
Problem 1:

(a) Indicate whether each statement of the following is correct (✓) or false (✗).

[10 Marks]

- 1- Current transformers are utilized essentially in the measurement of very small currents. ()
- 2- Lissajous patterns are patterns that appear on the oscilloscope display when two signals are connected to its two channels in XY mode and can be used to measure the frequency ratio given that the numerator and denominator of the frequency ratio are integers. ()
- 3- Digital voltmeter is more accurate than analog voltmeter but its input resistance is lower than analog voltmeter. ()
- 4- Voltage to time digital voltmeter has – in general- less conversion time than voltmeters that utilize analog to digital converter. ()
- 5- Trigger controls in an oscilloscope controls the vertical scale of the display screen ()
- 6- When DC-coupling setting is selected in the oscilloscope, only the DC-average of the signal is displayed. ()
- 7- The tube of CRT oscilloscope is filled with a gas at high pressure. ()
- 8- Available chart recorders output their measurements on paper only. ()
- 9- Dot matrix displays can be used to display numbers only. ()
- 10- Regression techniques can be used reliably only if at least one of the variables is measured with very good certainty. ()

(b) A bridge is used to measure an unknown capacitance C_x as shown in Figure 1. The resistance R_1 is adjusted till the bridge is balanced.

Derive an expression for the unknown capacitance C_x in terms of R_1, C_1, R_2, R_3 . Given that $R_1=1\text{ KOhm}$, $R_2=2\text{ KOhm}$, $R_3= 5\text{ KOhm}$, and $C_1=1\text{ }\mu\text{F}$. Find the value of C_x and R_x .

[5 Marks]

(c) A dual slope digital voltmeter is used for measuring an unknown voltage V_i . The unknown voltage V_i is applied to the input of an

integrator for a known fixed time interval T_1 , then a known negative voltage $-V_{ref}$ is applied to the input of the integrator till the integrated voltage is zero after time T_2 . Derive an expression for the unknown voltage V_i in terms of the reference voltage V_{ref} , T_1 , and T_2 .

If $T_1=5\text{ ms}$, $T_2 =10\text{ ms}$, and $V_{ref}=10\text{V}$. Calculate the unknown voltage V_i . [5 Marks]

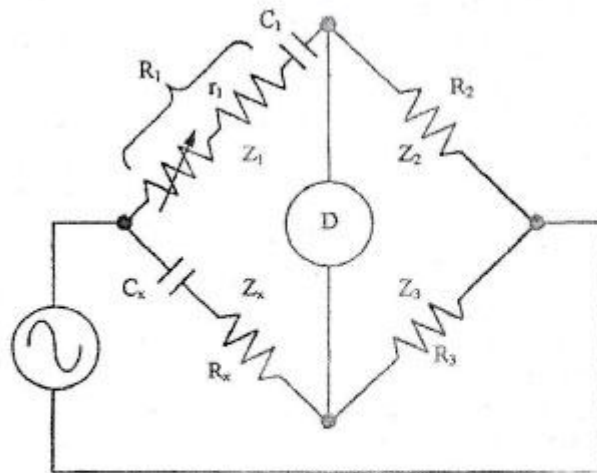


Figure 1

Problem 2:

(a) Select the correct answer: [8 Marks]

1. A sinusoidal signal is displayed on an oscilloscope. A complete cycle spans 5 horizontal divisions. The time per division setting of the oscilloscope is 10 ms. The measured signal frequency is:
a) 50 Hz b) 20 Hz c) 20 KHz d) 1 KHz
2. In the previous question, the time per division setting is changed to 20 ms with everything else fixed. The measured frequency will be:
a) 20 Hz b) 10 Hz c) 40 Hz d) 60 Hz
3. In the previous question, A complete cycle of the signal spans how many horizontal divisions?
a) 5 divisions. b) 2.5 divisions. c) 10 divisions d) 2 divisions

