First Semester Examination
2022/2023 Academic Session

February 2023

EMC 301 – Measurement & Instrumentation
(Pengukuran & Instrumentasi)

Duration: 3 hours
(Masa: 3 jam)

Please check that this examination paper consists of EIGHT (8) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LAPAN (8) muka surat yang bercetak sebelum anda memulakan peperiksaan ini].

Instructions : Answer **ALL FIVE (5)** questions.

*[**Arahan :** Jawab **KESEMUA LIMA (5)** soalan.]*

Appendix A: Student's t-Distribution

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1. [a] With suitable sketches, illustrate the difference between single-point and multi-point calibration (no explanation is required). State ONE (1) condition under which single-point calibration would be sufficient.

(20 marks)

[b] Table 1[b] shows the deflection/load characteristics of a spring-based weighing scale when it is calibrated in an environment with a temperature of 25°C and when it is used in an environment with a temperature of 35°C.

Table 1[b]

Load / *beban* (kg)	Deflection at / *pesongan pada* 25°C (mm)	Deflection at / *pesongan pada* 35°C (mm)
0	0	4
1	20	26
2	40	48
3	60	69
4	80	92
5	100	114

Based on the information given in Table 1b,

(i) Identify TWO (2) errors that might exist when the weighing scale is used at a temperature of 35°C.

(ii) Determine the measurement errors as identified in (i) separately.

(iii) Estimate the total error when the spring balance produces a deflection of 80 mm at a temperature of 35°C.

(45 marks)

[c] You as an instrumentation engineer is going to measure a cyclic pressure with variation of 0.25 kHz in a gas storage tank. You are given a line of pressure transducers with a fixed natural frequency of 0.60 kHz but with a range of damping ratios, ranging from 0.5 to 1.0 in increments of 0.05. Assuming that the transducer is a second order system, select a suitable pressure transducer for the application. The dynamic error of the measurement shall be less than 2%. The solution of the underdamped second-order system is expressed as:

$$\frac{P_d}{P_s} = \frac{1}{\sqrt{[1-(\Omega/\omega_n)^2]^2 + [2\xi(\Omega/\omega_n)]^2}}$$

…3/-

where, P_d/P_s is the amplification ratio of the system; Ω is the excitation frequency; ξ = damping ratio; ω_n = natural frequency of the system

(35 marks)

2. [a] Briefly explain why the standard deviation is not a good estimate to the accuracy of a measurement system in comparison to an uncertainty estimation.

(20 marks)

[b] Centrifugal force, F in a rotating system can be related to the angular velocity, ω through the formula $F = mr\omega^2$, where m is the mass of the rotating weight and r is the radius of rotation of the system. In an experiment, the following values are measured using appropriate methods each to determine angular velocity.

$r = 25 \pm 0.02$ mm
$m = 120 \pm 0.5$ g
$F = 600 \pm 0.2\%$ N

Hence,

(i) determine the rotational speed in rpm and its uncertainty.

(ii) identify which measurement contribute the most to the uncertainty in rotational speed and deserved the first attention to improve the accuracy of the rotational speed measurement. Justify your answer.

(*Note: All measured values shall have a confidence level of 95 % and 1 rpm = 2π/60 rads^{-1}*)

(30 marks)

[c] A quality control engineer in a 3-in-1 coffee mix packaging company needs to ensure every single sachet of the coffee mix to be filled with a consistent net weight of no less than 40 g. However, the surrounding temperature and humidity in the production floor, as well as the inconsistent moisture content of the incoming materials always impose uncertainty to the final weight of sachets. To ensure no customer complaint, the engineer set a nominal weight of a sachet as 40.5 g inclusive the plastic weight of the sachet. Weights of sachet are always monitored in daily production. Table 2(c) below shows weight samples of coffee mix sachet collected in a batch of production.

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Table 2[c]

Sample ID / *ID sampel*	Sample size / *saiz sampel*, n	Mean / *purata*, x (g)
0001	7	40.3
0002	9	40.5
0003	6	40.1
0004	3	39.5

(All uncertainties should be assumed to 95% of coverage.)

(i) Identify all factors that contribute to the weight deviation in coffee mix sachets as described in the above situation. Hence, classify them into bias and precision errors.

(ii) If the plastic weight is 0.25g, based on Table 2[c], should the engineer accept the batch of the coffee mix sachets to be delivered?

(50 marks)

3. [a] State the classification of first stage devices and give TWO (2) examples of primary detector-transducer elements.

(25 marks)

[b] Explain the working principle for the listed sensors below. Suggest ONE (1) application that is suitable for each sensor.

