UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2014/2015

December 2014 / January 2015

EMC 201 – Measurement & Instrumentation
[Pengukuran & Peralatan]

Duration : 3 hours
Masa : 3 jam

Please check that this paper contains **NINE** printed pages, **TWO** pages appendix and **FIVE** questions before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **SEMBILAN** mukasurat, **DUA** mukasurat lampiran dan **LIMA** soalan yang bercetak sebelum anda memulakan peperiksaan.]*

Appendix/*Lampiran :*

1. Student's *t*-Distribution (Values of $t_{\alpha,v}$) [1 page/*mukasurat*]

2. Voltage E in Millivolts versus Temperature T_m for Type K Thermocouples Having Reference Junctions at T_{ref} = 0°C

[1 page/*mukasurat*]

INSTRUCTIONS : Answer **ALL** questions.
*[**ARAHAN** : Jawab **SEMUA** soalan.]*

Answer questions in English OR Bahasa Malaysia.
[Jawab soalan dalam Bahasa Inggeris ATAU Bahasa Malaysia.]

Answer to each question must begin from a new page.
[Jawapan bagi setiap soalan mestilah dimulakan pada mukasurat yang baru.]

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

Q1. [a] With a suitable sketch, describe the process of measurement. Then, explain the significance of measurement in engineering experimentation.

Dengan lakaran yang sesuai, terangkan proses pengukuran. Kemudian, terangkan kepentingan pengukuran dalam eksperimen kejuruteraan.

(20 marks/*markah***)**

[b] A calibration process is carried out on a mercury-in-glass thermometer by placing the thermometer in a beaker of water and heating it up, from room temperature, 25°C, to 70°C. The water is then allowed to cooling down to the room temperature. The true temperature is measured with a high accuracy instrument in every change of 5°C. The corresponding temperature indicated by the thermometer is recorded.The data collection process is repeated for 5 cycles and the recorded temperature readings are summarizedin Table Q1[b].

Proses penentu-ukuran dijalankan pada jangka suhu merkuri-dalam-kaca dengan meletakkan jangka suhu ini di dalam satu bikar berair dan dipanaskan, daripada suhu bilik, 25°C kepada 70°C. Air tersebut kemudian dibenarkan untuk menyejuk ke suhu bilik. Suhu sebenar diukur dengan peralatan berketepatan tinggi dalam setiap perubahan 5°C. Suhu sepadan yang ditunjukkan oleh jangka suhu itu direkodkan. Proses pengumpulan data diulangi sebanyak 5 kitaran dan bacaan suhu dicatatkan diringkaskan dalam Jadual S1[b].

No. / *Bil.*	**True temperature /** *Suhusebenar***(°C)**	**Indicated temperature for 5 cycles /** *Suhutertunjukuntuk 5 kitran***(°C)**		
		Average / *purata*	**Maximum/** *Maksimum*	**Minimum /** *Minumum*
1	**25**	**24.8**	**26.0**	**24.6**
2	**30**	**31.4**	**32.0**	**29.8**
3	**35**	**36.8**	**38.6**	**35.6**
4	**40**	**42.5**	**43.1**	**40.8**
5	**45**	**47.4**	**48.6**	**46.3**
6	**50**	**52.4**	**53.5**	**51.5**
7	**55**	**57.8**	**58.1**	**56.2**
8	**60**	**62.6**	**63.3**	**60.9**
9	**65**	**66.6**	**68.0**	**65.6**
10	**70**	**70.2**	**70.5**	**69.9**
11	**65**	**65.4**	**66.4**	**64.3**
12	**60**	**59.2**	**60.1**	**58.4**
13	**55**	**54.6**	**54.8**	**53.8**
14	**50**	**49.2**	**50.7**	**47.2**
15	**45**	**43.5**	**44.1**	**41.9**
16	**40**	**38.5**	**38.9**	**37.6**
17	**35**	**34.0**	**35.6**	**32.4**
18	**30**	**29.5**	**29.7**	**28.9**
19	**25**	**25.0**	**26.4**	**24.9**

Table Q1[b]
JadualQ1[b]

Given that the best fit line plotted between the indicated temperature, *Y* and true temperature, *X* is expressed by the equation below:

