Second Semester Examination
2023/2024 Academic Session

July / August 2024

EPM 212 – Metrology & Quality Control
(Metrologi & Kawalan Kualiti)

Duration: 3 hours
(Masa: 3 Jam)

Please check that this examination paper consists of ELEVEN (11) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEBELAS (11) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

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

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

...2/-

1. (a) Define the meaning of uncertainty and tolerance in measurement. Give **ONE (1)** example of each term.

(30 marks)

(b) Abu wants to perform a measurement of plastic material according to ASTM D638 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	-0.102
Height	15.000, 2.500, 1.020	+1.150

Calculate the true value of 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.

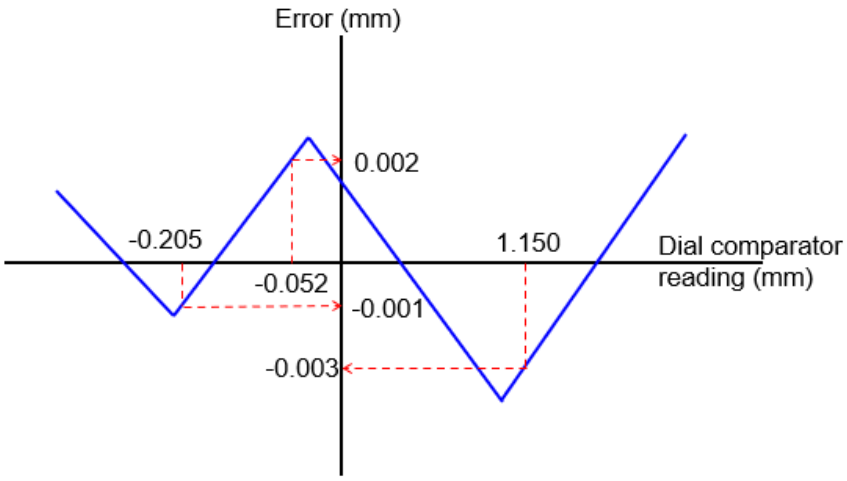


Figure 1 (c)

(50 marks)

...3/-

2. (a) Figure 2 (a) shows part of a trace measured over one sampling length. Each horizontal grid spacing represents 0.2 mm, while each vertical grid spacing represents 0.1 µm. What is the sampling length used?

(b) Determine the average height of the profile (in µm) measured from the reference line shown.

(c) Determine the values of the following roughness parameters: R_a,R_q and R_t

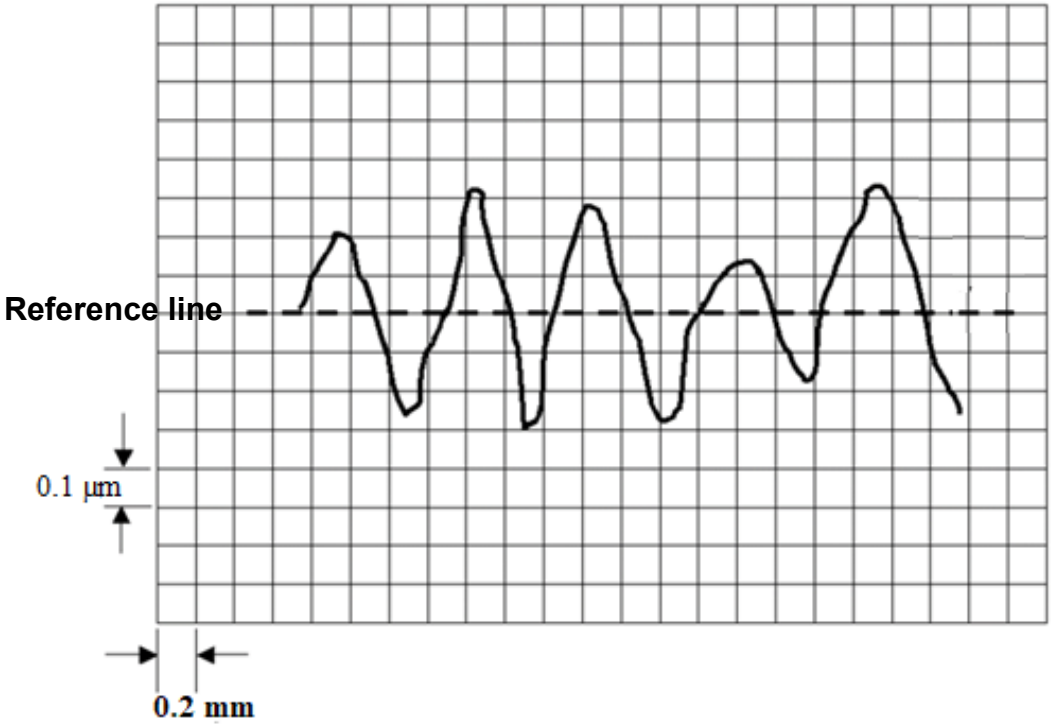


Figure 2 (a)

