

---

UNIVERSITI SAINS MALAYSIA

**Second Semester Examination  
Academic Session 2008/2009**

*Peperiksaan Semester Kedua  
Sidang Akademik 2008/2009*

**APRIL/MAY 2009**

**EPM 212/4 – METROLOGY & QUALITY CONTROL  
METROLOGI & KAWALAN KUALITI**

**Duration : 3 hours  
Masa : 3 jam**

---

**INSTRUCTIONS TO CANDIDATE :**

**ARAHAN KEPADA CALON :**

Please check that this paper contains **ELEVEN** (11) printed pages, and **THREE** (3) page appendix and **SIX** (6) questions before you begin answering the questions.

*Sila pastikan bahawa kertas soalan ini mengandungi **SEBELAS** (11) mukasurat, **TIGA** (3) Lampiran dan **ENAM** (6) soalan yang bercetak sebelum anda mula menjawab soalan.*

Answer **FIVE** (5) questions only.

*Sila jawab **LIMA** (5) soalan sahaja.*

Answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.

*Calon boleh menjawab semua soalan dalam **Bahasa Inggeris** ATAU **Bahasa Malaysia** ATAU kombinasi kedua-duanya.*

**Appendix/Lampiran :**

**Table B.1/Jadual B.1**

**[1] page/[1] mukasurat**

**Table B.8/Jadual B.8**

**[2] page/[2] mukasurat**

**Answer to each question must begin from a new page.**

*Jawapan bagi setiap soalan mestilah dimulakan pada mukasurat yang baru.*

- Q1. [a] List FIVE (5) possible causes of errors in dimensional measurement.**

*Senaraikan LIMA (5) perkara yang mungkin menyebabkan ralat dalam pengukuran dimensi.*

**(10 marks/markah)**

- [b] List FIVE (5) types of controllable errors in metrology. Which of these can be classified as systematic error?**

*Senaraikan LIMA (5) jenis ralat bolehkawal dalam metrologi. Manakah di antaranya boleh diklasifikasi sebagai ralat sistematik?*

**(20 marks/markah)**

- [c] The error  $\Delta L$  in the measured dimension  $L$  caused by temperature change is given by the following equation:**

$$\Delta L = L(\alpha_1 \Delta t_1 - \alpha_2 \Delta t_2)$$

where

- $\alpha_1$  = expansion coefficient of workpiece material
- $\alpha_2$  = expansion coefficient of instrument material
- $t_1$  = workpiece temperature
- $t_2$  = instrument temperature
- $\Delta t_1 = t_1 - 20^\circ\text{C}$
- $\Delta t_2 = t_2 - 20^\circ\text{C}$

*Ralat  $\Delta L$  dalam pengukuran dimensi  $L$  yang disebabkan oleh perubahan suhu diberikan oleh persamaan berikut:*

$$\Delta L = L(\alpha_1 \Delta t_1 - \alpha_2 \Delta t_2)$$

di mana

- $\alpha_1$  = pekali pengembangan bahan bahankerja
- $\alpha_2$  = pekali pengembangan bahan alatan
- $t_1$  = suhu bahankerja
- $t_2$  = suhu alatan
- $\Delta t_1 = t_1 - 20^\circ\text{C}$
- $\Delta t_2 = t_2 - 20^\circ\text{C}$

- i) List TWO (2) ways by which the error  $\Delta L$  due to temperature change can become zero. Can zero error be achieved in practice? Why?**

*Senaraikan DUA (2) kaedah di mana ralat  $\Delta L$  yang disebabkan oleh perubahan suhu boleh menjadi sifar. Bolehkah ralat sifar dicapai dalam praktik? Kenapa?*

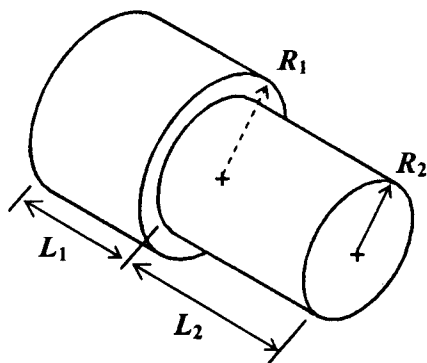
- ii) An aluminium rod of unknown diameter is measured using a vernier caliper. The reading shown by the caliper is 20.42 mm. If the rod and the caliper are initially left to attain a room temperature of 25°C, determine the magnitude of error in the measurement if the expansion coefficient of aluminium and caliper material are, respectively,  $22 \times 10^{-6}/^{\circ}\text{C}$  and  $14 \times 10^{-6}/^{\circ}\text{C}$ . Can this error be detected by the vernier caliper? Why?

