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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	DESIGN FOR MANUFACTURE AND ASSEMBLY (DFMA)
COURSE CODE	:	BNM 40103
PROGRAMME CODE	:	BNM
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FIVE (5)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

Q1 Manufacturers should consider the application of Design for Assembly (DFA) at all stages of the design process, especially in the early stages. As the design team to conceptualize the alternative solutions, it should give serious consideration to the ease of assembly of the product or subassembly.

(a) Discuss how the design team can use DFA in the conceptual design process.
(4 marks)

(b) Explain the DFA approach that leads to the design improvement process.
(4 marks)

(c) Identify the main benefits of implementing the Concurrent Engineering concept in the manufacturing enterprise.
(4 marks)

(d) As a new design engineer appointed by XYZ Engineering Sdn. Bhd., you have been given a task to evaluate the latest product of the company, as shown in **Figure Q1 (d)**. Construct an analysis report by employing the **EIGHT (8)** commandments of DFA in your evaluation process.
(8 marks)

Q2 (a) Boothroyd-Dewhurst DFA Method is a systematic approach to improve the product design process. Based on this method, construct a procedure and process flow for manual assembly design analysis.
(4 marks)

(b) The process of manual assembly can be divided into two separate areas, which are handling (acquiring, orienting and moving the parts) and insertion and fastening (mating a part to another part or group of parts). Explain and demonstrate the design guideline for part handling with the aid of sketch.
(8 marks)

(c) DFA can be employed either for a product with manual or automatic assembly method. Based on the characteristic of the technique, compare and contrast both assembly methods that may influence the decision for the selection of the assembly process.
(8 marks)

Q3 (a) Material and process selection are critical issues in the optimal design of industrial products. Construct a procedure that is commonly used for material–process selection in Design for Manufacture (DFM) analysis.

(4 marks)

(b) Compare the "material first approach" and "process first approach" for material-process selection procedure. Provide an example for each approach.

(8 marks)

(c) **Figure Q3 (c)** shows a product that needs to be manufactured in a large quantity (>20,000 units). Based on the given information, propose a suitable process and material for the production of the component, and you need to provide the justification for your answer.

(8 marks)

Q4 (a) The heart of any design for manufacturing system is a group of design principles or guidelines that are structured to help the designer reduce the cost and difficulty of manufacturing an item. Summarize **FIVE (5)** design guidelines or rules for product that easily and economically manufactured.

(10 marks)

(b) **Figure Q4 (b)** shows the turning operation to produce the flat surface where, it is accomplished by moving the cutting tool against the axis of workpart rotation. Given are the diameter of workpart (d_m = 30 mm), feed rate (f = 0.5 mm/min), (a_p =1mm) and workpart rotational speed (n_w = 800 rev/min). Determine;

(i) Machining time, (t_m)

(4 marks)

(ii) Cutting speed, (v_c)

(3 marks)

(iii) Maximum Material Removal Rate, (Z_{wmax} (MRR))

(3 marks)

Q5 **Figure Q5** is an exploded drawing of clamp light assembly. By using Boothroyd/Dewhurst DFMA method;
(Note: Refer **Table Q5 (a)** and **Q5 (b)** as a guide. Use **Table Q5 (c)** to write your answer)

(a) Calculate the total assembly time and design efficiency of the component for manual assembly.
(16 marks)

(b) Justify the components that can be eliminated and redesign.
(4 marks)

Q6 A batch of 18 cm diameter disks with a thickness of 4 mm are molded from Acrylonitrile-butadiene-styrene (ABS) in a six-cavity mold. Recommend the appropriate size for the injection molding machine for molding the disks. Start the analysis by determining the following information;
(Note: Refer **Table Q6 (a)**, **Q6 (b)** and **Q6 (c)** as a guide.)