(i) Potentiometer
(ii) Inductive loop detector

(35 marks)

[c] A capacitive transducer consists of two parallel plates of diameter 2 cm each and separated by an air gap of 0.25 mm as shown in Figure 3[c]. Calculate the displacement sensitivity.

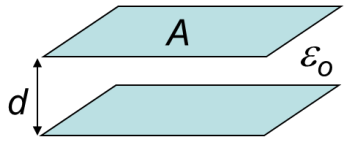

Figure 3[c]

(40 marks)

4. [a] (i) Construct a frequency spectrum with harmonics up to 7th harmonics for Figure 4[a](i).

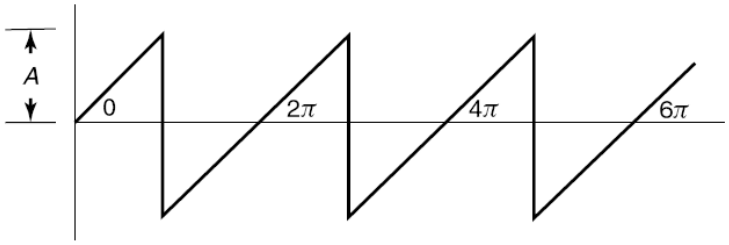

Figure 4(a](i)

(30 marks)

(i) With the help of sketch, define aliasing and suggest TWO (2) methods to solve the aliasing problem.

(20 marks)

[b] (i) Figure 4[b](i) shows the circuit diagram of an Op-amp differentiator. Derive an expression for the output voltage e_o in terms of the input voltages e_i, the resistance R and capacitance C as shown in the figure.

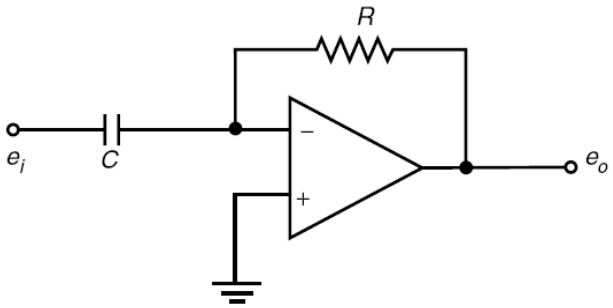

Figure 4[b](i)

(20 marks)

(ii) Plot the output waveform of the Op-amp differentiator in Figure 4[b](i) if the input waveform is a triangular waveform as shown in Figure 4[b](ii), given that the R = 10 $k\Omega$ and C = 0.1 nF.

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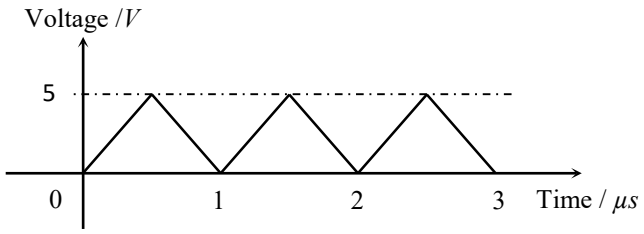

Figure 4(b)(ii)

(30 marks)

5. [a] Construct the truth table for the logic circuit shown in Figure 5[a] and show which input will cause a low output.

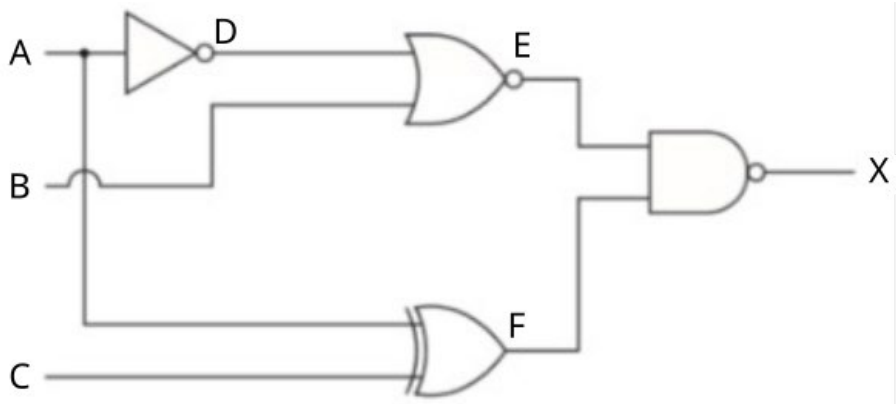

Figure 5[a]

(30 marks)

[b] The Digital to Analog Converter (DAC) of Figure 5[b] is required to give an output voltage in the range of 0 to 2.55 V, corresponding to an 8-bit digital input signal 00000000 to 11111111.

