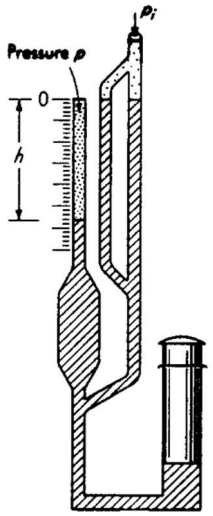
Final Examination Sensing and Actuation AT74.03 April 26, 2022

Time: 9:00-10:30 h. Open Book
Marks: 100

Attempt all questions.

Q.1 Mcleod gage is used to determine the unknown pressure, p_i. When the height of the liquid at the close-end side, h, is measured at 20 cm, the pressure, p_i, is 17.33 kPa. When the height of the liquid at the close-end side is measured at 30 cm, the pressure is 58.55 kPa. Determine the pressure when the height of the liquid at the close-end is measured at 40 cm.

(20)



Solution

$$p_i = \frac{A_t \rho g h^2}{V - A_t h} = \frac{h^2}{k_1 - k_2 h} \quad (1)$$

$$17330 = \frac{0.2^2}{k_1 - k_2 0.2} \quad (2)$$

$$58550 = \frac{0.3^2}{k_1 - k_2 0.3} \quad (3)$$

$$17330k_1 - 3466k_2 = 0.04 \quad (4)$$

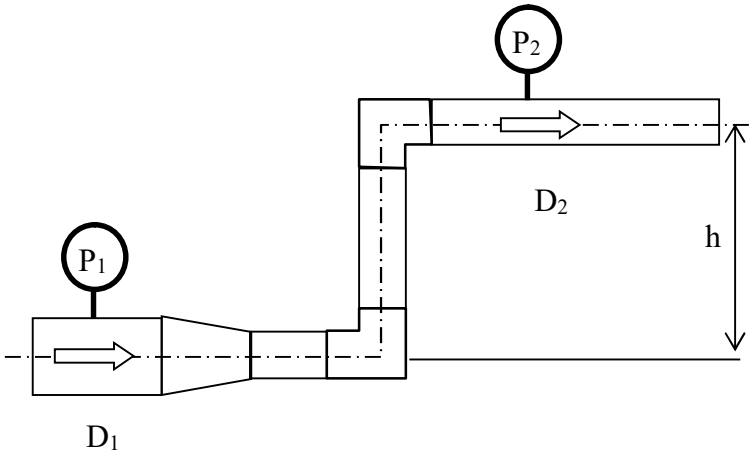
$$58550k_1 - 17565k_2 = 0.09 \quad (5)$$

$$k_1 = 0.385 \times 10^{-5} \quad (6)$$

$$k_2 = 0.771 \times 10^{-5} \quad (7)$$

$$p_i = \frac{0.4^2}{0.385\times10^{-5} - 0.771\times10^{-5}\times0.4} = 208880\ Pa = 208.88\ kPa \quad (8)$$

Q.2 Water flows from a pipe with 10 cm diameter (D_1) through a pipe fitting adapter to another pipe with 5 cm diameter (D_2). Two pressure sensors are used to measure the water pressure at two locations locating 4 m height difference (h) as shown in the below figure. Determine the volume flow rate of water (Q) when the pressure difference (P_1-P_2) indicates 80 kPa. Assume water is incompressible and its flow is frictionless. Use water density (ρ) of 1,000 kg/m^3 and gravitational acceleration (g) of 9.8 m/s^2. (20)



Solution

From Bernoulli's equation,

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gz_2 \quad (1)$$

$$Q = \frac{A_2}{\sqrt{1-(A_2/A_1)^2}} \sqrt{2\left(\frac{P_1-P_2}{\rho} + g(z_1 - z_2)\right)} \quad (2)$$

$$Q = \frac{\pi \times 0.05^2/4}{\sqrt{1-(0.05/0.10)^4}} \sqrt{2\left(\frac{80000}{1000} - 9.8 \times 4\right)} \quad (3)$$

$$Q = 0.0183\ m^3/s \quad (4)$$

Q.3 A thermistor is used to measure an unknown temperature. During the calibration experiments, at temperature 50°C, the thermistor resistance is measured as 587.10 Ω; at temperature 100°C, the thermistor resistance is measured as 73.71 Ω. What is the temperature when the thermistor is measured at 157.53 Ω. (20)

