UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2007/2008
Peperiksaan Semester Pertama
Sidang Akademik 2007/2008

October / November 2007
Oktober / November 2007

EMC 201/3 – Measurement and Instrumentation
Pengukuran & Peralatan

Duration : 3 hours
Masa : 3 jam

INSTRUCTIONS TO CANDIDATE:
ARAHAN KEPADA CALON:

Please check that this paper contains **NINE (9)** printed pages, **ONE (1)** page appendix and **SIX (6)** questions before you begin the examination.
Sila pastikan bahawa kertas soalan ini mengandungi ***SEMBILAN (9)*** *mukasurat bercetak,* ***SATU (1)*** *mukasurat lampiran dan* ***ENAM (6)*** *soalan sebelum anda memulakan peperiksaan.*

Answer **FIVE (5)** questions.
Jawab ***LIMA (5)*** *soalan.*

Answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.
Calon boleh menjawab semua soalan dalam ***Bahasa Malaysia*** *ATAU* ***Bahasa Inggeris*** *ATAU kombinasi kedua-duanya.*

Each question must begin from a new page.
Setiap soalan mestilah dimulakan pada mukasurat yang baru.

Appendix/*Lampiran*:

1. Students t – Distribution Table [1 page/*mukasurat*]

Q1. [a] State the condition under which the Student's t-distribution is used to find the uncertainty in the mean value of a population.

Nyatakan syarat penggunaan taburan-t Student untuk mencari ketakpastian dalam nilai purata bagi suatu populasi.

(15 markah)

[b] If the quantity $t_{\alpha/2,v}$ in the t-distribution is defined by the following equation, write an expression for the two-sided confidence interval for the mean μ of a population:

$$t_{\alpha/2,v} = \frac{\bar{x} - \mu}{S_x / \sqrt{n}}$$

where $\alpha = 1 - c$ **(c = level of confidence)**
$v = n - 1$ **(n = number of samples)**
$\bar{x}$ **= sample mean**
S_x **= sample standard deviation**

Jika kuantiti $t_{\alpha/2,v}$ dalam taburan-t ditakrifkan oleh persamaan berikut, tulis ungkapan untuk sela keyakinan dua-belah bagi purata μ suatu populasi.

$$t_{\alpha/2,v} = \frac{\bar{x} - \mu}{S_x / \sqrt{n}}$$

di mana $\alpha = 1 - c$ *(c = aras keyakinan)*
$v = n - 1$ *(n = bilangan sampel)*
$\bar{x}$ *= purata sampel*
S_x *= sisihan piawai sampel*

(15 markah)

[c] In a laboratory testing of a thin-walled pressure vessel, the cylindrical diameter D and thickness T were measured at 12 diffferent locations. The resulting data are as follows:

Mean diameter, $\bar{D} = 260.4$ mm
Standard deviation of diameter, S_D = 6.4 mm
Mean thickness, $\bar{T} = 4.2$ mm
Standard deviation of thickness, S_T = 0.8 mm

If the pressure P inside the vessel is measured to be 689 kPa with an uncertainty of ±5 kPa, determine, for 90% confidence level, the percentage uncertainty in the measurement of the hoop stress σ_θ in the vessel given by

$$\sigma_\theta = \frac{PD}{2T}$$

...3/-

Dalam suatu ujian makmal ke atas balang tekanan berdinding nipis, garispusat silinder D dan ketebalan T diukur pada 12 lokasi yang berbeza. Data yang terhasil adalah seperti berikut:

Garispusat purata, $\overline{D} = 260.4$ mm
Sisihan piawai garispusat, $S_D = 6.4$ *mm*
Ketebalan purata, $\overline{T} = 4.2$ mm
Sisihan piawai ketebalan, $S_T = 0.8$ *mm*

Jika tekanan P di dalam balang tersebut diukur sebagai 689 kPa dengan ketakpastian ±5 kPa, tentukan, bagi aras keyakinan 90%, peratus ketakpastian dalam pengukuran tegasan gegelang σ_θ *di dalam balang yang diberikan oleh:*

$$\sigma_\theta = \frac{PD}{2T}$$

(70 markah)

Q2. [a] Explain the following terms relating to sampling of data from a complex signal:

(i) Sample rate
(ii) Sampling interval
(iii) Nyquist frequency
(iv) Aliasing
(v) Frequency resolution

Write down the relationship between the Nyquist frequencey f_{Nyq} and samping interval Δt.