(50 marks)

(d) Autocollimator utilised optical laws such as Law of reflection and Snell's Laws to function. Explain the basic principal of autocollimator and its basic build. You may use drawing to illustrate your answer.

(20 marks)

(e) Optical tools are simple yet accurate for measuring flatness. To understand the contour of a surface, identifying the fringe pattern is essential. Sketch the fringe pattern of a surface for a given cross sections. Figure 2 (a) (i) show the example of the solution.

...4/-

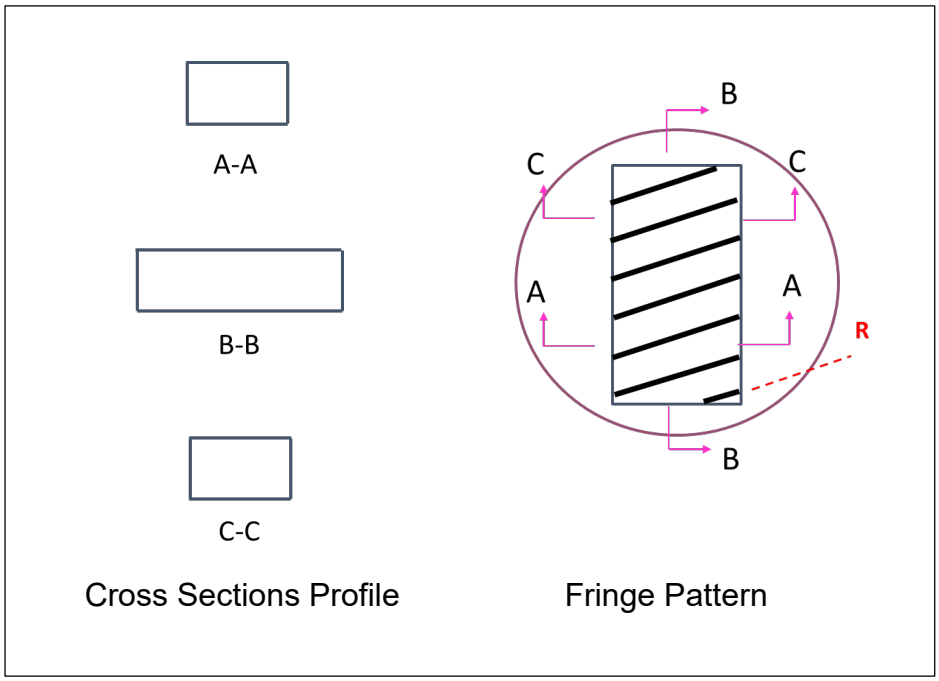
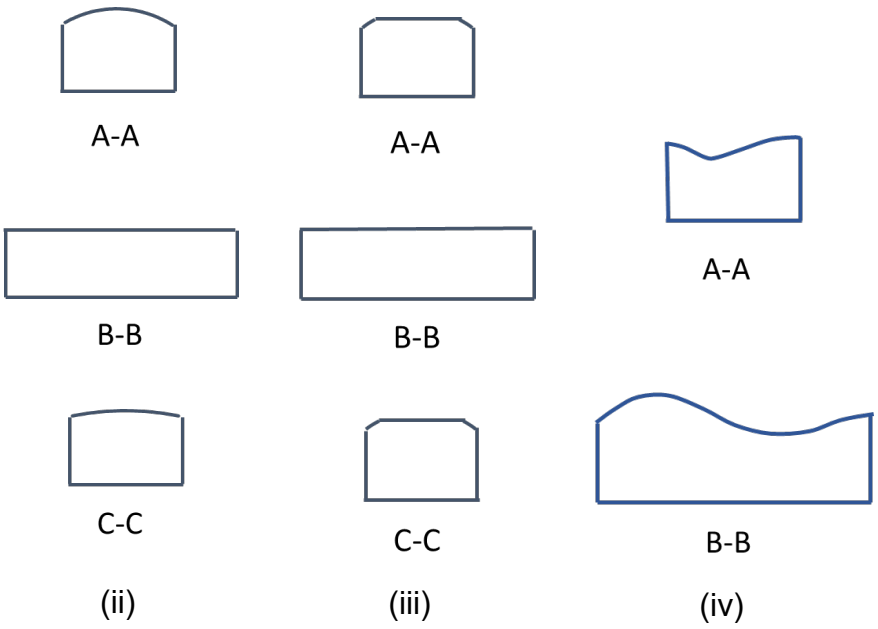


