



Second Semester Examination  
Academic Session 2018/2019

June 2019

**EPM212 – Metrology and Quality Control**  
***[Metrologi dan Kawalan Kontrol]***

Duration : 3 hours  
Masa : 3 jam

Please check that this examination paper consists of TWELVE [12] printed pages before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi DUA BELAS [12] mukasurat bercetak sebelum anda memulakan peperiksaan.]*

**INSTRUCTIONS** : Answer **ALL FIVE [5]** questions.

**ARAHAN** : Jawab **SEMUA LIMA [5]** soalan.]

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.]*

1. [a] Explain briefly the difference between the following terms used in metrology:

*Terangkan secara ringkas perbezaan antara istilah-istilah berikut yang digunakan dalam metrology*

- (i) **accuracy and error,**  
*kejituan dengan ralat*
- (ii) **sensitivity and resolution,**  
*kepekaan dengan resolusi,*
- (iii) **repeatability and reproducibility.**  
*kebolehulangan dengan kebolehduluaran semula.*

(30 marks/markah)

- [b] State any TWO (2) causes of systematic error in measuring instruments.

*Nyatakan mana-mana DUA (2) penyebab ralat sistematik dalam alatan pengukuran.*

(10 marks/markah)

- [c] A 0.001 mm resolution digital micrometer (calibrated at 20°C) was used to measure the diameter of AISI304 stainless steel (expansion coefficient  $9.6 \times 10^{-6} / ^\circ\text{C}$ ) cylinder. The measurement was carried out in a laboratory where the temperature fluctuated from 25°C to 34°C throughout the day. The reading shown by the micrometer is 53.215 mm. Neglecting the expansion of the micrometer,

*Sebuah micrometer digital beresolusi 0.001 mm (dikalibrasi pada 20 °C) telah digunakan untuk mengukur garispusat silinder keluli tahan karat AISI304 (koefisien pengembangan  $9.6 \times 10^{-6} / ^\circ\text{C}$ ). Pengukuran tersebut telah dilakukan di dalam sebuah makmal di mana suhu berubah dari 25°C sehingga 34°C sepanjang hari. Bacaan yang ditunjukkan oleh micrometer ialah 53.215mm. Dengan mengabaikan pengembangan mikrometer,*

- (i) **determine the minimum and maximum error in the micrometer reading due to the temperature change.**

*tentukan ralat minimum dan maksimum dalam bacaan mikrometer disebabkan oleh penukaran suhu.*

...3/-

- (ii) **suggest one method to eliminate the error completely.**  
*cadangkan satu cara untuk menghapuskan sepenuhnya ralat tersebut.*

(35 marks/markah)

- [d] **A new type of Vernier caliper having a resolution of 0.01 mm needs to be designed. Determine how the Vernier scale in the caliper should be designed in order to meet this specification. Hence, explain why the resolution of a Vernier caliper is limited.**

*Sebuah angkup Vernier jenis baharu yang mempunyai resolusi sebanyak 0.01 mm perlu direka bentuk. Tentukan bagaimana skala Vernier pada angkup tersebut perlu direka bentuk untuk memenuhi spesifikasi ini. Seterusnya, terangkan kenapa resolusi sebuah angkup Vernier adalah terhad.*

(25 marks/markah)

2. [a] **Define the term 'traceability'.**  
*Takrifkan istilah 'kebolehjejukan'.*

(10 marks/markah)

- [b] **An optical flat was used to inspect the surface of a polished metal disk. The fringe pattern observed under sodium light source (wavelength,  $\lambda = 0.585 \mu\text{m}$ ) is shown in Figure 2[b].**

*Keping optik telah digunakan untuk memeriksa permukaan cakera logam yang digilap. Corak pinggir yang diperhatikan di bawah punca cahaya natrium (jarak gelombang,  $\lambda = 0.585 \mu\text{m}$ ) ditunjukkan dalam Rajah 2[b].*

- (i) **Plot the surface profiles of the disk along section A-A, B-B and C-C.**

*Plotkan profil permukaan cakera tersebut sepanjang keratan A-A, B-B dan C-C.*

- (ii) **Estimate the height difference between the highest and lowest points along each of the sections A-A, B-B and C-C.**