*Rod aluminium yang garis pusatnya tidak diketahui diukur dengan menggunakan angkup vernier. Bacaan yang ditunjukkan oleh angkup tersebut ialah 20.42 mm. Jika rod dan angkup pada awalnya dibiarkan untuk mencapai suhu bilik 25°C, tentukan magnitud ralat dalam pengukuran tersebut jika pekali pengembangan aluminium dan bahan angkup ialah, masing-masing,  $22 \times 10^{-6}/^{\circ}\text{C}$  and  $14 \times 10^{-6}/^{\circ}\text{C}$ . Bolehkah ralat ini dikesan oleh angkup vernier tersebut? Kenapa?*

(40 marks/markah)

- [d] Figure Q1[d] shows a machined part. Determine the error in the volume of the part based on the data provided. Between the errors in length and radius measurement, which dimensional error contributes to a larger error in the volume?

*Rajah S1[d] menunjukkan satu komponen yang dimesin. Tentukan ralat dalam isipadu bahagian tersebut berasaskan data yang dibekalkan. Antara ralat-ralat dalam pengukuran panjang dan jejari yang manakah menyumbang lebih kepada ralat dalam isipadu?*



Dimension Dimensi	Value Nilai	Error Ralat
$L_1$	20 mm	$\pm 0.5$ mm
$L_2$	30 mm	$\pm 0.5$ mm
$R_1$	16 mm	$\pm 0.2$ mm
$R_2$	12 mm	$\pm 0.2$ mm

Figure Q1[d]  
Rajah S1[d]

(30 marks/markah)

Q2. [a] (i) State TWO (2) factors that limit the resolution of a vernier instrument.

*Nyatakan DUA (2) faktor yang menghadkan resolusi alatan vernier.*

(ii) Figure Q2[a] shows the scales of a vernier caliper. Determine the resolution of the caliper. What is the reading shown by the caliper?

*Rajah S2[a] menunjukkan skala-skala pada angkup vernier. Tentukan resolusi angkup tersebut. Apakah bacaan yang ditunjukkan oleh angkup tersebut?*

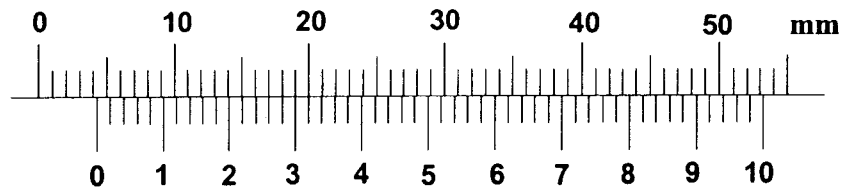
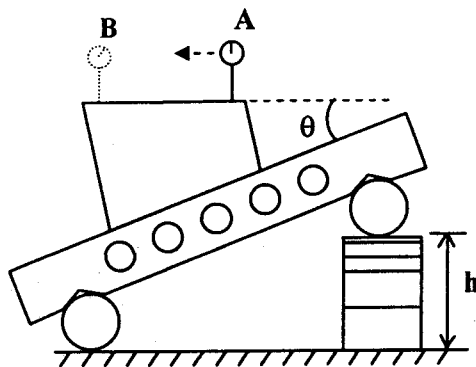


Figure Q2[a]  
Rajah S2[a]

(25 marks/markah)

[b] (i) A 100 mm sine bar was used to measure the angle  $\theta$  on a specimen to the nearest second shown in Figure Q2[b]. The angle was initially measured using the protractor head of a combination set and estimated to be  $18^\circ$ . Calculate the height  $h$  of the gage blocks (to three decimal places) required to set up the arrangement for angle measurement. Hence, select the appropriate gage blocks from the set given.

