Second Semester Examination
2022/2023 Academic Session

Julai/Ogos 2023

EPM 212 – Metrology and Quality Control
[Metrology & Quality Control]

Duration: 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of NINE (9) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN (9) muka surat yang bercetak sebelum anda memulakan peperiksaan ini].

Instructions : Answer **ALL FIVE (5)** questions.

*[**Arahan :** Jawab **KESEMUA LIMA (5)** soalan.]*

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1. [a] Differentiate the systematic error and random error in measurement. Give ONE (1) cause for each error and suggest ONE (1) solution to reduce or eliminate that error.

(30 marks)

[b] Ali wants to perform a measurement of plastic material using a micrometer. State TWO (2) main causes that contribute to the measurement errors.

(20 marks)

[c] A dial comparator was used to determine the dimensions of a specimen block. Each dimension was compared with the length of a combination of block gauges wrung together. The readings obtained are as Table 1[c]:

Table 1[c]

Dimension	Dimension of block gauges (mm)	Comparator reading (mm)
Length	50.000, 2.500, 1.080	-0.052
Width	20.000, 1.800, 1.120	-0.205
Height	15.000, 2.500, 1.020	+1.150

Calculate the error of the comparator readings for each reading by analyzing the calibration graph as shown in Figure 1[c]. Assume that the reading of the comparator was set to zero using the block gauges.

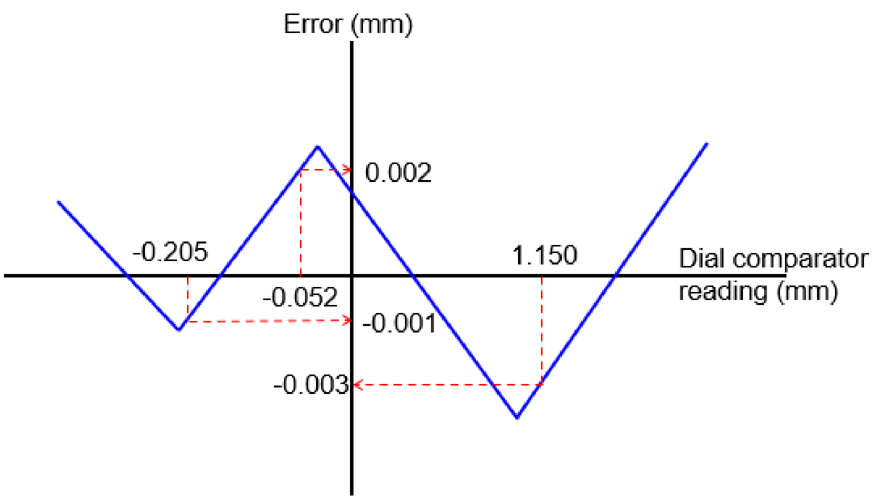

Figure 1[c]

(50 marks)

2. [a] A sine bar of length L = 300 mm (distance between rollers) is used to measure angle θ on a specimen block as shown in Figure 2[a]. The reading of the dial indicator at point A is 0 mm and the reading at point B is -0.009 mm. The distance between points A and B, d = 50 mm. The block gages have a stacked height of 56.780 mm. Prove that the correction to gage block height, $\Delta h = \Delta h_{AB} \times (L \times \cos\theta)/d$ where Δh_{AB} is the difference in dial reading.

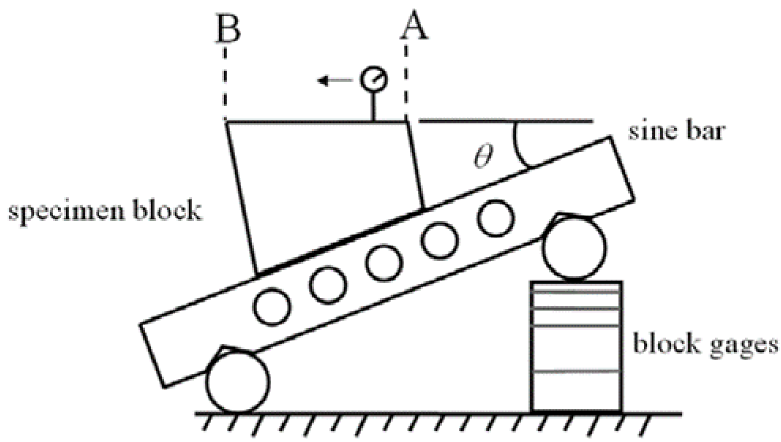

Figure 2[a]

(30 marks)

[b] Determine angle, θ to the nearest seconds.

(20 marks)

[c] Figure 2[c] shows the basic construction of autocollimator. Based on the laws of optics, (i) explain the light path from the light source until it hits the focal point and (ii) explain the light path from light source if the reflection surface is tilted.