*Anggarkan ketinggian di antara titik tertinggi dan titik terendah sepanjang setiap keratan A-A, B-B dan C-C.*

...4/-

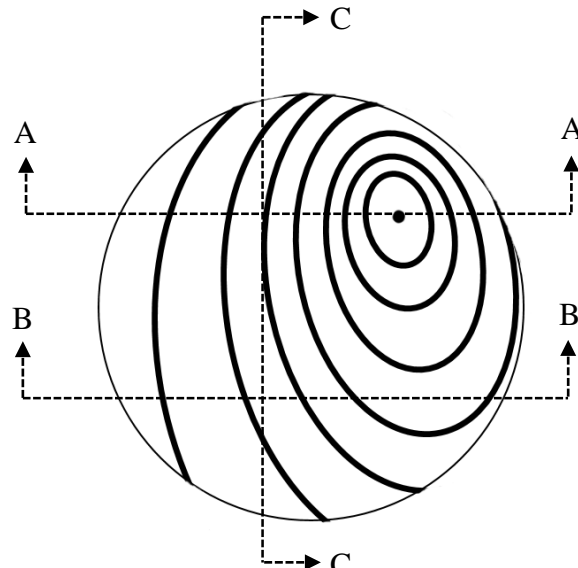


Figure 2[b]  
Rajah 2[b]

(30 marks/markah)

- [c] **State the quality grades of block gauges and the application of each grade?**

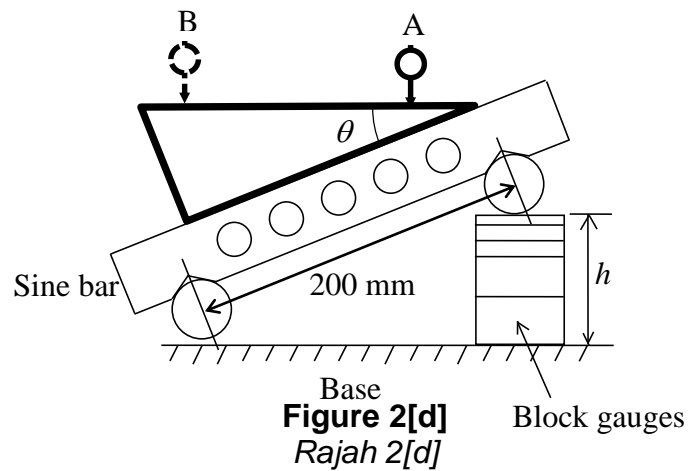
*Nyatakan gred-gred kualiti bagi tolok-tolok bongkah dan aplikasi bagi setiap gred.*

(15 marks/markah)

- [d] **A 200 mm sine bar was used to measure the angle  $\theta$  on a block as shown in Figure 2[d]. The angle was initially estimated using a combination set and found to be  $22^\circ$ . A set of block gauges shown in Table 2[d] is available for the application.**

*Bar sinus 200 mm telah digunakan untuk mengukur sudut  $\theta$  pada sebuah bongkah seperti ditunjukkan dalam Rajah 2[d]. Sudut tersebut pada awalnya telah dianggarkan dengan menggunakan set gabungan dan nilainya didapati sebanyak  $22^\circ$ . Suatu set tolok-tolok bongkah yang ditunjukkan dalam Jadual 2[d] didapati untuk aplikasi tersebut.*

...5/-



**Table 2[d]**  
*Jadual 2[d]*

Blocks per set	Size (mm)	Step (mm)	Quantity
122	1.0005		1
	1.001 – 1.009	0.001	9
	1.01 – 1.49	0.01	49
	1.6 – 1.9	0.1	4
	0.5 – 24.5	0.5	49
	30 – 100	10	8
	25, 75		2

- (i) Determine the suitable combination of block gauges to build the height  $h$  shown in the figure.

*Tentukan kombinasi tolok-tolok bongkah yang sesuai untuk membina ketinggian  $h$  yang ditunjukkan dalam rajah tersebut.*

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- (ii) If the dial indicator readings at positions A and B are, respectively, is 0.000 and -0.054 mm, determine the correction  $\Delta h$  needed to be applied to the height of the block gauges  $h$ . The distance between A and B is 100 mm. Hence, determine the angle  $\theta$  to the nearest arc seconds.

