/100 = 0.778. From the Fanno
    Tables, (fl_maxP/A) = 0.07
L=l_max*(21.37-0.07)/(21.37-5.21);

disp("Overall Length =")
disp(L)
disp("m")

disp("(c) the mass flow rate if the reservoir
    temperature is 294 K.")
T0=294; // K
R=287; // J/kg.K
y=1.4;
M=0.302;

m=%pi/4*d^2*pB*10^3*M_B*(y*(1+(y-1)*M^2/2)/R/T0)
    ^(1/2);
disp("mass flow rate =")
disp(m)
disp("kg/s")
```

Scilab code Exa 11.7 7

```
clc

p1=8*10^5; // N/m^2
p2=5*10^5; // N/m^2
```

```
f=0.006;
l=145; // m
m=0.32; // kg/s
R=287; // J/kg.K
T=288; // K
y=1.4;

d=(4*f*l*m^2*R*T/(%pi/4)^2/(p1^2-p2^2))^(1/5);
disp("(a) Diameter of pipe =")
disp(d)
disp("m")

rho=p1/R/T;
A=%pi/4*d^2;
u=m/rho/A;

a=sqrt(y*R*T);

M1=u/a;
M2=p1/p2*M1;

disp("(b) Entry and Exit Mach number =")

disp("Entry Mach number =")
disp(M1)

disp("Exit Mach number =")
disp(M2)

disp("(c) Determine the pressure halfway along the
   pipe.")
px=sqrt((p1^2+p2^2)/2);
disp("Pressure =")
disp(px)
disp("N/m^2")
```

Chapter 12

Unsteady Flow

Scilab code Exa 12.1 1

```
clc

Q=0.05; // m^3/s
d=0.15; // m^2
h=8; // m
g=9.81; // m/s^2
l=90; // m
f=0.007;

u1=Q/(%pi/4*d^2);

t=-integrate('1/((h*g/l)+(2*f/d)*u^2)', 'u', u1, 0);
disp("Time for which flow into the tank continues
   after the power failure = ")
disp(t)
disp("s")
```

Scilab code Exa 12.4 4

```
clc

disp("(b) Estimate the height of tank required")

f=0.006;
l=1400; // m
g=9.81; // m/s^2
d1=0.75; // m
d2=3; // m
Q=1.2; // m^3/s
a=20; // m

K=4*f*l/(2*g*d1);

// 2*K*Y = l*a/(g*A) = 8.919 s^2

// Y=2*K*Y/2*K

Y=8.919/(2*K);
// When t=0

u0=Q/(%pi/4*d1^2);

y0=K*u0^2;

C=-Y/K/exp(y0/Y);

// To determine the height of the surge tank, we
   consider the condition y = y_max when u = 0.

// 0 = 1/K*(y_max+Y) + C*exp(y_max/Y)

// From the above eqn we get

y_max=-Y;

H=a-y_max;
disp("The minimum height of the surge tank =")
```

```
disp(H)
disp("m")

disp("The actual design height should exceed the
   minimum required, say 23 m")
```

Chapter 13

Fluid Machines

Scilab code Exa 13.1 1

```
clc

// Maximum hydraulic efficiency occurs for minimum
   pressure loss , that is , when

// dp1/dQ=2.38Q−1.43=0

Q_opt=1.43/2.38;

p1_min=1.19*Q_opt^2-1.43*Q_opt+0.47; // MPa

rho=1000; // kg/m^3
g=9.81; // m/s^2
w=69.1; // rad/s
P=200*10^3; // W
Ohm_P=0.565; // rad
d=0.5; // m
h=0.06; // m

p1=p1_min*10^6/(rho*g); // mH2O, coversion of units

```

```
H=(w*P^(1/2)/(rho^(1/2)*Ohm_P))^(4/5)/g;

Hydraulic_efficiency=(H-p1)/H;
disp("Hydraulic Efficiency =")
disp(Hydraulic_efficiency)

Overall_efficiency=P/(Q_opt*rho*g*H);
disp("Overall Efficiency =")
disp(Overall_efficiency)

H_Euler=H-p1;

u1=w*0.25;
v_w1=g*H_Euler/u1;
A=%pi*d*h*0.95;
v_r=Q_opt/A;

alpha1=atand(v_r/v_w1);
disp("Outlet angles of the guide vanes =")
disp(alpha1)
disp("degrees")

beta1=atand(v_r/(v_w1-u1));
disp("Rotor blade angle at inlet =")
disp(beta1)
disp("degrees")
u2=w*0.325/2;
beta2=atand(v_r/u2);
disp("Rotor blade angle at outlet =")
disp(beta2)
disp("degrees")
```

Scilab code Exa 13.2 2

```
clc
```

```

w=6.25;
D=0.75; // m
gv_angle=15; // guide vane angle in degrees
g=9.81; // m/s^2
H=27.5; // m
A1=0.2; // m^2
rho=1000; // kg/m^3
p_atm=101.3*10^3;
p_min=35*10^3;

u1=%pi*w*D;
v1=u1*sind(105)/sind(60);
v_r1=v1*sind(gv_angle);
v_w1=v1*cosd(gv_angle);
v_w2=0;

n_hydraulic=u1*v_w1/g/H;

n_overall=0.97*n_hydraulic;
disp("Overall efficiency =")
disp(n_overall)