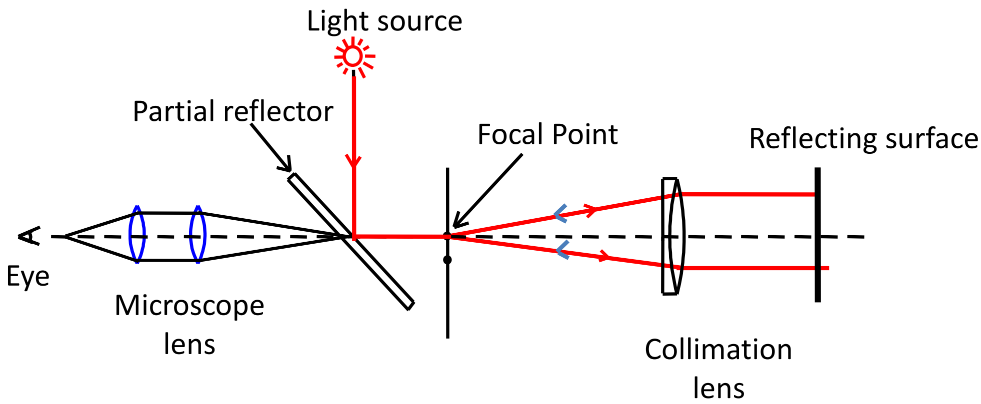

Figure 2[c]

(20 marks)

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[d] (i) The School of Mechanical Engineering is planning to purchase high-spec equipment for nanofabrication. As an equipment engineer, you have been asked to inspect the straightness of the XY-table guideways. Table 2 show the reading you obtained based on the reflector position in Figure 2[d]. Determine the deviation (correct to 7 decimal places) in straightness, Δh at each of the positions *A* to *F* measured relative to the reference line.

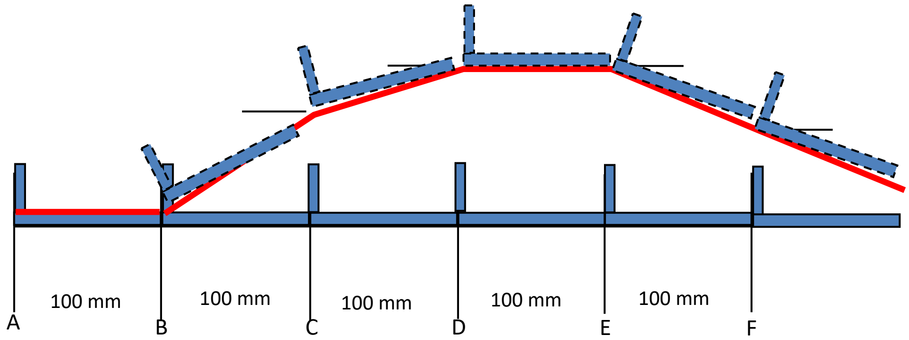

Figure 2[d]

Table 2[d]

Position	Autocollimator reading (arc second)
A	0
B	1
C	3
D	0
E	-1
F	-2

(12 marks)

(ii) Since the equipment's purpose is to fabricate on a micro or nanoscale, the guideways must be straight with cumulated deviation, Δh_{cum} less than 1 micron. Based on your answers at 2[d(i)], determine whether the guideways meet the specification or not?

(18 marks)

3. [a] Estimate the roundness error for the trace shown in Figure 3[a] below if the magnification is 200X using the (i) LSC method, (ii) MCC method and (iii) MIC method. Choose any point within the trace as initial datum.

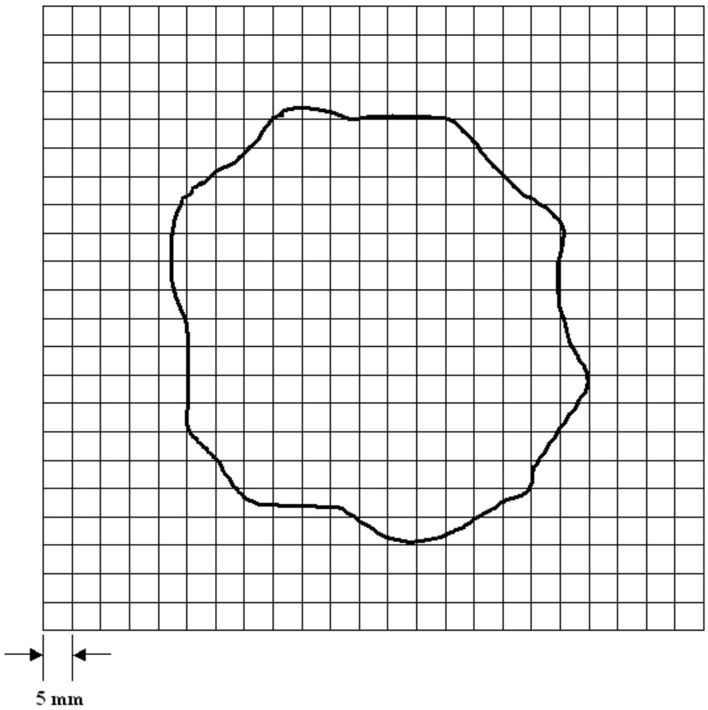

Figure 3[a]

(50 marks)

[b] What is the Quality means in the perspective of customers, manufacturer and government?

