UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2010/2011

November 2010

EMC 201/3 – Measurement & Instrumentation
Pengukuran & Peralatan

Duration : 3 hours
Masa : 3 jam

INSTRUCTIONS TO CANDIDATE:
ARAHAN KEPADA CALON:

Please check that this paper contains **ELEVEN (11)** printed pages, **ONE (1)** page appendix and **FIVE (5)** questions before you begin the examination.
*Sila pastikan bahawa kertas soalan ini mengandungi **SEBELAS (11)** mukasurat bercetak, **SATU (1)** mukasurat lampiran dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan.*

Answer **ALL** questions.
*Jawab **SEMUA** soalan.*

Appendix/*Lampiran :*

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

You may 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.*

Answer to each question must begin on 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] State the three main stages of a general measurement system. What is the function of each stage?

Nyatakan tiga peringkat utama bagi sebuah sistem pengukuran am. Apakah fungsi setiap peringkat?

(15 marks/*markah*)

[b] Figure Q1[b] shows a tire pressure gage modified to improve the sensitivity. Identify the three stages of measurement system in the device shown. Illustrate with a block diagram.

Rajah S1[b] menunjukkan tolok tekanan bagi tayar yang diubahsuai untuk meningkatkan kepekaan. Kenalpasti ketiga-tiga peringkat sistem pengukuran dalam peranti yang ditunjukkan. Buat ilustrasi dengan gambarajah blok.

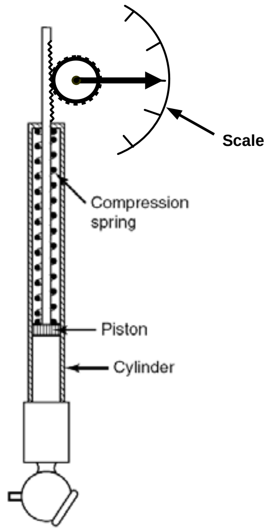


Figure Q1[b]
Rajah S1[b]

(15 marks/*markah*)

[c] What is the difference between 'error' and 'uncertainty'? In a measurement of temperatures (in °C) in a pipeline, the following readings were recorded:

248.0, 248.9, 249.6, 248.6, 248.2, 248.3, 248.2, 248.0, 247.1, 248.1

Determine the uncertainty in the true mean temperature in the pipeline for (i) 90% confidence level, (ii) 95% confidence level. Does the uncertainty increase or decrease when the confidence level is increased? Why?

Apakah perbezaan antara 'ralat' dengan 'ketakpastian'? Dalam pengukuran suhu (°C) di dalam saluran paip, bacaan-bacaan berikut dirakam:

248.0, 248.9, 249.6, 248.6, 248.2, 248.3, 248.2, 248.0, 247.1, 248.1

Tentukan ketakpastian dalam suhu purata sebenar di dalam paip bagi (i) paras keyakinan 90%, (ii) paras keyakinan 95%. Adakah ketakpastian bertambah atau berkurang apabila paras keyakinan bertambah? Kenapa?

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

[d] An orifice meter is used to measure the flow rate of a fluid. In an experiment, the flow coefficient *C* of an orifice is determined by collecting and weighing the water flowing through the orifice during a fixed time interval with the orifice under a constant head. *C* is calculated from the following equation:

$$C = \frac{m}{tA\rho(2g\Delta h)^{1/2}}$$

The values of the parameters were determined as follows, with 95% confidence:

Mass	$m = 393.00 \pm 0.03$ **kg**
Time	$t = 600.0 \pm 1.0$ **s**
Density	$\rho = 1000.0 \pm 0.1\%$ **kg/m^3**
Diameter	$d = 1.27 \pm 0.0025$ **cm (*A* is area)**
Head	$\Delta h = 366.0 \pm 0.3$ **cm**

Determine the nominal value of *C* and its uncertainty at 95% confidence. Take *g* as 9.81 m/s^2.