Diberikan bahawa garisan paling padan diplot di antara suhu tertunjuk, Y dan suhu sebenar, X boleh dinyatakan oleh persamaan di bawah:

$$\boldsymbol{Y = 1.0134X}$$

Prepare suitable deviation plots and estimate

Sediakan plot sisihan yang sesuai dan anggarkan

(i) Accuracy as a percentage of the output span

Ketepatan sebagai peratusan daripada rentang output

(ii) Repeatability error as a percentage of the output span

Ralat kebolehulangan sebagai peratusan daripada rentang output

(iii) Hysteresis error as a percentage of the output span

Ralat histerisis sebagai peratusan daripada rentang output

(iv) Linearity erroras a percentage of the output span

Ralat kelinearan sebagai peratusan daripada rentang output

(80 marks/*markah***)**

Q2. [a] State THREE main stages constituting a generalized measurement system. Hence describe the primary function of each stage.

Nyatakan TIGA peringkat utama yang membentuk sistem pengukuran umum. Seterusnya huraikan fungsi utama setiap peringkat.

(15marks/*markah***)**

[b] Figure Q2[b] shows a circuit diagram of a differential amplifier.

Rajah S2[b] menunjukkan satu gambarajah litar bagi penguat pembezaan.

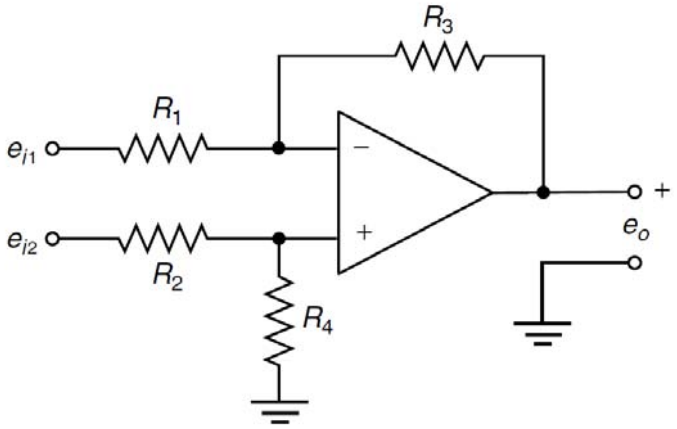

Figure Q2[b]
Rajah S2[b]

[i] Obtain an expression for the gain of the amplifier in terms of the output voltage e_o, the input voltages e_{i1}, and e_{i2} and the resistances $R_1$and R_3 shown in the figure. Given that $R_1 = 2R_2$ and $R_3 = 2R_4$

Dapatkan ungkapan bagi gandaan penguat ini dalam sebutan voltan keluaran e_o, voltan masukan e_{i1} dan e_{i2} dan rintangan R_1 dan R_3 yang ditunjukkan dalam rajah tersebut. Diberikan bahawa $R_1 = 2R_2$dan $R_3 = 2R_4$.

[ii] Given that R_1 = 1000 Ω and R_3 = 1500 MΩ. Determine the gain of the amplifier shown in Figure Q2[b].

Diberikan bahawa R_1 = 1000 Ω dan R_3 = 1500 MΩ. Tentukan gandaan penguat yang ditunjukkan dalam Rajah S2[b].

(45marks/*markah***)**

[c] The output signal from a thermistoris is expected to vary from 0.3 mV to 1.5 mV. If the signal is fed to a 12-bit single slope A/D converter having a ± 5.0 V range,

Isyarat keluaran daripada termistor dijangka boleh berubah daripada 0.3 mV kepada 1.5 mV. Jika isyarat ini dibekal kepada penukar A/D bercerun tunggal 12-bit yang mempunyai julat ± 5.0 V,

[i] Estimate the gain that the signal from the thermistor should be amplified. You have a choice of amplifier gains between 1000 and 10000 in increment of 1000.
Anggarkan gandaan yang perlu supaya isyarat dari termistor ini diamplifikasikan. Anda mempunyai pilihan gandaan penguat antara 1000 hingga 10000 dalam setiap pertambahan sebanyak 1000.

