UNIVERSITI SAINS MALAYSIA

First Semester Examination
2013/2014 Academic Session

December 2013/January 2014

EMC 201 – Measurement & Instrumentation
[Pengukuran & Peralatan]

Duration : 3 hours
[Masa : 3 jam]

Please check that this paper contains **TEN (10)** printed pages, **TWO (2)** page appendix and **FIVE (5)** questions before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **SEPULUH (10)** mukasurat bercetak, **DUA (2)** mukasurat lampiran dan **LIMA (5)** soalan 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. You may answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.

*[**ARAHAN :** Jawab **SEMUA** soalan. Calon boleh menjawab semua soalan dalam **Bahasa Malaysia** ATAU **Bahasa Inggeris** ATAU kombinasi kedua-duanya.]*

Answer to each question must begin from a new page.
[Jawapan untuk 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] Name the three stages of a generalized measurement system. Give ONE(1) example of an element in each stage for a measurement system which is (i) completely mechanical, (ii) completely electrical.

Namakan tiga peringkat yang terdapat dalam sistem pengukuran umum. Berikan SATU(1) contoh elemen di dalam setiap peringkat bagi sistem pengukuran (i) mekanikal sepenuhnya, (ii) elektrik sepenuhnya.

(20 marks/markah**)**

[b] A technician measured the diameter of a rod using a 0.001 mm resolution digital micrometer and obtained the following readings (units in mm):

12.502	**12.512**	**12.496**	**12.518**	**12.505**
12.498	**12.487**	**12.507**	**12.508**	**12.513**

Determine the uncertainty in the true mean of the diameter for a confidence level of (i) 90%, (ii) 95%. Does the uncertainty increase or decrease when the confidence level increases? Explain.

Seorang juruteknik mengukur garispusat rod dengan menggunakan mikrometer digital yang mempunyai resolusi 0.001 mm dan memperoleh bacaan-bacaan berikut (unit dalam mm):

12.502	*12.512*	*12.496*	*12.518*	*12.505*
12.498	*12.487*	*12.507*	*12.508*	*12.513*

Tentukan ketakpastian dalam purata sebenar bagi garispusat bagi paras keyakinan (i) 90%, (ii) 95%. Adakah ketakpastian bertambah atau berkurang apabila tahap keyakinan bertambah? Terangkan.

(30 marks/markah**)**

[c] The deflection y at the free end of a cantilever beam is given by

$$y = \frac{Fl^3}{3EI}$$

where F is the applied load, l is the length of the cantilever, E is the Young's modulus and I is the moment area. In a particular test, the nominal length of the cantilever is 150 mm, the area moment is 185 mm^4 and the Young's modulus of the cantilever material is 120 MPa. The load applied is 10 N. The uncertainty in the area moment, Young's modulus and load are known as ±5 mm^4, ±10 MPa and ±0.2 N respectively. However, the uncertainty in the length is unknown. From 15 repeated measurements the mean length of the cantilever was found to be 148 mm with a standard deviation of 0.5 mm. Assuming a confidence level of 95%, determine the uncertainty in the deflection y.

Pesongan y pada hujung bebas sebuah rasuk julur diberikan oleh

$$y = \frac{Fl^3}{3EI}$$

di mana F ialah beban dikenakan, l ialah panjang rasuk, E ialah modulus Young dan I ialah momen luas. Dalam suatu ujian, panjang nominal rasuk ialah 150 mm, momen luas ialah 185 mm^4 dan modulus Young bahan rasuk ialah 120 MPa. Beban yang dikenakan ialah 10 N. Ketakpastian dalam momen luas, modulus Young dan beban diketahui sebagai ±5 mm^4, ±10 MPa dan ±0.2 N masing-masing. Walau bagaimanapun, ketakpastian dalam jarak rasuk tidak diketahui. Daripada 15 ukuran berulang didapati panjang purata rasuk ialah 148 mm dengan sisihan piawai 0.5 mm. Dengan menganggapkan paras keyakinan sebanyak 95% tentukan ketakpastian di dalam pesongan y.

(50 marks/markah**)**

Q2. [a] Figure Q2[a] shows the output of an accelerometer (in volt) during the measurement of variation of acceleration in a test vehicle.

Rajah S2[a] menunjukkan output sebuah meter pecutan (dalam volt) ketika pengukuran perubahan pecutan bagi kenderaan ujian.

