UNIVERSITI KUALA LUMPUR
KAMPUS CAWANGAN MALAYSIAN SPANISH INSTITUTE

FINAL EXAMINATION

OCTOBER 2025 SEMESTER

COURSE CODE	:	SDB35203 (V2)
COURSE TITLE	:	METROLOGY
PROGRAMME NAME	:	BACHELOR OF ENGINEERING TECHNOLOGY (HONS) IN MECHANICAL DESIGN
DATE	:	23 JANUARY 2026
TIME	:	9:00AM - 12:00PM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper consist of TWO sections.
4. Answer ALL questions for Section A.
5. Section B consist of four questions. Answer THREE (3) questions only.
6. Please write your answer on the answer booklet provided.
7. Please answer all questions in English only.
8. Please answer MCQ/EMQ questions using OMR sheet. ☐ *Tick if applicable*
9. Refer to the attached Formula/ Appendies. ☑ *Tick if applicable*

SECTION A (Total: 40 marks)

Answer ALL questions.

Please use the answer booklet provided.

Question 1

Use both table below to answer the following questions:
Refer Below - Table1 : Types of Equipment . Table2 : Types of Work pieces .

Table 1: Types of Equipment

Equip. No	Equipment	Measuring Range	Measuring Accuracy
1	Vernier Caliper	0 ~ 200 mm	0.02 mm
2	Vernier Caliper	0 ~ 250 mm	0.02 mm
3	Outside Micrometer	0 ~ 25 mm	0.01 mm
4	Outside Micrometer	25 ~ 50 mm	0.01 mm
5	Digital Height Gauge	0 ~ 300 mm	0.01 mm
6	Gauge Blocks Set	0 ~ 100 mm	0.001 mm

Table 2: Types of Work pieces

Work piece	Feature	Max Dimension	Std Tolerance
A	Cylinder (Piston)	Φ40 mm	± 0.01 mm
B	Shaft (Cam Shaft)	Φ15 mm	± 0.05 mm
C	Round (Ball Bearing)	Φ100 mm	± 0.02 mm
D	Rectangular (Engine Block)	Length = 240 mm	± 0.04 mm
E	Hole (Blind)	Depth = 50 mm	± 0.02 mm
F	Rectangular Part	Height = 150 mm	± 0.04 mm
G	Hole	Φ10 mm	± 0.04 mm
H	Rectangular Block	Height = 50 mm	± 0.03 mm

(a) Select the appropriate **equipment number (s)** in table Types of Equipment that can be used to measure the dimension for each work piece A ~ H in table Types of Work pieces.

(16 marks)

(b) Indicate rating or ranking of the accuracy and precision for the equipment number 2 ~ 5 in table Types of Equipment with **"GOOD"** or **"POOR".**

(4 marks)

Question 2

You've just graduated from a local technical university in engineering technology and are keen on securing a position as a QA Engineer at XYZ Die Casting (Malaysia) Sdn. Bhd. After receiving an email from a friend detailing potential technical questions that might be asked during the interview, you're now preparing your responses ahead of the actual interview. Let's go through the questions together.

(a) What is the measuring equipment that can be used to determine the value of Ra (μm) for die casting parts?

(2 marks)

(b) You are tasked with producing two workpieces using different manufacturing processes while utilizing identical raw materials, as outlined in the table below. Please select the workpiece that exhibits a smooth surface finish and justify your choice based on the provided information.
Refer Below - Table3 : Surface Roughness Parameter Checking Results .