[ii] Calculate the voltage increment represented by least significant bit (LSB)
Hitungkan kenaikan voltan yang diwakili oleh bit terkurang bererti (LSB)

[iii] Compute the digital output for the input of 0.5 mV if the output code is offset binary.
Kirakan output digital untuk input sebanyak 0.5 mV kalau kod keluar adalah binary 'offset'

[iv] Determine the maximum input resolution errorthat might exist
Tentukan ralat input resolusi maksimum yang mungkin wujud

(40marks/*markah***)**

Q3. [a] Explain the phenomena of aliasing when an analog waveform is recorded by discrete sampling.

Terangkan fenomena pengaliasan apabila satu gelombang analog direkodkan dengan pensampelan diskrit.

(5 marks/*markah***)**

[b] Determine the lowest expected alias frequency when a 1000 Hz sine wave signal is sampled at 1500 Hz. Hence, suggest the minimum sampling frequency so that aliasing can be avoided.

Tentukan frekuensi alias yang dijangka terendah apabila isyarat gelombang sinus 1000 Hz disampel pada 1500 Hz. Seterusnya, cadangkan frekuensi pensampelan minimum supaya pengaliasan boleh dielakkan.

(15 marks/*markah***)**

[c] An analog signal can be approximated by the following equation:

Satu isyarat analog boleh dijangka oleh persamaan berikut:

$$y = \frac{15}{\pi}\sum_{n=1}^{\infty}\left[\frac{1}{2n-1}\sin(2n-1)\omega t\right]$$

Prepare the frequency spectrum up to the 9th harmonic.
Sediakan spektrum frekuensi sehingga harmonik ke-9.

[i] If ω =25 Hz, determine the minimum sample rate f_s and the number of points N recorded so that the analog signal can be accurately resolved up to the 9th harmonic.

Jika ω = 25 Hz, tentukan kadar pensampelan f_s minimum dan bilangan titik N untuk direkodkan supaya isyarat analog ini boleh diuraikan dengan jitunya sehingga harmonik ke-9.

(30 marks/*markah***)**

[d] Explain the difference between resolution and sensitivity. Why a more sensitive instrument need to have higher resolution compared to a less sensitive instrument?

Terangkan perbezaan antara resolusi dan kepekaan. Kenapakah alatan yang lebih peka perlu mempunyai resolusi yang lebih tinggi berbanding dengan alatan yang kurang peka?

(10 marks/*markah***)**

[e] The temperature in a steam pipeline was measure at every 5 minutes over a period of one hour and the following readings (in °C) were obtained:

287.5 288.2 286.5 290.4 287.0 286.4
289.2 291.5 290.3 286.0 288.6 292.5

[i] Determine the uncertainty in the true mean temperature for a confidence level of 95%.

[ii] If an additional six readings are taken as given below, determine the new value of uncertainty at the same confidence level of 95%. Does the uncertainty increase or decrease? Explain.

282.6 288.0 290.8 290.0 284.6 291.7

Suhu di dalam paip stim diukur pada setiap 5 minit dalam jangka masa satu jam dan bacaan-bacaan berikut (dalam ℃) didapati:

287.5 288.2 286.5 290.4 287.0 286.4
289.2 291.5 290.3 286.0 288.6 292.5

[i] Tentukan ketakpastian pada suhu purata sebenar bagi paras keyakinan 95%.

[ii] Jika enam bacaan tambahan diambil, tentukan nilai ketakpastian baru pada paras keyakinan 95%. Adakah nilai ketakpastian bertambah atau menurun. Terangkan.

282.6 288.0 290.8 290.0 284.6 291.7

(40 marks/*markah***)**

Q4. [a] What is meant by thermoelectric (Seebeck) effect? A type *K* thermocouple was used to measure the temperature of an engine block. The reference temperature is 32°C. Determine the temperature of the engine block if the e.m.f. measured is 1.785 mV. If the reference temperature drops to 25°C, what will be the e.m.f. measured? Assume that temperature of the engine block does not change.

Apakah yang dimaksudkan dengan kesan termoelektrik (Seebeck)? Pengganding suhu jenis K digunakan untuk mengukur suhu dalam blok enjin. Suhu rujukan ialah 32℃. Tentukan suhu blok enjin tersebut jika d.g.e. yang diukur ialah 1.785 mV. Jika suhu rujukan menurun kepada 25℃, apakah nilai d.g.e. yang diukur? Anggapkan bahawa suhu blok enjin tidak berubah.

(30 marks/*markah***)**

[b] Figure Q4[b] shows a resistance bridge circuit used in strain measurement.