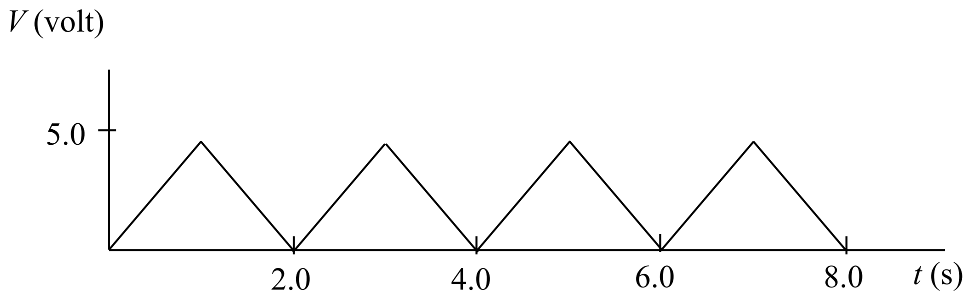

Figure Q2[a]
Rajah S2[a]

(i) Obtain an expression for the output voltage *V*(*t*) in the form of a Fourier series.

Dapatkan suatu ungkapan bagi voltan output V(t) dalam bentuk siri Fourier.

(ii) Determine the mean output voltage from the expression in (i).

Tentukan voltan output purata daripada ungkapan dalam (i)

(iii) Sketch the frequency spectrum up to the 7th harmonic for the output voltage based on the expression derived in (i).

Lakarkan spekrum frekuensi sehingga harmonik ke-7 bagi voltan output berasaskan ungkapan yang diterbitkan dalam (i).

(iv) Determine the sampling frequency required to sample the output voltage signal so that frequencies up to the 7th harmonic can be detected.

Tentukan frekuensi pensampelan yang diperlukan untuk mensampel isyarat voltan output supaya frekuensi-frekuensi sehingga harmonik ke-7 dapat dikesan.

(60 marks/markah**)**

The following expressions are given:

Ungkapan-ungkapan berikut diberikan:

$$y(t) = \frac{A_0}{2} + \sum_{n=1}^{\infty}(A_n \cos n\omega t \pm B_n \sin n\omega t)$$

$$A_n = \frac{2}{T}\int_0^T y(t)\cos\left(\frac{2\pi}{T}nt\right)dt \qquad n = 0, 1, 2, \ldots,$$

$$B_n = \frac{2}{T}\int_0^T y(t)\sin\left(\frac{2\pi}{T}nt\right)dt \qquad n = 1, 2, 3, \ldots$$

$$\int x\cos ax\,dx = \frac{\cos ax}{a^2} + \frac{x\sin ax}{a} \qquad \int x\sin ax\,dx = \frac{\sin ax}{a^2} - \frac{x\cos ax}{a}$$

$$\int \cos ax\,dx = \frac{\sin ax}{a}$$

[b] What is the basic difference between a first order and a second order measurement system? Give an example of a first order measurement system that is subjected to a step input.

Apakah perbezaan asas di antara sistem pengukuran tertib pertama dan tertib kedua? Berikan contoh sistem pengukuran tertib pertama yang dikenakan input langkah.

(10 marks/markah**)**

[c] A temperature sensor, assumed to be a first order system, has a time constant of 0.4 s. The sensor is required to measure a harmonically varying input temperature with frequency of 50 Hz. Determine the maximum percentage error in the measured temperature.

Sensor suhu, dianggapkan sebagai sistem tertib pertama, mempunyai pemalar masa 0.04 s. Sensor tersebut diperlukan mengukur suhu masukan yang berubah secara harmonik dengan frekuensi 50 Hz. Tentukan peratus ralat maksimum dalam suhu yang diukur.

(30 marks/markah**)**

The following expression is given:

Ungkapan berikut diberikan:

$$\frac{P_d}{P_s} = \frac{1}{\sqrt{1 + \left(\frac{2\pi\tau}{T}\right)^2}}$$

Q3. [a] Explain the term 'loading error' with respect to the voltage-dividing potentiometer circuit shown in Figure Q3[a].

Terangkan istilah 'ralat pembebanan' berkaitan dengan litar potentiometer membahagi-voltan yang ditunjukkan dalam Rajah S3[a].