(i) Assuming V_{REF} = -15 V, R= 1 kΩ, calculate the value of R_F required.

(ii) Determine the output voltage corresponding to an input signal of 11000101.

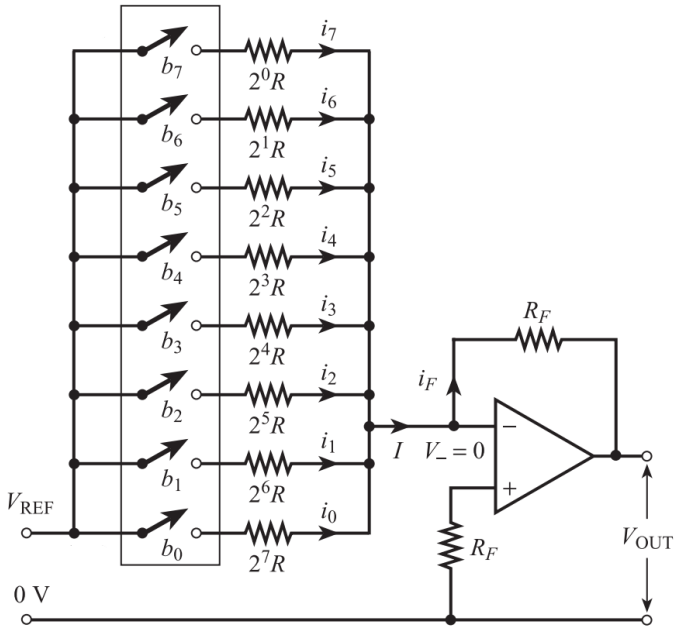

Figure 5[b]

(50 marks)

[c] Every Arduino sketch includes void setup() and void loop().

(i) Briefly explain the difference between void setup() and void loop().

(ii) In the list of statements below, identify which statement should be written in the void setup() and void loop().

pinMode()
digitalWrite()
Serial.print()
Serial.begin()

(20 marks)

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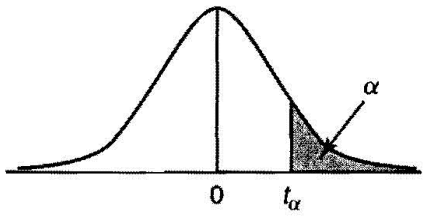
Student's t-Distribution (Values of $t_{\alpha,\nu}$)



ν	$t_{0.10,\nu}$	$t_{0.05,\nu}$	$t_{0.025,\nu}$	$t_{0.01,\nu}$	$t_{0.005,\nu}$	ν
1	3.078	6.314	12.706	31.821	63.657	1
2	1.886	2.920	4.303	6.965	9.925	2
3	1.638	2.353	3.182	4.541	5.841	3
4	1.533	2.132	2.776	3.747	4.604	4
5	1.476	2.015	2.571	3.365	4.032	5
6	1.440	1.943	2.447	3.143	3.707	6
7	1.415	1.895	2.365	2.998	3.499	7
8	1.397	1.860	2.306	2.896	3.355	8
9	1.383	1.833	2.262	2.821	3.250	9
10	1.372	1.812	2.228	2.764	3.169	10
11	1.363	1.796	2.201	2.718	3.106	11
12	1.356	1.782	2.179	2.681	3.055	12
13	1.350	1.771	2.160	2.650	3.012	13
14	1.345	1.761	2.145	2.624	2.977	14
15	1.341	1.753	2.131	2.602	2.947	15
16	1.337	1.746	2.120	2.583	2.921	16
17	1.333	1.740	2.110	2.567	2.898	17
18	1.330	1.734	2.101	2.552	2.878	18
19	1.328	1.729	2.093	2.539	2.861	19
20	1.325	1.725	2.086	2.528	2.845	20
21	1.323	1.721	2.080	2.518	2.831	21
22	1.321	1.717	2.074	2.508	2.819	22
23	1.319	1.714	2.069	2.500	2.807	23
24	1.318	1.711	2.064	2.492	2.797	24
25	1.316	1.798	2.060	2.485	2.787	25
26	1.315	1.706	2.056	2.479	2.779	26
27	1.314	1.703	2.052	2.473	2.771	27
28	1.313	1.701	2.048	2.467	2.763	28
29	1.311	1.699	2.045	2.462	2.756	29
∞	1.282	1.645	1.960	2.326	2.576	∞