NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

CONCURRENT ENGINEERING

EIE 3222

Main Examination Paper

March 2025

This examination paper consists of 8 printed pages

Time Allowed: **3 hours**

Total Marks: 100

Special Requirements: Graph Paper

Examiner's Name: Mr. I. Mapindu

INSTRUCTIONS AND INFORMATION TO CANDIDATE

1. Answer all questions from Section A and any other 3 questions from Section B
2. Question One has 40 marks and the rest of the questions have 20 marks each.
3. Use of calculators is permissible
4. Necessary tables are attached at the end of the paper.

SECTION A (Compulsory)

QUESTION ONE

a) Define Concurrent Engineering and explain its importance in Engineering and business in general. **[10]**

Urban areas in developing countries face significant challenges in managing solid waste, leading to environmental pollution, public health risks, and inefficient resource utilization. Your task is to design a community-based waste management system that promotes recycling, reduces landfill use, and is easy to implement in low-income urban neighbourhoods. The system should be cost-effective, scalable, and encourage community participation.

b) You are required to generate 3 different possible solutions that solve this problem and express the concepts in the form of clearly labelled diagrams. **[10]**

c) Using 5 important factors for consideration in evaluating these concepts, use Concept Screening methodology to screen your concepts and remain with 2. Use an appropriate table in the process. **[10]**

d) Assign justified weights to the factors that you used in b), stating why you assigned those weights, and conduct a concept scoring exercise using an appropriate table. **[10]**

SECTION B (Answer any 3 Questions)

QUESTION TWO

a) You are an environmental consultant hired by a beverage company to assess the environmental impact of plastic water bottles. Your task is to conduct a "cradle to grave" analysis for a single plastic water bottle from raw material extraction to disposal to evaluate the product's environmental impact **[12]**

b) Discuss the importance of studying product lifecycle in the development of sustainable and environmentally friendly products. **[8]**

QUESTION THREE

a) Explain the Pahl and Beitz phase model of product development. **[10]**

b) Using a relevant example, discuss how research and development have led to economic growth. **[10]**

QUESTION FOUR

Figure Q4 below shows a schematic for a controller assembly. Calculate its design efficiency **[20]**