*Bar sinus 100 mm telah digunakan untuk mengukur sudut  $\theta$  pada spesimen kepada saat yang terdekat seperti ditunjukkan dalam Rajah S2[b]. Sudut tersebut pada awalnya diukur dengan menggunakan kepala jangkasadut pada set gabungan dan dianggarkan sebagai  $18^\circ$ . Kira ketinggian  $h$  pada tolok-tolok bongkah (kepada tiga titik perpuluhan) yang diperlukan untuk membina susunan tersebut untuk pengukuran sudut pada spesimen. Seterusnya, pilih tolok-tolok yang sesuai daripada set yang diberikan.*



Blocks per set	Blocks included in set (mm)	
122		1.0005 (1 pc.)
	Step of 0.001:	1.001 – 1.009 (9 pcs.)
	Step of 0.01:	1.01 – 1.49 (49 pcs.)
	Step of 0.1:	1.6 – 1.9 (4 pcs.)
	Step of 0.5:	0.5 – 24.5 (49 pcs.)
	Step of 10:	30 – 100 (8 pcs.) 25, 75 (2 pcs.)

Figure Q2[b]  
Rajah S2[b]

- (ii) If the dial indicator is set to zero at  $A$  and shows a reading of  $+0.020$  mm when moved to the left (at  $B$ ) by 50 mm, determine the angle  $\theta$  to the nearest second.

*Jika petunjuk dail dilaraskan kepada sifar pada  $A$  dan menunjukkan bacaan  $+0.020$  mm apabila digerakkan ke kiri ( $B$ ) sebanyak 50 mm, tentukan sudut  $\theta$  kepada saat yang terdekat.*

(35 marks/markah)

- [c] (i) Optical flats are commonly used for the measurement of flatness of highly polished surfaces. State TWO (2) factors that influence the number of fringes observed on a surface.

*Keping optik biasanya digunakan untuk pengukuran kerataan permukaan-permukaan yang digilap. Nyatakan DUA (2) faktor yang mempengaruhi bilangan pinggir yang dilihat pada permukaan tersebut.*

- (ii) Figure Q2[c] shows the fringe pattern formed when an optical flat is placed on a test surface. The optical flat contacts the surface at point  $O$ . Sketch cross-sectional views along  $A-A$  and  $B-B$  showing the profile of the surface. Hence, determine the height difference between the highest point and the outermost fringe along each cross-section, given that the wavelength of light used is  $0.585 \mu\text{m}$ .

*Rajah S2[c] menunjukkan corak pinggir yang terbentuk apabila keping optik diletakkan di atas permukaan ujian. Keping optik tersebut menyentuh permukaan pada titik  $O$ . Lakaran pandangan keratan rentas sepanjang  $A-A$  dan  $B-B$  yang menunjukkan profil permukaan tersebut. Seterusnya, tentukan perbezaan ketinggian di antara titik tertinggi dan pinggir paling luar sepanjang setiap keratan, diberikan bahawa jarak gelombang cahaya yang digunakan ialah  $0.585 \mu\text{m}$ .*

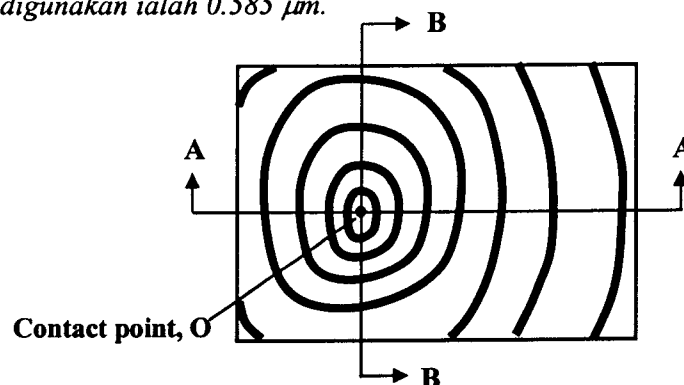


Figure Q2[c]  
Rajah S2[c]

(40 marks/markah)

Q3. [a] Explain, with the aid of sketches, how the following roughness parameters are determined:

- (i) Ten-point average roughness,  $R_z$
- (ii) Centerline average roughness,  $R_a$
- (iii) Peak-to-valley roughness,  $R_t$

Determine the roughness parameters  $R_a$  for the profiles shown in Figures Q3[a](i) and Q3[a](ii). Compare the  $R_a$  values between the two profiles and comment on the result. Is  $R_a$  a reliable parameter when comparing these profiles? What roughness parameters could characterize these profiles more accurately?

