

Scilab Textbook Companion for
Measurement Systems
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Book Description

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

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

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

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

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Chapter 2

Generalized Configurations and Functional Descriptions of measuring instruments

Scilab code Exa 2.1 Error in measurement

```
1 // Chapter 2_Generalized Configurations and
   // Functional Descriptions of measuring instruments
2 //Caption_Error in measurement
3 //Ex_1 part_2 //page 22
4 disp(" ts=0.1")
5 disp(" ps=2.5")
6 disp(" dT=20")
7
8 ts=0.1 //('enter the temperature sensitivity=:')
9 ps=2.5 //('enter the pressure sensitivity(in units
   //MPa)=:')
10 dT=20 //('enter the temperature change during
   //pressure measurement=:')
11 P=120 //('enter the pressure to be measured (in
   //MPa)=:')
12 error=(ts*dT)/(ps*P);
13 printf('the error in measurement is %fd percent\n',
```

error)

Chapter 3

Generalized Performance Characteristics Of Instruments

Scilab code Exa 3.1 Gaussian distribution

```
1 //Chapter_3 Generalized Performance Characteristics
  Of Instruments
2 //Caption:Gaussian Distribution
3 // Example 1
4 clc;
5 close;
6 disp("me=7")
7 disp("stddev=0.5")
8 disp("x = 6 ")
9 disp("y= 7.5")
10 me=7 ;
11 stddev=0.5;
12 x = 6 //('enter the lower limit of the range=:')
13 y= 7.5 //('enter the upper limit of the range=:')
14 n= 200 //('enter the number of samples=:')
15 disp("using k =abs((x-me)/((2^0.5)*stddev));")
16 k =abs((x-me)/((2^0.5)*stddev));
17 printf('Value of eta1 is %1.2f \n',k)
18
```

```

19 p=abs((y-me)/((2^0.5)*stddev));
20 printf('Value of eta2 is %1.2f \n',p)
21 //Using the gaussian probability error function
    table, find the error function corresponding to
    the value of k and p
22 //LET IT BE s
23 s= 0.95 // ('enter the error function corresponding
    to k value=:')
24 F(x)=(1/2)+(1/2*s);// Probability of having lengths
    less than x
25 l= 0.68 // ('enter the error function
    corresponding to p value=:')
26 F(y)=(1/2)+(1/2*l);// Probability of having lengths
    less than y
27
28 printf('probability of having length less than 6 cm
    is %1.3f ',F(x));
29 printf('probability of having length less than 67.5
    cm is %1.3f ',F(y));
30
31 P(x)=abs(F(y)-F(x));
32 printf("Number of samples in the given length range=
    ")
33 m=(n*P(x));
34 disp(m);

```

Scilab code Exa 3.2 Combination of component errors in overall system

```

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

```

```

        rotating sheft
6  disp("R=1202 ")
7  disp("F=45")
8  disp("L=0.397 ")
9  disp("t=60")
10 R=1202  //('Enter the revolutions of shaft during
        time t=:')
11 F=45   //('Enter the force at end of torque arm=:')
12 L=0.397 //('Enter the length of torque arm=:')
13 t=60   //('Enter the time length of run=:')
14 W=(2*%pi*R*F*L)/t;
15 //Computing various partial dervatives
16 dWF=(2*%pi*R*L)/t;
17 disp(dWF) //dWF represents dW/dF
18 dWR=(2*%pi*F*L)/t;
19 dWL=(2*%pi*F*R)/t;
20 dWt=-(2*%pi*R*F*L)/(t^2);
21 //Let f, r, l and t represent the uncertainties
22 disp("f=0.18")
23 disp("r=1 ")
24 disp("l=0.00127 ")
25 disp("t=0.5")
26 disp("Ea=(dWF*f)+(dWR*r)+(dWL*l)+abs(dWt*t); ")
27 f=0.18 //('Enter the uncertainty in force=:')
28 r=1    //('Enter the uncertainty in the no of
        revolutions=:')
29 l=0.00127 //('Enter the uncertainty in the length
        =:')
30 t=0.5   //('Enter the uncertainty in the time length
        of run=:')
31 Ea=(dWF*f)+(dWR*r)+(dWL*l)+abs(dWt*t); //
        absolute error
32 printf("The absolute error is ")
33 disp(Ea);
34 //To find total uncertainty
35 U=(((dWF*f)^2)+(dWR*r)^2+(dWL*l)^2+abs(dWt*t)^2)^0.5
36 printf("Total uncertainty is ")
37 disp(U)

```

Scilab code Exa 3.5 First order instrument

```
1 // Chapter_3 Generalized Performance Characteristics
  Of Instruments
2 //Caption:First order instrument
3 //Example 5
4 //Page no. 96
5 d=.004 //('Enter the diameter of the diameter of
  the sphere in meters=:')
6 p=13600 //('Enter the density of the liquid in
  glass bulb=:')
7 c=150 //('Enter the specific heat of liquid(in j/
  kg degree centigrade)=:')
8 U=40 //('Enter the heat transfer coefficient in W/m
  ^2-degree centigrade=:')
9
10 Vb=(%pi*d*d*d)/6; //Volume of sphere
11 Ab=%pi*d*d; //Surface area of sphere
12 timconstant=(p*c*Vb*1000)/(U*Ab); //time constant
13 disp(timconstant)
```

