BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2023-2024
Comprehensive Exam (Open book)
Transducers and Measurement Systems (INSTR F312)

PART - B

Time: 120 min | ***Max Marks***:60 | ***Date:*** 7th December 2023

Note: *This question paper (Part B) has 2 (TWO) printed pages. Assume and clearly specify any missing data suitably. Marks are indicated against each question. Write final answers in the designated space only.*

1. A drag force flowmeter, as shown in Fig. 1, is used for the measurement of flow rate of water in a 50 mm diameter pipe. The maximum flow rate of the water is 120 liters per minute with density of 1000 kg/m^3. The drag force is measured using a cantilever beam in ***temperature compensated half bridge*** configuration and the bridge output is fed into a voltage amplified with gain, 'A'. The bridge is balanced at zero flow rate with all resistances equal to unstrained resistance and a supply voltage of 10 V. The strain gauges are located at 2 cm from the fixed end of the beam and have an unstrained resistance (R_0) of 350 Ω and a gauge factor of 2.1. ***For the maximum flow rate***, calculate,

(a) Speed of water (in m/s)
(b) Developed drag force, 'F' (in N)
(c) Strain generated in cantilever beam at the location of strain gauges
(d) Bridge circuit and its output voltage (V_0) in mV
(e) Amplifier gain ('A') such that amplified output is 1 V at maximum flow rate. **[20]**

<u>**Cantilever beam data:**</u>
Length (l) = 20 cm, width (w) = 5 cm,
thickness (t) = 4 mm, Young's modulus = 70 GPa
<u>**Drag force flowmeter data:**</u>
Discharge coefficient (C_d) = 2.5,
Contact area for drag force (A) = 600 mm^2,
Drag force (F) = $C_d A \rho v^2 / 2$; v – fluid speed (m/s)

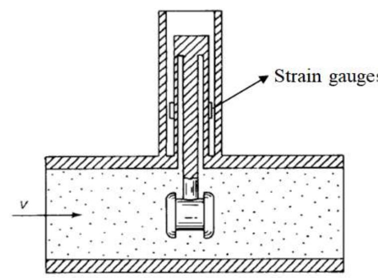

Fig. 1

2. Consider an automatic reference junction temperature compensation circuitry as shown in Fig. 2 with AD590. AD580 is a precision voltage regulator IC providing 2.5 V at its output terminal. Given, measuring junction is at temperature T_M °C and reference junction is at T_R °C. Calculate the resistance R_T, such that the circuitry provides compensation for iron-constantan thermocouple having sensitivity of 52.3 $\mu V/°C$ at a reference junction temperature of 25 °C. **[10]**

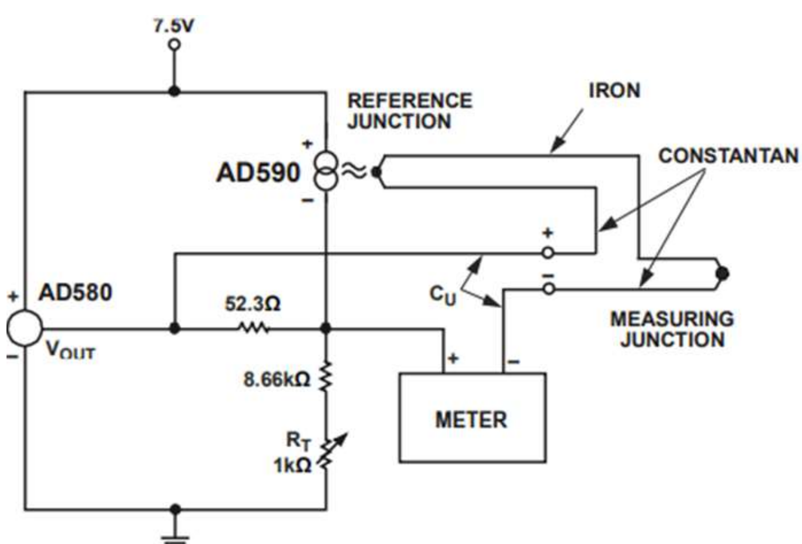

Fig. 2

3. A variable reluctance sensor (shown in Fig. 3a), which is incorporated into the bridge circuit (shown in Fig. 3b), is used to measure force. When the applied force is 0 N, the armature is positioned along center line *AB*. Given, effective mass of spring and armature = 30×10^{-3} kg, damping ratio = 0.7, inductance of each coil = 20/(1+3d) mH, where '*d*' is in mm, and supply voltage of bridge is $V_s = 2\sin(2000\pi t)$ V.