Solution

The relation between thermistor resistance and temperature is expressed by

$$R = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)} \quad (1)$$

At 50°C,

$$587.10 = R_0 e^{\beta\left(\frac{1}{323}-\frac{1}{T_0}\right)} \quad (2)$$

At 10°C,

$$73.71 = R_0 e^{\beta\left(\frac{1}{373}-\frac{1}{T_0}\right)} \quad (3)$$

(2)/(3),

$$\frac{587.10}{73.71} = e^{\beta\left(\frac{1}{323}-\frac{1}{373}\right)} \quad (4)$$

$$\beta = 5000 \quad (5)$$

When the thermistor is measured at 157.53 Ω,

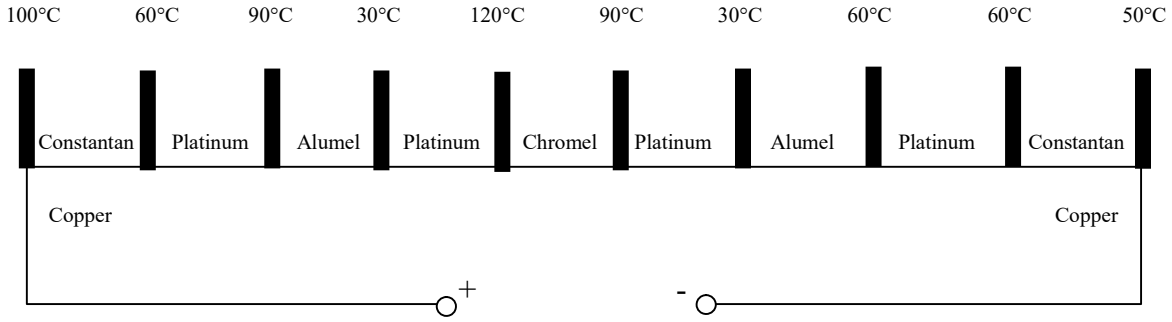
$$157.53 = R_0 e^{5000\left(\frac{1}{T}-\frac{1}{T_0}\right)} \quad (6)$$

(2)/(6),

$$\frac{587.10}{157.53} = e^{5000\left(\frac{1}{323}-\frac{1}{T}\right)} \quad (7)$$

$$T = 353°\text{K} = 80°\text{C} \quad (8)$$

Q.4 A multi-junction thermocouple is used to measure the temperature. Determine the voltage output of the thermocouple of the condition as shown in the below figure. Thermoelectric sensitivity in combination with platinum of several materials are given as follows: Copper is 6.5 μV/°C, Chromel is 25.8 μV/°C, Alumel is –13.6 μV/°C, and Constantan is -35 μV/°C. (20)



Solution

$$V_0 = (S_{Copper} - S_{Constantan})(100 - 50) + (S_{Constantan} - S_{Platinum})(60 - 60)$$
$$+(S_{Platinum} - S_{Alumel})(90 - 60 - 30 + 30) + (S_{Platinum} - S_{Chromel})(120 - 90) \quad (1)$$

$$V_0 = (6.5 + 35) \times 50 - 35 \times 0 + 13.6 \times 30 - 25.8 \times 30 = 1709\ \mu V = 1.709\ mV \quad (2)$$

Q.5 Performance of an EV is tested and determined.

(a) At a constant power mode, when the speed of 60 km/h, the acceleration is measured at 30 m/s. Determine the acceleration at the speed of 120 km/h. (10)

(b) At a constant acceleration mode, when the speed of 60 km/h, the power is measured at 100 kW. Determine the power at the speed of 120 km/h. (10)

Solution

(a)

$$P = FV = maV \quad (1)$$

$$a = \frac{P}{mv} \quad (2)$$

$$30m/s = \frac{K_1}{60km/h} \quad (3)$$

$$K_1 = 1800 \quad (4)$$

$$a = \frac{1800}{120km/h} = 15m/s \quad (5)$$

(b)

$$P = FV = maV \quad (6)$$

$$100kW = K_2 60km/h \quad (7)$$

$$K_2 = 1.67 \quad (8)$$

$$P = K_2 120km/h = 200kW \quad (9)$$