Terangkan, dengan bantuan lakaran, bagaimana parameter-parameter kekasaran berikut ditentukan:

- (i) Kekasaran purata sepuluh-titik,  $R_z$
- (ii) Kekasaran purata garistengah,  $R_a$
- (iii) Kekasaran puncak-ke-lembah,  $R_t$

Tentukan parameter kekasaran  $R_a$  bagi profil-profil yang ditunjukkan dalam Rajah-rajah S3[a](i) dan S3[a](ii). Bandingkan nilai  $R_a$  antara profil-profil tersebut dan berikan komen anda. Adakah  $R_a$  suatu parameter yang boleh dipercayai apabila membandingkan profil-profil tersebut? Apakah parameter kekasaran yang boleh mencirikan profil-profil tersebut dengan lebih jitu?

(50 marks/markah)

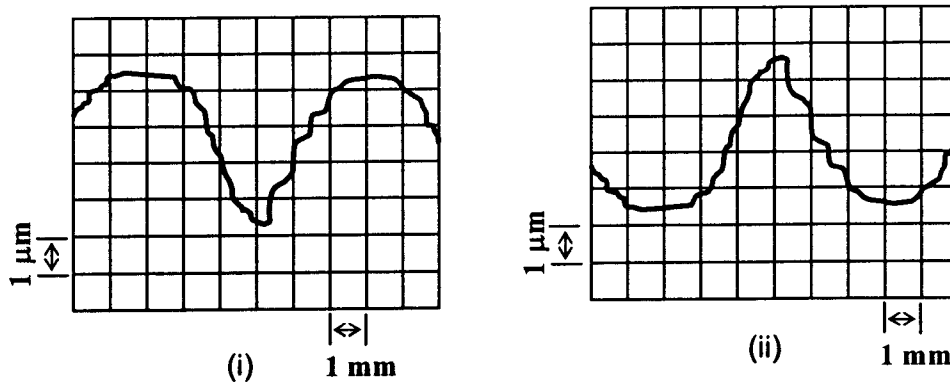


Figure Q3[a]  
Rajah S3[a]

- [b] (i) What is the objective of a perpendicularity test on a drilling machine?

*Apakah objektif ujian keserenjangan pada mesin gerudi?*

- (ii) A perpendicularity test was carried out on a drilling machine using a dial indicator as shown in Figure Q3[b]. The stylus of the dial indicator was placed 200 mm from the axis of the spindle. The reading at the first position (A) was adjusted to zero. If the dial indicator is rotated through  $180^\circ$  and reading at the second position is +0.4 mm, determine the perpendicularity error of the drilling machine.

*Ujian keserenjangan dilakukan ke atas mesin gerudi dengan menggunakan petunjuk dail seperti dalam Rajah S3[b]. Kuar petunjuk dail diletakkan 200 mm dari paksi pengumpar. Bacaan pada kedudukan pertama (A) dilaraskan kepada sifar. Jika petunjuk dail tersebut diputar melalui  $180^\circ$  dan bacaan pada kedudukan kedua ialah +0.4 mm, tentukan ralat keserenjangan pada mesin gerudi tersebut.*

(20 marks/markah)

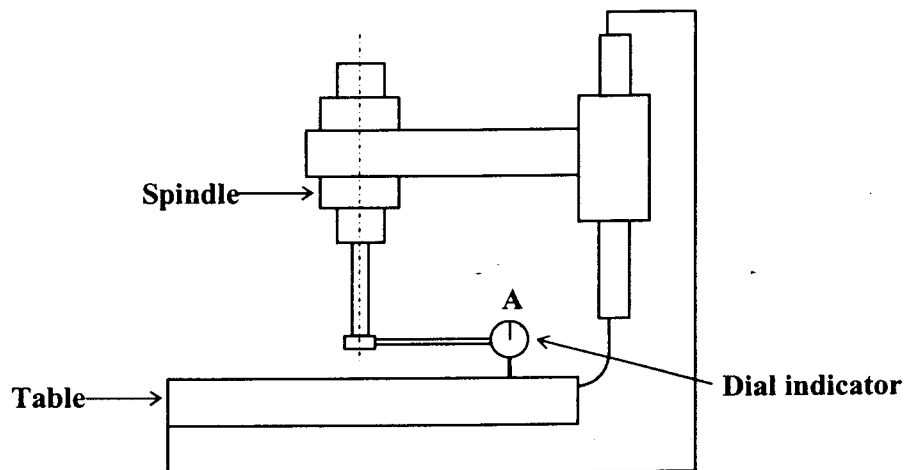


Figure Q3[b]  
Rajah S3[b]

