Scilab Textbook Companion for Measurement Systems by E. O. Doebelin And D. N. Manik[1]

Created by
KRITI SUNEJA
B.TECH
Electronics Engineering
LAXMI NIWAS MITTAL INSTITUTE OF INFORMATION TECHNO
College Teacher
NA
Cross-Checked by

May 18, 2016

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Textbook Companion and Scilab codes written in it can be downloaded from the "Textbook Companion Project" section at the website http://scilab.in

Book Description

Title: Measurement Systems

Author: E. O. Doebelin And D. N. Manik

Publisher: Tata McGraw - Hill Education

Edition: 5

Year: 2007

ISBN: 9780070616721

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 4

2 Generalized Configurations and Functional Descriptions of measuring instruments 5

3 Generalized Performance Characteristics Of Instruments 7

4 Motion and Dimensional Measurement 13

5 Force Torque and Shaft power measurement 24

6 Pressure and sound measurement 29

7 Flow measurement 38

8 TEMPRATURE MEASUREMENT 47

List of Scilab Codes

Exa 2.1 Error in measurement 5
Exa 3.1 Gaussian distribution 7
Exa 3.2 Combination of component errors in overall system . . 8
Exa 3.5 First order instrument 10
Exa 3.6 Step response of first order instrument 10
Exa 3.7 Adequate frequency response conditions for first o . . 11
Exa 4.1 Resistance strain gage 13
Exa 4.2 Rosette 14
Exa 4.3 Strain gage 15
Exa 4.4 Capacitance pick ups 16
Exa 4.5 Piezoelectric transducer 16
Exa 4.7 Seismic vibrations 17
Exa 4.8 Seismic velocity pick ups 18
Exa 4.9 Piezoelectric transducer 19
Exa 4.10 Seismic pick ups 20
Exa 4.11 Accelerometers 22
Exa 4.12 Strain gage 22
Exa 5.1 Load cell 24
Exa 5.2 Load cell 25
Exa 5.3 Load cell 26
Exa 5.4 Piezoelectric transducer 26
Exa 5.5 Torque measurement on rotating shaft 27
Exa 6.1 manometers 29
Exa 6.2 manometers 30
Exa 6.3 elastic transducers 30
Exa 6.4 design of pressure transducers 31
Exa 6.5 pressure gage 33
Exa 6.6 high pressure measurement 34

Exa 6.7	Mc Leod gage	35
Exa 6.8	Knudsen gage	35
Exa 6.9	sound measurement	36
Exa 6.10	sound measurement	36
Exa 7.1	Flow measurement	38
Exa 7.2	Anemometers	39
Exa 7.3	Gross volume flow rate	39
Exa 7.4	Gross volume flow rate	41
Exa 7.5	Gross volume flow rate	42
Exa 7.6	sonic nozzle	43
Exa 7.7	venturi	44
Exa 7.8	constant pressure drop	45
Exa 8.1	thermocouple	47
Exa 8.2	thermocouple and thermopile	48
Exa 8.3	electrical resistance sensors	49
Exa 8.4	thermistors	50
Exa 8.5	pyrometers	51

Chapter 2

Generalized Configurations and Functional Descriptions of measuring instruments

Scilab code Exa 2.1 Error in measurement

```
// Chapter 2_Generalized Configurations and Functional Descriptions of measuring instruments
//Caption_Error in measurement
//Ex_1 part_2 //page 22
disp("ts=0.1")
disp("ps=2.5")
disp("dT=20")

ts=0.1   //('enter the temperature sensitivity=:')
ps=2.5   //('enter the pressure sensitivity(in units/MPa)=:')
dT=20   //('enter the temperature change during pressure measurement=:')
P=120   //('enter the pressure to be measured (in MPa)=:')
error=(ts*dT)/(ps*P);
printf('the error in measurement is %fd percent\n',
```

```
    error)
```

Chapter 3

Generalized Performance Characteristics Of Instruments

Scilab code Exa 3.1 Gaussian distribution

```
//Chapter_3 Generalized Performance Characteristics
   Of Instruments
//Caption:Gaussian Distribution
// Example 1
clc;
close;
disp("me=7")
disp("stddev=0.5")
disp("x = 6  ")
disp("y= 7.5")
me=7 ;
stddev=0.5;
x = 6  //('enter the lower limit of the range=:')
y= 7.5  //('enter the upper limit of the range=:')
n= 200  //('enter the number of samples=:')
disp("using    k =abs((x-me)/((2^0.5)*stddev));")
k =abs((x-me)/((2^0.5)*stddev));
printf('Value of eta1 is %1.2f \n',k)

```

```
p=abs((y-me)/((2^0.5)*stddev));
printf('Value of eta2 is %1.2f \n',p)
//Using the gaussian probability error function table, find the error function corresponding to the value of k and p
//LET IT BE s
s= 0.95 // ('enter the error function corresponding to k value=:')
F(x)=(1/2)+(1/2*s);// Probability of having lengths less than x
l= 0.68 // ('enter the error function corresponding to p value=:')
F(y)=(1/2)+(1/2*l);// Probability of having lengths less than y

printf('probability of having length less than 6 cm is %1.3f ',F(x));
printf('probability of having length less than 67.5 cm is %1.3f ',F(y));

P(x)=abs(F(y)-F(x));
printf("Number of samples in the given length range=")
m=(n*P(x));
disp(m);
```

Scilab code Exa 3.2 Combination of component errors in overall system

```
//Caption:Combination of component errors in overall system-accuracy calculations
//example2
//page 62
clc;
//Consider an experiment for measuring, by means of a dynamometer, the average power transmitted by a
```

```
rotating sheft
disp("R=1202 ")
disp("F=45")
disp("L=0.397 ")
disp("t=60")
R=1202 //('Enter the revolutions of shaft during time t=:')
F=45 //('Enter the force at end oftorque arm=:')
L=0.397 //('Enter the length of torque arm=:')
t=60 //('Enter the time length of run=:')
W=(2*%pi*R*F*L)/t;
//Computing various partial dervatives
dWF=(2*%pi*R*L)/t;
disp(dWF) //dWF represents dW/dF
dWR=(2*%pi*F*L)/t;
dWL=(2*%pi*F*R)/t;
dWt=-(2*%pi*R*F*L)/(t^2);
//Let f, r, l and t represent the uncertainties
disp("f=0.18")
disp("r=1 ")
disp("l=0.00127 ")
disp("t=0.5")
disp("Ea=(dWF*f)+(dWR*r)+(dWL*l)+abs(dWt*t); ")
f=0.18 //('Enter the uncertainty in force=:')
r=1 //('Enter the uncertainty in the no of revolutions=:')
l=0.00127 //('Enter the uncertainty in the length=:')
t=0.5 //('Enter the uncertainty in the time length of run=:')
Ea=(dWF*f)+(dWR*r)+(dWL*l)+abs(dWt*t); //absolute error
printf("The absolute error is ")
disp(Ea);
//To find total uncertainty
U=(((dWF*f)^2)+(dWR*r)^2+(dWL*l)^2+abs(dWt*t)^2)^0.5
printf("Total uncertainty is ")
disp(U)
```