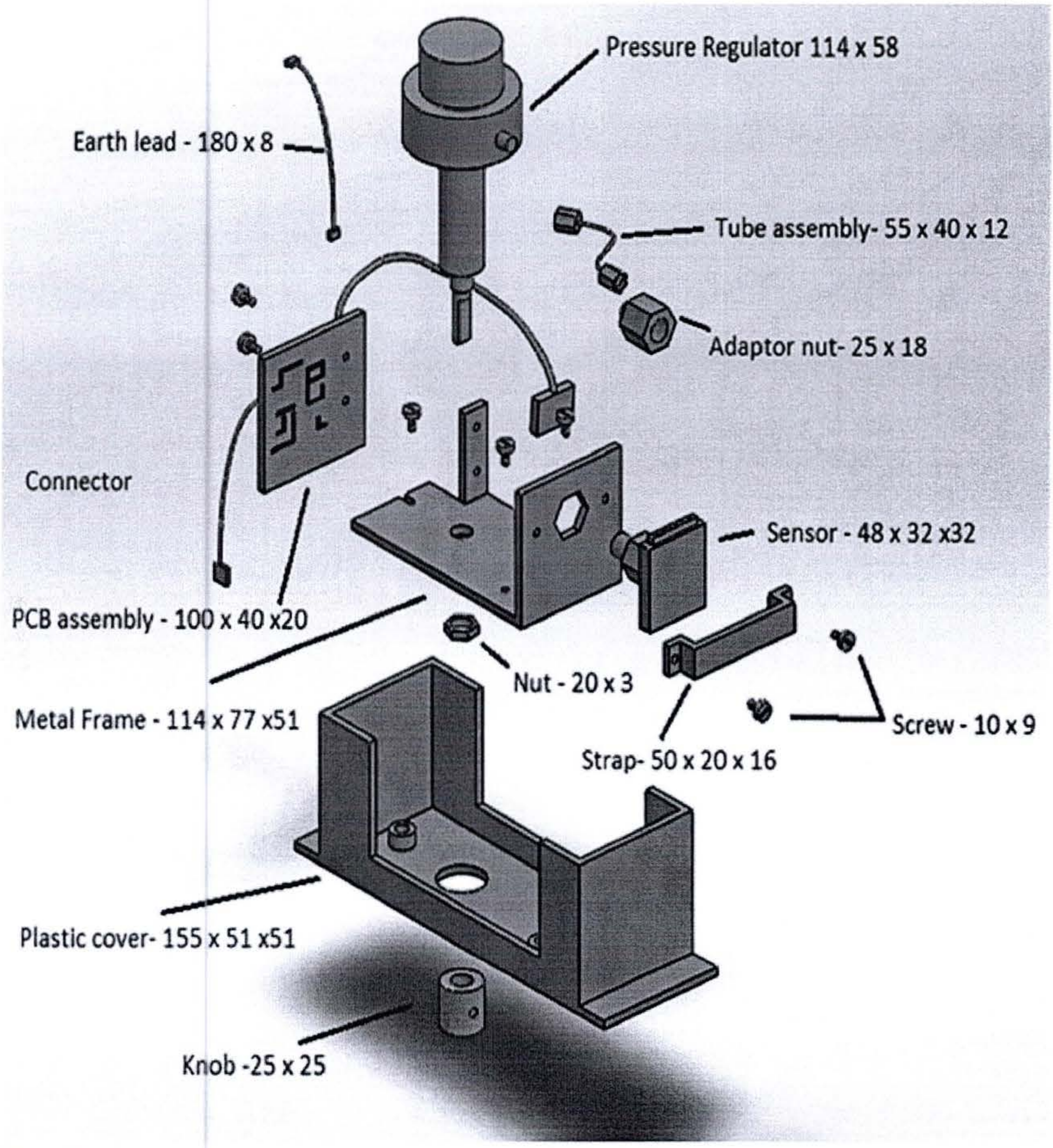

Figure Q4: Schematic of controller assembly

QUESTION FIVE

You are an industrial engineer working at a manufacturing plant that produces plastic injection-moulded components. The quality of the components is measured by their tensile strength (in MPa), which is influenced by four key process parameters. Your task is to use the Taguchi method to optimize these parameters and improve the tensile strength of the components. The process parameters are shown in Table Q5 below.

Table Q5a: Process factors and levels

	Level 1	Level 2
Injection Pressure	80	100
Mold Temperature	40	60
Cooling Time	10	20
Plastic Type	Polypropylene	Acrylonitrile Butadiene Styrene

Two trials were done, and the results are shown below in Table Q5b

Table Q5b: Results of experiments

Experiment	Tensile Strength (MPa) - Trial 1	Tensile Strength (MPa) - Trial 2
1	32.5	33.0
2	34.0	34.5
3	36.0	35.5
4	33.5	33.0
5	38.0	37.5
6	35.0	35.5
7	37.0	36.5
8	39.0	39.5

a) Show the full experimental layout of the combinations of levels for each factor in these experiments. **[4]**

b) Calculate the average effects of the factors on these experiments. **[7]**

c) Graphically represent these averages. **[7]**

d) State the best combination of levels for the factors that give the best results **[2].**

IMPORTANT EXAMINATION TABLES

MANUAL HANDLING — ESTIMATED TIMES (seconds)

Key:

ONE HAND

parts can be grasped and manipulated by one hand without the aid of grasping tools

	parts are easy to grasp and manipulate					parts present handling difficulties (1)				
	thickness > 2 mm			thickness ≤ 2 mm		thickness > 2 mm			thickness ≤ 2 mm	
	size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm	size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm
	0	1	2	3	4	5	6	7	8	9
(α+β) < 360°	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
360° ≤ (α+β) < 540°	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
540° ≤ (α+β) < 720°	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
(α+β) = 720°	3	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

ONE HAND with GRASPING AIDS

parts can be grasped and manipulated by one hand but only with the use of grasping tools

		parts need tweezers for grasping and manipulation								parts need standard tools other than tweezers	parts need special tools for grasping and manipulation
		parts can be manipulated without optical magnification				parts require optical magnification for manipulation					
		parts are easy to grasp and manipulate		parts present handling difficulties (1)		parts are easy to grasp and manipulate		parts present handling difficulties (1)			
		thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm	thickness > 0.25 mm	thickness ≤ 0.25 mm		
		0	1	2	3	4	5	6	7	8	9
α ≤ 180°	0 ≤ β ≤ 180°	4	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	7	7
	β = 360°	5	4	7.25	4.75	8	6	8.75	6.75	9	8	8
α = 360°	0 ≤ β ≤ 180°	6	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
	β = 360°	7	5.1	8.35	5.85	9.1	7.1	9.55	7.85	10.1	9	10

TWO HANDS for MANIPULATION

	parts present no additional handling difficulties					parts present additional handling difficulties (e.g. sticky, delicate, slippery, etc.) (1)				
	α ≤ 180°			α = 360°		α ≤ 180°			α = 360°	
	size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm	size > 15 mm	6 mm ≤ size ≤ 15 mm	size < 6 mm	size > 6 mm	size ≤ 6 mm
	0	1	2	3	4	5	6	7	8	9
parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary) (2)	8	4.1	4.5	5.1	5.6	6.75	5	5.25	5.85	6.35	7