- [c] Sketch diagrams to show the basic construction of the following types of coordinate measuring machines (CMMs):

- (i) Cantilever type
- (ii) Bridge type
- (iii) Horizontal arm type

Label the axes clearly. State TWO (2) advantages and TWO (2) disadvantages of the horizontal arm type CMM compared to the bridge type.

Lakarkan gambarajah yang menunjukkan binaan asas bagi mesin mengukur koordinat (CMM) berikut:

- (i) Jenis julur
- (ii) Jenis jejambat
- (iii) Jenis lengan mendatar

Labelkan paksi-paksi dengan jelas. Nyatakan DUA (2) kelebihan dan DUA (2) kelemahan CMM jenis lengan mendatar dibandingkan dengan jenis jejambat.

(30 marks/markah)

- Q4. [a] State the definition of quality from the customer, manufacturer and the law enforcement perspective.**

*Nyatakan definisi kualiti daripada pandangan pengguna, pengeluar dan pihak berkuasa.*

(10 marks/markah)

- [b] Explain briefly FOUR (4) disadvantages of quality control by inspection method.**

*Terangkan secara ringkas EMPAT (4) keburukan kawalan kualiti menggunakan kaedah pemeriksaan.*

(20 marks/markah)

- [c] Differentiate between common-cause and special-cause variation? Discuss the importance of separating these two types of variation in process control.**

*Bezakan antara penyebab 'lazim' dan perubahan 'penyebab khas'?. Bincangkan kepentingan memisahkan dua jenis perubahan ini dalam kawalan proses.*

(40 marks/markah)

- [d] List FIVE (5) symptoms of organizational trouble as outlined by Crosby and explain any TWO (2) of them.**

*Senaraikan LIMA (5) petanda organisasi bermasalah seperti digariskan oleh Crosby dan terangkan mana-mana DUA (2) daripadanya.*

(30 marks/markah)



Q5. [a] Table Q5[a] shows the daily number of defective screws from a production process for a period of 52 days.

- (i) Prepare a tally sheet showing the frequency of number of defective screws.
- (ii) Plot a frequency histogram from the tally sheet. Calculate the range  $R$ , the cell interval  $i$ , and the cell midpoints  $MP_i$

*Jadual S5[a] menunjukkan jumlah skru yang defektif setiap hari dalam satu proses pengeluaran untuk tempoh 52 hari.*

- (i) *Sediakan carta 'tally' menunjukkan kekerapan bilangan skru yang defektif.*
- (ii) *Plotkan histogram frekuensi daripada carta 'tally' tersebut. Tunjukkan dengan jelas bagaimana anda menentukan julat  $R$ , julat sel  $i$ , dan titik tengah sel  $MP_i$*

**Table Q5[a]: Number of defective screws daily**  
*Jadual S5[a]: Jumlah skru tercela setiap hari*

0	1	3	0	1	0	1	0
1	5	4	1	2	1	2	0
1	0	2	0	0	2	0	1
2	1	1	1	2	1	1	
0	4	1	3	1	1	1	
1	3	4	0	0	0	0	
1	3	0	1	2	2	3	

(30 marks/markah)

- [b] The mean value of the weight of a particular preserved fruit jar when filled up is 0.297kg with a standard deviation of 0.024kg and a lower specification limit of 0.274kg. Assuming the weight distribution follow normal distribution, determine (i) the percent of data that falls below the lower specification limit; (ii) the percent of data that falls above 0.347kg.

*Nilai min bagi berat balang sejenis jeruk buah apabila dipenuhi ialah 0.297kg dengan sisihan piawai 0.024kg dan had spesifikasi bawah 0.274kg. Andaikan taburan berat balang menepati taburan normal, tentukan (i) peratusan data yang berada di bawah had spesifikasi bawah; (ii) Peratusan data yang berada di atas 0.347kg.*

(30 marks/markah)

- [c] Table Q5[c] shows sample measurements data for 10 samples. Construct the  $\bar{x}$  and R-chart. Determine the LCL and UCL for  $\bar{x}$  and R.