Scilab code Exa 3.5 First order instrument

```
// Chapter_3 Generalized Performance Characteristics
    Of Instruments
//Caption:First order instrument
//Example 5
//Page no. 96
d=.004    //('Enter the diameter of the diameter of
   the sphere in meters=:')
p=13600  //('Enter the density of the liquid in
   glass bulb=:')
c=150   //('Enter the specific heat of liquid(in j/
   kg degree centigrade)=:')
U=40  //('Enter the heat transfer coefficient in W/m
   ^2-degree centigrade=:')

Vb=(%pi*d*d*d)/6;    //Volume of sphere
Ab=%pi*d*d;    //Surface area of sphere
timconstant=(p*c*Vb*1000)/(U*Ab);    //time constant
disp(timconstant)
```

Scilab code Exa 3.6 Step response of first order instrument

```
//Caption:Step response of first order systems
//Example 6
// page 100
clc;
// Given:In air, probe dry          timeconstant(tc)
   =30s
//       In water                              tc
   =5s
```

```
//        In air, probe wet                         tc
   =20s
// for t<0,T=25 degree C(initial temperature)
//     0<t<7, T=35 degree C(dry probe in air)
//     7<t<15, T=70 degree C(probe in water)
//     15<t<30, T=35 degree C(wet probe in air)

//case i T(a)=25
T(7)=35+(25-35)*%e^(-(7/30))
printf("Temperature at the end of first interval")
disp(T(7));
//case ii T(a)=T(7)
T(15)=70+(T(7)-70)*%e^(-((15-7)/5))
printf("Temperature at the end of second interval")
disp(T(15));
//case iii T(a)=T(15)
T(30)=35+(T(15)-35)*%e^(-((30-15)/20))
printf("Temperature at the end of third interval")
disp(T(30));
```

Scilab code Exa 3.7 Adequate frequency response conditions for first o

```
//Caption:Adequate frequency response conditions for
    first order instruments
//Example 7
//Page 103
// To measure qi given by
// qi=sin2t+0.3sin20t
// timeconstant=0.2s
H=1/((0.16+1)^0.5);        //H(jw)=qo/qiK
phi=((atan(-2*0.2))*180)/%pi ;
H2=1/((16+1)^0.5);
phi2=((atan(-20*0.2))*180)/%pi;
printf("sinusoidal transfer function at 2 rad/sec is
   ")
```

```
disp(H);
disp(phi)
printf("sinusoidal transfer function at 20rad/sec is
   ")
disp(H2)
disp(phi2)

printf("qo/K can be written as")

printf("        qo=0.93K sin(2t-21.8)+(0.24K) 0.3sin
   (20t-76)")
//Suppose we consider use of an instrument with
   timeconstant=0.002s
H=1/((1.6*(10)^(-5)+1)^0.5);
phi=((atan(-2*.002))*180)/%pi ;
H2=1/((1.6*(10^-3)+1)^0.5);
phi2=((atan(-20*0.002))*180)/%pi;
printf("sinusoidal transfer function at 2 rad/sec is
   ")
disp(H);
disp(phi)
printf("sinusoidal transfer function at 20rad/sec is
   ")
disp(H2)
disp(phi2)
printf("qo/K can be written as")

printf("        qo=K sin(2t-0.23)+K 0.3sin(20t-2.3)")
printf("Clearly, this instrument measures the given
   qi faithfully")
```

Chapter 4

Motion and Dimensional Measurement

Scilab code Exa 4.1 Resistance strain gage

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Resistance strain gage
// Example 1// Page 163

disp("Rg=120")
disp("E=200 *10^9")
disp("dL=3 ")
disp("dp=0.3")
disp("v=0.3 ")
Rg=120   //('enter the resistance of strain gage=:')
E=200 *10^9   // given
dL=3  //('enter the percent change in the length of
    nthe rod due to loading=:')
dp=0.3  //('enter the corresponding change in the
    resistivity of strain gage=:')
v=0.3   // poissons ratio
e=dL/100;
dp_p=dp/100
disp("dR_R=dp_p+e*(1+2*v)")
```

```
dR_R=dp_p+e*(1+2*v)
Sg=dR_R/e;
printf('So the gage factor is %fd \n',Sg)
u_dr=0.02   //('enter the uncertainty in resistance =:')
u_sig=E*u_dr/(Rg*Sg)*10^-6;
printf(' Stress uncertainty is %1.1f MPa\n',u_sig)
// To calculate strain uncertainty
u_e=u_dr/(Rg*Sg)
printf('Strain uncertainty is %fd\n',u_e)
```

Scilab code Exa 4.2 Rosette

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Rosette
// Example 2// Page 168
Eh=625*10^-6  //('enter the circumferential strain =:')
Ea= 147*10^-6   //('enter the longitudinal strain =:')
E=200*10^9    // given
v=0.3;    // poissons ratio
// to calculate circumferential stress
sig_h=E/(1-v^2)*(Eh+v*Ea)*10^-6;
printf('Circumferential stress (hoops stress) is %1.1f MPa\n',sig_h);
sig_a=E/(1-v^2)*(v*Eh+Ea)*10^-6;
printf('Axial stress is %1.2f M Pa\n',sig_a);
// To calculate ratio of stresse
disp("Let the ratio be represented by RR")
RR=sig_h/sig_a;
printf('Ratio of stresses is %fd\n',RR)
disp("Let the ratio of strains be represented by SS")
SS=Eh/Ea;
```

```
printf('THe ratio of strains is %1.2f', SS)
```

Scilab code Exa 4.3 Strain gage

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Strain gage
// Example 3// Page 176
disp("Rg=120")
disp("Sg=2;")
disp("Rs=120000")
Rg=120;     // given
Sg=2;  // gage factor
Rs=120000    //('enter the value of shunt resistor =:')
disp("The input bridge excitation is represented by Eex")
A=10    //('enter the amplifier gain=:')
// The shunt resistance has to be very large since we intend to measure only very small change in resistanc
eo=30*10^-3     //('enter the unbalanced bridge voltage=:')
dR=Rg/(Rg+Rs);
r=1;//ratio of resistances of adjacent arms
Eex=eo*(1+r)^2/(r*dR*A);
printf('The input excitation voltage is %fd V\n',Eex)
p1=2 *(1+v) // bridge factor
Eo=.5    //('enter the voltmeter reading when shunt is removed=:')
E_axial=Eo*(1+r)^2/(r*Sg*p1*Eex*A);
printf(' Axial strain is %fd\n ',E_axial)
E_trans=E_axial*v;
printf('The transverse strain is -%fd',E_trans)
```

Scilab code Exa 4.4 Capacitance pick ups

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Capacitance pick ups
// Example 4// Page 192
disp("h=.005")
disp("A=200*10^-6")
disp("n=0.03")
h=.005  //('enter the distance between the
    capacitors=:')
A=200*10^-6  //('enter the area of the transducer
    =:')
n=0.03  //('enter the non linearity=:')
w=.014  //('enter the side of the square capacitor
    =:')
er=1   // given that air if filled
eo=8.85  ;
// to calculate the sensitivity of this transducer,
    let it be represented by c
c=eo*er*A/h^2;
printf('sensitivity of the transducer is %1.2f pF/m
    \n',c)
// to calculate the sensitivity of the square moving
     plate sensor cl
cl=eo*er*w/h;
printf('the sensitivity of the square moving plate
    sensor is %1.2f pF/m ',cl)
```