Meter orifis digunakan untuk mengukur kadar aliran suatu bendalir. Dalam suatu ujikaji, pekali aliran orifis C ditentukan dengan mengumpul dan menimbang air yang mengalir melalui orifis dalam masa tertentu dengan orifis di bawah kepala tekanan tetap. C dikira daripada persamaan berikut:

$$C = \frac{m}{tA\rho(2g\Delta h)^{1/2}}$$

Nilai parameter-parameter ditentukan seperti berikut, pada paras keyakinan 95%:

Jisim	*m* = 393.00 $\pm$ 0.03 *kg*
Masa	*t* = 600.0 $\pm$ 1.0 *s*
Ketumpatan	ρ = 1000.0 $\pm$ 0.1% kg/m^3
Garispusat	*d* = 1.27 $\pm$ 0.0025 *cm (A ialah luas)*
Kepala tekanan	Δh = 366.0 $\pm$ 0.3 *cm*

Tentukan nilai nominal C dan ketakpastiannya pada paras keyakinan 95%. Ambil g sebagai 9.81 m/s^2.

(50 marks/*markah*)

Q2. [a] Figure Q2[a] shows a periodic signal.

(i) Determine the fundamental frequency of the signal.

(ii) Determine the amplitude of the first, second and third harmonic components.

(iii) Sketch the frequency spectrum for the signal.

Rajah S2[a] menunjukkan suatu isyarat berkala.

(i) Tentukan frekuensi asas bagi isyarat tersebut.

(ii) Tentukan amplitud komponen-komponen harmonik pertama, kedua dan ketiga.

(iii) Lakarkan spektrum frekuensi bagi isyarat tersebut.

Given:

Diberikan:

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

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

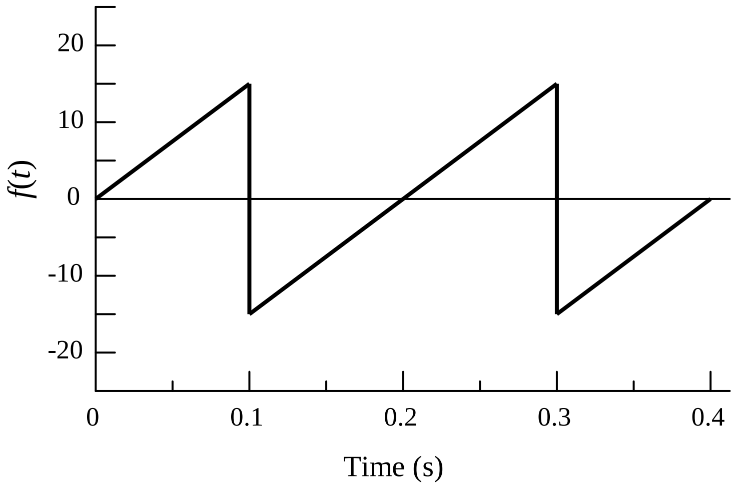


Figure Q2[c]
Rajah S2[c]

(60 marks/*markah*)

[b] **A load cell deflects by 0.005 mm when a force of 100 N is applied.**

Suatu sel beban berpesong sebanyak 0.005 mm apabila daya 100 N dikenakan.

(i) **Determine the natural frequency of the load cell. The following formula for the natural frequency of a spring-mass system is given:**

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where *k* is the stiffness of the spring and *m* is the mass suspended from the spring.

Tentukan frekuensi nisbi bagi sel beban tersebut. Rumus berikut bagi frekuensi nisbi bagi sistem pegas-jisim diberikan sebagai:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

di mana k ialah kekakuan pegas dan m ialah jisim yang digantung daripada pegas.

(ii) If the load cell is assumed to be a second-order system with negligible damping, determine the frequency range over which it can measure dynamically varying loads with an error less than 10%. Given the following equation for a second-order system:

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

where P_d is the amplitude of the periodic dynamic response, P_s is the amplitude of the excitation function, Ω is the frequency of the external excitation, ω_n is the natural frequency of the system and ξ is the damping ratio.

Jika sel beban tersebut dianggapkan sebagai sistem tertib-kedua dengan redaan bolehabai, tentukan julat frekuensi di mana ia boleh mengukur beban berubah dinamik dengan ralat kurang daripada 10%. Diberikan persamaan berikut bagi sistem tertib kedua:

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

di mana P_d ialah amplitud respon berkala dinamik, P_s ialah amplitud fungsi 'excitation', Ω ialah frekuensi 'excitation' luar, ω_n ialah frekuensi nisbi sistem dan ξ ialah nisbah redaan.

(40 marks/*markah*)

Q3. [a] A speed pickup triggers the spark circuit in a small motorcycle. The signal voltage is shown in Figure Q3[a[. The engine is running at approximately 5400 rpm.

