Second Semester Examination
2020/2021 Academic Session

July/August 2021

# EPM 212 – METROLOGY AND QUALITY CONTROL

Duration : 2 hours

Please check that this examination paper consists of SEVEN (7) pages pages including appendixes before you begin the examination.

**Instructions** : Answer ALL **FOUR (4)** questions.

Answer to each question must begin from a new page.

This is an open-book examination.

Please answer all questions. All answers must be handwritten and upon submission please save the file as Online Test2_student's name_matrix no.doc or Online Test2_student's name_matrix no.pdf

Submission via elearning@usm.my

1. [a] Give TWO (2) examples of products where straightness measurement is important.

(2 marks)

[b] An autocollimator was used to test the straightness of the guideway of a lathe machine as shown in Figure 1[b]. The length *l* of the reflector base is 100 mm. The readings taken at positions of the reflector at *A*, *B*, *C*, *D* and *E* are shown in Table 1[b].

(i) Determine the deviation in straightness Δh at each of the positions *A* to *F* shown in Figure 1[b] measured from the reference line (correct to three decimal places).

(6 marks)

(ii) Hence, state the straightness error of the guideway, correct to three decimal places.

(2 marks)

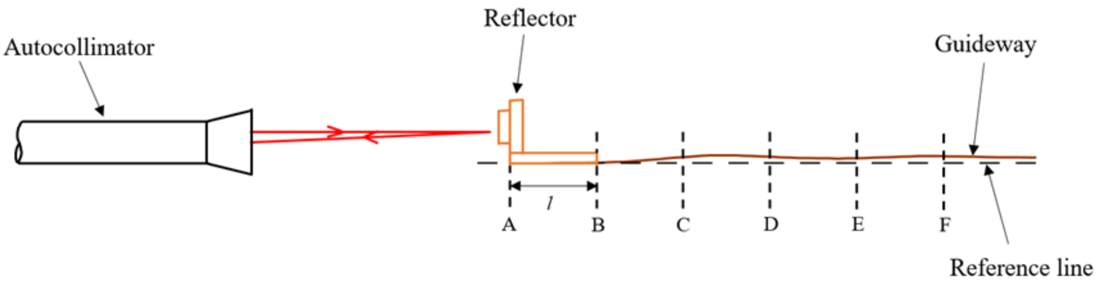


**Figure 1[b]**

| Position | Autocollimator reading (arc minute) |
|---|---|
| *A* | 5 |
| *B* | 8 |
| *C* | -4 |
| *D* | 6 |
| *E* | -2 |

2. [a] Figure 2[a] shows the fringe patterns formed on a hard disk substrate when viewed under an optical flat with the aid of sodium light. The figure on the left shows the pattern formed on the surface before lapping, while that on the right shows the pattern after lapping. What can you infer from the two patterns?

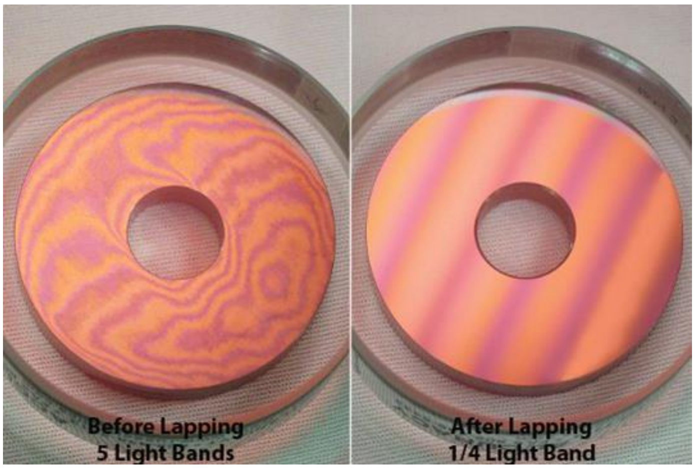


**Figure 2[a]**

(2 marks)

[b] Figure 2[b] shows the fringes observed on a test surface observed under an optical flat with the aid of sodium light ($\lambda$ = 0.585 µm). Draw the cross-sectional profiles along sections A-A and B-B to show the profile of the surface. Hence, determine the height difference between the highest point and lowest point along each section.

IMPORTANT: Select the figure based on your matrix number as in the table below:

| **Matrix number range** | **Sub-figure** |
|---|---|
| 135977 to 146216 | (i) |
| 146223 to 147486 | (ii) |
| 147581 to 148802 | (iii) |
| 148827 to 149707 | (iv) |