Scilab code Exa 3.6 Step response of first order instrument

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

```

7 //          In air , probe wet          tc
      =20s
8 // for t<0,T=25 degree C(initial temperature)
9 //      0<t<7, T=35 degree C(dry probe in air)
10 //     7<t<15, T=70 degree C(probe in water)
11 //     15<t<30, T=35 degree C(wet probe in air)
12
13 //case i T(a)=25
14 T(7)=35+(25-35)*%e^(-(7/30))
15 printf("Temperature at the end of first interval")
16 disp(T(7));
17 //case ii T(a)=T(7)
18 T(15)=70+(T(7)-70)*%e^-(((15-7)/5))
19 printf("Temperature at the end of second interval")
20 disp(T(15));
21 //case iii T(a)=T(15)
22 T(30)=35+(T(15)-35)*%e^-(((30-15)/20))
23 printf("Temperature at the end of third interval")
24 disp(T(30));

```

Scilab code Exa 3.7 Adequate frequency response conditions for first o

```

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

```

```

12 disp(H);
13 disp(phi)
14 printf("sinusoidal transfer function at 20rad/sec is
    ")
15 disp(H2)
16 disp(phi2)
17
18 printf("qo/K can be written as")
19
20 printf("          qo=0.93K sin(2t-21.8)+(0.24K) 0.3 sin
    (20t-76)")
21 //Suppose we consider use of an instrument with
    timeconstant=0.002s
22 H=1/((1.6*(10)^(-5)+1)^0.5);
23 phi=((atan(-2*.002))*180)/%pi ;
24 H2=1/((1.6*(10^-3)+1)^0.5);
25 phi2=((atan(-20*0.002))*180)/%pi;
26 printf("sinusoidal transfer function at 2 rad/sec is
    ")
27 disp(H);
28 disp(phi)
29 printf("sinusoidal transfer function at 20rad/sec is
    ")
30 disp(H2)
31 disp(phi2)
32 printf("qo/K can be written as")
33
34 printf("          qo=K sin(2t-0.23)+K 0.3 sin(20t-2.3)")
35 printf("Clearly, this instrument measures the given
    qi faithfully")

```

Chapter 4

Motion and Dimensional Measurement

Scilab code Exa 4.1 Resistance strain gage

```
1 //CHAPTER 4_ Motion and Dimensional Measurement
2 //Caption : Resistance strain gage
3 // Example 1// Page 163
4
5 disp("Rg=120")
6 disp("E=200 *10^9")
7 disp("dL=3 ")
8 disp("dp=0.3")
9 disp("v=0.3 ")
10 Rg=120 //('enter the resistance of strain gage=:')
11 E=200 *10^9 // given
12 dL=3 //('enter the percent change in the length of
    nthe rod due to loading=:')
13 dp=0.3 //('enter the corresponding change in the
    resistivity of strain gage=:')
14 v=0.3 // poissons ratio
15 e=dL/100;
16 dp_p=dp/100
17 disp("dR_R=dp_p+e*(1+2*v)")
```

```

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

```

Scilab code Exa 4.2 Rosette

```

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

```



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

Scilab code Exa 4.3 Strain gage

```
1 //CHAPTER 4_ Motion and Dimensional Measurement
2 //Caption : Strain gauge
3 // Example 3// Page 176
4 disp("Rg=120")
5 disp("Sg=2;")
6 disp("Rs=120000")
7 Rg=120; // given
8 Sg=2; // gauge factor
9 v=0.3;
10 Rs=120000 //('enter the value of shunt resistor
    =:')
11 disp("The input bridge excitation is represented by
    Eex")
12 A=10; //('enter the amplifier gain=:')
13 // The shunt resistance has to be very large since
    we intend to measure only very small change in
    resistance
14 eo=30*10^-3 //('enter the unbalanced bridge
    voltage=:')
15 dR=Rg/(Rg+Rs);
16 r=1;//ratio of resistances of adjacent arms
17 Eex=eo*(1+r)^2/(r*dR*A);
18 printf('The input excitation voltage is %fd V\n',Eex
    )
19 p1=2 *(1+v) // bridge factor
20 Eo=.5 //('enter the voltmeter reading when shunt
    is removed=:')
21 E_axial=Eo*(1+r)^2/(r*Sg*p1*Eex*A);
22 printf(' Axial strain is %fd\n ',E_axial)
23 E_trans=E_axial*v;
24 printf('The transverse strain is -%fd',E_trans)
```