Scilab code Exa 4.5 Piezoelectric transducer

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Piezoelectric transducer
```

```
// Example 5// Page 207
g=15  //('enter the value constant g for the crystal
    =:')
A=%pi*((5*10^-3)^2)/4   //('enter the area of cross
    section of the crystal=:')
f=50  //('enter the frequency of sinusoidally
    varying pressure=:')
 eoer=15*10^-9  // for the crystal
 E=120 *10^9  // youngs modulus of elasticity
 t=.003   //('enter the thichness of the crystal=:')
 Kq=g*eoer*A*E/t;
 printf('Charge sensitivity is %fd mC/m \n',Kq)
 Ccr=eoer*A/t;
 Camp=2000*10^-12;
 Ccable=100*10^-12;
 C=Ccr+Camp+Ccable;
 Ramp=2000000   //('enter the input impedance of the
     amplifier ')
 Req=Ramp;
 tou=Req*C;     // time constant
 // Let the amplitude ratio is given by EOP
 w=2*%pi*f;
 EOP=Kq*t*w*tou/(C*E*sqrt(1+(w*tou)^2))
 printf('The amplitude ratio is %fd mV/V\n',EOP)
 // let the phase lag be represented by phi
 phi=360*atan(1/(w*tou))/(2*%pi);
 printf(' The phase lag is %fd deg',phi);
```

Scilab code Exa 4.7 Seismic vibrations

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Seismic vibration
// Example 7// Page 232
disp("ty=0.6")
disp("fn=10")
```

```
disp(" f=25")
disp("M=0.15")
disp(" xo=1.5*10^-3")
ty=0.6  //(' enter the damping ratio of seismic
    vibration pickup=:')
fn=10  //('enter the natural frequency =:')
f=25  //('enter the frequency at which the table is
    vibrating=')
M=0.15  //( 'enter the seismic mass=:')
xo=1.5*10^-3  //('enter the relative amplitude of
    the mass=:')
r=f/fn;
disp(" xi=xo/((r^2)/sqrt((1-r^2)^2+(2*ty*r)^2));")
xi=xo/((r^2)/sqrt((1-r^2)^2+(2*ty*r)^2));
error=(xi-xo)/xo;
printf('error in measurement is %fd\n',error)
wn=2*%pi*fn;
Ks=wn^2*M;
printf('spring constant is %fd N/m\n',Ks)
B=ty*(2*sqrt(Ks*M));
printf(' damping coefficient of pickup is %fdN-s/m\n
    ',B)
```

Scilab code Exa 4.8 Seismic velocity pick ups

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Seismic velocity pickup
// Example 8// Page 235
disp(" fn=4")
disp("S=500")
disp("m=0.2")
disp(" v=1.5*10^-2")
fn=4  //('enter the natural frequency=:')
S=500  //('enter the sensitivity=:')
m=0.2  //('enter the mass =:')
```

```
v=1.5*10^-2  //('enter the maximum velocity with which the surface is vibrating=:')
f=10 //('enter the frequency=:')
r=f/fn;
tou=0.2 // given
w=2*%pi*f;
eo=(v*S*r^2)/sqrt((1-r^2)^2+(2*tou*r)^2);
printf('The peak voltage corresponding to 10Hz frequency is %fd mV\n',eo)
phi1=360*atan(2*tou*r/(1-r^2))/(2*%pi);
printf('phase angle corresponding to the 10 Hz frequency is %fd deg\n',phi1)
f2=20   //('enter the other frequency=:')
r=f2/fn;
eo=(v*S*r^2)/sqrt((1-r^2)^2+(2*tou*r)^2);
printf('The peak voltage corresponding to 20Hz frequency is %fd mV\n',eo)
phi2=360*atan(2*tou*r/(1-r^2))/(2*%pi);
printf('phase angle corresponding to the 20 Hz frequency is %fd deg\n',phi2)
```

Scilab code Exa 4.9 Piezoelectric transducer

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Piezoelectric transducer
// Example 9// Page 237
disp("Ccr=1200")
disp("Kq=100")
disp("Cc=250")
Ccr=1200  //('enter the capacitance of the transducer=:')
Kq=100  //('enter the charge sensitivity of the transducer=:')
Cc=250  //('enter the capacitance of the connecting cable=:')
```

```
//to calculate the sensitivity of transducer alone
Ktrans=Kq/Ccr;
printf('the sensitivity of the transducer alone is %fd V/micro m\n',Ktrans)
Camp=75  //('enter the capacitance of amplifier=:')
Ceq=Ccr+Cc+Camp
Ktot=Kq/Ceq;
printf('total sensitivity of the transducer is %fdV/micro m\n',Ktot)
Ramp=2*10^6  //('enter the resistance of the amplifier=:')
disp("tou=Ramp*Ceq*10^-12")
tou=Ramp*Ceq*10^-12;
e=5  //('enter the error in percent=:')
e1=1-(e/100);
// let tou*w1=l
l=sqrt(e1^2/(1-e1^2));
f1=l/(2*%pi*tou);
printf('The lowest frequency that can be measured with 5 per cent amplitude error by the entire system is %fd Hz\n',f1)
tou1=l/(2*%pi*100)
disp("Ceq1=tou1*10^12/Ramp")
Ceq1=tou1*10^12/Ramp
Creq=Ceq1-Ceq;
printf(' The capacitance that needs to be connected in parallel to extend the range of 5percent error to 100hz is %fd pF\n',Creq)
K_hf=Kq/Ceq1
printf('high frequency sensitivity is %fd V/micro m\n',K_hf)
```

Scilab code Exa 4.10 Seismic pick ups

```
//CHAPTER 4_ Motion and Dimensional Measurement
```

```
//Caption : Seismic pickup
// Example 10// Page 238
disp("r1=0.2;")
disp("r2=0.6 ")
disp("tou=0.05")
r1=0.2;
r2=0.6  // given
tou=0.05;   //given
wn=1600  //(' enter the natural frequency=:')
disp("H1=1/sqrt((1-r1^2)^2+(2*tou*r1)^2)")
H1=1/sqrt((1-r1^2)^2+(2*tou*r1)^2);
H1_phase=-atan((2*tou*r1)/(1-r1^2))*360/(2*%pi);
disp("H1_phase=-atan((2*tou*r1)/(1-r1^2))*360/(2*%pi)")
H2=1/sqrt((1-r2^2)^2+(2*tou*r2)^2);
H2_phase=-atan((2*tou*r2)/(1-r2^2))*360/(2*%pi);
//In order to obtain the amplitude of relative displacement , transfer function must be multiplied by amplitude of the input signal and the static sensitivty of the pickup (1/wn^2) for each frequency
//amp1=H1/wn^2;
//amp2=H2/wn^2;
tou2=0.6;  // given
H11=1/sqrt((1-r1^2)^2+(2*tou2*r1)^2);
H11_phase=-atan((2*tou2*r1)/(1-r1^2))*360/(2*%pi);
H22=1/sqrt((1-r2^2)^2+(2*tou2*r2)^2);
H22_phase=-atan((2*tou2*r2)/(1-r2^2))*360/(2*%pi);
//amp11=H11/wn^2;
//amp22=H22/wn^2;
printf('the magnitude of the transfer function will be %fd and %fd while the phases will shift by %fd and %fd for tou=0.05\n',H1,H2,H1_phase,H2_phase)
printf('the magnitude of the transfer function will be %fd and %fd while the phases will shift by %fd and %fd for tou=0.6\n',H11,H22,H11_phase,H22_phase)
```