A temperature measuring circuit responds fully to frequencies below 5.5 kHz. Above this frequency the circuit attenuates the signal. This circuit is to be used to measure a temperature signal with unknown frequency spectrum. Accuracy of ±1 Hz is required in the frequency components. If no frequency components above 5.5 kHz are present in the signal, determine (i) the Nyquist frequency, (ii) sample rate, (iii) frequency resolution and (iv) number of samples required to sample the output signal.

Terangkan sebutan-sebutan berikut yang berkaitan dengan pensampelan data daripada isyarat kompleks:

(i) Kadar sampel
(ii) Julat pensampelan
(iii) Frekuensi Nyquist
(iv) 'Aliasing'
(v) Resolusi frekuensi

Tuliskan hubungkait antara frekuensi Nyqyist f_{Nyq} dengan julat pensampelan Δt.

Litar mengukur suhu menyambut sepenuhnya kepada frekuensi-frekuensi di bawah 5.5 kHz. Ke atas frekuensi ini litar tersebut merendahkan isyarat. Litar tersebut perlu digunakan untuk mengukur isyarat suhu dengan spektrum frekuensi yang tidak diketahui. Kejituan sebanyak ±1 Hz diperlukan dalam komponen-komponen frekuensi. Jika tiada komponen frekuensi lebih daripada 5.5 kHz wujud dalam isyarat tersebut, tentukan (i) frekuensi Nyquist, (ii) kadar sampel, (iii) resolusi frekuensi dan (iv) bilangan sampel yang diperlukan untuk mensampel isyarat keluaran.

(60 markah)

[b] **What is the main difference between a first-order and a second-order measurement systems?**

A mercury in glass thermometer (assumed to be a first-order system) initially at 28°C is suddenly immersed into water maintained at 80°C. If the time constant of the thermometer is 3.5 s, determine how long does it takes for the temperature shown by the thermometer to reach 95% of the input value.

Apakah perbezaan utama antara sistem pengukuran tertib pertama dan tertib kedua?

Jangkasuhu merkuri di dalam kaca (dianggapkan sebagai sistem tertib pertama) awalnya pada 28°C tiba-tiba dibenam ke dalam air yang dikekalkan pada 80°C. Jika pemalar masa bagi jangkasuhu tersebut ialah 3.5 s, tentukan masa yang ambil oleh jangkasuhu tersebut untuk mencapai 95% daripada nilai inputnya.

(40 markah)

Q3. [a] **State FIVE (5) characteristics that an ideal amplifier should have. Which of these characteristics is not satisfied by an operational amplifier?**

Nyatakan LIMA (5) ciri yang perlu ada pada amplifier unggul. Manakah di antara ciri-ciri tersebut yang tidak dipuaskan oleh sebuah penguat kendalian.

(15 markah)

[b] **Figure Q3[b] shows the circuit diagram of a summing amplifier. Derive an expression for the output voltage e_o in terms of the input voltages e_1, e_2 and e_3 and the resistances shown in the figure.**

Rajah S3[b] menunjukkan gambarajah litar bagi penguat menjumlah. Terbitkan ungkapan bagi voltan keluaran e_o dalam sebutan voltan-voltan masukan e_1, e_2 dan e_3 dan rintangan-rintangan yang ditunjukkan dalam rajah tersebut.

