Register Number:
Date : 11-01-2020

ST. JOSEPH'S COLLEGE (AUTONOMOUS), BANGALORE-27
M.Sc. PHYSICS - I SEMESTER
SEMESTER EXAMINATION: JANUARY 2021
PH74 - EXPERIMENTAL PHYSICS-I

Time- 2 1/2 hrs **Max Marks-70**

This paper contains 2 parts and 3 printed pages.

Part-A

Answer any 5 questions. Each question carries 10 marks. **(5X10=50)**

1. a) To monitor the position of steam control valves in power generation plants, plant operators must always precisely know the position of valves to within thousandth of an inch as they need to be fully or partially (like precisely 25% or 40%) open them depending on the power generation requirement. Which transducer should be used for this purpose? Explain how this transducer works and how is the output voltage related to this movement.

   b) In order to monitor the pressure in the tyres of an aircraft, should the pressure transducer measure gauge pressure or absolute pressure? Explain your answer. Identify a pressure gauge that would be appropriate for this application.
   You can use the following data to support your answer- Pressure at sea level is 14.7 psi, pressure in the tyres is 32 psi and pressure at an altitude of 10,000 feet is 10 psi where psi is pounds per square inch. (7+3)

2. a) If the transducer containing resistive sensing element is connected to the instrumentation system using lead wires then discuss what errors can possibly be introduced in the measurements.

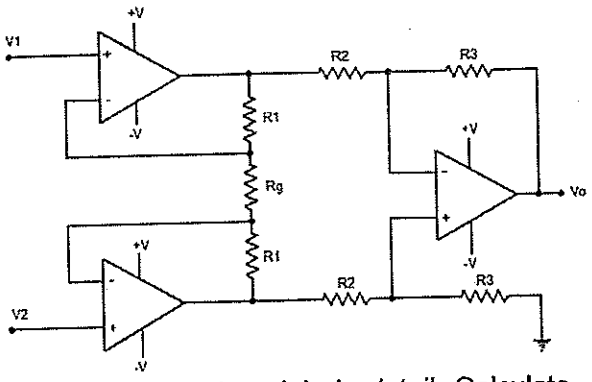
   b) Stating the basic principle of working of accelerometers, explain how MEMS capacitive accelerometer works. For what kind of applications are they used? (3+7)

3. The 1- Dimensional Fourier differential equation for heat flow can be obtained from the given equation on rearrangement $KA\frac{d^2\theta}{dx^2}\delta x = A\rho c\frac{d\theta}{dt}\delta x + Ep\theta\,\delta x$ where the direction of heat flow is along x-axis, dθ/dt is the rate of rise in temperature, c is specific heat of the material of the bar, E is emissivity of the surface of bar, p is perimeter of its cross-section, K is thermal conductivity of the material of bar of cross-sectional area A.
   Now, if the bar is periodically heated and cooled at one end such that the temperature at the hot end of the bar varies as $\theta = \theta_o \cos\omega t$, then derive and discuss how the heat propagates along the length of the bar i.e. derive an expression to show how the amplitude of temperature varies and what is the velocity with which the heat wave travels in the bar. Assume that the bar is insulated from the surroundings.

4. Stating the disadvantages of two-probe method, explain how four-probe method is experimentally used to determine the resistivity of a given semiconducting material. Derive expressions for resistivity of bulk sample and for thin sheet sample.

5. a) Explain the working of the Instrumentation amplifier (as shown in figure) with input voltages V_1 and V_2 ,stating clearly the differences between op-amps and instrumentation amplifiers. Also, derive an expression for the gain of this amplifier.

b) If the input voltage V_1 = 2.25 V and V_2 = 2.5 V, the supply voltage to each operational amplifier is ±V=±10 V, $R_1=R_2=R_3=5$ kΩ and $R_g=500\Omega$, then calculate the output voltage for this circuit. (7+3)



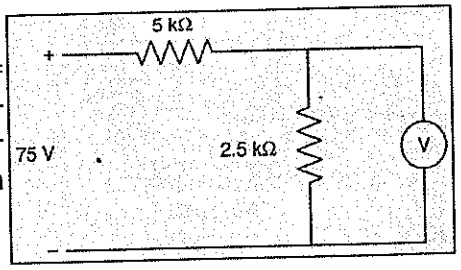
6. Design a 4-bit binary weighted Digital-to-Analog (DAC) converter that gives output voltages with step size 0.5 volts. Draw the circuit diagram and explain in detail. Calculate the analog output for the digital code 1111.
b) Compare the total propagation delay time in the output of a 4-bit synchronous and asynchronous counter. (8+2)

7. a) Explain the principle of working of a Differential Scanning calorimeter (DSC).
b) Explain how magnetoresistive effect in produced in Anisotropic Magnetoresistance (AMR) sensor. (5+5)

Part-B

Answer any 4 questions. Each question carries 5 marks. **(4X5=20)**

8. With reference to the given figure, the voltage across 2.5 kΩ resistor is to be measured using a voltmeter of sensitivity 1 kΩ/V. Calculate the voltmeter reading for this case. Also, calculate the output voltage reading for the case of an ideal voltmeter and find the % error in actual measurement.



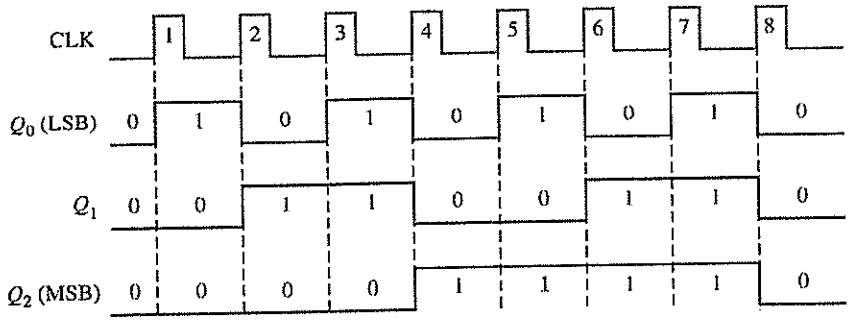
9. a) A 1 kΩ strain gauge, having a gauge factor of 2.0 is attached to a load cell made of material with Young's modulus of 10^5 MPa. The cross-sectional area of the load cell is 200 mm^2. Calculate the change in resistance when the load cell supports a load of 2000 kg. Consider $g=10\ m/s^2$.
b) If this unstrained load cell is connected as one of the arms of an initially balanced Wheatstone bridge, then find the output voltage (in mV) when the load cell is strained. The Wheatstone bridge is powered by a 10 V dc power supply. (2.5+2.5)

10. Using the power law series for a platinum RTD, calculate the resistance at 1000° C for a transducer which has the resistance of 100Ω at 20° C. If it was assumed erroneously that the calibration was linear over this temperature range, then what would be the error in the measured value at 500° C? The temperature coefficients of resistance for Platinum are: $\alpha = 3.926 \times 10^{-3}$ /° C, $\beta = -5.77 \times 10^{-7}/(°C)^2$.

11. Which op-amp circuit can be used to make a water level detector to detect whether or not the water has been filled to a pre-defined level? Draw and Explain.

12. The Hall voltage is a low-level signal of the order of 30 microvolts in the presence of 1 Gauss magnetic field. This low-level output requires an amplifier with low noise, high input impedance and moderate gain. The obtained output further needs to be converted to digital form to use the sensor as a switch. Draw a circuit showing the components(as blocks with their symbols) used for appropriate amplification and digitization of the sensor output. Explain its working.

13. Sketch a 3-bit asynchronous counter to obtain the output as the given timing diagram for ideal counter performance.



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