Scilab code Exa 4.11 Accelerometers

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Accelerometer
// Example 11// Page 240
disp("fn=20000")
disp("tou=0.6")
disp("f=10000 ")
fn=20000  //('enter the natural frequency of the
    accelerometer =:')
tou=0.6  //('enter the daping ratio of the
    accelerometer=:')
f=10000   //('enter the frequency at which transfer
    function is to be calculated=:')
r=f/fn;
H_mag=1/sqrt((1-r^2)^2+(2*tou*r)^2);
H_phase=atan((2*tou*r)/(1-r^2))*360/(2*%pi);
printf(' The magnitude is %fd and phase is %fd deg\n
    ',H_mag,H_phase)
error=(H_mag-1)*100/1;
printf(' Error at %fd Hz is %d percent\n',f,error)
```

Scilab code Exa 4.12 Strain gage

```
//CHAPTER 4_ Motion and Dimensional Measurement
//Caption : Strain gage
// Example 12// Page 172
Rg=120;     // given
Sg=2  // gage factor is given
stress=7*10^6;   //given
Ia=.03   //('enter the gage current=:')
//maximum allowable bridge voltage is
```

```
Eex=240*Ia;
strain=7*10^6/(200*10^9);
dR=strain*Sg*Rg;
Eo=Eex*dR/(4*Rg);
printf('output voltage is %fd V\n',Eo)
k=1.38*10^-23;   //boltzmann constant
T=300    //room temperature
dF=100000// bandwidth
E_noise=sqrt(4*k*Rg*T*dF)
printf('rms noise voltage is %fd V\n',E_noise)
SN=Eo/E_noise;
printf('Signal to noise ratio is %fd\n',SN)
```

Chapter 5

Force Torque and Shaft power measurement

Scilab code Exa 5.1 Load cell

```
//CHAPTER 5_ Force ,Torque and Shaft Power
    Measurement
//Caption : Load cell
// Example 1// Page 294

disp("Sg=2;")
disp("Rg=120;")
disp("v=0.3")
disp("E=210*10^9;")
Sg=2;    // Strain gage factor
Rg=120;     // Gage resistance
v=0.3    // poissons ratio
E=210*10^9;     // for steel
Pd=1    //('enter the power dissipation capacity=:')
// Looking for a suitable voltage measuring system
sig_f=700*10^6    //('enter the fatigue strength=:')
P_max=10000    //('enter the maximum load=:')
// For a load cell of square cross-section d,
d=sqrt(P_max/sig_f);
```

```
Ei=sqrt(4*Rg*Pd)    //input excitation to the bridge circuit
x=(Sg*sig_f*(1+v))/(2*E);
dEo_max=x*Ei*10^3;
disp("x=(Sg*sig_f*(1+v))/(2*E)")
printf('a voltmeter with a maximum range of %1.2f mV is suitable for measurement',dEo_max)
disp("Round it off to get the suitable range voltmeter")
```

Scilab code Exa 5.2 Load cell

```
//CHAPTER 5_ Force,Torque and Shaft Power Measurement
//Caption : Load cell
// Example 2// Page 295
disp("b=.2")
disp("h=.05")
disp("Sg=2")
disp("Rg=120")
disp("sig_f=150*10^6")
b=.2    //('enter the width of load cell=:')
h=.05    //('enter the thickness of load cell=:')
Sg=2;
Rg=120;
sig_f=150*10^6    //('enter the fatigue strength=:')
E=70;        //(in GPa) for aluminium
v=0.33;              //poissons ratio
// Let dE/V_max be represented by W
W=Sg*sig_f/E;
printf('(dE/V)_max= %fd\n ',W)
P_max=100000    //('enter the value of maximum load=:')
l=sig_f*b*h^2/(6*P_max);

```

```
S=(6*Sg*l)/(E*b*h^2);
printf('Sensitivity of this load cell is %1.2f nV/N/ per unit excitation',S);
```

Scilab code Exa 5.3 Load cell

```
//CHAPTER 5_ Force,Torque and Shaft Power Measurement
//Caption : Load cell
// Example 3// Page 296
Sg=2;
v=0.3;     //poissons ratio
Ei=10   //('enter the excitation voltage=:')
A=5*10^-4  //('enter the area of load cell=:')
E=200;    //(in Gpa) Youngs modulus
// Let sensitivity Eo/P be represented by Se
Se=Sg*(1+v)*Ei/(2*A*E)*.001;
printf('Sensitivity of this load cell is %1.2f micro V/N\n',Se)
Rg=120   //given
Pd=1 //('enter the power dissipated in each gage=:')
Ei_max=sqrt(4*Rg*Pd)
Se_max=Sg*(1+v)*Ei_max/(2*A*E)*.001
printf('The maximum density that can be achieved without endangering the strain gage sensors is %1.2fmicro V/N\n',Se_max)
// Let (Eo/Ei)_max be represented by Em
sig_f=600*10^6  //('enter the fatigue strength=:')
Em=Sg*sig_f*(1+v)/(2*E)*10^-6
printf('The voltage ratio is %1.1f mV/V',Em)
```

Scilab code Exa 5.4 Piezoelectric transducer

```
//CHAPTER 5_ Force,Torque and Shaft Power
    Measurement
//Caption : Piezoelectric Transducers
// Example 4// Page 302
mc=0.04   //('enter the connector mass=:')
m=0.01   //('enter the seismic mass=:')
k=10^9   //('enter the stiffness of the sensing
    element=:')
Sf=.005   //('enter the sensitivity of the
    transducer=:')
Xi=100*10^-6 //  ('enter the displacement amplitude
    of the shaker vibration=:')
Eo=.1   //('enter the reading of voltage recorder
    connected to the transducer=:')
wnc=sqrt(k/(m+mc));
R=20;    //20N (rms)
Z=(1/(m+mc))*(1/wnc^2)*R;
printf('Relative displacement is %fd',Z)
disp("wnc^2 is approx. 10^9. So,")
disp("Z is approx. 20nm(rms)")
f=100;   // given

F=R-((2*%pi*f)^2*(m+mc)*Xi);
printf('Actual force transmitted to the plate is %fd
    N',F)
```

Scilab code Exa 5.5 Torque measurement on rotating shaft