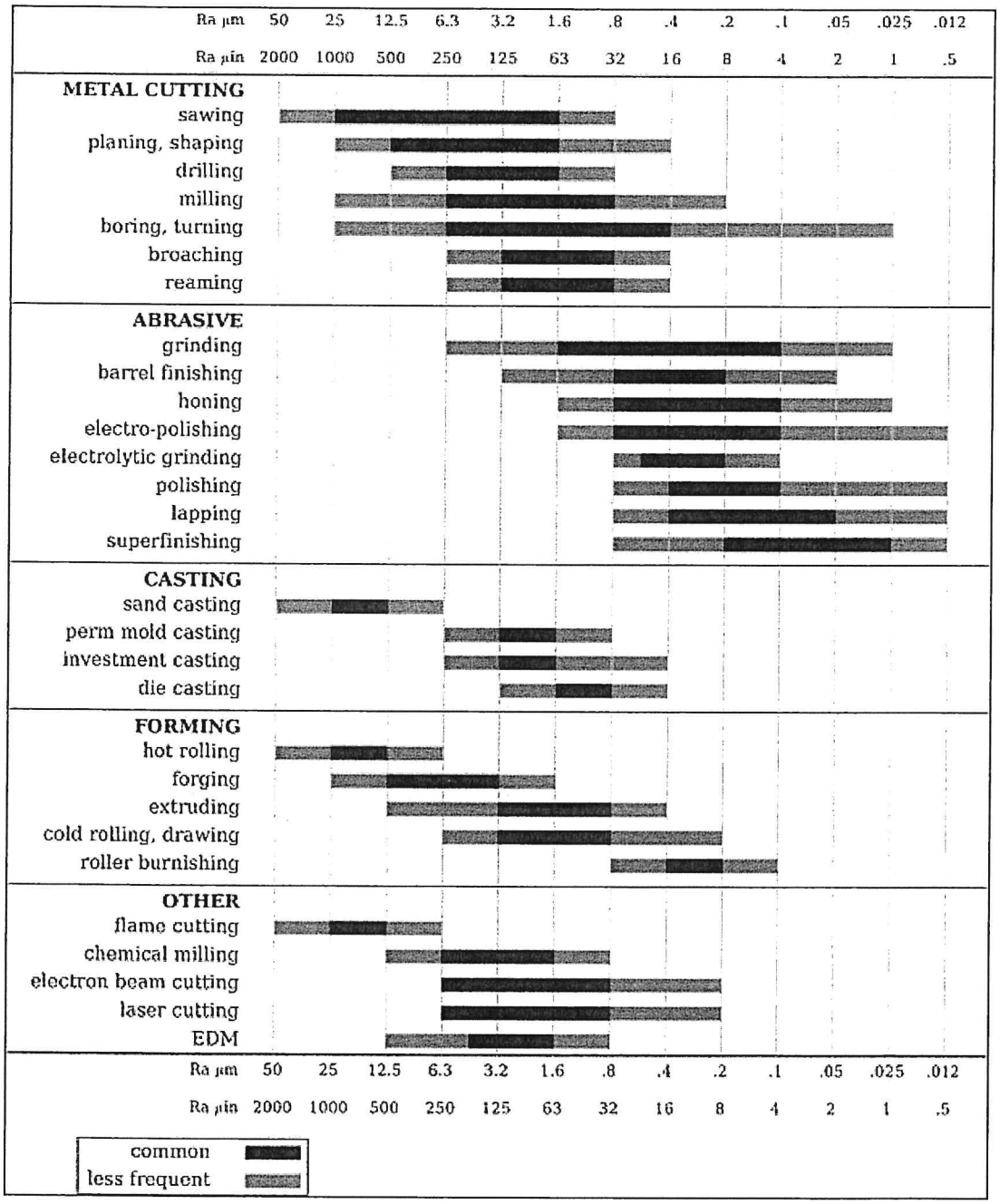
(4 marks)

Table 3: Surface Roughness Parameter Checking Results

Workpiece(s)	Raw Material	Metal Cutting Process	Surface Roughness (Ra) (μm)
A	Mild Steel	X	3.34
B	Mild Steel	Y	1.55

(c) Referring to table Surface Roughness Comparison Chart:
Refer Below - Table4 : Surface Roughness Comparison Chart: .

Table 4: Surface Roughness Comparison Chart:



i. Consider the metal cutting processes denoted as X and Y in the table Surface Roughness Parameter Checking Results. Select which process predominates for each workpiece and provide reasoning for the selection of these processes.