Rajah S4[b] menunjukkan litar tetimbang rintangan yang digunakan dalam pengukuran terikan.

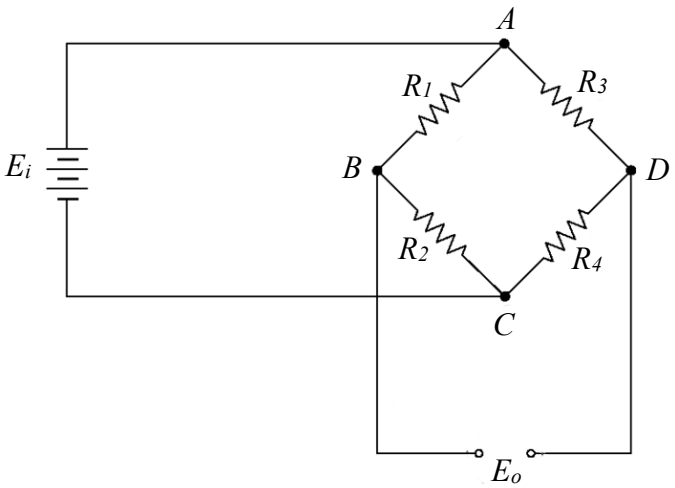

Figure Q4[b]
Rajah S4[b]

[i] Obtain an expression for the output voltage E_o. Hence, show that the bridge is balanced when

Dapatkan suatu ungkapan bagi voltan output E_o. Seterusnya, tunjukkan bahawa tetimbang tersebut seimbang apabila

$$\frac{R_1}{R_3} = \frac{R_2}{R_4}$$

[ii] If all resistances are equal and R_2 represents the resistance of a strain gage whose resistance changes by δR, show that the change in output voltage δE_o is given by

Jika semua rintangan adalah sama dan R_2 mewakili rintangan tolok terikan di mana nilai rintangannya berubah sebanyak δR, tunjukkan bahawa perubahan voltan output δE_o diberikan oleh

$$\delta E_o = \frac{\delta R/R}{4 + 2(\delta R/R)} E_i$$

[iii] If the strain gage in part (ii) has a gage factor of 2.0 and experiences a strain of 100 μ-strain, determine the change in the output voltage. Given that the input voltage E_i is 12 V.

Jika tolok terikan dalam (ii) mempunyai faktor tolok 2.0 dan mengalami nilai terikan 100 μ-terikan, tentukan perubahan voltan output. Diberikan bahawa voltan masukan E_i ialah 12 V.

(70 marks/*markah***)**

Q5. [a] Explain how the use of a denser measuring fluid can increase the pressure range of a simple U-tube manometer.

Terangkan bagaimana penggunaan bendalir mengukur yang lebih tumpat boleh menambahkan julat tekanan pada sebuah manometer tiub-U mudah.

(5 marks/*markah***)**

[b] Figure Q5[b] shows a manometer that uses mercury as the working fluid. The manometer is used to measure the differential pressure across an orifice plate in a pipeline of diameter D at points P_1 and P_2. The density of the fluid in the pipeline is ρ_f, where as the density of mercury is ρ_m.

Rajah S5[b] menunjukkan sebuah manometer yang menggunakan raksa sebagai bendalir kerja. Manometer tersebut digunakan untuk mengukur tekanan kebezaan melintasi plat orifis di dalam paip bergaris pusat D pada titik P_1 dan P_2. Ketumpatan bendalir di dalam paip ialah ρ_f, manakala ketumpatan raksa ialah ρ_m.

[i] Obtain an expression for the differential pressure ΔP, given by $P_1 - P_2$, if the difference in the mercury level in the two arms of the manometer is h.

Dapatkan suatu ungkapan bagi tekanan kebezaan ΔP, diberikan oleh $P_1 - P_2$, jika perbezaan paras raksa dalam kedua-dua lengan ialah h.

[ii] Determine the differential pressure ΔP in N/m^2 if ρ_f = 850 kg/m^3, ρ_m = 13600 kg/m^3, D = 200 mm, d = 100 mm, h = 60 mm and g = 9.81 m/s^2.

Tentukan tekanan kebezaan ΔP dalam N/m^2 jika ρ_f = 850 kg/m^3, ρ_m = 13600 kg/m^3, D = 200 mm, d = 100 mm, h = 60 mm dan g = 9.81 m/s^2.