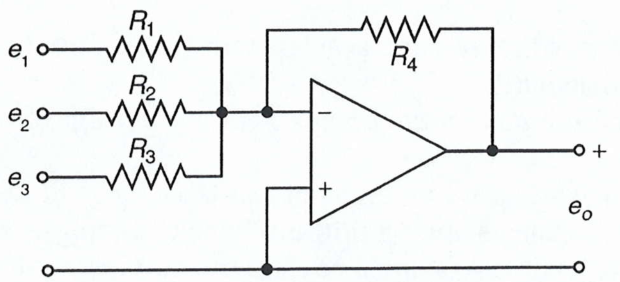


Figure Q3[b]
Rajah S3[b]

(50 markah)

[c] **Simplify the expression derived in Q3[b] if $R_1 = R_2 = R_3 = R$. Hence, determine the value of R_4 if $R = 10\ k\Omega$, $e_1 = e_2 = e_3 = 2$ V and the output voltage is -12 V.**

Permudahkan ungkapan yang diterbitkan dalam Q3[b] jika $R_1 = R_2 = R_3 = R$. Seterusnya, tentukan nilai R_4 jika $R = 10\ k\Omega$, $e_1 = e_2 = e_3 = 2$ V dan voltan keluaran ialah -12 V.

(35 markah)

Q4. **An Antilock Braking System (ABS) sensor measures the speed of a 14 inch diameter automotive wheel. It picks up a signal from the teeth on a 48-tooth gear as they pass by the sensor. The period from one tooth to the next is measured to be 3.25 ms. One revolution later it is measured to be 3.31 ms.**

Sebuah penderia Sistem Membrek Anti-kekunci mengukur kelajuan roda automotif berdiameter 14 inci. Ia menerima isyarat dari gigi-gigi bagi gear 48-gigi apabila melalui penderia. Tempoh antara satu gigi ke gigi yang berikutnya ialah 3.25 ms. Satu pusingan kemudian, tempoh yang diukur ialah 3.31 ms.

(a) **What was the velocity of the vehicle during the initial measurement (in km/h)?**
Apakah halaju kenderaan bagi pengukuran asal (dalam km/jam)

(b) **What was the velocity of the vehicle during the second measurement (in km/h)?**
Apakah halaju kenderaan ketika pengukuran kedua (dalam km/jam)

(c) **Assuming a constant acceleration, how long did the wheel take to complete one revolution (in sec)?**
Dengan mengandaikan pecutan seragam, berapa lamakah pusingan roda (di dalam saat)?

(d) **How far did the vehicle travel between the 1st and 2nd measurement (in meters)?**
Berapa jauhkan kenderaan bergerak di antara pengukuran pertama dan kedua (dalam meter)?

(e) **What was the average acceleration (in m/s^2) between the first and second measurement?**
Apakah pecutan purata (in m/s^2) di antara pengukuran pertama dan kedua?

(f) **If we wish to have an error of less than 0.5% in the speed at the maximum speed, what is our minimum clock sampling frequency of the speed signal? (Hint: Assume a reasonable maximum vehicle speed)**

Jika ralat yang dihasilkan perlu dihadkan kepada 0.5% pada halaju maksima, apakah frekuensi sampel jam minima bagi isyarat halaju? (Petunjuk: andaikan halaju kenderaan maksima yang munasabah).

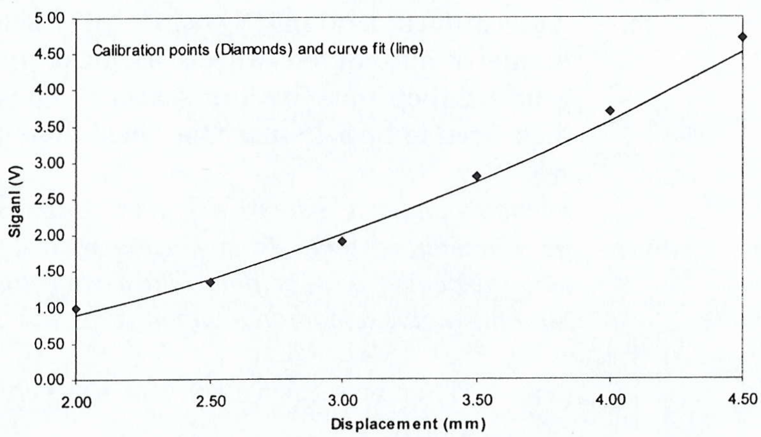
(100 markah)