*Jadual Q5[c] menunjukkan data pengukuran bagi 10 sampel. Bina carta  $\bar{x}$  dan carta R. Tentukan LCL dan UCL untuk  $\bar{x}$  dan R.*

**Table Q5[c]**  
*Jadual S5[c]*

Sample number	1	2	3	4	5	6	7	8	9	10
Sample measurements	933	911	889	882	903	890	892	908	895	916
	897	898	915	913	930	940	912	920	920	890
	885	900	905	930	890	895	895	896	922	891
	900	905	902	900	890	909	896	894	928	920
	879	862	873	871	900	915	902	906	926	916

(40 marks/markah)

- Q6. [a] Explain why normal distribution curve is widely accepted as a standard tool for statistical analysis and control of processes? Describe THREE (3) major characteristics of the normal distribution curve that explains the state of data distribution from a given process.

*Terangkan kenapa taburan normal diterimapakai secara meluas sebagai satu kaedah untuk analisa statistik dan kawalan proses? Perihalkan TIGA (3) ciri utama bagi plot taburan normal yang menjelaskan keadaan taburan data daripada sesuatu proses.*

(30 marks/markah)

- [b] Figure Q6[b] is a normal distribution curve obtained from a particular process. Based on the curve, determine the following:

- (i) Process capability ratio, PCR
- (ii) Is the process centered? Explain why?
- (iii) Is the process good, fair or poor? Explain why.
- (iv) Capability index,  $C_p$
- (v) Minimal Capability index,  $C_{pk}$

Rajah S6[b] merupakan satu plot taburan normal diperolehi daripada satu proses. Berdasarkan plot tersebut, tentukan yang berikut:

- (i) Nisbah keupayaan proses, PCR
- (ii) Adakah proses 'centered'? Terangkan kenapa
- (iii) Adakah proses baik, agak baik atau buruk? Terangkan kenapa.
- (iv) Indeks keupayaan,  $C_p$
- (v) Indeks keupayaan minima,  $C_{pk}$

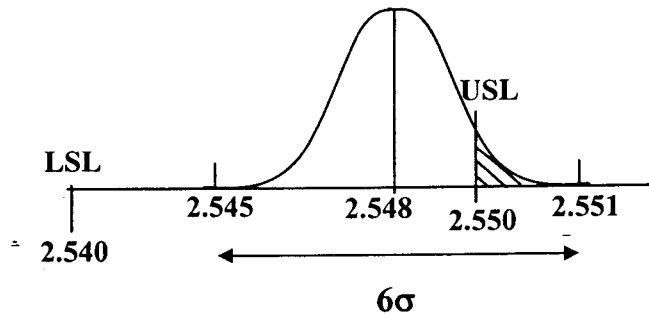


Figure Q6[b]  
Rajah S6[b]

(40 marks/markah)

[c] Location pins for workholding devices are ground to a diameter of 12.50 mm, with a tolerance of  $\pm 0.05$  mm.

- (i) If the process is centred at 12.50 mm, and the standard deviation is 0.02 mm, what percent age the product must be scrapped and what percent can be reworked?
- (ii) How can the process centre be changed to eliminate the scrap?
- (iii) What is the rework percentage after the change in (ii)?

Pin untuk alatan pemegang bahan kerja dimesin ke diameter 12.50 mm dengan 'tolerance'  $\pm 0.05$  mm.

- i) Jika proses dipusatkan pada 12.50 mm, dan sisihan piawai ialah 0.02 mm, berapakah peratusan produk yang mesti dibuang dan apakah peratusan yang boleh dikerjakan semula?
- ii) Bagaimanakah pusat proses dapat diubahkan supaya tidak berlaku sekerap.
- iii) Berapakah peratusan kerja semula selepas perubahan dalam (ii) berlaku?