*Jika bacaan petunjuk dail pada kedudukan-kedudukan A dan B ialah, masing-masing, 0.000 dan -0.054 mm, tentukan pembetulan  $\Delta h$  yang perlu dikenakan pada ketinggian  $h$  tolok-tolok bongkah. Jarak antara A dengan B ialah 100 mm. Seterusnya, tentukan sudut  $\theta$  kepada saat arka terdekat.*

(45 marks/markah)

3. [a] State the FIVE (5) types of dimensioning control used in Geometric Dimensioning and Tolerancing (GD&T).

*Nyatakan LIMA(5) jenis kawalan pendimensian yang digunakan dalam Pendimensian dan Toleransi Geometri (GD&T).*

(10 marks/markah)

- [b] Figure 3[b] shows an engineering drawing containing various GD&T dimensioning control frames. Copy the feature control frames labeled (i) to (v) and explain the type of dimensioning control applied by each frame.

*Rajah 3[b] menunjukkan sebuah lukisan kejuruteraan yang mengandungi pelbagai rerangka kawalan ciri GD&T. Salin setiap rerangka berlabel (i) hingga (v) tersebut dan terangkan jenis kawalan dimensi yang dikenakan oleh setiapnya.*

...7/-

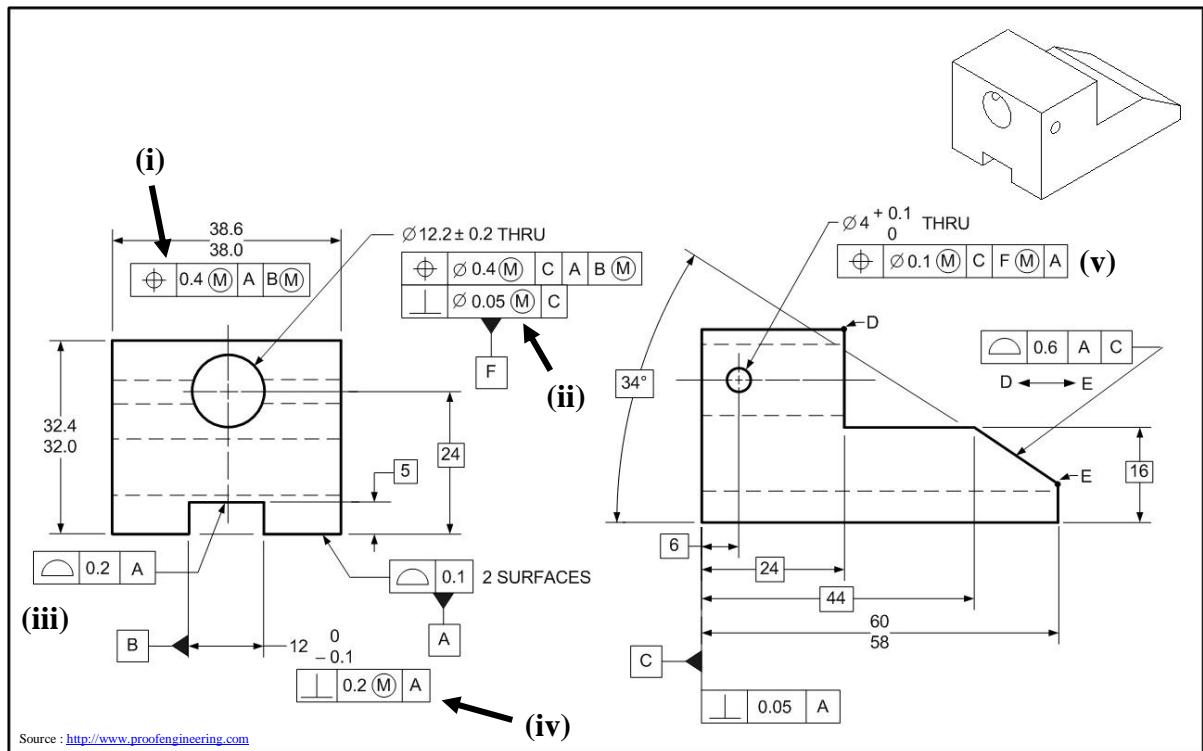


Figure 3[b]  
Rajah 3[b]

(40 marks/markah)