Scilab code Exa 4.4 Capacitance pick ups

```
1 //CHAPTER 4_ Motion and Dimensional Measurement
2 //Caption : Capacitance pick ups
3 // Example 4// Page 192
4 disp("h=.005")
5 disp("A=200*10^-6")
6 disp("n=0.03")
7 h=.005 //('enter the distance between the
          capacitors=:')
8 A=200*10^-6 //('enter the area of the transducer
               =:')
9 n=0.03 //('enter the non linearity=:')
10 w=.014 //('enter the side of the square capacitor
            =:')
11 er=1 // given that air if filled
12 eo=8.85 ;
13 // to calculate the sensitivity of this transducer ,
    let it be represented by c
14 c=eo*er*A/h^2;
15 printf('sensitivity of the transducer is %1.2f pF/m
          \n',c)
16 // to calculate the sensitivity of the square moving
    plate sensor c1
17 c1=eo*er*w/h;
18 printf('the sensitivity of the square moving plate
          sensor is %1.2f pF/m ',c1)
```

Scilab code Exa 4.5 Piezoelectric transducer

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

```

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

```

Scilab code Exa 4.7 Seismic vibrations

```

1 //CHAPTER 4_ Motion and Dimensional Measurement
2 //Caption : Seismic vibration
3 // Example 7// Page 232
4 disp(" ty=0.6")

```

```

5 disp("fn=10")
6 disp("f=25")
7 disp("M=0.15")
8 disp("xo=1.5*10^-3")
9 ty=0.6 //(' enter the damping ratio of seismic
          vibration pickup=:')
10 fn=10 //('enter the natural frequency =:')
11 f=25 //('enter the frequency at which the table is
          vibrating=')
12 M=0.15 //(' enter the seismic mass=:')
13 xo=1.5*10^-3 //('enter the relative amplitude of
          the mass=:')
14 r=f/fn;
15 disp("xi=xo/(((r^2)/sqrt((1-r^2)^2+(2*ty*r)^2));)")
16 xi=xo/((r^2)/sqrt((1-r^2)^2+(2*ty*r)^2));
17 error=(xi-xo)/xo;
18 printf('error in measurement is %fd\n',error)
19 wn=2*pi*fn;
20 Ks=wn^2*M;
21 printf('spring constant is %fd N/m\n',Ks)
22 B=ty*(2*sqrt(Ks*M));
23 printf(' damping coefficient of pickup is %fdN-s/m\n
          ',B)

```

Scilab code Exa 4.8 Seismic velocity pick ups

```

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

```

```

10 m=0.2 //('enter the mass =:')
11 v=1.5*10^-2 //('enter the maximum velocity with
    which the surface is vibrating=:')
12 f=10 //('enter the frequency=:')
13 r=f/fn;
14 tou=0.2 // given
15 w=2*%pi*f;
16 eo=(v*S*r^2)/sqrt((1-r^2)^2+(2*tou*r)^2);
17 printf('The peak voltage corresponding to 10Hz
    frequency is %fd mV\n',eo)
18 phi1=360*atan(2*tou*r/(1-r^2))/(2*%pi);
19 printf('phase angle corresponding to the 10 Hz
    frequency is %fd deg\n',phi1)
20 f2=20 //('enter the other frequency=:')
21 r=f2/fn;
22 eo=(v*S*r^2)/sqrt((1-r^2)^2+(2*tou*r)^2);
23 printf('The peak voltage corresponding to 20Hz
    frequency is %fd mV\n',eo)
24 phi2=360*atan(2*tou*r/(1-r^2))/(2*%pi);
25 printf('phase angle corresponding to the 20 Hz
    frequency is %fd deg\n',phi2)

```

Scilab code Exa 4.9 Piezoelectric transducer

```

1 //CHAPTER 4_ Motion and Dimensional Measurement
2 //Caption : Piezoelectric transducer
3 // Example 9// Page 237
4 disp(" Ccr=1200")
5 disp(" Kq=100")
6 disp(" Cc=250")
7 Ccr=1200 //('enter the capacitance of the
    transducer=:')
8 Kq=100 //('enter the charge sensitivity of the
    transducer=:')
9 Cc=250 //('enter the capacitance of the connecting

```

```

        cable=:')
10 //to calculate the sensitivity of transducer alone
11 Ktrans=Kq/Ccr;
12 printf('the sensitivity of the transducer alone is
        %fd V/micro m\n',Ktrans)
13 Camp=75 //('enter the capacitance of amplifier=:')
14 Ceq=Ccr+Cc+Camp
15 Ktot=Kq/Ceq;
16 printf('total sensitivity of the transducer is %fdV/
        micro m\n',Ktot)
17 Ramp=2*10^6 //('enter the resistance of the
        amplifier=:')
18 disp("tou=Ramp*Ceq*10^-12")
19 tou=Ramp*Ceq*10^-12;
20 e=5 //('enter the error in percent=:')
21 e1=1-(e/100);
22 // let tou*wl=1
23 l=sqrt(e1^2/(1-e1^2));
24 f1=1/(2*%pi*tou);
25 printf('The lowest frequency that can be measured
        with 5 per cent amplitude error by the entire
        system is %fd Hz\n',f1)
26 tou1=1/(2*%pi*100)
27 disp("Ceq1=tou1*10^12/Ramp")
28 Ceq1=tou1*10^12/Ramp
29 Creq=Ceq1-Ceq;
30 printf(' The capacitance that needs to be connected
        in parallel to extend the range of 5percent error
        to 100hz is %fd pF\n',Creq)
31 K_hf=Kq/Ceq1
32 printf('high frequency sensitivity is %fd V/micro m\
        n',K_hf)