Suatu pengesan kelajuan memicu litar pencucuh di dalam sebuah motosikal kecil. Isyarat voltan ditunjukkan dalam Rajah S3[a]. Enjin tersebut berputar pada kelajuan lebih kurang 5400 psm.

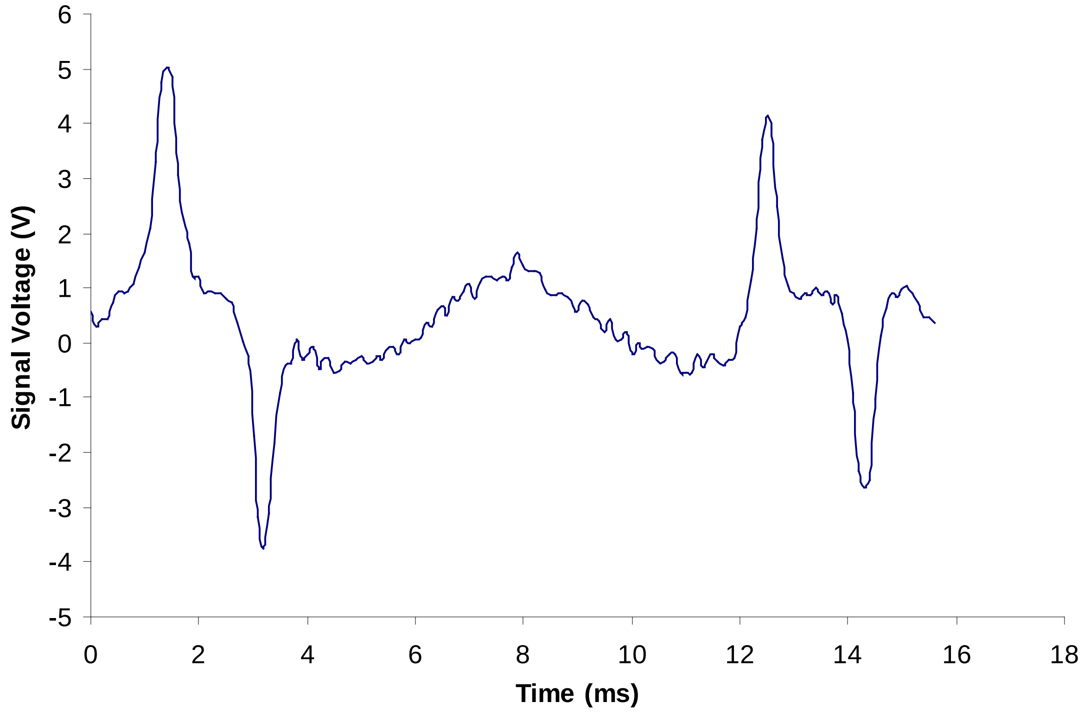


Figure Q3[a]
Rajah S3[a]

(i) **What are the minimum and maximum POSITIVE voltages we can trigger the circuit on a rising edge and read the real engine speed?**

Apakah voltan-voltan POSITIF maksimum dan minimum yang boleh kita picu litar tersebut pada tepi meningkat dan membaca kelajuan enjin?

(12 marks/*markah***)**

(ii) **If the trigger level is 1.2 V for a down going transition, at what time(s) do the transitions(s) occur?**

Jika paras pemicuan ialah 1.2 V bagi peralihan bergerak bawah, pada masa berapakah peralihan tersebut berlaku?

(18 marks/*markah***)**

(iii) **What speed(s) will be reported in the case of a down going transition at a 1.2 V trigger level [rpm]?**

Apakah kelajuan-kelajuan yang akan dilaporkan dalam kes peralihan ke bawah pada paras pemicuan 1.2 V (dalam psm)?

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

[b] **Figure Q4[b] shows an old "ball-type" computer mouse uses a 20 mm diameter ball turning a 3.5 mm diameter shaft connected to a radial fringe type relative position encoder being read by 2 photo diodes. The encoder has a radius of 7.5 mm.**

Rajah S4[b] menunjukkan sebuah tetikus jenis bebola yang lama menggunakan bola bergarispusat 20 mm untuk memutarkan aci bergarispusat 3.5 mm yang dipasangkan kepada pengekod kedudukan nisbi jenis pinggir jejarian dan dibaca oleh dua diod foto. Pengekod tersebut mempunyai jejari 7.5 mm.