[c] Maximillian Ringelmann, a French engineer studied that the horse performance in 1913. He concluded that the strength of two horses to tow a car was unequal to the strength of one horse by double. Further investigation was done to human strength. Then he observed that few men could pull and the pulling force of each individual was determined. In average, when two men pull the rope, 93% of the individual strength was used. When three men pull the rope, 85% of the individual strength was used, and when four men pull the rope, the pulling strength for each man only at 49%. Based on Pareto method, illustrate the bar chart and give TWO (2) reasons why the strength of horse and men differ. Propose how the experiment could be done in a proper way by giving ONE (1) corrective and ONE (1) preventive activity for the experiment to be conducted.

...8/-

*Maximillian Ringelmann, jurutera Perancis mengkaji pencapaian kuda pada tahun 1913. Beliau merumuskan bahawa kekuatan dua kuda yang menarik sebuah kereta adalah tidak sama dengan kekuatan seekor kuda dengan dua kali ganda. Siasatan lanjut telah dijalankan untuk mengkaji kekuatan manusia. Maka dilihatnya bahawa beberapa orang lelaki menarik dan daya tarikan setiap individu telah diukur. Secara puratanya, apabila dua orang lelaki menarik tali, 93% kekuatan individu telah dikeluarkan. Apabila tiga lelaki menarik tali, 85% dari kekuatan individu telah digunakan, dan apabila empat lelaki menarik tali, kekuatan menarik bagi setiap orang hanya pada 49%. Berdasarkan kaedah Pareto, lukiskan jadual bar dan berikan DUA (2) sebab mengapa kekuatan kuda dan lelaki berbeza. Cadangkan bagaimana ujikaji boleh dilakukan dengan cara yang betul dengan memberi SATU (1) aktiviti pembedahan dan SATU (1) aktiviti pencegahan bagi ujikaji yang hendak dijalankan.*

**(50 marks/markah)**

4. [a] **Define and differentiate Quality Assurance and Quality Control.**  
*Definisi dan bezakan Jaminan Kualiti dan Kawalan Kualiti.*

**(20 marks/markah)**

- [b] **Three measurements have been taken by operators A and B for each of 10 parts number as shown in Table 4[b]. Use Appendix A for references in answering the questions.**

*Tiga ukuran telah diambil oleh operator A dan B bagi setiap 10 bahagian nombor seperti yang ditunjukkan dalam Jadual 4[b]. Gunakan Lampiran A sebagai rujukan untuk menjawab soalan-soalan.*

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**Table 4[b]**  
*Jadual 4[b]*

Part number	Operator A Measurements ( <i>Vickers hardness</i> )			Operator B Measurements ( <i>Vickers hardness</i> )		
	1	2	3	1	2	3
1	250	249	250	250	248	251
2	252	252	251	251	251	251
3	253	250	250	254	252	251
4	249	251	250	248	250	251
5	248	249	248	248	249	248
6	252	250	250	252	250	250
7	251	251	251	251	250	250
8	252	250	249	253	248	250
9	250	251	250	251	248	249
10	247	246	249	246	247	248

- (i) Determine the standard deviation, upper control limit, lower control limit and central limit of the measurement error in the collected data. Plot the charts.

*Kirakan sisihan piawai, had kawalan atas, had kawalan bawah dan had tengah ralat pengukuran yang boleh didapati daripada data yang terkumpul. Plotkan carta-carta tersebut.*

(40 marks/markah)

- (ii) If the specification are at  $250 \pm 10$ , comment on the gauge specification?

*Jika spesifikasi adalah pada  $250 \pm 10$ , komen mengenai spesifikasi tolok?*

(20 marks/markah)

- (iii) Does the control chart analysis of the data indicate any potential problem in using the gauge?

*Adakah analisis carta kawalan data menunjukkan sebarang masalah yang berpotensi dalam menggunakan tolok.*

(20 marks/markah)

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5. [a] Sketch a diagram showing a comparison of normal ( $N$ ), tightened ( $T$ ) and reduced ( $R$ ) curves and discuss the pros and cons of using acceptance sampling procedures compared to traditional quality inspection.