```

Scilab code Exa 4.10 Seismic pick ups

```

1 //CHAPTER 4_ Motion and Dimensional Measurement
2 //Caption : Seismic pickup
3 // Example 10// Page 238
4 disp(" r1=0.2;")
5 disp(" r2=0.6 ")
6 disp(" tou=0.05")
7 r1=0.2;
8 r2=0.6 // given
9 tou=0.05; //given
10 wn=1600 //(' enter the natural frequency=:')
11 disp("H1=1/sqrt((1-r1^2)^2+(2*tou*r1)^2)")
12 H1=1/sqrt((1-r1^2)^2+(2*tou*r1)^2);
13 H1_phase=-atan((2*tou*r1)/(1-r1^2))*360/(2*pi);
14 disp(" H1_phase=-atan((2*tou*r1)/(1-r1^2))*360/(2*pi
    )")
15 H2=1/sqrt((1-r2^2)^2+(2*tou*r2)^2);
16 H2_phase=-atan((2*tou*r2)/(1-r2^2))*360/(2*pi);
17 //In order to obtain the amplitude of relative
    displacement, transfer function must be
    multiplied by amplitude of the input signal and
    the static sensitivity of the pickup (1/wn^2) for
    each frequency
18 //amp1=H1/wn^2;
19 //amp2=H2/wn^2;
20 tou2=0.6; // given
21 H11=1/sqrt((1-r1^2)^2+(2*tou2*r1)^2);
22 H11_phase=-atan((2*tou2*r1)/(1-r1^2))*360/(2*pi);
23 H22=1/sqrt((1-r2^2)^2+(2*tou2*r2)^2);
24 H22_phase=-atan((2*tou2*r2)/(1-r2^2))*360/(2*pi);
25 //amp11=H11/wn^2;
26 //amp22=H22/wn^2;
27 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)
28 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

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

Scilab code Exa 4.12 Strain gage

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



```
8 //maximum allowable bridge voltage is
9 Eex=240*Ia;
10 strain=7*10^6/(200*10^9);
11 dR=strain*Sg*Rg;
12 Eo=Eex*dR/(4*Rg);
13 printf('output voltage is %fd V\n',Eo)
14 k=1.38*10^-23; //boltzmann constant
15 T=300 //room temperature
16 dF=100000// bandwidth
17 E_noise=sqrt(4*k*Rg*T*dF)
18 printf('rms noise voltage is %fd V\n',E_noise)
19 SN=Eo/E_noise;
20 printf('Signal to noise ratio is %fd\n',SN)
```

Chapter 5

Force Torque and Shaft power measurement

Scilab code Exa 5.1 Load cell

```
1 //CHAPTER 5_ Force ,Torque and Shaft Power
  Measurement
2 //Caption : Load cell
3 // Example 1// Page 294
4
5 disp("Sg=2;")
6 disp("Rg=120;")
7 disp("v=0.3")
8 disp("E=210*10^9;")
9 Sg=2; // Strain gage factor
10 Rg=120; // Gage resistance
11 v=0.3 // poissons ratio
12 E=210*10^9; // for steel
13 Pd=1 //('enter the power dissipation capacity=:')
14 // Looking for a suitable voltage measuring system
15 sig_f=700*10^6 //('enter the fatigue strength=:')
16 P_max=10000 //('enter the maximum load=:')
17 // For a load cell of square cross-section d,
18 d=sqrt(P_max/sig_f);
```

```

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

```

Scilab code Exa 5.2 Load cell

```

1 //CHAPTER 5_ Force ,Torque and Shaft Power
    Measurement
2 //Caption : Load cell
3 // Example 2// Page 295
4 disp("b=.2")
5 disp("h=.05")
6 disp("Sg=2")
7 disp("Rg=120")
8 disp(" sig_f=150*10^6")
9 b=.2    //('enter the width of load cell=:')
10 h=.05  //('enter the thickness of load cell=:')
11 Sg=2;
12 Rg=120;
13 sig_f=150*10^6    //('enter the fatigue strength=:')
14 E=70;            //(in GPa) for aluminium
15 v=0.33;         //poissons ratio
16 // Let dE/V_max be represented by W
17 W=Sg*sig_f/E;
18 printf('(dE/V)_max= %fd\n ',W)
19 P_max=100000    //('enter the value of maximum load
    =:')
20 l=sig_f*b*h^2/(6*P_max);
21

```

```

22 S=(6*Sg*1)/(E*b*h^2);
23 printf('Sensitivity of this load cell is %1.2f nV/N/
    per unit excitation ',S);

```

Scilab code Exa 5.3 Load cell

```

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

```

Scilab code Exa 5.4 Piezoelectric transducer