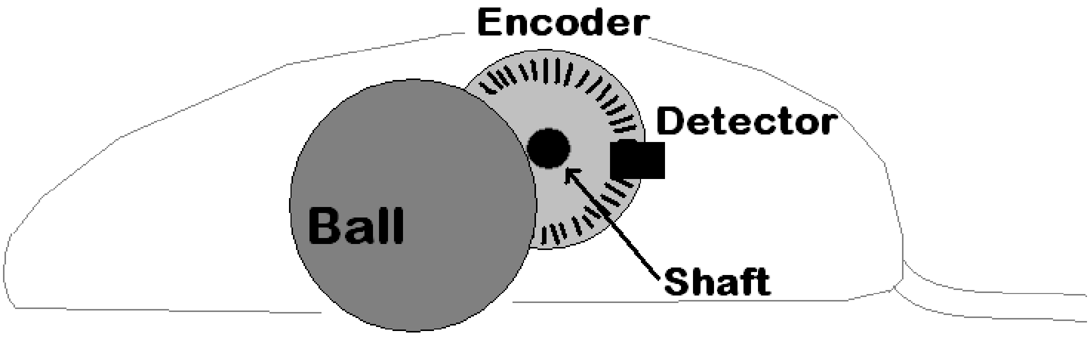


Figure Q4[b]
Rajah S4[b]

(i) **For each millimeter of mouse motion, how many degrees does the encoder rotate?**

Bagi setiap milimeter gerakan tetikus, berapakan darjah putaran bagi pengekod?

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

(ii) **If we assume quadrature decoding of the signal, how many fringes must there be to give a resolution of 0.1 mm of mouse motion?**

Jika kita andaikan penyahkodan kuadratur bagi isyarat, berapakah bilangan pinggir untuk memberikan resolusi sebanyak 0.1 mm bagi gerakan tetikus?

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

(iii) **If there are 42 fringes on the encoder, and the mouse is moved at 60 cm/sec, what frequency will the detector see?**

Jika terdapat 42 pinggir pada pengekod, dan tetikus digerakkan pada 60 sm/saat, apakah frekuensi yang dinampak oleh pengesan?

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

Q4. [a] A turbine type flow meter is used to measure the flow of jet fuel into an engine. The turbine mounted in the fuel line has 24 blades, each one triggering a proximity sensor mounted outside the fuel line. Turbine speed is proportional to fuel flow rate, and at the maximum fuel flow rate of 5 kg/sec the turbine is rotating at 10,000 rpm. The proximity sensor feeds an "Event per Unit Time" (EPUT) counter.

Meter aliran jenis turbin digunakan untuk mengukur aliran bahanapi jet ke dalam enjin. Turbin yang dipasangkan pada talian bahanapi mempunyai 24 bilah, setiapnya yang memicu sensor kehampiran yang dipasangkan pada luar talian bahanapi tersebut. Kelajuan turbin berkadar terus kepada kadar aliran bahanapi, dan pada kadar aliran maksimum sebanyak 5 kg/saat turbin berputar pada kelajuan 10,000 psm. Sensor kehampiran menyuap pengira 'Event per Unit Time (EPUT)'.

(i) If we wish to have a reading directly in grams/second what should the count duration of the EPUT counter be?

Jika kita ingin mendapatkan bacaan secara langsung dalam gram/saat, apabila harusnya tempoh kiraan bagi pengkur EPUT?

(15 marks/*markah*)

(ii) What will the maximum signal frequency (at proximity sensor) be?

Apakah frekuensi maksimum (pada sensor kehampiran)?

(5 marks/*markah*)

(iii) How many bits will the accumulator (counter) in the EPUT require?

Berapakah bilangan bit yang diperlukan oleh akumulator (pengira) dalam EPUT?

(15 marks/*markah*)

(iv) If we wish to have an updated flow number every 500 ms what is the resolution of the resulting measurement (in gm/sec)?

Jika kita ingin mendapatkan nilai aliran terkini setiap 500 ms, apakah resolusi pengukuran yang terhasil (dalam gm/saat)?