Q=A1*v_r1;

P=n_overall*Q*rho*g*H;
Ohm_P=w*2*%pi/(g*H)^(5/4)*(P/rho)^(1/2);

// sigma > 0.119*(0.5)^(1.84) = 0.0331

sigma=0.0331;

//((p_atm-p_min)/(rho*g)-z0)/H > 0.0331

z0=((p_atm-p_min)/(rho*g))-sigma*H;
disp("Limiting value for the height of the draft
   tube above =")
disp(z0)
```

```
disp("m")
```

Scilab code Exa 13.3 3

```
clc

// Static head upstream = -11 mm H2O = -11*1000/1.2
   mm air = -9.167 m air

h=9.167; // m air
g=9.81; // m/s^2
d1=0.75; // m, tip diameters
d2=0.4; // m, hub diameters
d3=0.075; // m, diameter above atmospheric pressure
d4=0.011; // m, diameter below atmospheric pressure
P=6500; // W
w=25;
rho=1000; // kg/m^3

v=sqrt(2*g*h); // Velocity upstream
Q=%pi/4*d1^2*v; // Volume flow rate

H=d3+d4; // Total head rise across fans
p=rho*g*H;

n_fan=Q*p/P;
disp("Total efficiency =")
disp(n_fan)

p_ideal=p/n_fan;
u=%pi*w*(d1+d2)/2;

v_w2_A=p_ideal/(2*1.2*u);

v1=Q/(%pi/4*(d1^2-d2^2 ));
```

```
beta1_A=atand(v1/u);

beta2_A=atand(v1/(u-v_w2_A));

beta1_B=atand(v1/(u+v_w2_A));

beta2_B=atand(v1/u);

printf("Inlet angles for resp. fans %f & %f \n\n",
    beta1_A, beta1_B)

printf("Outlet angles for resp. fans %f & %f",
    beta2_A, beta2_B)
```

Scilab code Exa 13.5 5

```
clc

Q=0.04; // m^3/s
d=0.15; // m
h=28; // m
f=0.006;
l=38; // m
g=9.81;
fre=50; // Hz
n_manometer = 0.75;
theta=30; // degrees

v=Q/(%pi/4*d^2);
h1=(3+4*f*l/d)*v^2/2/g; // Total head loss through
    pipes and valves

h_m=h+h1; // Manometric head

```

```
// w=2*%pi*50/n; where n = number of pairs of poles.
// Ohm_s=w*Q^(1/2)/(g*H)^(3/4) = 0.876/n rad

// If n = 2, Ohm_s = 0.438 rad, which suggests pump
    1 or 2, and  = 157 rad/s. Outlet flow area =
    %pi*D*D/10

// v_r2=0.04/(%pi*D^2/10)
// u2= *D/2 = 78.54 D

// v_w2= g*h_m/(n_manometer*u2) = 5.06/D; // m^2/s

// tan(theta) = v_r2/(u2-v_w2)

// Solving above equation, we get
// 78.54*D^3 - 5.06*D - 0.2205 = 0;

// Solving above cubic equation we get

D = 0.272; // m
disp("D = ")
disp(D)
disp("m")
disp("That is near enough. So we choose pump 1")
```

Scilab code Exa 13.6 6

```
clc

f=0.0085;
l=21.1; // m
d=0.09; // m
g=9.81; // m/s^2
rho=1000; // kg/m^3

```

```
// h1=hf=(4*f*l/d)*(16*Q^2/(2*%pi^2*d^4*g)) = (100*Q
   )^2

disp("(a)The head loss due to pipe friction in terms
    of flow rate Q is given as")
disp("(100*Q)^2")

// For Pump
Q=[0:0.006:0.042 0.052];
H=[15 16 16.5 16.5 15.5 13.5 10.5 7 0]
plot(Q,H,"r")
xlabel("Q(m^3/s)")
ylabel("H(m)")

// For Pipe System

// H1 = 11.5 + (100*Q)^2;

Q=[0:0.01:0.06];
plot(Q,(11.5+10000*Q^2),"b")

legend("pipe system", "pump")

// From the plot of the pump and pipe
   characteristics , the intersection is at

H=16; // m
Q=0.021; // m^3/s
n=0.74;

P=rho*g*H*Q/n;

disp("(b)Power required =")
disp(P)
disp("W")
```

Scilab code Exa 13.7 7

```
clc

H=16.5; // m
Q=0.015; // m^3/s
n=0.63;
H_s=11.5;
rho=1000; // kg/m^3
g=9.81; // m/s^2

h_f=(100*Q)^2; // frictional head loss

h_valve = H - H_s - h_f;

P=rho*g*H*Q/n;
disp("(i) the power consumption of the pump =")
disp(P/1000)
disp("kW")

disp("(ii) The power dissipated in the pump =")
P_d=P*(1-n)/1000;
disp(P_d)
disp("kW")

disp("(iii) The power lost by pipe friction =")
P_f=rho*g*h_f*Q;
disp(P_f/1000)
disp("kW")

disp("(iv) The power lost in the valve =")
P_valve=rho*g*h_valve*Q;
disp(P_valve/1000)
disp("kW")
```

```
P_s=rho*g*H_s*Q;

n_overall = P_s/P*100;

disp("(b) Overall efficiency of the installation =")
disp(n_overall)
disp("%")
```