[iii] Recalculate the differential pressure if the density of the fluid ρ_f in the pipeline is neglected. What is the % error introduced if ρ_f is neglected?

Kira semula tekanan kebezaan jika ketumpatan bendalir ρ_f di dalam paip diabaikan. Apakah % ralat yang diperkenalkan jika ρ_f diabaikan?

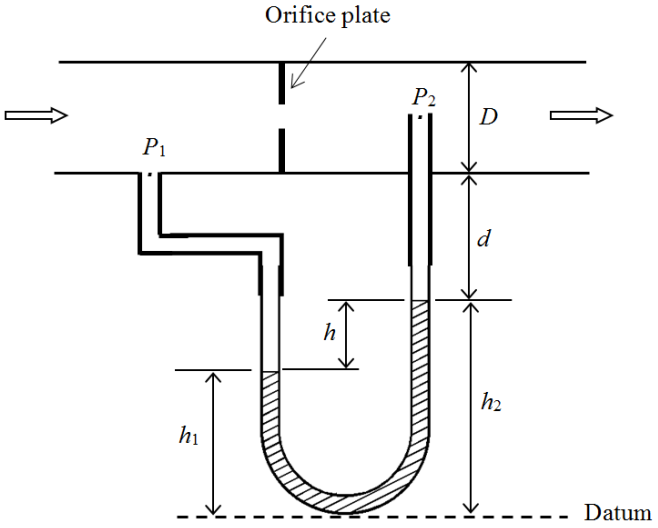

Figure Q5[b]
Rajah S5[b]

(55 marks/*markah***)**

[c] With the aid of sketches, explain the basic principles of the following types of flow meters:

[i] Coriolis flow meter
[ii] Vortex shedding flow meter
[iii] Ultrasonic flow meter
[iv] Variable area flow meter

Dengan bantuan lakaran, terangkan prinsip asas bagi setiap meter aliran berikut:

[i] Meter aliran 'Coriolis'
[ii] Meter aliran 'vortex shedding'
[iii] Meter aliran ultrasonic
[iv] Meter aliran luas berubah.

(40 marks/*markah***)**

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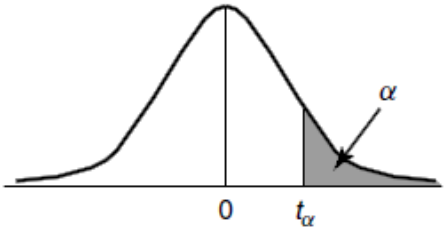
APPENDIX 1/*LAMPIRAN 1*

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

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



v	$t_{0.10,v}$	$t_{0.05,v}$	$t_{0.025,v}$	$t_{0.01,v}$	$t_{0.005,v}$	v
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

APPENDIX 2/*LAMPIRAN 2*

Voltage E in Millivolts versus Temperature T_m for Type K Thermocouples Having Reference Junctions at $T_{\text{ref}} = 0°\text{C}$

	Type K				
°C	0	5	10	15	20
−200	−5.891	−5.813	−5.730	−5.642	−5.550
−175	−5.454	−5.354	−5.250	−5.141	−5.029
−150	−4.913	−4.793	−4.669	−4.542	−4.411
−125	−4.276	−4.138	−3.997	−3.852	−3.705
−100	−3.554	−3.400	−3.243	−3.083	−2.920
−75	−2.755	−2.587	−2.416	−2.243	−2.067
−50	−1.889	−1.709	−1.527	−1.343	−1.156
−25	−0.968	−0.778	−0.586	−0.392	−0.197
0	0.000	0.198	0.397	0.597	0.798
25	1.000	1.203	1.407	1.612	1.817
50	2.023	2.230	2.437	2.644	2.851
75	3.059	3.267	3.474	3.682	3.889
100	4.096	4.303	4.509	4.715	4.920
125	5.124	5.328	5.532	5.735	5.937
150	6.138	6.340	6.540	6.741	6.941
175	7.140	7.340	7.540	7.739	7.939
200	8.139	8.338	8.539	8.739	8.940
225	9.141	9.343	9.545	9.747	9.950
250	10.153	10.357	10.561	10.766	10.971
275	11.176	11.382	11.588	11.795	12.002