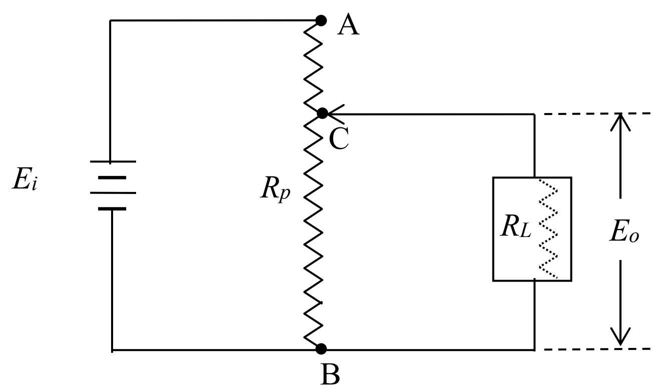

Figure Q3[a]
Rajah S3[a]

(10 marks/markah**)**

[b] In the voltage-dividing circuit shown in Figure Q3[a] the potentiometer resistance is R_p while the internal resistance of the voltmeter is R_L. If the length ratio AC:AB is 2:5, obtain an expression for the loading error in the output voltage E_o due to the internal resistance of the voltmeter. Assume that

the resistance per unit length of the potentiometer is constant. Hence, determine the loading error if the following data are given:

E_i =12 V **R_p = 500 Ω** **R_L = 200 kΩ**

Dalam litar membahagi-voltan yang ditunjukkan dalam Rajah S3(a) rintangan pontentiometer ialah R_p manakala rintangan dalaman voltmeter ialah R_L. Jika nisbah panjang AC:AB ialah 2:5, dapatkan suatu ungkapan bagi ralat pembebanan dalam voltan keluaran E_o yang disebabkan oleh rintangan dalaman voltmeter tersebut. Andaikan bahawa rintangan per unit panjang bagi potentiometer adalah malar. Seterusnya tentukan ralat pembebanan jika data berikut diberikan:

E_i =12 V R_p = 500 Ω R_L = 200 kΩ

(50 marks/markah**)**

[c] **(i)** **Explain the term 'common mode rejection' as applied to operational amplifiers.**

Terangkan istilah 'penolakan mod sepunya' yang digunakan bagi penguat operasi.

(ii) **Figure Q3[c] shows a non-inverting amplifier circuit. Obtain an expression for the gain G in terms of the parameters shown in the figure.**

Rajah S3[c] menunjukkan litar penguat tak-menyongsang. Dapatkan ungkapan bagi gandaan G dalam sebutan parameter-parameter yang ditunjukkan dalam rajah tersebut.

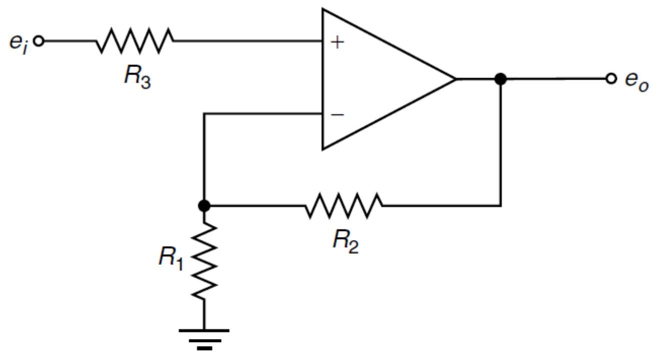

Figure Q3[c]
Rajah S3[c]

If R_3 = 100 Ω, determine the suitable values of R_1 and R_2 to obtain a gain of 1000.

Jika R_3 = 100 Ω, tentukan nilai-nilai R_1 dan R_2 yang sesuai untuk mendapatkan gandaan sebanyak 1000.

(40 marks/markah**)**

Q4. [a] Construct the truth table for the combination of logic gates shown in Figure Q4[a]. Include the outputs at the intermediate points D and E in your table. What combinations of inputs at A, B and C produce a high output from the circuit at F?

Bina jadual kebenaran bagi gabungan get-get logik yang ditunjukkan dalam Rajah S4[a]. Ambilkira output-output pada titik-titik peralihan D dan E dalam jadual anda. Apakah gabungan input pada A, B dan C yang menghasilkan output tinggi pada F dalam litar tersebut?

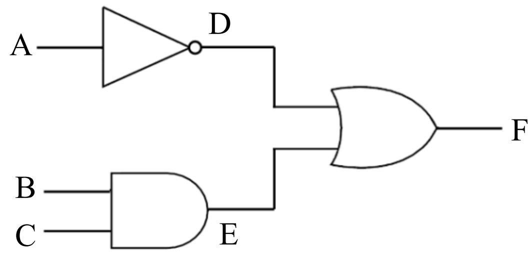

Figure Q4[a]
Rajah S4[a]

(30 marks/markah**)**

[b] (i) State the law of intermediate temperatures as applied to thermocouples.