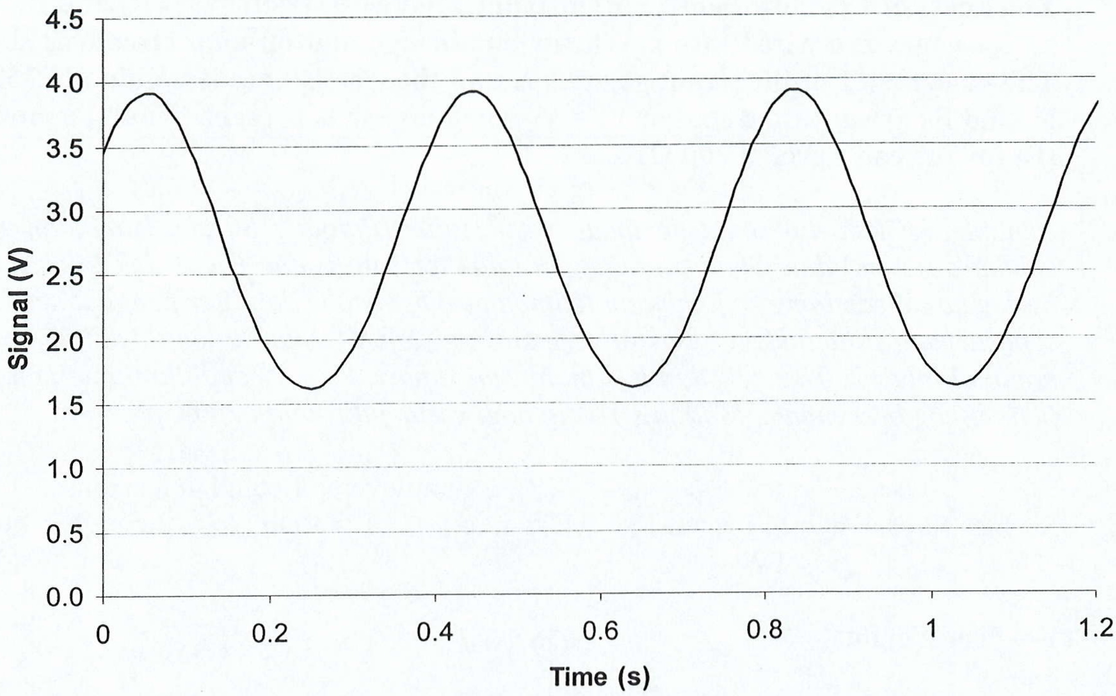
Q5. **A reflective type displacement probe is used to measure the displacement of an oscillating component in an engine. The calibration data (given below) is used to establish a quadratic fit. An approximately sinusoidal signal is measured.**

Sebuah kuar anjakan jenis pantulan digunakan bagi mengukur anjakan komponen mengayun di dalam enjin. Data tertentukur (diberikan di bawah) digunakan bagi menghasilkan padanan kuadratik. Sebuah isyarat anggaran sinusoidal diukur.

Calibration Data	
Displacment (mm)	Signal (V)
2.00	1.00
2.50	1.35
3.00	1.90
3.50	2.80
4.00	3.70
4.50	4.70

Curve Fit:
Voltage = ($Displacement^2$) / 4.5





(a) **How far is the component moving (in mm)?**
Berapa jauhkah pergerakan komponen (dalam mm)

(b) **Based on the difference between the calibration data and the curve fit, what is the maximum error (in terms of % of actual displacement) in the measured position?**
Berdasarkan perbezaan antara data tertentukur dan lengkuk padanan, apakah ralat maksima (di dalam bentuk % dari anjakan sebenar) di dalam kedudukan pengukuran?

(c) **What is the amplitude of acceleration in m/s^2?**
Apakah amplitud pecutan di dalam m/s^2?

(d) **If the output is read by a 12 bit +/- 5V ADC, what are the minimum and maximum digital outputs (corresponding to the min and max voltages input from the sin wave)?**
Jika keluaran dibaca oleh sebuah ADC 12 bit +/- 5V, apakah keluaran digit minimum dan maksima (sepadan dengan voltan masukan minima dan maksima dari gelombang sin)?