```
//CHAPTER 5_ Force,Torque and Shaft Power
    Measurement
//Caption : Torque measurement on rotating shaft
// Example 5// Page 308
Sg=2;
Rg=120;
G=80*10^9   //('enter the sheer modulus of
```

```
    elasticity=:')
D=0.05    //('enter the shaft diameter=:')
dR=0.1    // given
// we have to find the load torque
y=2*dR/(Rg*Sg);
tou_xy=y*G;
j=%pi*D^4;
T=tou_xy*2*j/(D*32);
printf('The load torque is%fd N-m',T)
```

Chapter 6

Pressure and sound measurement

Scilab code Exa 6.1 manometers

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : MANOMETERS
// Example 1 // Page 329
D1=0.1   //('Enter the diameter of well =:')
D2=0.01    //('Enter the diameter of the tube =:')
g=9.81;
pho_air=1.23   //('Enter the density of air in kg/m^3 =:')
pho_liquid=1200  //('Enter the density of liquid in manometer =:')
h=1     //('Enter the height by which liquid decreases in smaller area arm when exposed to the nominal pressure of p2 =:')
// Let the pressure difference is represented by P=p1-p2
disp("The pressure difference is given by:")
disp("P=h*(1+((D2/D1)^2)*g*(pho_liquid-pho_air))")
P=h*(1+((D2/D1)^2)*g*(pho_liquid-pho_air))*10^-3;
printf('So the pressure difference is given by %1.2f
```

```
kPa \n',P)
```

Scilab code Exa 6.2 manometers

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : MANOMETERS
// Example 2 // Page 329
pho_l=900
disp("pho_l=900 ")   //('Enter the density of the
   fluid =:')
Pa= 500000
disp("Pa= 500000 ")  //('Enter the air pressure =:')
t=298
disp("t=298 ")    //('Air is at what temperature(in
   deg cent) =:')
R=287;
disp("R=287;")
g=9.81;
T=t+273;
disp("pho_a=Pa/(R*T);")
pho_a=Pa/(R*T);
printf('The density of air is %fd kg/m^3 \n',pho_a)
h=.2    //('Enter the difference in the height of
   the fluid in the manometer=:')
disp("Pres_diff=(g*h)*(pho_l-pho_a)")
Pres_diff=(g*h)*(pho_l-pho_a)*10^-3
printf('The differential pressure is %1.2f kPa\n',
   Pres_diff)
```

Scilab code Exa 6.3 elastic transducers

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : Elastic Transducers
```

```
// Example 3 // Page 337
Sa=1000
disp("Sa=1000")    //('Enter the sensitivity of LVDT=:')
//Properties of diaphragm
E=200*10^9   //('Enter the value of modulus of elasticity=:')
disp("E=200*10^9 ")
v=0.3  //('Enter the Poissons ratio=:')
disp("v=0.3 ")
d=0.2   //('Enter the diameter of diaphragm=:')
disp("d=0.2  ")
R=d*(1/2);
P_max=2*10^6  //('What is the maximum pressure?')
disp("P_max=2*10^6 ")
p=7800   //('What is the density of steel?')
disp("Thickness is given by:")
disp("t=(3*P_max*R^4*(1-v^4)/(4*E))^(1/4);")
t=(3*P_max*R^4*(1-v^4)/(4*E))^(1/4)
T=t*1000;
printf('Thickness is %1.1f mm\n',T)
//To calculate the lowest pressure in kPa which may be sensed by this instrument , resolution and the natural frequency of the diaphragm
y=.001   //('Enter  the l)east value of measurement=:')
p_min=(y*16*E*t^3)/(3*R^4*(1-v^2)*Sa)
printf('So the minimum pressure and resolution is %d Pa \n',p_min)
f=(10.21/R^2)*((E*t^2)/(12*(1-v^2)*p))^(1/2)
printf('The natural frequency of diaphragm is %fd Hz',f)
```

Scilab code Exa 6.4 design of pressure transducers

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : Design of Pressure Transducers
// Example 4 // Page 338
p_max=10*10^6    //('Enter the capacity of the transducer=:')
D=.05   //('Enter the diameter of diaphragm=:')
R=D/2;
v=0.3;   // poissons ratio
E=200*10^9;
// We know that
// y=3pR^4(1-v^2)/16t^3E
// if y<t/4, the non linearity is restricted to 0.3%
//So t is given by
t=(3*p_max*R^4*(1-v^2)/(4*E))^(1/4)
disp(t)
printf('thickness comes out to be %fd m\n',t);
Sr_max=(3*p_max*R^2)/(4*t^2)
printf('So the max radial stress is %fd Pa\n',Sr_max)
printf('The given fatigue strength is 500MPa\n' )
if Sr_max > 500*10^6 then
      disp("The diaphragm must be redesigned");
      t1=((3*p_max*R^2)/(4*500*10^6))^(1/2);
printf('The required thickness is %fd m\n',t1)

else
    disp("The design is OK");
end
// Let the voltage ratio be represented by Err
Err=(820*p_max*R^2*(1-v^2))/(E*(t1^2))
printf('The voltage ratio is %fd\n', Err)
// For maximum power dissipation
PT=1
RT=120
Ei=2*(PT*RT)^(1/2);
disp("Let the sensitivity of the transducer be represented by ss")
ss=(820*R^2*(1-v^2)*Ei)/(E*t1^2)
```

```
printf('sensitivity is %fd\n', ss)
// Part c
S_LVDT=(ss*16*t^3*E)/(3*R^4*(1-v^2)*Ei)
printf('SENSITIVITY OF LVDT IS %fd \n',S_LVDT)
```

Scilab code Exa 6.5 pressure gage

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : Pressure Gage
// Example 5 // Page 347
p_max=10*10^6     //('Enter the maximum differential pressure')
fn=20000   //(' Enter the frequency')
E=200*10^9;    // modulus of elasticity
v=0.3;    // poissons ratio
p=7800     // density of steel
disp("Let t/R be represented by TR ")
TR=((3*p_max*(1-v^2))/(4*E))^(1/4)
// we know R^2/t = r2t=10.21(Et^2/12(1-v^2)p)^0.5/R^2      using it , we have
r2t=(10.21*sqrt(E/(12*(1-v^2)*p)))/fn
R=TR*r2t;
printf('value of R is %fd m\n', R)

t=R*TR;
printf(' value of t is %fd m \n',t)

eo=8.85*10^-12
er=1.0006;
d=.001    //('Enter the distance between the plates of capacitor=:')
S=-(eo*er*%pi*R^2)/d^2;
// variation of capacitor distance with respect to pressure is given by
q=(3*R^4*(1-v^2))/(16*E*t^3)
```

```
// total sensitivity of the pressure transducer is
   given by
sensitivity=S*q*10^18;
printf(' So the total sensitivity of the pressure
   transducer is given by %1.2f pF/MPa\n',
   sensitivity)
```