Nyatakan hukum suhu perantaraan seperti mana yang dikenakan bagi pengganding-pengganding suhu.

(ii) A type K thermocouple was used to measure the temperature rise inside a furnace during power up. The reference junction temperature was maintained at 26°C. Determine the temperature rise if the e.m.f. outputs measured were -1.205 mV and 2.835 mV during two different time intervals.

Pengganding suhu jenis K telah digunakan untuk mengukur peningkatan suhu di dalam sebuah ketuhar semasa 'power up'. Tentukan peningkatan suhu jika output-output e.m.f. yang diukur adalah -1.205 mV dan 2.835 mV pada dua julat masa tertentu.

(30 marks/markah**)**

[c] Figure Q4[c] shows a ballast circuit used to measure strain applied to a tensile specimen. The strain gage has resistance R_g while the ballast resistance is R_b. The supply voltage is e_i. If the tensile specimen is subjected to a strain ε show that the change de_o in the output voltage e_o is given by

$$de_o = \frac{e_i R_b R_g}{\left(R_b + R_g\right)^2} F\epsilon$$

where *F* is the gage factor of the strain gage.

If R_g = R_b = 150 Ω, e_i = 12 V and F = 2.0, find the change in the output voltage if the strain experienced by the tensile specimen is 5 μ-strain. Hence, explain why the simple ballast circuit is unsuitable for measuring strain.

Rajah S4[c] menunjukkan litar balas yang digunakan untuk mengukur terikan yang dikenakan pada spesimen tegangan. Tolok terikan mempunyai rintangan R_g manakala rintangan balas ialah R_t. Voltan bekalan ialah e_i. Jika spesimen tegangan dikenakan terikan ε tunjukkan bahawa perubahan de_o dalam voltan output e_o diberikan oleh

$$de_o = \frac{e_i R_b R_g}{\left(R_b + R_g\right)^2} F\epsilon$$

di mana F ialah faktor tolok bagi tolok terikan tersebut.

Jika R_g = R_b = 150 Ω, e_i = 12 V dan F = 2.0, tentukan perubahan dalam voltan output jika terikan yang dialami oleh spesimen tensil ialah 5 μ-strain. Seterusnya, terangkan kenapa litar balas mudah tersebut tidak sesuai bagi mengukur terikan.

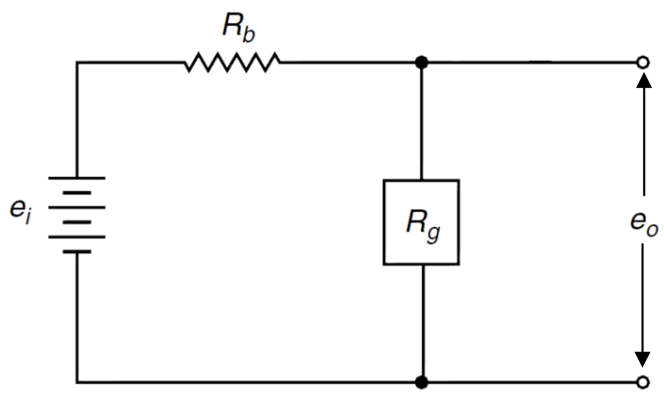

Figure Q4[c]
Rajah S4[c]

(40 marks/markah**)**

Q5. [a] Explain the difference between static pressure, stagnation pressure and dynamic pressure. Figure Q5[a] shows the setup for measuring the dynamic pressure of a fluid moving in a pipeline of diameter *d*. Point B is located at the centre of the pipe.

Terangkan perbezaan antara tekanan statik, tekanan stagnasi dan tekanan dinamik. Rajah S5[a] menunjukkan susunan untuk mengukur tekanan dinamik bagi bendalir yang mengalir melalui paip bergarispusat d. Titik B terletak pada pusat paip.

(i) **Obtain an expression for the dynamic pressure in terms of the other variables given in the figure by taking into account the density of the fluid ρ_f in the pipeline.**

Dapatkan ungkapan untuk tekanan dinamik dalam sebutan pemboleh-pemboleh yang lain di dalam rajah tersebut dengan mengambilkira ketumpatan bendalir ρ_f di dalam paip.