```

1 //CHAPTER 5_ Force ,Torque and Shaft Power
  Measurement
2 //Caption : Piezoelectric Transducers
3 // Example 4// Page 302
4 mc=0.04 //('enter the connector mass=:')
5 m=0.01 //('enter the seismic mass=:')
6 k=10^9 //('enter the stiffness of the sensing
  element=:')
7 Sf=.005 //('enter the sensitivity of the
  transducer=:')
8 Xi=100*10^-6 // ('enter the displacement amplitude
  of the shaker vibration=:')
9 Eo=.1 //('enter the reading of voltage recorder
  connected to the transducer=:')
10 wnc=sqrt(k/(m+mc));
11 R=20; //20N (rms)
12 Z=(1/(m+mc))*(1/wnc^2)*R;
13 printf('Relative displacement is %fd',Z)
14 disp("wnc^2 is approx. 10^9. So,")
15 disp("Z is approx. 20nm(rms)")
16 f=100; // given
17
18 F=R-((2*%pi*f)^2*(m+mc)*Xi);
19 printf('Actual force transmitted to the plate is %fd
  N',F)

```

Scilab code Exa 5.5 Torque measurement on rotating shaft

```

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

```

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

Chapter 6

Pressure and sound measurement

Scilab code Exa 6.1 manometers

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

kPa \n',P)

Scilab code Exa 6.2 manometers

```
1 //CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
2 //Caption : MANOMETERS
3 // Example 2 // Page 329
4 rho_l=900
5 disp("rho_l=900 ") //('Enter the density of the
    fluid =:')
6 Pa= 500000
7 disp("Pa= 500000 ") //('Enter the air pressure =:')
8 t=298
9 disp("t=298 ") //('Air is at what temperature(in
    deg cent) =:')
10 R=287;
11 disp("R=287;")
12 g=9.81;
13 T=t+273;
14 disp("rho_a=Pa/(R*T);")
15 rho_a=Pa/(R*T);
16 printf('The density of air is %fd kg/m^3 \n',rho_a)
17 h=.2 //('Enter the difference in the height of
    the fluid in the manometer=:')
18 disp("Pres_diff=(g*h)*(rho_l-rho_a)")
19 Pres_diff=(g*h)*(rho_l-rho_a)*10^-3
20 printf('The differential pressure is %1.2f kPa\n',
    Pres_diff)
```

Scilab code Exa 6.3 elastic transducers

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



```

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

```

Scilab code Exa 6.4 design of pressure transducers

```

1 //CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
2 //Caption : Design of Pressure Transducers
3 // Example 4 // Page 338
4 p_max=10*10^6 //('Enter the capacity of the
   transducer=:')
5 D=.05 //('Enter the diameter of diaphragm=:')
6 R=D/2;
7 v=0.3; // poissons ratio
8 E=200*10^9;
9 // We know that
10 //  $y=3pR^4(1-v^2)/16t^3E$ 
11 // if  $y<t/4$ , the non linearity is restricted to 0.3%
12 //So t is given by
13  $t=(3*p_max*R^4*(1-v^2)/(4*E))^(1/4)$ 
14 disp(t)
15 printf('thickness comes out to be %fd m\n',t);
16 Sr_max=(3*p_max*R^2)/(4*t^2)
17 printf('So the max radial stress is %fd Pa\n',Sr_max
   )
18 printf('The given fatigue strength is 500MPa\n' )
19 if Sr_max > 500*10^6 then
20     disp("The diaphragm must be redesigned");
21      $t1=((3*p_max*R^2)/(4*500*10^6))^(1/2)$ ;
22 printf('The required thickness is %fd m\n',t1)
23
24 else
25     disp("The design is OK");
26 end
27 // Let the voltage ratio be represented by Err
28  $Err=(820*p_max*R^2*(1-v^2))/(E*(t1^2))$ 
29 printf('The voltage ratio is %fd\n', Err)
30 // For maximum power dissipation
31 PT=1
32 RT=120
33  $Ei=2*(PT*RT)^(1/2)$ ;
34 disp("Let the sensitivity of the transducer be
   represented by ss")
35  $ss=(820*R^2*(1-v^2)*Ei)/(E*t1^2)$ 

```

```

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

```

Scilab code Exa 6.5 pressure gage

```

1 //CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
2 //Caption : Pressure Gage
3 // Example 5 // Page 347
4 p_max=10*10^6 //('Enter the maximum differential
   pressure ')
5 fn=20000 //(' Enter the frequency ')
6 E=200*10^9; // modulus of elasticity
7 v=0.3; // poissons ratio
8 p=7800 // density of steel
9 disp("Let t/R be represented by TR ")
10 TR=((3*p_max*(1-v^2))/(4*E))^(1/4)
11 // we know R^2/t = r2t=10.21(Et^2/12(1-v^2)p)^0.5/R
   ^2 using it , we have
12 r2t=(10.21*sqrt(E/(12*(1-v^2)*p)))/fn
13 R=TR*r2t;
14 printf('value of R is %fd m\n', R)
15
16 t=R*TR;
17 printf(' value of t is %fd m \n',t)
18
19 eo=8.85*10^-12
20 er=1.0006;
21 d=.001 //('Enter the distance between the plates
   of capacitor=')
22 S=-(eo*er*pi*R^2)/d^2;
23 // variation of capacitor distance with respect to
   pressure is given by
24 q=(3*R^4*(1-v^2))/(16*E*t^3)

```