(4 marks)

ii. Discuss the surface roughness (Ra) values for both sand casting and die casting processes. From your perspective, which process requires more finishing processes, and why?

(6 marks)

(d) Provide a concise explanation of the manufacturing lay direction established by the die casting process, and create a sketch illustrating this direction.

(4 marks)

SECTION B (Total: 60 marks)

Answer THREE (3) questions only.

Please use the answer booklet provided.

Question 1

Gauge Repeatability and Reproducibility (GR&R) studies is a measure of the capability of a gauge or instrument to obtain the same measurement reading every time the measurement process is undertaken for the same characteristic or parameter. The following table shows the measurement result of part diameter (Tolerance = + 0.004mm – 0.001) by two appraisers (observers) through the use of an outside micrometer. Answer the following questions in order to perform a GR&R study. Refer Appendix 1 for major equations and constant factors. ***Refer Below - Table5 : GR&R Study Worksheet .***

Table 5: GR&R Study Worksheet

Appraiser	A					B				
Sample (n)	Trial 1 (r1)	Trial 2 (r2)	Trial 3 (r3)	Mean ($X_{bar.A}$)	Range (R_A)	Trial 1 (r1)	Trial 2 (r2)	Trial 3 (r3)	Mean ($X_{bar.B}$)	Range (R_B)
1	0.473	0.472	0.471	0.472	0.002	0.472	0.469	0.470	0.470	0.003
2	0.468	0.471	0.470	0.470	0.003	0.471	0.469	0.470	0.470	0.002
3	0.472	0.470	0.471	0.471	0.001	0.470	0.471	0.470	0.470	0.001
4	0.471	0.473	0.472	0.472	0.002	0.470	0.471	0.470	0.470	0.001
5	0.468	0.470	0.470	0.469	0.002	0.467	0.469	0.469	0.468	0.002
Σ	-	-	-			-	-	-		

(a) Calculate:

i. The mean of each appraiser's means ($X_{doublebar.A}$ and $X_{doublebar.B}$)

(2 marks)

ii. The different ($X_{doublebar.diff.}$) between the maximum appraiser mean value and the minimum appraiser mean value.

(2 marks)

iii. The mean of range for each appraiser ($R_{bar.A}$ and $R_{bar.B}$) and the grand range (R_{bar}).

(4 marks)

iv. The control limit (LCL and UCL) for R-chart.

(4 marks)

v. The Equipment Variation (EV), Appraiser Variation (AV) and GR&R

(3 marks)

vi. The Equipment Variation % (EV%), Appraiser Variation % (AV%) and GR&R%.

(3 marks)

(b) Briefly explain the conclusion on the Measurement System Analysis (MSA) based on the result you have calculated.

(2 marks)

Question 2

Geometric Dimensioning and Tolerance (GD&T) is a unique system that uses standard, international symbols to describe a part. Most of the symbols are substitute for written notes that traditionally appear in part design.

(a) Define Least Material Condition (LMC) and Maximum Material Condition (MMC) in holes and shafts.

(4 marks)

(b) Identify the suitable GD&T symbol for P, Q, R and S as shown as in figure below.
Refer Below - Figure1 : Part Drawing .

(4 marks)