4. In the previous question, the signal frequency is changed to 5 Hz. What is the number of horizontal divisions of one complete cycle of the measured signal?
a) 20 b) 10 c) 5 d) other
5. A sinusoidal signal of amplitude 5 V is displayed on an oscilloscope. Which trigger level setting of the following is not valid?
a) -2 V b) 0 V c) 3 V d) 6 V
6. As the number of turns in the secondary winding of a current transformer increases, the secondary measured current
a) Increases. b) decreases c) no change.
7. An oscilloscope with two channels have a number of time/division control knobs equal to
a) One knob. b) two knobs c) three knobs. d) other
8. Two signals with a frequency of 2 KHz are connected to the two channels of an oscilloscope. One of the signals have a phase lead of 90° with respect to the other. If the time per division setting of the oscilloscope is 0.1 ms. One of the signals will be displaced horizontally with respect to the other by Horizontal divisions.
a) 1.5 b) 3 c) 1.25 d) 2

- (b) The characteristics of a chromel-constantan thermocouple is known to be approximately linear over the temperature range 300°C – 800°C . The output e.m.f. was measured practically at a range of temperatures and the following table of results obtained. Using least squares regression, calculate the coefficients a and b for the relationship $E = aT + b$ that best describes the temperature (T) versus e.m.f. (E) characteristic. (show details of your work). [7 Marks]

| | | | | | | | | | |
|-----------------------|------|------|------|------|------|------|------|------|------|
| Temp $^\circ\text{C}$ | 300 | 325 | 350 | 375 | 400 | 425 | 450 | 475 | 500 |
| e.m.f (mV) | 21.0 | 23.2 | 25.0 | 26.9 | 28.6 | 31.3 | 32.8 | 35.0 | 37.2 |

| | | | | | | | | | |
|-----------------------|------|------|------|------|------|------|------|------|------|
| Temp $^\circ\text{C}$ | 525 | 550 | 575 | 600 | 625 | 650 | 675 | 700 | 725 |
| e.m.f (mV) | 38.5 | 40.7 | 43.0 | 45.2 | 47.6 | 49.5 | 51.1 | 53.0 | 55.5 |

| | | | |
|-----------------------|------|------|------|
| Temp $^\circ\text{C}$ | 750 | 775 | 800 |
| e.m.f (mV) | 57.2 | 59.0 | 61.0 |

Problem 3:

- (a) Indicate whether each statement of the following is correct (\checkmark) or false (\times):
[10 Marks]

1. The width of an ultrasonic beam decreases as the frequency of the ultrasonic wave increases. ()
2. If an ultrasonic source is moving far away from a stationary target, the target receives the ultrasonic wave with a frequency less than that generated by the source. ()
3. The 3-D position of a moving object can be determined using an ultrasonic transmitter attached to the body and at least two ultrasonic receivers placed at known reference positions. ()
4. The radiated power from a hot body is dependent only on its temperature. ()
5. Thermoelectric effect temperature sensors are contact-less sensors while pyrometers are contact sensors. ()
6. Semiconductor strain gauges have lower sensitivity than conventional metallic strain gauges. ()
7. A piezo-electric transducer is a sensor that converts stress to a change in resistance. ()
8. Dead weight gauge is used for in-field quick measurement of pressure. ()
9. A pirani gauge is a pressure sensor used for very high pressures. ()
10. Bourdon tube measures pressure by converting it to a measurable deflection. ()

(b) An Ultrasonic transmitter is attached to a flying object. Three ultrasonic receivers are attached to ground at the positions $(0,0,0)$ and $(B,0,0)$ and $(0,C,0)$. The ultrasonic receivers measure the propagation delays from the transmitter to each of them and are given by: 46 ms, 35 ms, and 50 ms respectively. The sound velocity is 340 m/s. Derive an expression for the moving body position in terms of the ground receivers locations and the distance between each receiver and the transmitter. Calculate the flying object position if $B=10$ m and $C=20$ m. [10 Marks]

Problem 4:

- (a) Select the correct answer: [10 Marks]
1. Which of the following temperatures cannot be measured using a manual optical pyrometer?
 - a) 400 °C b) 800 °C c) 900 °C d) 700 °C
 2. Which of the following rotational displacement devices have a range from 0°C to 360 °C.
 - a) Rotational differential transformer b) Resolver c) Gyroscope d) The synchro.
 3. The minimum number of rate integrating gyroscopes required to measure the full orientation is:
 - a) 2 b) 3 c) 4 d) 5

4. Bellows is a pressure measurement device that converts change in pressure to a change in.....
 - a) Resistance b) inductance c) deflection d) current
5. In a Hall-effect sensor, the current flows in the x-direction while there is an applied magnetic field in the y-direction. The induced hall voltage is in.....
 - a) X-direction. b) Y- direction c) Z-direction
6. A sound wave has a frequency 1KHz. Given that the sound velocity=340m/s. The wavelength is:
 - a) 0.68 m b) 0.34 m c) 0.17 m d) 1 m
7. Which of the following temperatures can be measured using a radiation pyrometer?
 - a) 100 °C b) 400 °C c) 1000 °C d) All
8. Which of the following rotational displacement sensors is suitable for harsh environments?
 - a) Optical incremental shaft encoders. b) circular potentiometer. c) The gyroscope. d) magnetic digital shaft encoder.
9. Which of the following sensors can measure rotational displacement more than 360°?
 - a) Resolver b) helical potentiometer. c) incremental encoder. d) none
10. Which of the following devices employ the electromagnetic induction in its operation?
 - a) Incremental encoder. b) bourdon tube. c) synchro d) thermistor

(b) In a particular industrial situation, a nicrosil–nisi thermocouple with nicrosil–nisi extension wires is used to measure the temperature of a fluid. In connecting up this measurement system, the instrumentation engineer responsible has inadvertently interchanged the extension wires from the thermocouple. The ends of the extension wires are held at a reference temperature of 0°C and the output e.m.f. measured is 21.0 mV. If the junction between the thermocouple and extension wires is at a temperature of 50°C, what temperature of fluid is indicated and what is the true fluid temperature?

You are given the following data:

$$\Delta E_{\text{nicrosil-nisi } 50^{\circ}\text{C}} = 1.339 \text{ mV} \quad \Delta E_{\text{nicrosil-nisi } 610^{\circ}\text{C}} = 21.0 \text{ mV}$$

$$\Delta E_{\text{nicrosil-nisi } 678.4^{\circ}\text{C}} = 23.68 \text{ mV}$$

[5 Marks]

(c) A McLeod gauge is used to measure an unknown pressure as shown in Figure 2. The volume of the Y tube is $V_u = 1$ litre and the liquid density $\rho = 1000 \text{ kg/m}^3$. The Y-tube cross-sectional area = 10 cm^2 and the liquid height after measurement is $h = 20 \text{ cm}$.

- Derive an expression for the unknown pressure P_u
- Calculate the unknown pressure P_u

[5 Marks]

Problem 5:

- (a) Discuss in brief why it is preferable to utilize gray code shaft encoders than binary code shaft encoders. [+ 3 Marks]
- (b) Explain how the fibre-optic angular velocity gyroscope operates. [+3 Marks]
- (c) Discuss the working principle of the manual pyrometer and how it is used to measure an unknown temperature. [+4 Marks]

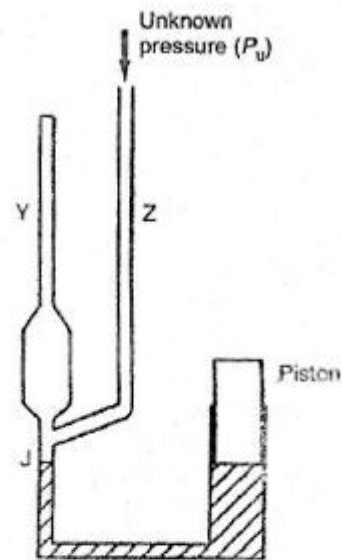


Figure 2