Figure 2 (a) (i)



(30 marks)

3. (a) Estimate the roundness error for the trace shown in Figure 3 (a) below if the magnification is 100X using the LSC method. Choose any point within the trace as the initial datum. Use **APPENDIX C** to sketch your answer.

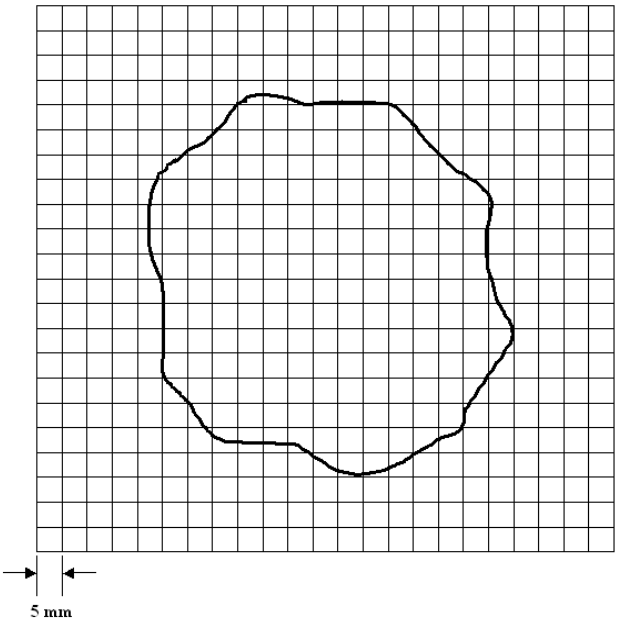


Figure 3 (a)

(50 marks)

(b) Figure 3 (a) shows an indoor drying house for dried product such fish and meat. In Malaysia, manufacturers of food products are required to obtain certifications and adhere to standards such as MeSTI or GMP. This is important not only to ensure safety but also quality. Elaborate on how customers, company managers, and MeSTI accreditation officers define and view quality in these manufacturing activities.

Figure 3 (a)

(30 marks)

(c) Trace of oxidised metal were found in the packaged product and most likely coming from contact with corrosion. As an engineer, you suspected the corrosion come from the drying house. Construct a cause and effect diagram that are focusing for the drying house.

(20 marks)

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

(10 marks)

(b) In an air-cooled engine cylinder simulation study, a circular cooling fin was heated in the central region and placed in an air stream as shown in Figure 4. Ten thermocouples were placed at equal distances radially on the fin for temperature measurements. During a test run, the following data were obtained as shown in Table 4.