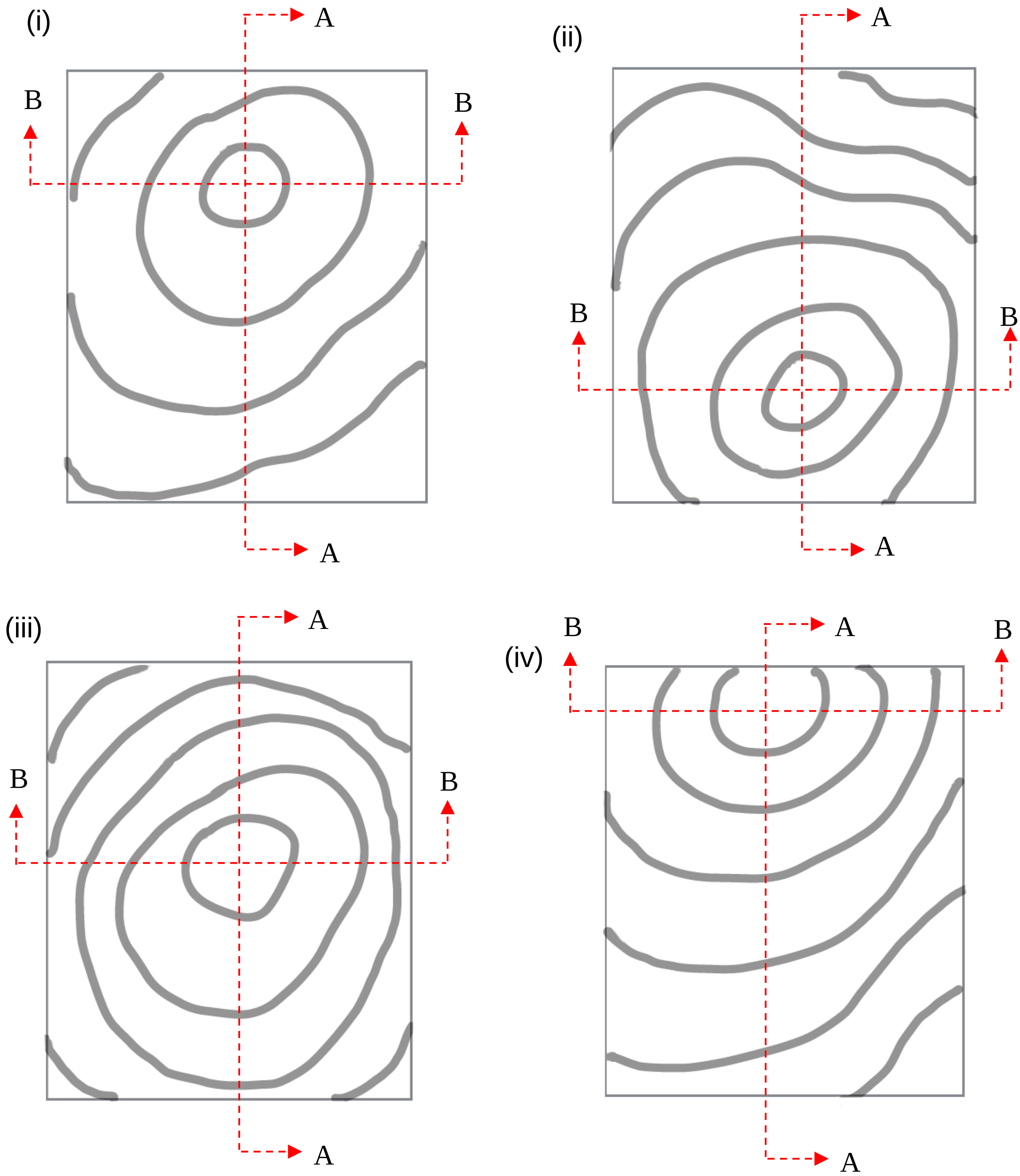


**Figure 2[b]**

(8 marks)

3. [a] Write a brief answers to the following questions.

(i) Define and differentiate Quality Assurance and Quality Control.

(1 mark)

(ii) The inspection on a batch of respiratory masks during a given time period is shown in Table 3[a]. The following defects are noted: Discolouration, loose strap, dents, tears and pin holes. Plot a suitable chart to represent the data and analyse the two types of defects that should receive the most attention. Recommend TWO (2) corrective and TWO (2) preventive activities for the defects.

Table 3[a]

| | | |
|---|---|---|
| Discolouration | Discolouration | Discolouration |
| Loose Strap | Loose Strap | Loose Strap |
| Discolouration | Dent | Loose Strap |
| Discolouration | Loose Strap | Discolouration |
| Loose Strap | Discolouration | Discolouration |
| Discolouration | Discolouration | Dent |
| Discolouration | Dent | Tear |
| Tear | Pinhole | Discolouration |
| Dent | Discolouration | Pinhole |
| Discolouration | Tear | Tear |

(4 marks)

[b] A passenger vehicle speeds were recorded as in Table 3[b] during a 15 minute interval on North-South Bound PLUS Highway.

Table 3[b]

| Boundaries (*km/h*) | Midpoint (*Xi*) | Frequency (*fi*) |
|---|---|---|
| *72.6-81.5* | *77.0* | *5* |
| *81.6-90.5* | *86.0* | *19* |
| *90.6-99.5* | *95.0* | *31* |
| *99.6-108.5* | *104.0* | *27* |
| *108.6-117.5* | *113.0* | *14* |
| *117.6-126.5* | *122.0* | *10* |

Calculate the $f_iX_i$ and $f_iX_i^2$ for the data given. Determine the average and standard deviation, *s* as given in the formula below. Comment on the results.

$$\mathbf{s} = \sqrt{\frac{\mathbf{n}\sum_{\mathbf{i=1}}^{\mathbf{h}}\left(\mathbf{f_i X_i^2}\right) - \left(\sum_{\mathbf{i=1}}^{\mathbf{h}}\mathbf{f_i X_i}\right)^2}{\mathbf{n(n-1)}}}$$

(5 marks)

4. [a] Sketch a diagram showing a comparison of normal (*N*), tightened (*T*) and reduced (*R*) curves.

(2 marks)

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

Table 4[b]

| Part number | Tester A Measurements*(mm)* | | | Tester B Measurements *(mm)* | | |
|---|---|---|---|---|---|---|
| | 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 (UCL), lower control limit (LCL) and central limit (CL) of the measurement error in the collected data. Plot the graphs to show the UCL, LCL and CL. Comment on the results.

(6 marks)

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

(2 marks)

**-oooOooo-**

# 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.**

| 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 |