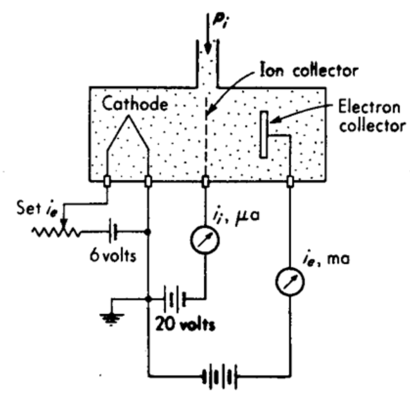
Final Examination Sensing and Actuation AT74.03 November 23, 2018

Time: 13:00-14:30 h. Open Book

Marks: 100

Attempt all questions.

Q.1 Ionization gage is applied to measure a gas pressure as shown in the below figure. When the pressure is 5 Pa, the ion current is measured as 100 mA and the electron current is measured as 2 A. Determine the pressure when the ion current is measured as 250 mA and the electron current is measured as 3 A. (20)



Solution

$$i_i = Spi_e \quad (1)$$

$$100\ mA = S(5\ Pa)(2\ A) \quad (2)$$

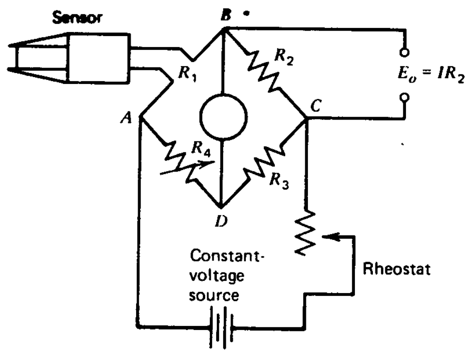
$$250\ mA = S(p)(3\ A) \quad (3)$$

(3)/(2)

$$2.5 = \frac{p(1.5)}{5} \quad (4)$$

$$p = 8.33\ Pa \quad (5)$$

Q.2 A constant temperature anemometer is applied to determine water flow rate at a point in a water pipe. When the water flow rate is 0.2 m/s, the voltage across R_2 with the balanced bridge circuit is measured at 2.4 V. When the water flow rate is 45 m/s, the voltage across R_2 with the balanced bridge circuit is measured at 3.2 V. Determine the water flow rate if the voltage across R_2 with the balanced bridge circuit is measured at 2.5 V. (20)



Solution

The volume flow rate of constant temperature anemometer is determined from,

$$V = C_0\left[\left(\frac{I}{I_0}\right)^2 - 1\right]^2 = C_0\left[\left(\frac{E}{E_0}\right)^2 - 1\right]^2 \tag{1}$$

At 0.2 m/s flow rate,

$$0.2 = C_0\left[\left(\frac{2.4}{E_0}\right)^2 - 1\right]^2 \tag{2}$$

At 45 m/s flow rate,

$$45 = C_0\left[\left(\frac{3.2}{E_0}\right)^2 - 1\right]^2 \tag{3}$$

(3)/(2),

$$\frac{45}{0.2} = \left[\frac{\left(\frac{3.2}{E_0}\right)^2 - 1}{\left(\frac{2.4}{E_0}\right)^2 - 1}\right]^2 = \left[\frac{(3.2)^2 - E_0^2}{(2.4)^2 - E_0^2}\right]^2 \tag{4}$$

$$E_0 = 2.33\ V \tag{5}$$

When the voltage across R_2 is 2.5 V,

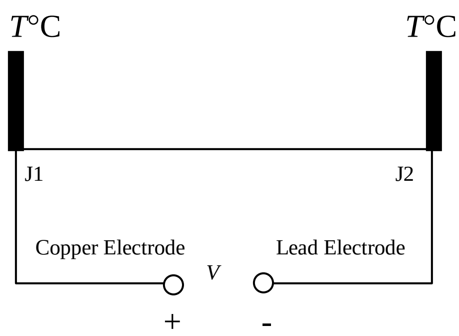
$$\frac{x}{0.2} = \left[\frac{2.5^2 - 2.33^2}{2.4^2 - 2.33^2}\right]^2 \tag{6}$$

$$x = 0.5\ m/s \tag{7}$$

Q.3 A thermocouple is used to determine unknown temperature. When the temperatures at both junctions, *T*, are the same at 60 °C, the voltage output, *V*, is 300 mV and when the temperatures at both junctions, *T*, are 80 °C, the voltage output, *V*, is 450 mV.