*Lakarkan gambarajah menunjukkan graf perbandingan biasa ( $N$ ), diperketat ( $T$ ) dan dikurangkan ( $R$ ) dan bincangkan kebaikan dan keburukan menggunakan tatacara penerimaan peng sampelan berbanding menjalani pemeriksaan kualiti tradisional.*

(20 marks/markah)

- [b] An experiment has been carried out to monitor the temperature dependence of the CarbonX fabrics which are made to avoid burning, shrinking, charring, melting and decomposing when exposed to heat and flame. The fabric used for this shirt is tough enough, and safe enough, for firefighters and racing crews who are exposed to dangerous heat. The ideal variation is represented by:

$$R=R_0(1 + \alpha T)$$

where  $R$  is the resistance of temperature  $T$  ( $^{\circ}\text{C}$ ),  $R_0$  is the resistance at  $0$   $^{\circ}\text{C}$  and  $\alpha$  is the temperature coefficient of resistance. The following observations of  $R$  and  $T$  were obtained as in Table 5[b]:

*Satu eksperimen telah dijalankan untuk memantau suhu kebergantungan kepada fabrik CarbonX yang dibuat untuk mengelakkan kebakaran, pengecutan, kehangusan, peleburan dan penguraian apabila terdedah kepada haba dan api. Fabrik yang digunakan untuk baju ini adalah cukup kuat, dan selamat untuk ahli bomba dan krew perlumbaan yang terdedah kepada haba yang merbahaya. Perubahan sesuai diwakili oleh:*

$$R=R_0(1 + \alpha T)$$

*di mana  $R$  adalah rintangan,  $T$  suhu ( $^{\circ}\text{C}$ ),  $R_0$  adalah ketahanan pada  $0$   $^{\circ}\text{C}$  dan  $\alpha$  is pekali suhu rintangan. Pemerhatian berikut pada  $R$  dan  $T$  diperolehi seperti dalam Jadual 5 [b].*

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**Table 5[b]**  
*Jadual 5 [b]*

Temperature (°C)	Three set of resistance R readings, R ( $\Omega$ )		
10	12.4	12.3	12.5
20	13.2	13.0	13.1
30	13.5	13.6	13.7
40	13.7	13.8	13.9
50	14.5	14.6	14.6
60	15.1	15.3	15.2
70	15.4	15.5	15.3
80	15.2	15.1	15

- (i) Plot  $\bar{x}$  and R charts for this data collected in Table 5[b]. Is the process in statistical control? Give your comment on the plotted graphs.

*Plotkan carta  $\bar{x}$  dan R untuk data-data terkumpul di Jadual 5[b]. Adakah proses ini di dalam kawalan statistik? Berikan komen anda ke atas graf yang diplotkan itu.*

(40 marks/markah)

- (ii) Determine the process standard deviation of the population for the data.

*Kirakan sisihan piawai proses dengan menggunakan kaedah populasi untuk data tersebut.*

(20 marks/markah)

- (iii) Determine the process capability ratio,  $C_p$ . If the specifications are at nominal  $\pm 100$ , justify your opinion on the capability of the process.

*Kirakan nisbah keupayaan proses,  $C_p$ . Jika spesifikasi yang berada di nominal  $\pm 100$ , beri justifikasi pendapat anda mengenai keupayaan proses itu.*

(20 marks /markah)