TWO HANDS required for LARGE SIZE

	parts can be handled by one person without mechanical assistance									
	parts do not severely nest or tangle and are not flexible								parts severely nest or tangle or are flexible (2)	parts need special tools for grasping and manipulation
	part weight < 10 lb				parts are heavy (> 10 lb)					
	parts are easy to grasp and manipulate		parts present other handling difficulties (1)		parts are easy to grasp and manipulate		parts present other handling difficulties (1)			
	α≤180°	α=360°	α ≤180°	α=360°	α ≤180°	α =360°	α ≤180°	α =360°		
	0	1	2	3	4	5	6	7	8	9
two hands required for grasping and transporting parts	9	2	3	2	3	3	4	4	5	7	9

CHART . - 1

MANUAL INSERTION—ESTIMATED TIMES (seconds)

Key:

PART ADDED but NOT SECURED

PART SECURED IMMEDIATELY

SEPARATE OPERATION

				after assembly no holding down required to maintain orientation and location (3)				holding down required during subsequent processes to maintain orientation or location (3)			
				easy to align and position during assembly (4)		not easy to align or position during assembly		easy to align and position during assembly (4)		not easy to align or position during assembly	
				no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)
				0	1	2	3	6	7	8	9
addition of any part (1) where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) can easily reach the desired location		0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
	part and associated tool (including hands) cannot easily reach the desired location	due to obstructed-access or restricted vision (2)	1	4	5	5	6	8	9	9	10
		due to obstructed access and restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5

				no screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion (6)	
						plastic bending or torsion			rivetting or similar operation				
				easy to align and position with no resistance to insertion (4)	not easy to align or position during assembly and/or resistance to insertion (5)	easy to align and position during assembly (4)	not easy to align or position during assembly		easy to align and position during assembly (4)	not easy to align or position during assembly		easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (5)
							no resistance to insertion	resistance to insertion (5)		no resistance to insertion	resistance to insertion (5)		
				0	1	2	3	4	5	6	7	8	9
addition of any part (1) where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily		3	2	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily	due to obstructed access or restricted vision (2)	4	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
		due to obstructed access and restricted vision (2)	5	6	9	8	9	10	11	12	13	10	12

				mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) already in place but not secured immediately after insertion)				non-fastening processes	
				none or localized plastic deformation				metallurgical processes					
				bending or similar processes	rivetting or similar processes	screw tightening (6) or other processes	snap fit, snap clip, press fit, etc.	no additional material required (e.g. resistance, friction welding, etc.)	additional material required		chemical processes (e.g. adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
									soldering processes	weld/braze processes			
				0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place			9	4	7	5	3.5	7	8	12	12	9	12

CHART 2

TAGUCHI DOE ORTHOGONAL ARRAYS

		Number of parameters								
		2	3	4	5	6	7	8	9	10
Number of levels	2	L4	L4	L8	L8	L8	L8	L12	L12	L12
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27
	4	L16	L16	L16	L16	L32	L32	L32	L32	L32
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50

	OA_4 Column		
Row	1	2	3
1	1	1	1
2	1	2	2
3	2	2	1

	OA_8 Column						
Row	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

	OA_9 Column			
Row	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

	OA_{16} Column														
Row	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
3	1	1	1	2	2	2	2	1	1	1	1	2	2	2	2
4	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1
5	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2
6	1	2	2	1	1	2	2	2	2	1	1	2	2	1	1
7	1	2	2	2	2	1	1	1	1	2	2	2	2	1	1
8	1	2	2	2	2	1	1	2	2	1	1	1	1	2	2
9	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
10	2	1	2	1	2	1	2	2	1	2	1	2	1	2	1
11	2	1	2	2	1	2	1	1	2	1	2	2	1	2	1
12	2	1	2	2	1	2	1	2	1	2	1	1	2	1	2
13	2	2	1	1	2	2	1		2	2	1	1	2	2	1
14	2	2	1	1	2	2	1	2	1	1	2	2	1	1	2
15	2	2	1	2	1	1	2	1	2	2	1	2	1	1	2
16	2	2	1	2	1	1	2	2	1	1	2	1	2	2	1

	OA_{18} Column							
Row	1	2	3	4	5	6	7	8
1	1	1	1	1	1	1	1	1
2	1	1	2	2	2	2	2	2
3	1	1	3	3	3	3	3	3
4	1	2	1	1	2	2	3	3
5	1	2	2	2	3	3	1	1
6	1	2	3	3	1	1	2	2
7	1	3	1	2	1	3	2	3
8	1	3	2	3	2	1	3	1
9	1	3	3	1	3	2	1	2
10	2	1	1	3	3	2	2	1
11	2	1	2	1	1	3	3	2
12	2	1	3	2	2	1	1	3
13	2	2	1	2	3	1	3	2
14	2	2	2	3	1	2	1	3
15	2	2	3	1	2	3	2	1
16	2	3	1	3	2	3	1	2
17	2	3	2	1	3	1	2	3
18	2	3	3	2	1	2	3	1

End of Examination