(a) Determine the unknown temperature at both junctions when the voltage output becomes 500 mV. (10)

(a) Determine the voltage output when both junctions are kept at 0°C. (10)



Solution

Voltage output in the first condition follows,

$$300 = S_1(60) + C_1 + S_2(60) + C_2 = (S_1 + S_2)(60) + (C_1 + C_2) \tag{1}$$

Voltage output in the second condition follows,

$$450 = S_1(80) + C_1 + S_2(80) + C_2 = (S_1 + S_2)(80) + (C_1 + C_2) \tag{2}$$

(2)-(1),

$$150 = (S_1 + S_2)(20) \tag{3}$$

$$(S_1 + S_2) = 7.5\ mV/°\mathrm{C} \tag{4}$$

Substitute (4) into (1)

$$300 = 7.5(60) + (C_1 + C_2) \tag{5}$$

$$(C_1 + C_2) = -150\ mV \tag{6}$$

(a) Voltage output in the third condition follows,

$$500 = S_1(T) + C_1 + S_2(T) + C_2 = (S_1 + S_2)(T) + (C_1 + C_2) \tag{7}$$

(7)-(1),

$$200 = 7.5(T - 60) \tag{8}$$

$$T = 86.67\ °\mathrm{C} \tag{9}$$

(b) At 0°C,

$$V = (S_1 + S_2)(0) + (C_1 + C_2) = -150\ mV \tag{10}$$

Q.4 Optical pyrometer is used to determine temperature of an unknown object. Determine the material of the object based on the emissivity of material at 0.65 μm wavelength as shown in below table, if equal intensity is achieved when the temperature of the pyrometer made of tungsten is 500 °C and the object temperature is 552°C. (20)

Material	Solid	Liquid	Material	Solid	Liquid
Beryllium	0.61	0.61	Thorium	0.36	0.40
Carbon	0.80–0.93	—	Titanium	0.63	0.65
Chromium	0.34	0.39	Tungsten	0.43	—
Cobalt	0.36	0.37	Uranium	0.54	0.34
Columbium	0.37	0.40	Vanadium	0.35	0.32
Copper	0.10	0.15	Zirconium	0.32	0.30
Iron	0.35	0.37	Steel	0.35	0.37
Manganese	0.59	0.59	Cast Iron	0.37	0.40
Molybdenum	0.37	0.40	Constantan	0.35	—
Nickel	0.36	0.37	Monel	0.37	—
Platinum	0.30	0.38	90 Ni–10 Cr	0.35	—
Rhodium	0.24	0.30	80 Ni–20 Cr	0.35	—
Silver	0.07	0.07	60 Ni–24 Fe–16 Cr	0.36	—
Tantalum	0.49	—			

Solution

When the intensities are equal,

$$\frac{\varepsilon_u C_1}{\lambda^5\left(e^{C_2/(\lambda T_u)}-1\right)} = \frac{\varepsilon_t C_1}{\lambda^5\left(e^{C_2/(\lambda T_t)}-1\right)} \quad (1)$$

$$\varepsilon_u = \frac{0.43(e^{(1.44\times10^{-2})/(0.65\times10^{-6}\times825)}-1)}{e^{(1.44\times10^{-2})/(0.65\times10^{-6}\times773)}-1} = 0.07 \quad \underline{(2)}$$

From the table, silver has the closest emissivity. Thus, the object is made of silver.

Q.5 Determine the required power, P, in W from the motor of an electrical vehicle in order to increase the speed at constant acceleration from the rest position to 120 km/h in 10 seconds when the total mass of the vehicle is 500 kg and coulomb friction at all the joints is 100 N. (20)

Solution

The acceleration is determined.

$$a = \frac{120\times1000}{3600\times10} = 3.33\ m/s^2 \quad (1)$$

The power is maximum at the maximum speed.

$$P = (ma + f_{coulomb})v \quad (2)$$

$$P = (500 \times 3.33 + 100)\frac{120\times1000}{3600} = 58827\ W \quad \underline{(3)}$$

$$P = 25.66 sin\theta + 3.93 \quad \underline{(4)}$$

$$P_{max} = 29.59\ W, P_{max} = -21.73\ W \quad \underline{(5)}$$