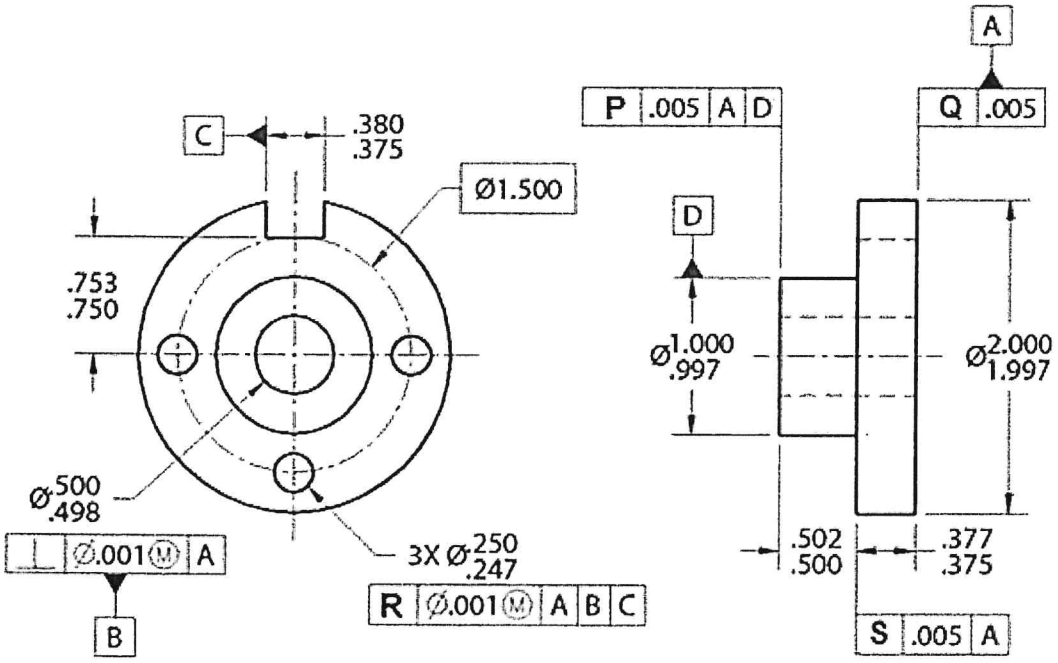


Figure 1: Part Drawing

(c) Construct the feature control frame (FCF) of the following characteristics:

i. Profile of a surface tolerance zone .05 at MMC to datum A

(3 marks)

ii. Circularity tolerance zone .007 in diameter.

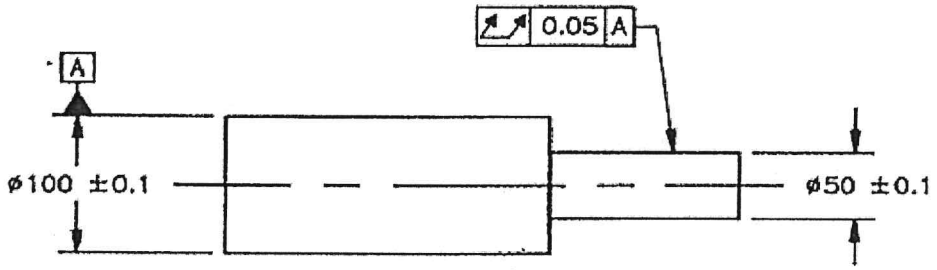
(2 marks)

iii. Position tolerance zone .0115 in diameter at MMC to datum A, B at MMC and C.

(3 marks)

(d) With reference to the post-inspection drawing, are there any measurements in this part that should be considered for rejection? If so, what are the underlying reasons for potential rejection of this part? Please explain your answer clearly.
Refer Below - Figure2 : Inspection Drawing .

(4 marks)



as produced:

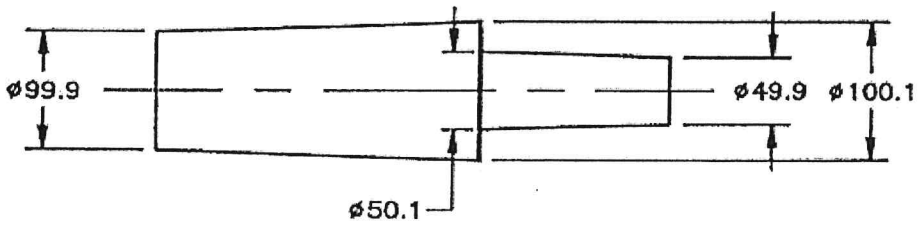


Figure 2: Inspection Drawing

Question 3

Nowadays, manufacturing industries are struggling to sustain its competitive advantage. One reason is due to higher manufacturing cost. Allow a looser tolerance in the product design through the use of Geometric Dimensioning and Tolerancing (GD&T) is believed to be one solution to minimize the cost of the manufacturing.