**Appendix A**  
*Lampiran A*

**Table 11. Factors Used when Constructing Control Charts.**

NUMBER OF OBSERVATIONS IN SAMPLE <i>n</i>	CHART FOR AVERAGES			CHART FOR STANDARD DEVIATIONS					
	FACTORS FOR CONTROL LIMITS			FACTORS FOR CENTRAL LINE		FACTORS FOR CONTROL LIMITS			
	<i>A</i>	<i>A<sub>1</sub></i>	<i>A<sub>2</sub></i>	<i>C<sub>2</sub></i>	<i>1/C<sub>2</sub></i>	<i>B<sub>1</sub></i>	<i>B<sub>2</sub></i>	<i>B<sub>3</sub></i>	<i>B<sub>4</sub></i>
2	2.121	3.760	1.880	.5642	1.7725	0	1.843	0	3.267
3	1.732	2.394	1.023	.7236	1.3820	0	1.858	0	2.568
4	1.501	1.880	.729	.7979	1.2533	0	1.808	0	2.266
5	1.342	1.596	.577	.8407	1.1894	0	1.756	0	2.089
6	1.225	1.410	.483	.8686	1.1512	.026	1.711	.030	1.970
7	1.134	1.277	.419	.8882	1.1259	.105	1.672	.118	1.882
8	1.061	1.175	.373	.9027	1.1078	.167	1.638	.185	1.815
9	1.000	1.094	.337	.9139	1.0942	.219	1.609	.239	1.761
10	.949	1.028	.308	.9227	1.0837	.262	1.584	.284	1.716
11	.905	.973	.285	.9300	1.0753	.299	1.561	.321	1.679
12	.866	.925	.266	.9359	1.0684	.331	1.541	.354	1.646
13	.832	.884	.249	.9410	1.0627	.359	1.523	.382	1.618
14	.802	.848	.235	.9453	1.0579	.384	1.507	.406	1.594
15	.775	.816	.223	.9490	1.0537	.406	1.492	.428	1.572
16	.750	.788	.212	.9523	1.0501	.427	1.478	.448	1.552
17	.728	.762	.203	.9551	1.0470	.445	1.465	.466	1.534
18	.707	.738	.194	.9576	1.0442	.461	1.454	.482	1.518
19	.688	.717	.187	.9599	1.0418	.477	1.443	.497	1.503
20	.671	.697	.180	.9619	1.0396	.491	1.433	.510	1.490
21	.655	.679	.173	.9638	1.0376	.504	1.424	.523	1.477
22	.640	.662	.167	.9655	1.0358	.516	1.415	.534	1.466
23	.626	.647	.162	.9670	1.0342	.527	1.407	.545	1.455
24	.612	.632	.157	.9684	1.0327	.538	1.399	.555	1.445
25	.600	.619	.153	.9696	1.0313	.548	1.392	.565	1.435
Over 25	$\frac{3}{\sqrt{n}}$	$\frac{3}{\sqrt{n}}$				a	b	a	b

$$a = 1 - \frac{3}{\sqrt{2n}}, b = 1 + \frac{3}{\sqrt{2n}}$$

(continued)

Continued.

NUMBER OF OBSERVATIONS IN SAMPLE <i>n</i>	CHART FOR RANGES						
	FACTORS FOR CENTRAL LINE		FACTORS FOR CONTROL LIMITS				
	<i>d<sub>2</sub></i>	<i>1/d<sub>2</sub></i>	<i>d<sub>3</sub></i>	<i>D<sub>1</sub></i>	<i>D<sub>2</sub></i>	<i>D<sub>3</sub></i>	<i>D<sub>4</sub></i>
2	1.128	.8865	.853	0	3.686	0	3.276
3	1.693	.5907	.888	0	4.358	0	2.575
4	2.059	.4857	.880	0	4.698	0	2.282
5	2.326	.4299	.864	0	4.918	0	2.115
6	2.534	.3946	.848	0	5.078	0	2.004
7	2.704	.3698	.833	.205	5.203	.076	1.924
8	2.847	.3512	.820	.387	5.307	.136	1.864
9	2.970	.3367	.808	.546	5.394	.184	1.816
10	3.078	.3249	.797	.687	5.469	.223	1.777
11	3.173	.3152	.787	.812	5.534	.256	1.744
12	3.258	.3069	.778	.924	5.592	.284	1.719
13	3.336	.2998	.770	1.026	5.646	.308	1.692
14	3.407	.2935	.762	1.121	5.693	.329	1.671
15	3.472	.2880	.755	1.207	5.737	.348	1.652
16	3.532	.2831	.749	1.285	5.779	.364	1.636
17	3.588	.2787	.743	1.359	5.817	.379	1.621
18	3.640	.2747	.738	1.426	5.854	.392	1.608
19	3.689	.2711	.733	1.490	5.888	.404	1.596
20	3.735	.2677	.729	1.548	5.922	.414	1.586
21	3.778	.2647	.724	1.606	5.950	.425	1.575
22	3.819	.2618	.720	1.659	5.979	.434	1.566
23	3.858	.2592	.716	1.710	6.006	.443	1.557
24	3.895	.2567	.712	1.759	6.031	.452	1.548
25	3.931	.2544	.709	1.804	6.058	.459	1.541