6 June 2015

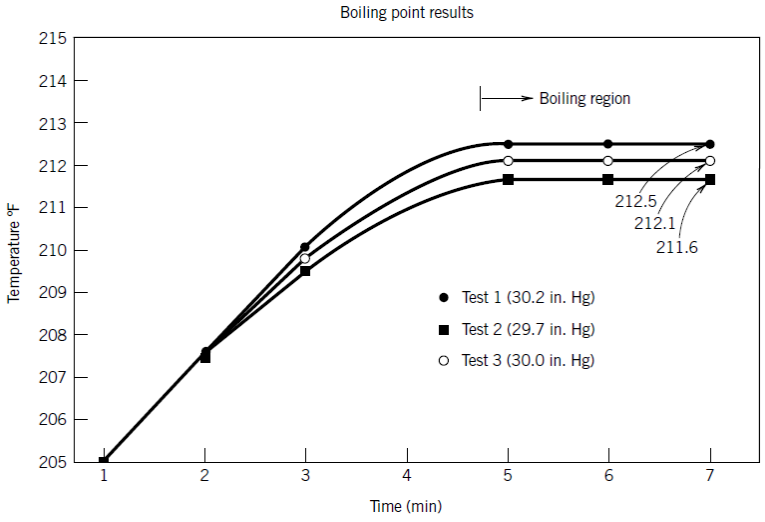
Examination

Measurement systems and Signal Processing

PART 1: Measurement Systems

1. a. Explain the hierarchy of standards. Explain the term *standard*.
   b. Search the Internet to find an example of standard.
   (5p)

2. a. Why calibrate? What does calibrated mean?
   b. Draw an example of a calibration curve.
   (5p)
3. Discuss interference in the test of Figure below.
   (5p)



4. What is hysteresis? Make a drawing. (2p)

5. Find the input and output range of the calibration data and calculate the corresponding span. (5p)

Table 1.5 Calibration Data

X [cm]	*Y* [V]	*X* [cm]	*Y* [V]
0.5	0.4	10.0	15.8
1.0	1.0	20.0	36.4
2.0	2.3	50.0	110.1
5.0	6.9	100.0	253.2

6. For the calibration data of Table 1.5, determine the static sensitivity of the system at
(a) X = 5;
(b) X = 10; and
(c) X = 20.
(5p)

For which input values is the system more sensitive? Explain what this might mean in terms of a measurement and in terms of measurement errors.
(8p)

7. Research on Internet the following test standards Write a short (200-word) report that describes the intent and an overview of the standards:
a. ASTM F 558-88 (Air Performance of Vacuum Cleaners)
b. ANSI Z21.86 (Gas Fired Space Heating Appliances)
c. ISO 10770-1:1998 (Test Methods for Hydraulic Control Valves)
d. ANSI/ASME PTC19.1-2005 (Test Uncertainty)
e. ISO 7401:1988 (Road Vehicles: Lateral Response Test Methods)
(5p)

Part 1: Static and Dynamic Signals

8. List the important characteristics of input and output signals and define each.
(5p)

9. Determine the average and rms values for the function
$y(t) = 25 + 10 \sin 6\pi t$ over the time periods

(a) 0 to 0.1 s,
(b) 0.4 to 0.5 s,
(c) 0 to 1/3 s, and
(d) 0 to 20 s.
Comment on the nature and meaning of the results in terms of analysis of dynamic signals.
(5p)

10. Determine the value of the spring constant that would result in a spring-mass system that would execute one complete cycle of oscillation every 2.7 s, for a mass of 0.5 kg. What natural frequency does this system exhibit in radians/second?
(5p)

11. A spring with k = 5000 N/cm supports a mass of 1 kg. Determine the natural frequency of this system in radians/second and hertz. (5p)

12. For the following sine and cosine functions determine the period, the frequency in hertz, and the circular frequency in radians/second. (Note: t represents time in seconds).
a. $\sin 10\pi t/5$
b. $8 \cos 8t$
c. $\sin 5n\pi t$ for n=1 to ∞
(5p)

13. Express the function
$y(t) = 4 \sin 2\pi t + 15 \cos 2\pi t$
in terms of (a) a cosine term only and (b) a sine term only.
(5p)
(70p)

