Second Semester Examination
2021/2022 Academic Session

July/August 2022

EPM212 – Metrology and Quality Control
(Metrologi dan Kawalan Kualiti)

Duration : 2 hours
(Masa : 2 jam)

Please check that this examination paper consists of EIGHT [8] pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LAPAN (8) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

INSTRUCTIONS : Answer **ALL FOUR [4]** questions.

[**Arahan** : Jawab **EMPAT (4)** soalan.]

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1. [a] Give TWO (2) examples of standard that normally used metrologist when performing a measurement process.

(20 marks)

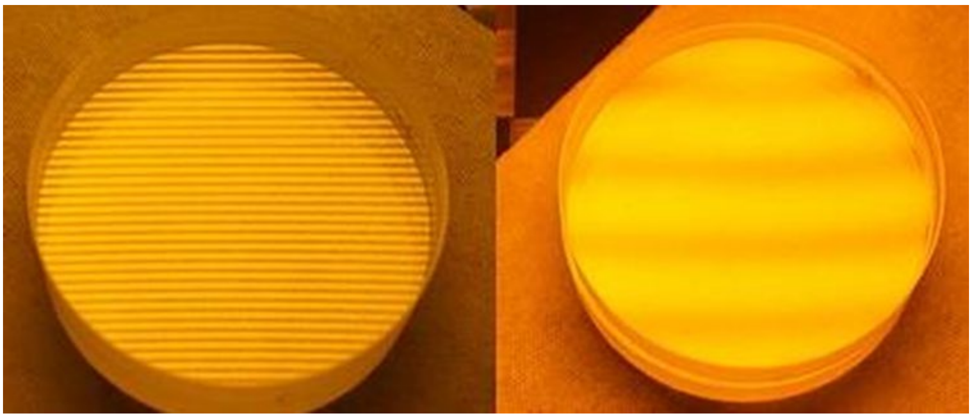
[b] Ali wants to perform a measurement of plastic material using a micrometer. Determine THREE (3) main of causes that contribute to the measurement errors.

(20 marks)

[c] The diameter of an aluminum rod was measured using a micrometer in a laboratory where the temperature is 28°C. The reading shown by the micrometer is 53.725 mm. If the coefficient of thermal expansion of aluminum is $26 \times 10^{-6}/°C$. If the different temperature between the micrometer and specimen is 8°C and the error of the measurement is 7µm. Calculate the coefficient of thermal expansion of the micrometer material.

(30 marks)

[d] Figure 1 shows the fringe patterns formed when a polished surface is viewed under an optical flat with the aid of monochromatic light source. State ONE (1) main factor that determines the density of the fringes observed. Is the surface shown on Figure 1 (b) perfectly flat? Provide justification.



(a) (b)

Figure 1

(30 marks)

2. Figure 2 shows part of a trace measured over one sampling length. Each horizontal grid spacing represents 0.125 mm, while each vertical grid spacing represents 0.1 μm.

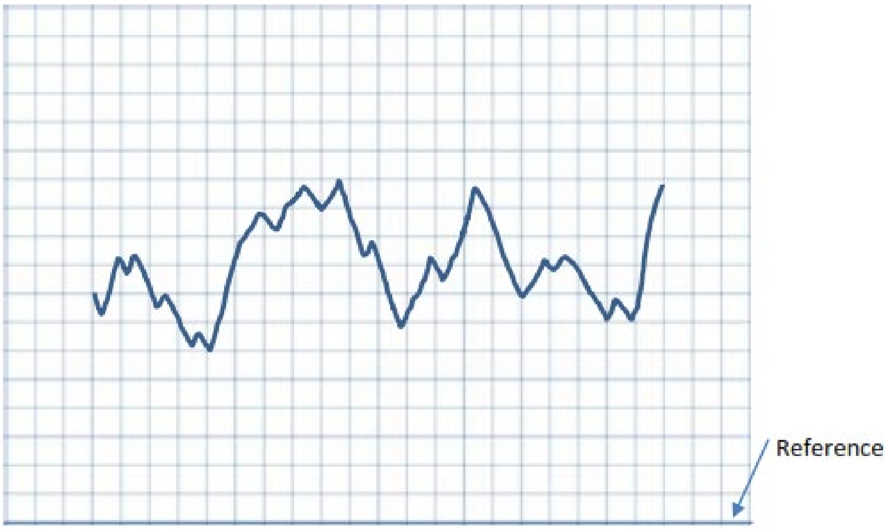


Figure 2

Table 1

Lc	**Profile Length**
80 μm	0.4 mm
250 μm	1.25 mm
800 μm	4 mm
2500 μm	12.5 mm
8000 μm	40 mm

[a] From the Table 1, determine the evaluation length and cut-off length (Lc) used in Figure 2?

(40 marks)

[b] Determine the Average Roughness value of the profile (in μm) measured from the reference line shown.

(30 marks)

[c] Determine the Maximum Peak-to-Valley Roughness value?

(10 marks)

[d] Based on your answer at [b] and [c], if the customer set the maximum value of the surface roughness of the machined surface is 0.9 μm, is the both Average Roughness and Maximum Peak-to-Valley meet the customer requirement? Provide justification.

(20 marks)

3. [a] (i) What are the relationships between Quality Control and Metrology?

(20 marks)

(ii) With the help of sketches, list and briefly describe the FOUR (4) statistical process control (SPC) tools.

(20 marks)

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

(10 marks)

[c] Inside diameters measurement (mm) for automotive engine piston rings were measured for its roundness and tolerance limit study using a micrometer vernier as shown in Table 3.

(i) Construct and interpret the $\bar{x}$ and s control charts using the given values and Appendix A.

(30 marks)

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

(10 marks)

(iii) If the measurements need to be revised, how many additional data needed to be measured to conform to the specification of +/- 95% acceptance readings?

(10 marks)

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Table 3

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
11	73.994	73.998	73.994	73.995	73.990
12	74.004	74.000	74.007	74.000	73.996
13	73.983	74.002	73.998	73.997	74.012
14	74.006	73.967	73.994	74.000	73.984
15	74.012	74.014	73.998	73.999	74.007
16	74.000	73.984	74.005	73.998	73.996
17	73.994	74.012	73.986	74.005	74.007
18	74.006	74.010	74.018	74.003	74.000
19	73.984	74.002	74.003	74.005	73.997
20	73.982	73.984	73.995	74.013	74.013

4. [a] Plot a diagram of operational curves (OC) indicating the normal, tighten and reduced curves.

(20 marks)

[b] A process is in statistical control with $\bar{\bar{x}} = 199$ and $\bar{R} = 3.5$. The control chart uses a sample size of $n = 4$. The specifications are at 200 ± 8. The quality characteristic is normally distributed.

(i) Determine the estimated process capability, Cp.

(30 marks)

(ii) Determine the actual process capability, Cpk.

(20 marks)

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

(20 marks)

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(iv) How much improvement could be made in process performance if the mean could be centered at the nominal value?

(10 marks)

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Appendix A

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.

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