(15 marks/*markah*)

[b] **A Throttle Position Sensor (TPS) is used to measure the position of the throttle cable in a car. The cable travels a total distance of 3 cm from idle to Wide Open Throttle (WOT). The radius of the pulley is 15 mm, and the POT is a 10 kΩ, 270 degree device. The mechanism is adjusted such that when the throttle is half open (i.e. 50% throttle) the TPS signal is 2.5 V. The TPS signal is read by a 10 bit 0-12 V ADC.**

Suatu Sensor Kedudukan Pendikit (TPS) digunakan untuk mengukur kedudukan kabel pendikit di dalam sebuah kereta. Kabel tersebut melintasi jarak sejauh 3 sm daripada leka kepada Pendikit Buka Penuh (WOT). Jejari takal ialah 15 mm, dan POT ialah peranti 10 kΩ, 270 darjah. Mekanisma tersebut dilaraskan supaya apabila pendikit dibuka separuh (iaitu pendikitan 50%) isyarat TPS ialah 2.5 V. Isyarat TPS dibaca oleh ADC 0-12V, 10 bit.

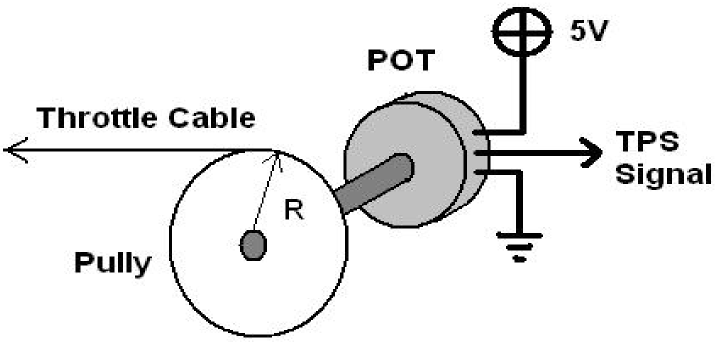


Figure Q5[b]
Rajah S5[b]

(i) **How many degrees does the pulley rotate (idle-WOT)?**

Berapakah darjah putaran takal (leka – WOT)?

(10 marks/*markah*)

(ii) **What is the voltage when the throttle is at the idle position?**

Apakah nilai voltan apabila pendikit berada dalam kedudukan leka?

(10 marks/*markah*)

(iii) **What digital number is read when the throttle is wide open?**

Apakah nombor digital yang dibaca apabila pendikit dibuka penuh?

(10 marks/*markah*)

(iv) **If the ADC gives a digital number of 555, what is the throttle position in terms of % throttle (idle = 0%, WOT = 100%)?**

Jika ADC memberikan nombor digital 555, apakah kedudukan pendikit dalam sebutan % pendikitan (leka = 0%, WOT = 100%).

(20 marks/*markah*)

Q5. **Give the most appropriate sensor for each of the following applications, and explain why you would choose that kind of sensor. Be very specific (e.g. for a temperature sensor for high temperature, precision applications in an engine, your answer would be "Thermocouple" not "Temperature sensor"!):**

Berikan sensor yang paling sesuai bagi setiap aplikasi berikut, dan terangkan kenapa anda memilih jenis sensor tersebut. Berikan jawapan paling tepat (contoh, untuk sensor suhu bagi aplikasi suhu tinggi dan berkepersisan di dalam enjin, jawapan anda ialah 'Pengganding suhu' dan bukan 'Sensor suhu'!):

[a] **Measurement of deflection of a moth's wing when flapping.**

Pengukuran pesongan sayap rama-rama apabila berkepakan.

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

[b] **Engine Coolant Temperature (CLT) sensor for motorcycle Electronic Fuel Injection applications.**

Sensor suhu penyejuk engine (CLT) bagi aplikasi penyuntikan bahanapi elektronik motosikal.

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

[c] **Measurement of the speed of an approaching aircraft**

Pengukuran kelajuan pesawat yang menghampiri.

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

[d] **Non-contact measurement of the height of water in a municipal water tower.**

Pengukuran tak-sentuh bagi ketinggian paras air di dalam menara air bandaraya.

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

[e] **Measurement of the position of a nuclear fuel rod in a reactor core.**

Pengukuran kedudukan rod bahanapi nuklear di dalam teras reaktor.

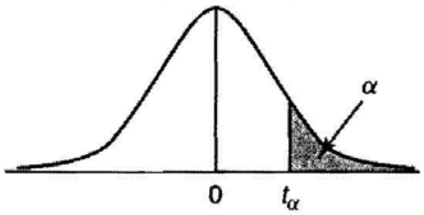
(20 marks/*markah***)**

-oooOOooo-

APPENDIX 1/*LAMPIRAN 1*

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

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	∞