(ii) **Determine the dynamic pressure if the following data are given:**

Tentukan tekanan dinamik jika data berikut diberikan:

d = 200 mm	H = 300 mm	h = 120 mm
ρ_f = 12 kg/m^3	ρ_m = 680 kg/m^3	

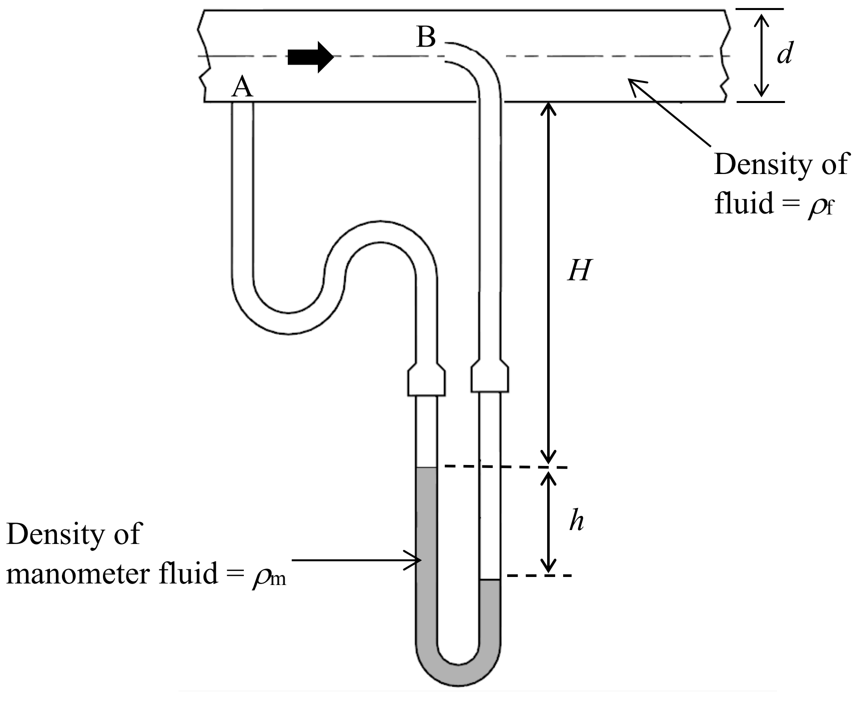

Figure Q5[a]
Rajah S5[a]

(60 marks/markah**)**

[b] **Figure Q5[b] shows an obstruction flow meter. Starting from Bernoulli's equation obtain an expression for the ideal mass flow rate in terms of the differential pressure ΔP_{12} between section 1 and 2, the cross-sectional areas A_1 and A_2 and density of the liquid ρ.**

Rajah S5[b] menunjukkan meter aliran halangan. Bermula daripada persamaan Bernoulli dapatkan ungkapan bagi aliran jisim ideal dalam sebutan tekanan bezaan ΔP_{12} di antara bahagian 1 dan 2, luas keratin A_1 dan A_2 dan ketumpatan cecair ρ.

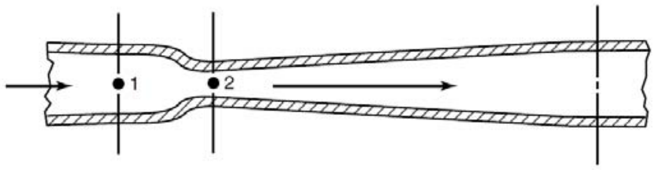

Figure Q5[a]
Rajah S5[a]

Hence, determine the ideal mass flow rate if the fluid flowing through the meter is water (density 990 kg/m^3). Given that the diameters at section 1 and 2 are, respectively, 100 mm and 50 mm and the differential pressure ΔP_{12} = 50 mmHg (take density of mercury as 13600 kg/m^3).

Seterusnya, tentukan kadar aliran jisim ideal jika bendalir yang mengalir melalui meter tersebut ialah air (ketumpatan 990 kg/m^3). Diberikan bahawa garipusat pada bahagian 1 dan 2 ialah masing-masing 100 mm dan 50 mm dan tekanan bezaan ΔP_{12} = 50 mmHg (ambil tekanan merkuri sebagai 13600 kg/m^3).

(40 marks/markah**)**

The following expression is given:

Ungkapan berikut diberikan:

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

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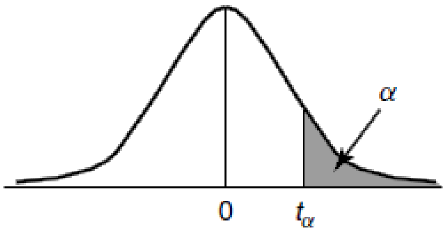
APPENDIX 1/*LAMPIRAN 1*

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

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

APPENDIX 2/*LAMPIRAN 2*

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

	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