(100 markah)

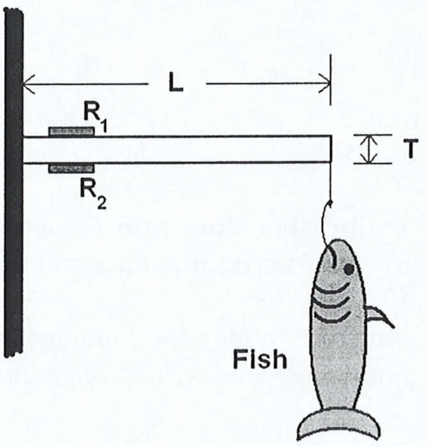
Q6. A fish scale has been fabricated from a cantilevered beam (Length of 80 cm, Thickness of 1 cm, width of 2 cm) instrumented with strain gages R_1 and R_2. The strain gages are wired into a Wheatstone bridge and op-amp circuit as shown. The gage factor of the strain gages is 2, and their resistance is nominally 250 Ω. R_3 and R_4 are adjusted so that $V_a = V_b$ when no fish is present. Young's modulus (E) for the cantilever is 200 GPa.

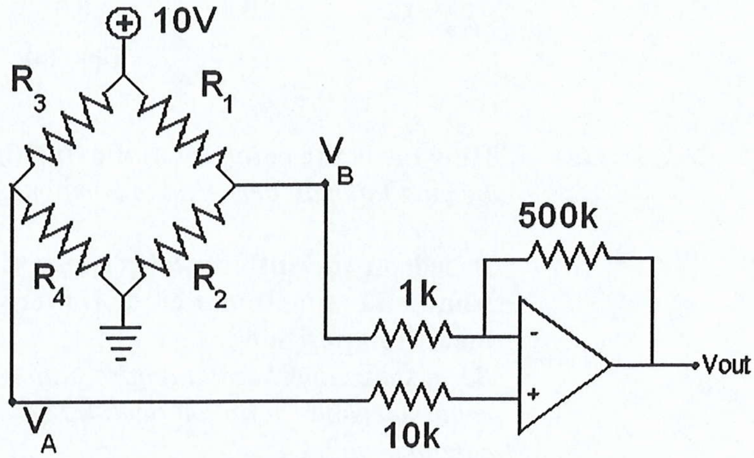
Penimbang ikan diperbuat daripada rasuk julur (Panjang 80 cm, ketebalan 1 cm, kelebaran 2 cm) dan dilengkapi dengan tolok terikan R_1 dan R_2. Tolok-tolok terikan berkenaan disambung ke jambatan tetimbang Wheatstone dan litar penguat kendalian seperti yang ditunjukkan. Faktor terikan bagi tolok terikan ialah 2, dan rintangan nominal ialah 250 Ω. R_3 dan R_4 diubahsuai supaya $V_a = V_b$ apabila tiada ikan pada penimbang berkenaan. Modulus Young bagi rasuk julur ialah 200 Gpa.

Cantilevered Beam Dimensions:

Surface Stress: $\sigma = \frac{24\,LF}{TW}$ $E = \sigma / \varepsilon$ T = 1 cm, W = 2 cm, L = 80 cm

F = Fish Weight





(a) **When no fish is present, what is the Voltage at point Va?**
Apabila tiada ikan pada penimbang, apakah nilai voltan pada titik V_a?

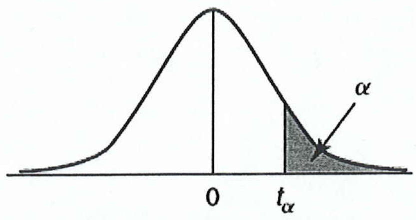
(b) **When a 10 kg Fish is hung on the scale, what is the Surface Stress in the cantilever beam?**
Apabila ikan seberat 10 kg diletakkan pada penimbang, apakah nilai tegasan permukaan pada rusuk jalur?

(c) **Calculate the voltage at Vb when the fish is present?**
Kirakan nilai voltan pada Vb apabila ikan diletakkan?

(d) **What is the voltage Vout when the fish is on the scale?**
Apakah voltan keluaran Vout apabila ikan diletakkan pada penimbang?

(e) **What is the voltage Vout when there is no fish?**
Apakah nilai voltan Vout apabila tiada ikan?

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	∞