(30 marks)

[c] “Prevention is better than cure”, is the quote we usually heard from a medical doctor. However, this proverb is true for control quality too. (i) Explain how Traditional Quality Control (TQC) work and (ii) explain the drawback of TQC as compare to other quality managements techniques.

(20 marks)

4. [a] List TWO (2) types of Control Chart (CC) and their sub-control charts respectively.

(30 marks)

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[b] The hardness in N/mm^2 for ten samples of metal were received from two different hardening processes i.e. (1) Saltwater quenching and (2) Oil quenching. The data are as shown in Table 4[b].

Table 4[b]

Sample	Saltwater quench	Oil quench
1	145	150
2	150	150
3	153	147
4	148	155
5	141	140
6	152	146
7	146	158
8	154	152
9	139	151
10	148	143

(i) Plot a regression graph from the data given.

(20 marks)

(ii) Construct a 95% confidence interval on the differences in mean hardness.

(30 marks)

(iii) Justify if the assumption of normality seems appropriate for this data?

(20 marks)

5. [a] Sketch a diagram of operational curves (OC) indicating the normal, tightened, and reduced curves.

(10 marks)

[b] A process is in statistical control with $\bar{\bar{x}} = 299$ and $\bar{R} = 3.5$. The control chart uses a sample size of $n = 4$. The specifications are at 300 ± 8. The quality characteristic is normally distributed. Refer Appendix A for references.

(i) Determine the estimated process capability, C_p.

(10 marks)

(ii) Determine the actual process capability, C_{pk}.

(10 marks)

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(iii) Calculate and compare the Process Capability Ratios (PCRs).

(10 marks)

[c] Inside diameters measurement (mm) for ten piston rings were measured for its tolerance limit study using a micrometer as shown in Table 5[c].

(i) Construct an appropriate control chart using the given data.

(30 marks)

(ii) Give ONE (1) chance assignable error and TWO (2) on the errors of the measurements.

(30 marks)

Table 5[c]

Sample number	X_1	X_2	X_3	X_4	X_5
1	74.030	74.002	74.019	73.992	74.008
2	73.995	73.992	74.001	74.011	74.004
3	73.988	74.024	74.021	74.005	74.002
4	74.002	73.996	73.993	74.015	74.009
5	73.992	74.007	74.015	73.989	74.014
6	74.009	73.994	73.997	73.985	73.993
7	73.995	74.006	73.994	74.000	74.005
8	73.985	74.003	73.993	74.015	73.988
9	74.008	73.995	74.009	74.005	74.004
10	73.998	74.000	73.990	74.007	73.995

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Appendix A
Appendik A

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

NUMBER OF OBSERVATIONS IN SAMPLE	CHART FOR AVERAGES			CHART FOR STANDARD DEVIATIONS					
	FACTORS FOR CONTROL LIMITS			FACTORS FOR CENTRAL LINE		FACTORS FOR CONTROL LIMITS			
n	A	A_1	A_2	C_2	$1/C_2$	B_1	B_2	B_3	B_4
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.

X-Bar and S Chart				
Subgroup Sample Size	X-Bar Factor	Standard Deviation Factors		Variance Factor
n	A_3	B_3	B_4	c_4
2	2.659	-	3.267	0.7979
3	1.954	-	2.568	0.8862
4	1.628	-	2.266	0.9213
5	1.427	-	2.089	0.9400
6	1.287	0.030	1.970	0.9515
7	1.182	0.118	1.882	0.9594
8	1.099	0.185	1.815	0.9650
9	1.032	0.239	1.761	0.9693
10	0.975	0.284	1.716	0.9727
15	0.789	0.428	1.572	0.9823
20	0.680	0.510	1.490	0.9869
25	0.606	0.565	1.435	0.9896

Continued.

NUMBER OF OBSERVATIONS IN SAMPLE	CHART ROR RANGES							
	FACTORS FOR CENTRAL LINE		FACTORS FOR CONTROL LIMITS					
n	d_2	$1/d_2$	d_3	D_1	D_2	D_3	D_4	
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	