```

25 // total sensitivity of the pressure transducer is
    given by
26 sensitivity=S*q*10^18;
27 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

```

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

```

```

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

```

Scilab code Exa 6.7 Mc Leod gage

```

1 //CHAPTER 6 _ PRESSURE AND SOUND MEASUREMENT
2 //Caption : McLeod Gage
3 // Example 7 // Page 362
4 disp("Vb=150*10^-6")
5 disp("d=1.5*10^-3")
6 disp("a=%pi*d^2/4;")
7 Vb=150*10^-6 //('enter the volume of the Mc Leod
    gage=:')
8 d=1.5*10^-3 //('enter the diameter of capillary
    =:')
9 a=%pi*d^2/4;
10 p=40*10^-6 //('enter the pressure for which the
    gage reading is to be noted=:')
11 //y=(-p*area_cap+sqrt((p*area_cap)^2-4*p*area_cap*Vb
    ))/(2*area_cap);
12 l=p*a;
13
14 y=(sqrt(1^2+(4*l*Vb))-1)/(2*a)
15 printf('The gage reading comes out to be %fd mof Hg\
    n',y)

```

Scilab code Exa 6.8 Knudsen gage

```

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

```

Scilab code Exa 6.9 sound measurement

```

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

```

Scilab code Exa 6.10 sound measurement

```

1 //CHAPTER 6 - PRESSURE AND SOUND MEASUREMENT

```

```

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

```

Chapter 7

Flow measurement

Scilab code Exa 7.1 Flow measurement

```
1 //CHAPTER 7_ Flow Measurement
2 //Caption : Flow Measurement
3 // Example 1// Page 406
4 t=293 //('Entering the temperature(in k) of pitot
   tube =:')
5 p1=0.1*10^6 //('entering the air pressure in
   pitot tube=:')
6 v=10 //('entering the velocity of air in pitot
   tube=:')
7 R=287;
8 disp("Density is given by:")
9 disp("rho1=p1/(R*t);")
10 rho1=p1/(R*t);
11 // dynamic pressure
12 Pd=rho1*v^2/2;
13 //we know that v=sqrt(2Pd/rho)
14 // dv/dP=1/2(2/rho*Pd)^0.5
15 // Let the error or uncertainty in velocity is
   represented by Wv and in pressure by Wp
16 Wp=1 //('entering the uncertainty in the
   measurement of dynamic pressure=:')
```



```

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

```

Scilab code Exa 7.2 Anemometers

```

1 //CHAPTER 7_ Flow Measurement
2 //Caption : Anemometers
3 // Example 2// Page 426
4 // 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.
5 disp(" C0+C1(v)^.5)(Tw-Tr)=Iw^2Rw")
6 disp("Rw= Rr[1+a(Tw-Tr)]")
7 disp("Rw/Rr=1+a(Tw-Tr)")
8 disp("Tw-Tr=1/a[Rw/Rr-1]")
9 disp("Tw=1/a[Rw/Rr-1]+Tr")
10 disp(" Co+C1(v)^0.5=Iw^2Rw/Tw-Tr")
11 disp(" so ,")
12 disp(" v=1/C1[{ Iw^2Rw/(1/a[Rw/Rr-1]+Tr-Tr)}]^2-C0")

```

Scilab code Exa 7.3 Gross volume flow rate

```

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

```

```

5 dt=0.01      //('entering the diameter of venturi=:')
6 B=0.5;      // given
7 // The discharge coefficients remains in the flat
  portion of the curve for reynolds numbers 10^4 to
  10^6 Cd=0.95
8 u=8.6*10^-4  //('entering the viscosity=:')
9 Cd=0.95;
10 Rn_min=10^4;
11 disp("Minimum flow rate is given by:")
12 disp("mdot_min=%pi*dp*u*Rn_min/4")
13 mdot_min=%pi*dp*u*Rn_min/4
14 g=9.81;
15 printf('Minimum flow rate at 25 deg cent is %1.3f kg
  /s\n',mdot_min)
16 pf=1000     // density of water
17 At=78.53*10^-6 //('entering the throat area=:')
18 pm=13.6     //('entering the density of manometer
  fluid=:')
19
20 //h is the height of mercury column due to flow
21 disp("To calculate the mercury reading corresponding
  to minimum flow , using-")
22 disp("h_min=((mdot_min*sqrt(1-B^4))/((sqrt(2*g*(pm-
  pf/pf))*pf*At*Cd)))^2;")
23 h_min=((mdot_min*sqrt(1-B^4))/((sqrt(2*g*(pm-pf/pf))
  *pf*At*Cd)))^2;
24 //in mm
25 H_min=h_min*1000
26 printf('So the pressure reading observed for the
  given flow ratre is %1.1f mm of Hg\n',H_min)
27 h_max=.25   //('entering the value of h maximum
  =:')
28 m_max=(pf*At*Cd*sqrt(2*g*(pm-pf/pf))*sqrt(h_max))/
  sqrt(1-B^4);
29 printf('The maximum flow rate is %1.1f kg/s\n',m_max
  )