Part 1: Data Acquisition

14. Determine the alias frequency that results from sampling f1 at sample rate fs:
a. f1 = 60 Hz; fs = 90 Hz
b. f1 = 1.2 kHz; fs = 2 kHz
c. f1 = 10 Hz; fs = 6 Hz
d. f1 = 16 Hz; fs = 8 Hz

(5p)

15. Convert the analogue signal $E(t) = (4 + 2 \sin 4\pi t + 3 \sin 16\pi t)$ V into a discrete time signal using a sample rate of 32 Hz. Build the discrete time signal and its amplitude and phase spectra. Then try at fs = 16 Hz and at fs = 40 Hz. Discuss results.
(10p)

16. Convert the following straight binary numbers to positive integer base 10 numbers:
a. 1010 c. 10111011

b. 11111 d. 1100001
(2p)
17. Convert: (a) 1100111.1101 (binary) into a base 10 number; (b) 4B2F into straight binary; (c) 278.632 (base 10) into straight binary.
(3p)

18. Convert the following decimal (base 10) numbers into bipolar binary numbers using a twos complement code:
a. 10
b. -10
c. -247
d. 1013

(5p)

19. How is the largest negative binary number represented in twos complement code for an 8-bit byte. Subtract one from this number. What base 10 decimal numbers do these represent?
(5p)

20. A 12-bit A/D converter having an EFSR = 5 V has a relative accuracy of 0.03% FS (full-scale). Estimate its quantization error in volts. What is the total possible error expected in volts? What value of relative uncertainty might be used for this device?
(5p)

21. An 8-bit D/A converter shows an output of 3.58 V when straight binary 10110011 is applied. What is the output voltage when 01100100 is applied?
(105)

Part 2: Measurement System Behaviour

22. A mass measurement system has a static sensitivity of 2 V/kg. An input range of 1 to 10 kg needs to be measured. A voltmeter is used to display the measurement. What range of voltmeter is needed? What would be the significance of changing the static sensitivity?
(5p)

23. Determine the 75%, 90%, and 95% response time for each of the systems given (assume zero initial conditions):

a. $0.4\dot{T} + T = 4U(t)$
b. $\ddot{y} + 2\dot{y} + 4y = U(t)$
c. $2\ddot{P} + 8\dot{P} + 8P = 2U(t)$
d. $5\dot{y} + 5y = U(t)$

(5p)

24. A measurement system can be modelled by the equation

$$0.5\dot{y} + y = F(t)$$

Initially, the output signal is steady at 75 volts. The input signal is then suddenly increased to 100 volts.

a. Determine the response equation.
b. On the same graph, plot both the input signal and the system time response from t = 0 s through steady response.
(10p)

25. A thermocouple, which responds as a first-order instrument, has a time constant of 20 ms. Determine its 90% rise time.
(5p)

Part 3: Probability and Statistics

26. Construct a histogram and frequency distribution for the data in Table 4.1

Table 4.1 Sample of Random Variable x

i	x_i	i	x_i
1	0.98	11	1.02
2	1.07	12	1.26
3	0.86	13	1.08
4	1.16	14	1.02
5	0.96	15	0.94
6	0.68	16	1.11
7	1.34	17	0.99
8	1.04	18	0.78
9	1.21	19	1.06
10	0.86	20	0.96

Note: the number of intervals K is derived from:

$$K = 1.87(N-1)^{0.40} + 1$$

(5p)

27.

The statistics of a well-defined varying voltage signal are given by $x' = 8.5$ V and $\sigma^2 = 2.25$ V^2. If a single measurement of the voltage signal is made, determine the probability that the measured value indicated will be between 10.0 and 11.5 V.

(5p)

28. Consider the data of Table 4.1. (a) Compute the sample statistics for this data set. (b) Estimate the interval of values over which 95% of the measurements of x should be expected to lie. (c) Estimate the true mean value of x at 95% probability based on this finite data set.
(5p)

29.

Ten steel tension specimens are tested from a large batch, and a sample variance of 40,000 (kN/m^2)^2 is found. State the true variance expected at 95% confidence.

(5p)

30. The following data are suspected to follow a linear relationship. Find an appropriate equation of the first-order form using regression analysis.

x (cm)	y (V)
1.0	1.2
2.0	1.9
3.0	3.2
4.0	4.1
5.0	5.3

(10p)

Total 160p