Scilab code Exa 6.6 high pressure measurement

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : High Pressure Measurement
// Example 6 // Page 357
R1=100    //(' Enter the resistance of Mangnin wire
   =:')
disp("R1=100")
b=25*10^-12; // standard for mangnin
disp("b=25*10^-12;")
disp("u=0.5")
u=0.5     //(' enter the uncertainty in measuring
   pressure for gage=:')
// to calculate maximum uncertainty in differential
   pressure
udp=u*(10-0.1)*10^6/100;
uR=R1*b*udp;
printf('So the maximum uncertainty in measuring
   resistance is %fd ohm \n',uR)
//to calculate the output bridge voltage for 10 MPa
Ei=5    //('enter the input voltage=:')
disp("p1=0.1*10^6")
disp("R2=R1*(1+b*p1)")
disp("p2=10*10^6 ")
p1=0.1*10^6       //('enter the pressure at which
   bridge is assumed to be balanced=:')
R2=R1*(1+b*p1)
p2=10*10^6     //('enter the pressure at which output
```

```
voltage is to be calculated=:')
R3=R1*(1+b*p2);
dR=R3-R2;
r=1;
Eo=(r*dR*Ei)/((1+r)^2*R2)
printf(' The output bridge voltage is %fd volt\n',Eo)
```

Scilab code Exa 6.7 Mc Leod gage

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : McLeod Gage
// Example 7 // Page 362
disp("Vb=150*10^-6")
disp("d=1.5*10^-3")
disp("a=%pi*d^2/4;")
Vb=150*10^-6    //('enter the volume of the Mc Leod gage=:')
d=1.5*10^-3    //('enter the diameter of capillary=:')
a=%pi*d^2/4;
p=40*10^-6     //('enter the pressure for which the gage reading is to be noted=:')
//y=(-p*area_cap+sqrt((p*area_cap)^2-4*p*area_cap*Vb))/(2*area_cap);
l=p*a;

y=(sqrt(l^2+(4*l*Vb))-l)/(2*a)
printf('The gage reading comes out to be %fd mof Hg\n',y)
```

Scilab code Exa 6.8 Knudsen gage

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : Knudsen Gage
// Example 8 // Page 363
disp("Td=40")
disp("Tv=300")
disp("p=2*10^-6")
Td=40   //('enter the temperature difference=:')
Tv=300 //('enter the gas temperature at which the
    force has to be calculated=:')
p=2*10^-6    //('enter the pressure(in m of Hg)=:')
pa=p*13600*9.81;
k=4*10^-4;     // knudsen constant
F=(pa*Td)/(k*Tv);
printf('So the  required force is %1.1f N',F)
```

Scilab code Exa 6.9 sound measurement

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
//Caption : Sound Measurement
// Example 9// Page 369
disp("Lp=104")
Lp=104  //('enter the sound pressure level in
    decibles=:')
disp("pa=20*10^-6;")
disp("p=sqrt(10^(Lp/10)*pa^2);")
pa=20*10^-6;    // rms pressure threshold of hearing
p=sqrt(10^(Lp/10)*pa^2);
printf('root mean square sound pressure is %1.3fPa\n
    ',p)
```

Scilab code Exa 6.10 sound measurement

```
//CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
```

```
//Caption : Sound Measurement
// Example 10// Page 370
Lp1=75   //('enter the sound level first machine=:')
Lp2=77   //('enter the sound level second machine=:')
Lp3=79   //('enter the sound level third machine=:')
disp("Since the noise levels are incoherent,the total sound pressure is the sum of the mean square value of the individual sound pressures")
disp("Lp_total=10*log10(10^(Lp1/10)+10^(Lp2/10)+10^(Lp3/10))")
Lp_total=10*log10(10^(Lp1/10)+10^(Lp2/10)+10^(Lp3/10));
printf('The total sound pressure is %ddB',Lp_total)
//decibles are normally rounded off to the nearest integers
```

Chapter 7

Flow measurement

Scilab code Exa 7.1 Flow measurement

```
//CHAPTER 7_ Flow Measurement
//Caption : Flow Measurement
// Example 1// Page 406
t=293   //('Entering the temperature(in k) of pitot
   tube =:')
p1=0.1*10^6    //('entering the air pressure in
   pitot tube=:')
v=10     //('entering the velocity of air in pitot
   tube=:')
R=287;
disp("Density is given by:")
disp("pho1=p1/(R*t);")
pho1=p1/(R*t);
// dynamic pressure
Pd=pho1*v^2/2;
//we know that  v=sqrt(2Pd/pho)
// dv/dP=1/2(2/pho*Pd)^0.5
// Let the error or uncertainty in velocity is
   represented by Wv and in pressure by Wp
Wp=1   //('entering the uncertainty in the
   measurement of dynamic pressure=:')
```

```
disp("Uncertainty in velocity is given by ")
disp("Wv=(1/2)*(2/(pho1*Pd))^0.5*Wp;")
Wv=(1/2)*(2/(pho1*Pd))^0.5*Wp;
per_unc=Wv*100/10;
printf('So the percentage uncertainty in the measurement of velocity is %fd %% \n',per_unc)
```

Scilab code Exa 7.2 Anemometers

```
//CHAPTER 7_ Flow Measurement
//Caption : Anemometers
// Example 2// Page 426
// To derive an expression for velocity across a hot wire anemometer in terms of the wire resistance Rw, the current through the wire Iw and the empirical constants C0 and C1 and the fluid temperature.
disp("C0+C1(v)^.5)(Tw-Tf)=Iw^2Rw")
disp("Rw= Rr[1+a(Tw-Tr)]")
disp("Rw/Rr=1+a(Tw-Tr)")
disp("Tw-Tr=1/a[Rw/Rr-1]")
disp("Tw=1/a[Rw/Rr-1]+Tr")
disp("Co+C1(v)^0.5=Iw^2Rw/Tw-Tf")
disp("so,")
disp("v=1/C1[{Iw^2Rw/(1/a[Rw/Rr-1]+Tr-Tf)]}^2-C0")
```

Scilab code Exa 7.3 Gross volume flow rate

```
//CHAPTER 7_ Flow Measurement
//Caption : Gross volume flow rate(venturi)
// Example 3// Page 438
dp=0.02      //('entering the diameter of the line in which water is flowing=:')
```

```
dt=0.01     //('entering the diameter of venturi=:')
B=0.5;    // given
// The discharge coefficients remains in the flat portion of the curve for reynolds numbers 10^4 to 10^6 Cd=0.95
u=8.6*10^-4     //('entering the viscosity=:')
Cd=0.95;
Rn_min=10^4;
disp("Minimum flow rate is given by:")
disp("mdot_min=%pi*dp*u*Rn_min/4")
mdot_min=%pi*dp*u*Rn_min/4
g=9.81;
printf('Minimum flow rate at 25 deg cent is %1.3f kg/s\n',mdot_min)
pf=1000    // density of water
At=78.53*10^-6     //('entering the throat area=:')
pm=13.6       //('entering the density of manometer fluid=:')

//h is the height of mercury column due to flow
disp("To calculate the mercury reading corresponding to minimum flow, using-")
disp("h_min=((mdot_min*sqrt(1-B^4))/((sqrt(2*g*(pm-pf/pf))*pf*At*Cd)))^2;")
h_min=((mdot_min*sqrt(1-B^4))/((sqrt(2*g*(pm-pf/pf))*pf*At*Cd)))^2;
//in mm
H_min=h_min*1000
printf('So the pressure reading observed for the given flow ratre is %1.1f  mm of Hg\n',H_min)
h_max=.25     //('entering the  value of h maximum=:')
m_max=(pf*At*Cd*sqrt(2*g*(pm-pf/pf))*sqrt(h_max))/sqrt(1-B^4);
printf('The maximum flow rate is %1.1f kg/s\n',m_max)
```