```

Scilab code Exa 7.4 Gross volume flow rate

```
1 //CHAPTER 7_ Flow Measurement
2 //Caption : Gross volume flow rate(venturi)
3 // Example 4// Page 439
4 dt=0.15 //('entering the throat diameter=:')
5 dp=0.3 //('entering the upstream diameter=:')
6 Cd=0.95;
7 B=0.5;
8 pm=13600 //('entering the density of manometer
   fluid=:')
9 At=%pi*dt^2/4;
10 g=9.81;
11
12 pf=995.8
13 h=0.2 //('entering the height of mercury column
   due to flow (in m)=:')
14 q=pf*At*Cd;
15 w=(1-B^4)^(1/2);
16 e=sqrt(2*g*((pm/pf)-1));
17 mdot_25=q*e*sqrt(h)/w
18 disp("Mass flow is given by :")
19 disp("mdot=pf*At*Cd*(1/(1-B^4)^(1/2))*sqrt(2*g*((pm/
   pf)-1)*sqrt h)")
20 printf('So the mass flow at 25 deg cent is %fd kg/
   s\n',mdot_25)
21
22
23
24 pf=999.8 //('entering density of water at 25 deg
   cent=:')
25 h=0.2 //('entering the height of mercury column
   due to flow (in m)=:')
26 q=pf*At*Cd;
```

```

27 w=(1-B^4)^(1/2);
28 e=sqrt(2*g*((pm/pf)-1));
29 mdot=q*e*sqrt(h)/w
30 // error is mdot(25 deg cent)-mdot(t deg cent)
31 printf(' The mass flow at 0 deg cent is %fd kg/s\n',
        mdot)
32 error1=abs(((mdot_25-mdot)/mdot_25)*100);
33
34
35
36 printf(' Change in temperature of water introduces
        insignificant error in mass flow measurement i.e.
        %1.2f%% \n',error1)
37 pf=988.8 //('entering density of water at 25 deg
        cent=:')
38 h=0.2 //('entering the height of mercury column
        due to flow (in m)=:')
39 q=pf*At*Cd;
40 w=(1-B^4)^(1/2);
41 e=sqrt(2*g*((pm/pf)-1));
42 mdot=q*e*sqrt(h)/w
43 // error is mdot(25 deg cent)-mdot(t deg cent)
44 printf(' The mass flow at 50 deg cent is %fd kg/s\n
        ',mdot)
45 error2=abs(((mdot_25-mdot)/mdot_25)*100);
46
47
48
49 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

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

```

2 //Caption : Gross volume flow rate(venturi)
3 // Example 5// Page 440
4 dt=.1      //('entering the throat diameter=')
5 dp=.2      //('entering the upstream diameter=')
6 Cd=0.95;
7 g=9.81
8 B=0.5;
9 At=%pi*dt^2/4;
10 pf=780    //('entering density of oil in the
           pipeline =')
11 pm=1000   //('entering the density of manometer
           fluid=')
12 w=(1-B^4)^(1/2);
13 e=sqrt(2*g*((pm/pf)-1));
14 S_ideal=At*e/w;
15 printf('The ideal volume flow rate sensitivity is %1
           .4f (m^3/s/h^0.5)\n',S_ideal)
16 // part b
17 disp("Actual volume rate sensitivity is given by :")
18 disp("S_actual=S_ideal/Cd")
19 S_actual=S_ideal/Cd;
20 printf('The actual volume rate sensitivity is %1.4f
           \n',S_actual)
21 h=.3      //('entering the manometer reading of water
           height=')
22 disp("Actual volume flow rate is given by:")
23 disp("Q_actual=S_actual*sqrt(h)")
24 Q_actual=S_actual*sqrt(h);
25 printf('The actual volume flow rate is %1.3f m^3/s\n
           ',Q_actual)

```

Scilab code Exa 7.6 sonic nozzle

```

1 //CHAPTER 7_ Flow Measurement
2 //Caption : Sonic nozzle

```

```

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

```

Scilab code Exa 7.7 venturi

```

1 //CHAPTER 7_ Flow Measurement
2 //Caption : Venturi
3 // Example 7// Page 446
4 p1=5*10^6 //('entering the pressure of air when
    venturi is to be used =:')
5 t1=298 //('entering the temperature of air for
    the same=:')
6 m_max=1 //('entering the maximum flow rate=:')
7 m_min=0.3 //('entering the minimum flow rate=:')
8 Re_min=10^5 //('entering the throats reynold
    number=:')
9 R=287; // for air
10 rho1=p1/(R*t1);
11 b=0.5;

```