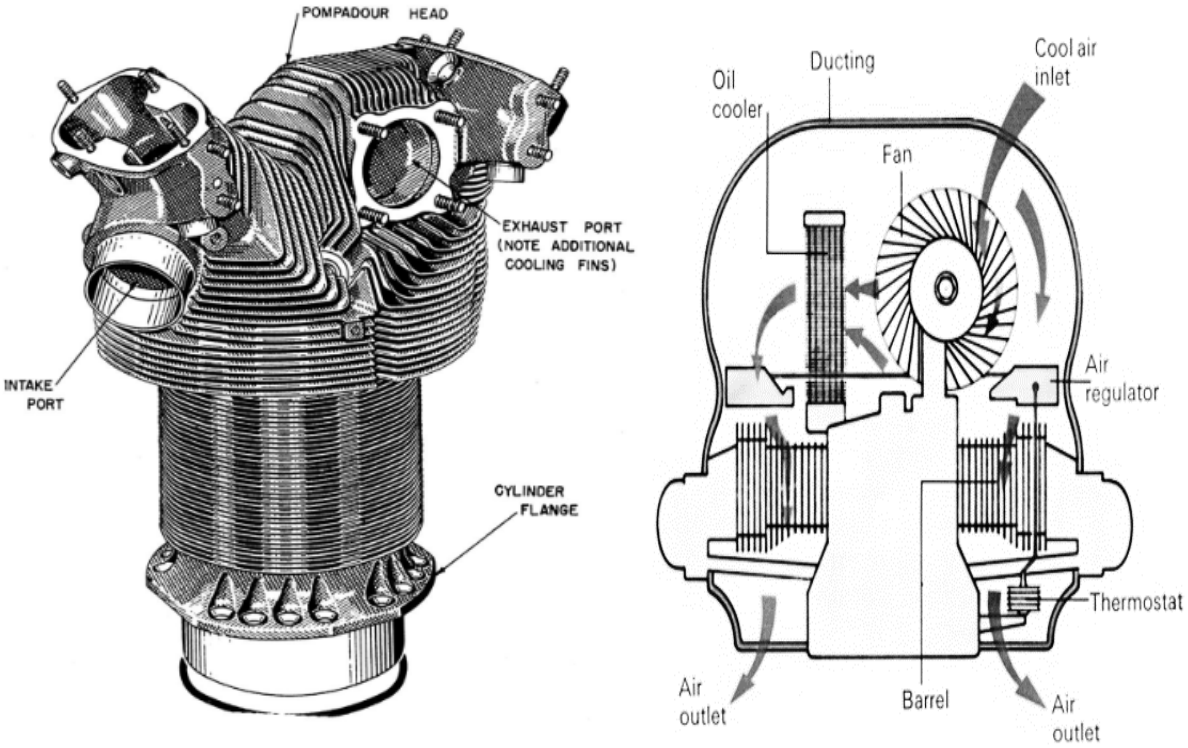


Figure 4

Table 4

Radius, R, (cm)	Temperature, T, (°C)	Radius, R, (cm)	Temperature, T, (°C)
2	75.5	12	62.1
4	73.1	14	59.4
6	70.5	16	57.2
8	67.7	18	54.8
10	64.2	20	52.2

From the data given, determine the coefficients for the curve of the form, $T = C_0 + C_1 R$, using:

(i) Graphical method. **(30 marks)**

(ii) Method of sequential differences. **(20 marks)**

(iii) Method of least squares. **(20 marks)**

(iv) Comment on the differences between using the data in (i), (ii) and (iii) is statistical process control?

(20 marks)

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

(10 marks)

(b) A set of machine bearings of a particular make were tested for wear at different operating temperatures controlled by an oil bath. The following test results were obtained as shown in Table 5.

Operating temperature x, (°C)	100	150	200	250	300	350	400
Amount of wear y (in mg/100 h of operation)	3.2	5.2	5.8	7.9	9.6	11.7	13.2

(i) Plot the points on a graph and verify that a linear relationship exists between x and y data. Is the data in control?

(30 marks)

(ii) Find the linear least square curve regressing y on x (i.e. assuming that the temperature values given in the data are without error).

(20 marks)

...8/-

iii. Estimate the amount of wear at 325 ^{o}C and 0 ^{o}C.

(20 marks)

iv. Comment on the estimated amount of wear given by the equation for an operating temperature of 0 ^{o}C.

(10 marks)

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

(10 marks)

- oooOOOooo -

APPENDIX 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.

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

APPENDIX B

FORMULAS

Difference $\Delta y_i = y_{n+1} - y_n$

Difference $\Delta x_i = x_{n+1} - x_n$

Slope, $m = \Delta y_i / \Delta x_i$

Internal estimate of the uncertainty, $\sigma_n^2(y) = \frac{1}{n}\{\sum y_i^2 - a_1 \sum x_i y_i - a_0 \sum y_i\}$

Uncertainty of y, $U_n(y) = \sigma_n(y)/\sqrt{n-2}$

Internal uncertainty of slope a_1 values $U_n(a_1) = \frac{\sqrt{n}}{\sqrt{\Delta}}\ U_n(y)$

Internal uncertainty of a_0, $U_n(a_0) = \frac{\sqrt{\sum x_i^2}}{\sqrt{\Delta}} U_n(y)$

APPENDIX C