Scilab code Exa 7.4 Gross volume flow rate

```
//CHAPTER 7_ Flow Measurement
//Caption : Gross volume flow rate(venturi)
// Example 4// Page 439
dt=0.15     //('entering the throat diameter=:')
dp=0.3      //('entering the upstream diameter=:')
Cd=0.95;
B=0.5;
pm=13600        //('entering the density of manometer
    fluid=:')
At=%pi*dt^2/4;
g=9.81;

pf=995.8
h=0.2       //('entering the height of mercury column
    due to flow (in m)=:')
q=pf*At*Cd;
w=(1-B^4)^(1/2);
e=sqrt(2*g*((pm/pf)-1));
mdot_25=q*e*sqrt(h)/w
disp("Mass flow is given by :")
disp("mdot=pf*At*Cd*(1/(1-B^4)^(1/2))*sqrt(2*g*((pm/
    pf)-1)*sqrt h)")
printf('So the mass flow at 25 deg cent   is %fd kg/
    s\n',mdot_25)



pf=999.8     //('entering density of water at 25 deg
    cent=:')
h=0.2     //('entering the height of mercury column
    due to flow (in m)=:')
q=pf*At*Cd;
```

```
w=(1-B^4)^(1/2);
e=sqrt(2*g*((pm/pf)-1));
mdot=q*e*sqrt(h)/w
// error is mdot(25 deg cent)-mdot(t deg cent)
printf(' The mass flow at 0 deg cent is %fd kg/s\n',
    mdot)
error1=abs(((mdot_25-mdot)/mdot_25)*100);



printf(' Change in temperature of water introduces
    insignificant error in mass flow measurement i.e.
    %1.2f%% \n',error1)
pf=988.8    //('entering density of water at 25 deg
    cent=:')
h=0.2    //('entering the height of mercury column
    due to flow (in m)=:')
q=pf*At*Cd;
w=(1-B^4)^(1/2);
e=sqrt(2*g*((pm/pf)-1));
mdot=q*e*sqrt(h)/w
// error is mdot(25 deg cent)-mdot(t deg cent)
printf('  The mass flow at 50 deg cent is %fd kg/s\n
    ',mdot)
error2=abs(((mdot_25-mdot)/mdot_25)*100);



printf('Therefore, change in temperature of water
    introduces insignificant error in mass flow
    measurement i.e. %1.2f%% \n',error2)
```

Scilab code Exa 7.5 Gross volume flow rate

```
//CHAPTER 7_ Flow Measurement
```

```
//Caption : Gross volume flow rate(venturi)
// Example 5// Page 440
dt=.1      //('entering the throat diameter=:')
dp=.2       //('entering the upstream diameter=:')
Cd=0.95;
g=9.81
B=0.5;
At=%pi*dt^2/4;
pf=780     //('entering density of oil in the
   pipeline =:')
pm=1000    //('entering the density of manometer
   fluid=:')
w=(1-B^4)^(1/2);
e=sqrt(2*g*((pm/pf)-1));
S_ideal=At*e/w;
printf('The ideal volume flow rate sensitivity is %1
   .4f (m^3/s/h^0.5)\n',S_ideal)
// part b
disp("Actual volume rate sensitivity is given by :")
disp("S_actual=S_ideal/Cd")
S_actual=S_ideal/Cd;
printf('The actual volume rate sensitivity is %1.4f
   \n',S_actual)
h=.3    //('entering the manometer reading of water
   height=:')
disp("Actual volume flow rate is given by:")
disp("Q_actual=S_actual*sqrt(h)")
Q_actual=S_actual*sqrt(h);
printf('The actual volume flow rate is %1.3f m^3/s\n
   ',Q_actual)
```

Scilab code Exa 7.6 sonic nozzle

```
//CHAPTER 7_ Flow Measurement
//Caption : Sonic nozzle
```

```
// Example 6// Page 443
disp("Let uncertainty in mass flow rate be represented by wm")
disp("Let uncertainty with pressure be represented by wp")
disp("Let uncertainty with temperature measurement be represented by wt")
// To calculate the uncertainty in the temperature measurement
wm_m=0.02    //('entering the uncertainty in mass flow=:')
wp_p=0.01    //('entering the uncertainty in pressure measurement=:')
disp("Uncertainty in temperature is given by:")
disp("wt_t=2*sqrt(wm_m^2-wp_p^2)*100")
wt_t=2*sqrt(wm_m^2-wp_p^2)*100
printf('uncertainty in the temperature measurement is %1.2f %%\n',wt_t)
```

Scilab code Exa 7.7 venturi

```
//CHAPTER 7_ Flow Measurement
//Caption : Venturi
// Example 7// Page 446
p1=5*10^6    //('entering the pressure of air when venturi is to be used =:')
t1=298    //('entering the temperature of air for the same=:')
m_max=1    //('entering the maximum flow rate=:')
m_min=0.3    //('entering the minimum flow rate=:')
Re_min=10^5    //('entering the throats reynold number=:')
R=287;    // for air
pho1=p1/(R*t1);
b=0.5;
```

```
mu=1.8462*10^-5    //('enter the absolute viscosity
    =:')
D_max=(4*m_max)/(%pi*Re_min*mu);
D_min=(4*m_min)/(%pi*Re_min*mu);
printf('So the throat diameters for maximum and
    minimum flows so the reynolds number does not
    exceed 10^5 are %1.4f m and %1.4f m respectively\
    n',D_max,D_min)
// To calculate the differential pressure
At=%pi*D_max^2/4;
C=1;     // discharge coefficient
M=1.0328;     // Velocity approach coefficient
Y=.9912;    // Expansion factor
dP_max=(m_max)^2/(Y^2*M^2*C^2*At^2*2*pho1);
printf('The differential pressure for maximum flow
    rate is %1.5f Pa\n',dP_max)
dP_min=(m_min)^2/(Y^2*M^2*C^2*At^2*2*pho1)*1000;
printf('The differential pressure for minimum flow
    rate is %1.2f mPa\n',dP_min)
```

Scilab code Exa 7.8 constant pressure drop

```
//CHAPTER 7_ Flow Measurement
//Caption : Constant-Pressure-Drop , Variable-Area
    Meters(Rotameters)
// Example 8// Page 455
Qd=.1/60    //('enter the maximum flow of water=:')
t=298   //('enter the temperature in k=:')
d=.03   //('enter the float diameter in m=:')
L=0.5   //('enter the total length of rotameter=:')
D=.03   //('enter the diameter of tube at inlet=:')
Vb=25*10^-6   //('enter the total volume of float=:')
Af=7.068*10^-4     // area of float
j=2*9.81*Vb/Af;
y=L;
```

```
disp("Tube taper is given by:")
disp("a=(Qd*2)/(%pi*D*y*j^(1/2))")
a=(Qd*2)/(%pi*D*y*j^(1/2));
printf('tube taper is %1.4f m/m(taper)\n',a)
```