```

12 mu=1.8462*10^-5    //('enter the absolute viscosity
    =:')
13 D_max=(4*m_max)/(%pi*Re_min*mu);
14 D_min=(4*m_min)/(%pi*Re_min*mu);
15 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)
16 // To calculate the differential pressure
17 At=%pi*D_max^2/4;
18 C=1;    // discharge coefficient
19 M=1.0328;    // Velocity approach coefficient
20 Y=.9912;    // Expansion factor
21 dP_max=(m_max)^2/(Y^2*M^2*C^2*At^2*2*pho1);
22 printf('The differential pressure for maximum flow
    rate is %1.5f Pa\n',dP_max)
23 dP_min=(m_min)^2/(Y^2*M^2*C^2*At^2*2*pho1)*1000;
24 printf('The differential pressure for minimum flow
    rate is %1.2f mPa\n',dP_min)

```

Scilab code Exa 7.8 constant pressure drop

```

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

```

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

Chapter 8

TEMPERATURE MEASUREMENT

Scilab code Exa 8.1 thermocouple

```
1 //CHAPTER 8 - TEMPERATURE MEASUREMENT
2 //Caption : Thermocouple
3 // Example 1 // Page 500
4 t1 = 100 //('entering the temperature(in deg cent
   ) =:')
5 e1= 5 // ('entering the emf (in mv)at
   temperature t1 =:')
6 t2=445 //('entering the second temperature(in deg
   cent)= :')
7 e2=25 //('entering the emf(in mv) at temperature
   t2 =:')
8 // TO CALCULATE CONSTANTS a AND b
9 //e1=a*(t1)+b*(t1^2);
10 //e2=a*(t2)+b*(t2^2);
11 A=[t1 t1^2;t2 t2^2];
12
13 B=[e1 0 ;e2 0]
14 Y=lsq(A,B); //computes the minimum norm least
   square solution of the equation A*Y=B,
```

```

15 disp(Y)
16
17 printf('value of constants a and b are %fd V/deg
        cent and %fd V/deg cent respectively ',Y(1,1),Y
        (2,1))
18 //PART B
19 //Let e(0-40) be represented by E1 , e(40-t) by E2
        and e(0-t) by E3
20
21 E1=(Y(1,1)*40)+(Y(2,1)*40^2);
22 disp(E1);
23 E2=2; // given
24 E3=E1+E2;
25 D=sqrt((Y(1,1)^2)+(4*Y(2,1)*E3));
26 t=(-Y(1,1)+D)/(2*Y(2,1));
27 disp(t)
28 printf('Hot junction temperature is %1.1f deg cent '
        ,t);
29 // PART C
30 // Let e(0-500) be represented by E4 and e(40-500)
        by E5
31 E4=Y(1,1)*500+Y(2,1)*500^2;
32 E5=E4-E1;
33 disp(E5)
34 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

```

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

```

```

7 // Let  $e(0-100) = E1$  and  $e(100-t) = E2$ 
8 E1= 5.27 // given
9 E2=h;
10 E3=E1+E2;
11 E4=5.325; // given emf at 101 deg cent
12 c=100 ; // given that cold junction is at 100 deg
    cent
13 // BT EXTRAPOLATION
14 t=c+((E3-E1)/(E4-E1));
15 printf('Required temperature difference is %1.2f deg
    cent ',t)

```

Scilab code Exa 8.3 electrical resistance sensors

```

1 //CHAPTER 8 - TEMPERATURE MEASUREMENT
2 //Caption : ELECTRICAL- RESISTANCE SENSORS
3 // Example 3 // Page 517
4 s =0.2 //('enter the sensitivity =:')
5 d=0.4*10^-3
6 A=%pi*(d^2)/4;
7 // R=pho *l/A
8 R=100
9 pho=0.8*10^-3;
10 l=(R*A)/pho;
11
12 printf('Length corresponding to resistance 100 ohm
    and diameter 0.4mm is %fd m\n',l)
13 d=2*10^-3
14 A=%pi*(d^2)/4;
15 R=100
16 pho=0.8*10^-3;
17 l=(R*A)/pho;
18 printf('Length corresponding to resistance 100 ohm
    and diameter 2mm is %1.2f m\n',l)
19 // The above lengths of wire indicate that their

```

```

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

```

Scilab code Exa 8.4 thermistors

```

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

```

```

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

```

Scilab code Exa 8.5 pyrometers

```

1 //CHAPTER 8 _ TEMPERATURE MEASUREMENT
2 //Caption : PYROMETERS
3 // Example 5// Page 545
4
5 //(i)Optical Pyrometer
6 // Ta(K) is the actual temperature and Ti(K) is the
    indicated temperature
7 TI=1200 //('Enter the indicated temperature in
    degree centigrade=:')
8 Ti=TI+273
9 disp("Ti=TI+273")
10 lamda=0.7*10^-6 //('Entering the wavelength(in
    meters) at which intensities are compared')
11 epsilon=0.6 //('Entering the emissivity of
    the body')
12 C2=0.014387 //('Entering the value of constant')
13 disp("Actual temperature is given by :")
14 disp("Ta=(Ti*C2)/(C2-lamda*Ti*log(epsilon));")
15 Ta=(Ti*C2)/(C2-lamda*Ti*log(epsilon));

```

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