(a) Calculate the spring stiffness 'k' (Nm^{-1}) such that the natural frequency of sensor is 40 Hz.

(b) Calculate the output voltage of the bridge if a force of F = 10N is applied to the sensor. **[10]**

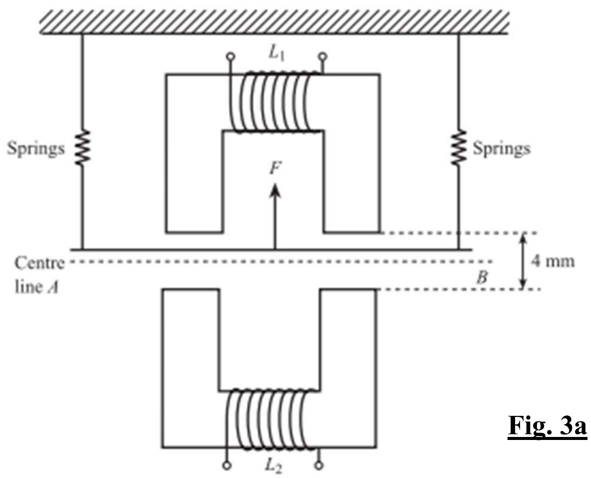

Fig. 3a

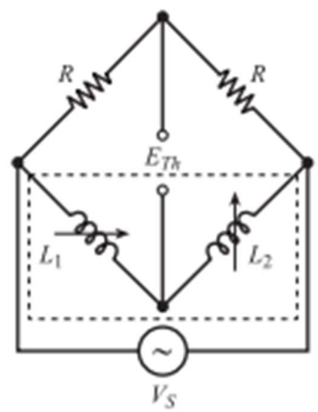

Fig. 3b

4. An open steel vessel contains liquid metal to a depth of about 0.9 m. It is proposed to measure the depth of liquid using ultrasonic pulse reflection techniques. A quartz crystal attached to the base of the vessel is to act alternatively as a transmitter and receiver. Characteristic impedance of steel is 4.7×10^7. Calculate,

(a) the 'round trip' time T_T

(b) the fraction of received power to transmitted power

(c) the repetition time (T_R), if $T_R = 10T_T$. Also justify with proper reasoning, if the chosen repetition time is appropriate for this system. **[10]**

Data: Velocity of sound in liquid metal = 1.5×10^3 ms^{-1}

Density of liquid metal = 5×10^3 kg m^{-3}

Power attenuation coefficient = 0.2 m^{-1}

Natural frequency of quartz crystal = 1 MHz

5. A thermistor has a resistance R_θ (Ω) which varies with temperature θ K, according to the equation, $R_\theta = K\exp\left(\frac{\beta}{\theta}\right)$. If $R_\theta = 8980\ \Omega$ at 0°C and $R_\theta = 3065\ \Omega$ at 27 °C then, **[10]**

(a) Calculate the values of K and β.

(b) Find the output voltage expression and output voltage sensitivity of circuit (shown in Fig. 4) in mV/K at 293 K.

(c) Will this circuitry be of any practical use for temperature measurement? Justify your answer. If your answer is 'NO', then what minimal changes you will do to make it more suitable for practical use.

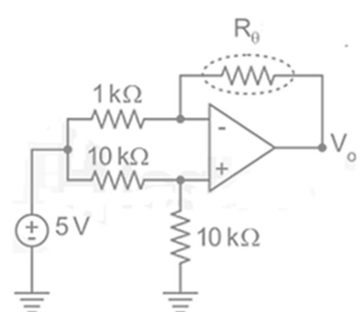

Fig. 4