Chapter 8

TEMPRATURE MEASUREMENT

Scilab code Exa 8.1 thermocouple

```
//CHAPTER 8 _ TEMPERATURE MEASUREMENT
//Caption : Thermocouple
// Example 1 // Page 500
t1 = 100    //('entering the temperature(in deg cent
    ) =:')
e1= 5       // ('entering the emf (in mv)at
    temperature t1 =:')
t2=445    //('entering the second temperature(in deg
     cent)= :')
e2=25    //('entering the emf(in mv) at temperature
    t2 =:')
// TO CALCULATE CONSTANTS a AND b
//e1=a*(t1)+b*(t1^2);
//e2=a*(t2)+b*(t2^2);
A=[t1 t1^2;t2 t2^2];

B=[e1 0 ;e2 0]
Y=lsq(A,B);    //computes the minimum norm least
    square solution of the equation A*Y=B,
```

```
disp(Y)

printf('value of constants a and b are %fd V/deg cent and %fd V/deg cent respectively',Y(1,1),Y(2,1))
//PART B
//Let e(0-40) be represented by E1 , e(40-t) by E2 and e(0-t) by E3

E1=(Y(1,1)*40)+(Y(2,1)*40^2);
disp(E1);
E2=2;     // given
E3=E1+E2;
D=sqrt((Y(1,1)^2)+(4*Y(2,1)*E3));
t=(-Y(1,1)+D)/(2*Y(2,1));
disp(t)
printf('Hot junction temperature is %1.1f deg cent ',t);
// PART C
// Let e(0-500) be represented by E4 and e(40-500) by E5
E4=Y(1,1)*500+Y(2,1)*500^2;
E5=E4-E1;
disp (E5)
printf('emf when the hot junction is at 500 and cold at 40 is %1.1f mV ',E5);
```

Scilab code Exa 8.2 thermocouple and thermopile

```
//CHAPTER 8 _ TEMPERATURE MEASUREMENT
//Caption : THERMOCOUPLE AND THERMOPILE
// Example 2 // Page 511
h=(100/5)*10^-3     // in mv
printf('emf per thermocouple is %1.2f mV \n', h);
// e(0-100)+e(100-t)=e(0-t)
```

```
// Let e(0-100) = E1 and e(100-t)= E2
E1= 5.27 // given
E2=h;
E3=E1+E2;
E4=5.325;   // given emf at 101 deg cent
c=100 ;   // given that cold junction is at 100 deg
    cent
// BT EXTRAPOLATION
t=c+((E3-E1)/(E4-E1));
printf('Required temperature difference is %1.2f deg
    cent ' ,t)
```

Scilab code Exa 8.3 electrical resistance sensors

```
//CHAPTER 8 _ TEMPERATURE MEASUREMENT
//Caption : ELECTRICAL- RESISTANCE SENSORS
// Example 3 // Page 517
s =0.2      //('enter the sensitivity =:')
d=0.4*10^-3
A=%pi*(d^2)/4;
// R=pho *l/A
R=100
pho=0.8*10^-3;
l=(R*A)/pho;

printf('Length corresponding to resistance 100 ohm
    and diameter 0.4mm is %fd m\n',l)
d=2*10^-3
A=%pi*(d^2)/4;
R=100
pho=0.8*10^-3;
l=(R*A)/pho;
printf('Length corresponding to resistance 100 ohm
    and diameter 2mm is %1.2f m\n',l)
// The above lengths of wire indicate that their
```

```
    diameters should be very small so reasonable lengths can be used in practical applications .
// Let resistance at 50deg cent be R1 and at 100 deg cent be R2
t=-50        //('Enter the temperture at which resistance has to be calculated = :')
R1= R+s*(t-20);
printf('Resistance at temperature %d is %f ohm \n',t,R1)
t2=100       //('Enter the temperture at which resistance has to be calculated = :')
R2= R+s*(t2-20);
printf('Resistance at temperature %d is %f ohm\n ',t2,R2)
```

Scilab code Exa 8.4 thermistors

```
//CHAPTER 8 _ TEMPERATURE MEASUREMENT
//Caption : THERMISTOR
// Example 4 // Page 521
To= 293      //('Enter the temperature in K=:')
Ro=1000      //('Entering the corresponding resistance in ohm=:')
B=3450        // (' Entering the val)ue of constant =:')
Rt=2500       //(' Entering the resistance at which temperature has to be calculated=:')
T=1/((1/To)+(1/B)*log(Rt/Ro));
disp("Temperature is given by:")
disp("T=1/((1/To)+(1/B)*log(Rt/Ro));")
printf('The temperature corresponding to resistance of %d ohm is %1.3f K \n ',Rt,T)
Wrt=5    //('Entering the error in Rt resistance measurement=:' )
Wro=2    //('Entering the error in Ro temperature
```

```
measurement=:')
// Let dT/dRt be represented by DRt and dT/dRo by DRo
DRt=-T^2/(B*Rt) ;
DRo=-T^2/(B*Ro);
disp ("Error in temperature measurement is given by:")
disp("Wt=sqrt((DRt*Wrt)^2+(DRo*Wro)^2);")
Wt=sqrt((DRt*Wrt)^2+(DRo*Wro)^2);
printf('Error in the required temperature measurement is %1.4f K \n',Wt)
printf('So the required temperature is %d+_%1.4f K \n',T,Wt)
```

Scilab code Exa 8.5 pyrometers

```
//CHAPTER 8 _ TEMPERATURE MEASUREMENT
//Caption : PYROMETERS
// Example 5// Page 545

//(i)Optical Pyrometer
// Ta(K) is the actual temperature and Ti(K) is the indicated temperature
TI=1200    //('Enter the indicated temperature in degree centigrade=:')
Ti=TI+273
disp("Ti=TI+273")
lamda=0.7*10^-6    //('Entering the wavelength(in meters) at which intensities are compared')
epsilon=0.6        //('Entering the emissivity of the body')
C2=0.014387      //('Entering the value of constant')
disp("Actual temperature is given by :")
disp("Ta=(Ti*C2)/(C2-lamda*Ti*log(epsilon));")
Ta=(Ti*C2)/(C2-lamda*Ti*log(epsilon));
```

```
ta=Ta-273;
printf('Actual temperature of the body is %d \n',ta)
//(ii) For radiation pyrometer
T=(epsilon*Ta^4)^(1/4);
ti=T-273;
printf('Indicated temperature in degree celsius of the total radiation pyrometer is %d degree cent \n',ti)
//To calculate error
Error1=Ta-Ti;
printf('Error using Optical Pyrometer is %d K \n',Error1)
Error2=Ta-T;
printf('Error using Radiation Pyrometer is %d K \n',Error2)
```