Refer Below - Figure3 : GD&T Drawing .

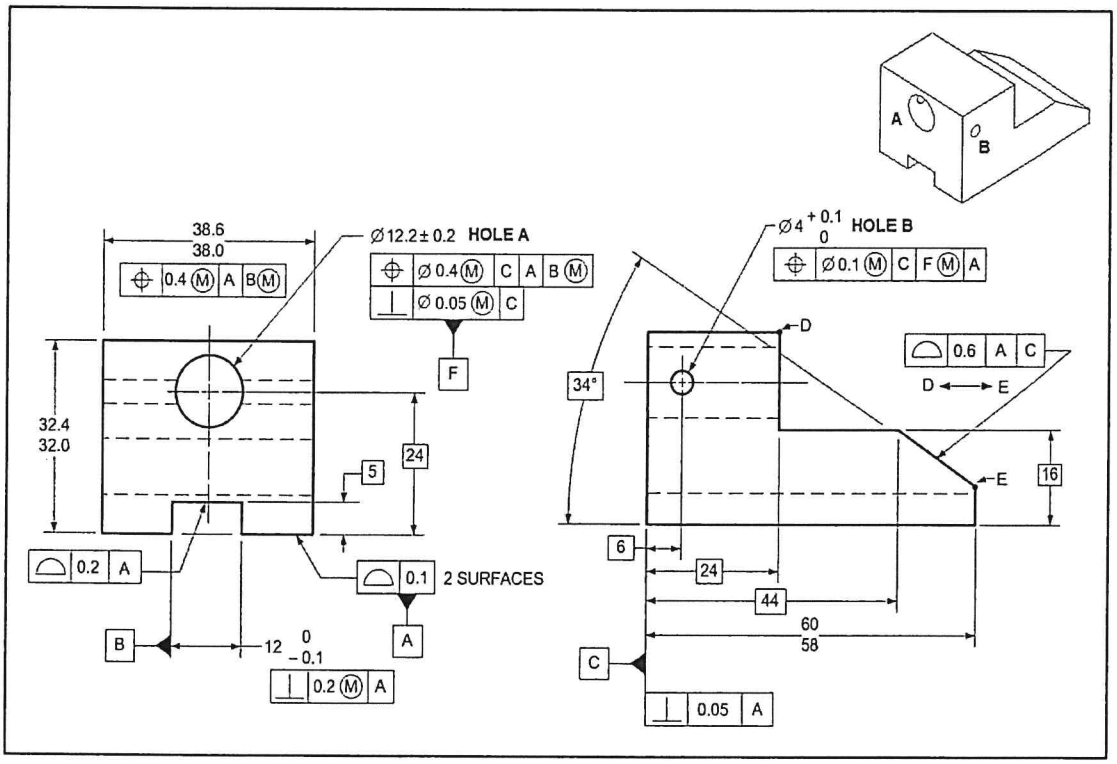


Figure 3: GD&T Drawing

(a) Fill up in Table below by referring to the drawing . Write only the answer in answer booklet provided.

Refer Below - Table6 : Answer for Figure 1 .

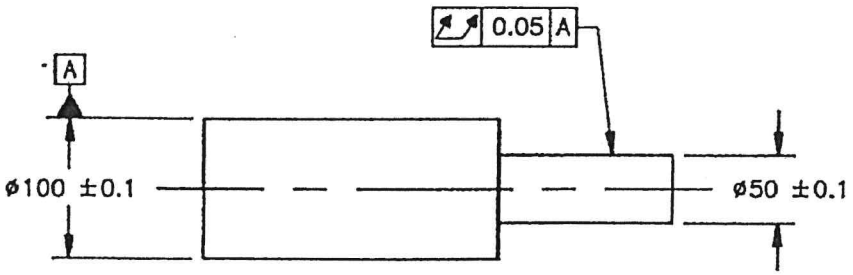
(10 marks)

Table 6: Answer for Figure 1

		Hole A	Hole B
i.	What is the MMC?		
ii.	What is the LMC?		
iii.	What is the geometric tolerance value?		
iv.	What material condition modifier is specified?		
v.	What datum(s) control(s) perpendicularity?		