(30 marks/markah)

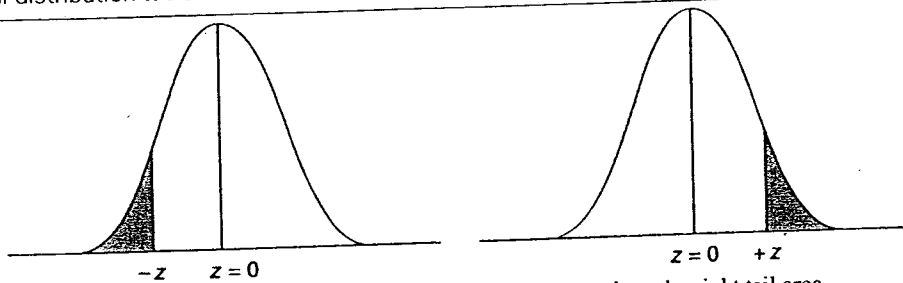
**APPENDIX 1**  
*LAMPIRANI***TABLE B.1**  
*JADUAL B.1***TABLE B.1**  
Constants for an  $\bar{x}$  and  $R$  chart

Sample size $n$	$A_2$	$D_3$	$D_4$	$d_2$
2	1.880	0	3.267	1.128
3	1.023	0	2.574	1.693
4	0.729	0	2.282	2.059
5	0.577	0	2.114	2.326
6	0.483	0	2.004	2.536
7	0.419	0.076	1.924	2.704
8	0.373	0.136	1.864	2.847
9	0.337	0.184	1.816	2.970
10	0.308	0.223	1.777	3.078

**APPENDIX 2**  
**LAMPIRAN 2**

**TABLE B.8**  
**JADUAL B.8**

**TABLE B.8**  
The normal distribution table



A negative  $z$  gives the left tail area.  
Area = probability that a measurement is less than  $x$ .

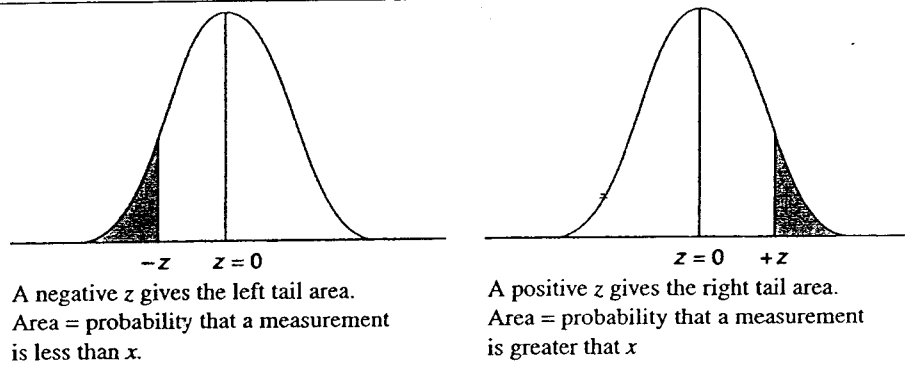
A positive  $z$  gives the right tail area.  
Area = probability that a measurement is greater than  $x$ .

$$z = \frac{x - \bar{x}}{s}$$

$ z $	0	1	2	3	4	5	6	7	8	9
0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641
0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
0.7	.2420	.2389	.2358	.2327	.2297	.2266	.2236	.2206	.2177	.2148
0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064

TABLE B.8  
JADUAL B.8

TABLE B.8  
continued



$$z = \frac{x - \bar{x}}{s}$$

$ z $	0	1	2	3	4	5	6	7	8	9
2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
3.0	.00135	.00131	.00126	.00122	.00118	.00114	.00111	.00107	.00104	.00100
3.1	.00097	.00094	.00090	.00087	.00084	.00082	.00079	.00076	.00074	.00071
3.2	.00069	.00066	.00064	.00062	.00060	.00058	.00056	.00054	.00052	.00050
3.3	.00048	.00047	.00045	.00043	.00042	.00040	.00039	.00038	.00036	.00035
3.4	.00034	.00032	.00031	.00030	.00029	.00028	.00027	.00026	.00025	.00024
3.5	.00023	.00022	.00022	.00021	.00020	.00019	.00019	.00018	.00017	.00017
3.6	.00016	.00015	.00015	.00014	.00014	.00013	.00013	.00012	.00012	.00011
3.7	.00011	.00010	.00010	.00010	.00009	.00009	.00008	.00008	.00008	.00008
3.8	.00007	.00007	.00007	.00006	.00006	.00006	.00006	.00005	.00005	.00005
3.9	.00005	.00005	.00004	.00004	.00004	.00004	.00004	.00004	.00003	.00003
4.0	.00003									