(b) Do any of the "as produced" measurements shown indicate the part should be rejected? Why? Give your reason.
Refer Below - Figure4 : GD&T and workpiece drawing .

(4 marks)



as produced:

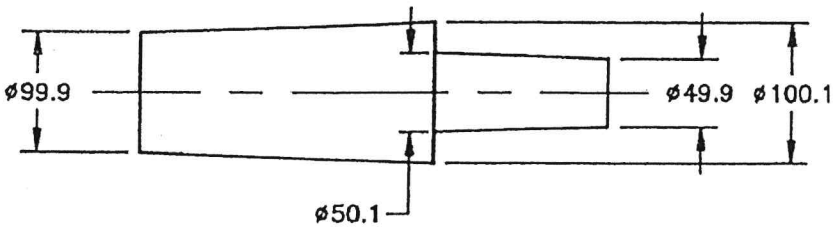


Figure 4: GD&T and workpiece drawing

(c) Name the symbol of GD&T and sketch the tolerance zone applied for Figure below
Refer Below - Figure5 : GD&T Drawing .

(6 marks)

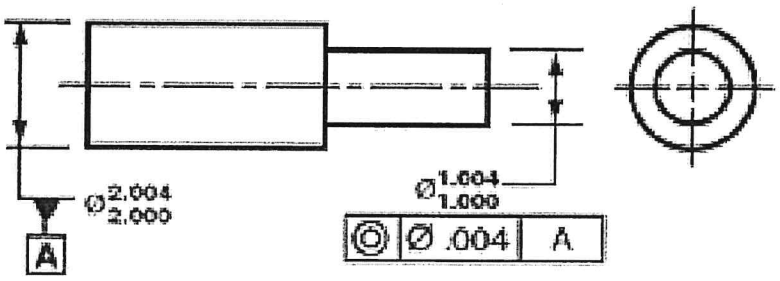


Figure 5: GD&T Drawing

Question 4

Instrument calibration is one of the primary processes used to maintain instrument accuracy. Calibration is the process of configuring an instrument to provide a result for a sample within an acceptable range. Eliminating or minimizing factors that cause inaccurate measurements is a fundamental aspect of instrumentation design.

(a) Explain three (3) roles of calibration.

(6 marks)

(b) A Measurement Systems Analysis (MSA) is a specially designed experiment that seeks to identify the components of variation in the measurement.

i. Identify five components of variation in measurement system with one example for each components variation.

(10 marks)

ii. Explain the meaning of:
a) Repeatability
b) Reproducibility

(4 marks)

END OF EXAMINATION PAPER

APPENDIX 1

Table A: Constant Factors for Variable Control Chart

Trials (r)	Factors for Variable Control Chart								
	A_2	A_3	B_3	B_4	D_3	D_4	d_2	D_1	D_2
2	1.880	2.659	0	3.267	0	3.267	1.128	0	3.686
3	1.023	1.954	0	2.568	0	2.575	1.693	0	4.358
4	0.729	1.628	0	2.266	0	2.282	2.059	0	4.698
5	0.577	1.427	0	2.089	0	2.115	2.326	0	4.918

Table B: Constant Factors for Trials and Appraisers

Trials (r)	K_1	Appraisers	K_2
2	4.56	2	3.65
3	3.05	3	2.70

Table C: Major Equations for MSA and GR&R

$$EV = R_{bar} \times K_1$$

$$AV = [(X_{doublebar.diff..} \times K_2)^2 - (EV^2 / nr)]^{1/2}$$

$$GR\&R = [(EV^2 + AV^2)]^{1/2}$$

$$LCL = R_{bar} \times D_3$$

$$UCL = R_{bar} \times D_4$$

$$EV\% = (EV / \text{Total Tolerance}) \times 100$$

$$AV\% = (AV / \text{Total Tolerance}) \times 100$$

$$GR\&R\% = (GR\&R / \text{Total Tolerance}) \times 100$$