(a) Total projected shot area
(5 marks)

(b) Maximum cavity pressure
(5 marks)

(c) Maximum separating force, F
(5 marks)

(d) Maximum clamp force
(5 marks)

END OF QUESTION

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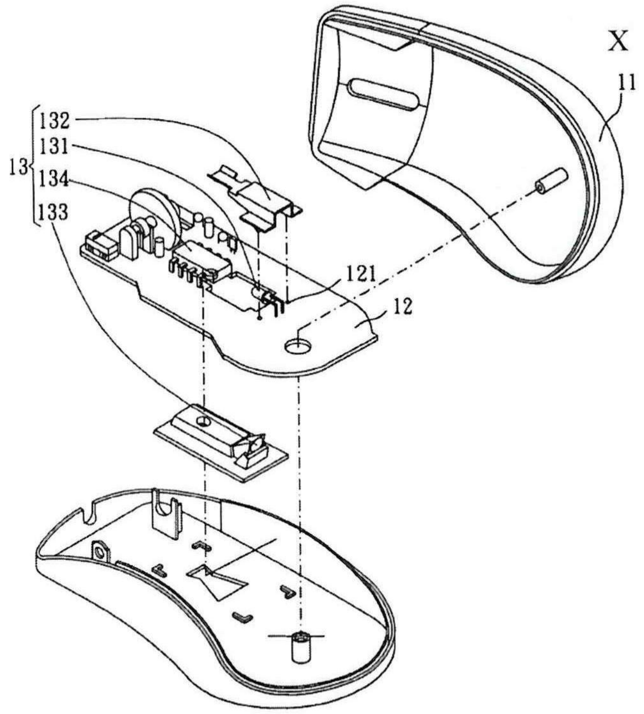

Figure Q1 (d)

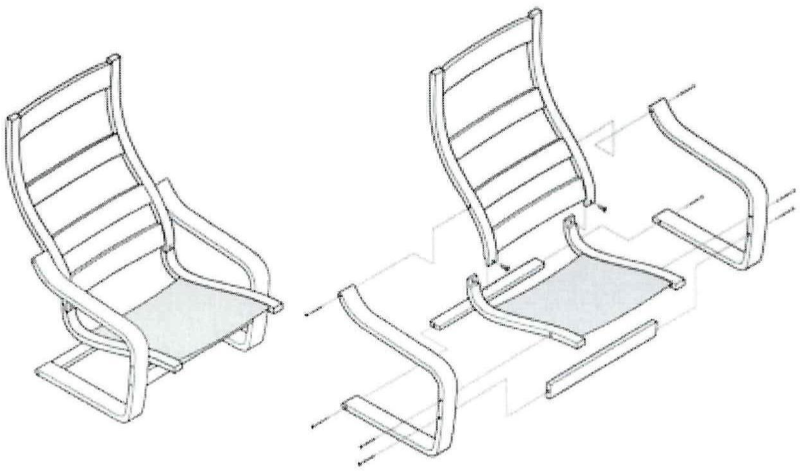

Figure Q3 (c)

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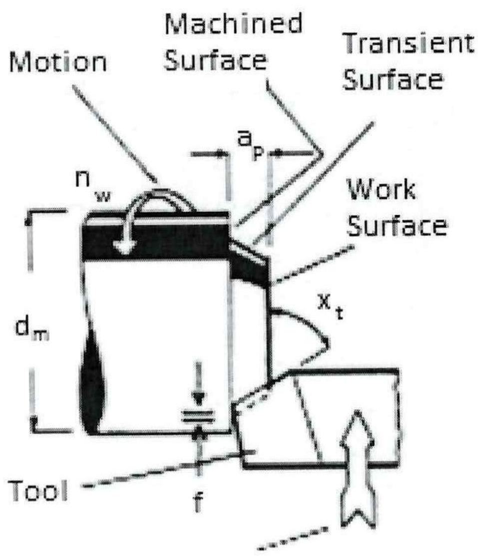

Figure Q4 (b) – Turning Operation (*Facing)*

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CLAMP LIGHT - Exploded View

		PROCESS	MATERIAL	FINISH	DIMENSION (mm)
A	Lamp Head	Spinning	Aluminum	Spray Paint	100 x 35
B	Screw	Cold Forged	Steel	Chrome Plated	10 x 9
C	Internal Housing	Rolled	Aluminum	Anodized	85 x 53
D	Lamp Head	Spinning	Aluminum	Spray Paint	105 x 130
E	Gooseneck	Stamped & Rolled	Steel	Chrome Plated	22 x 395
F	Clamp	Stamping	Aluminum	Spray Paint	110 x 605 x 65
G	Book Binding Screw	Cold Forged	Steel	Chrome Plated	10 x 62
H	Nut	Hot Forged	Steel	Galvinized	28 x 4
I	Spring	Rolled	Steel	Chrome Plated	110 x 604 x 66

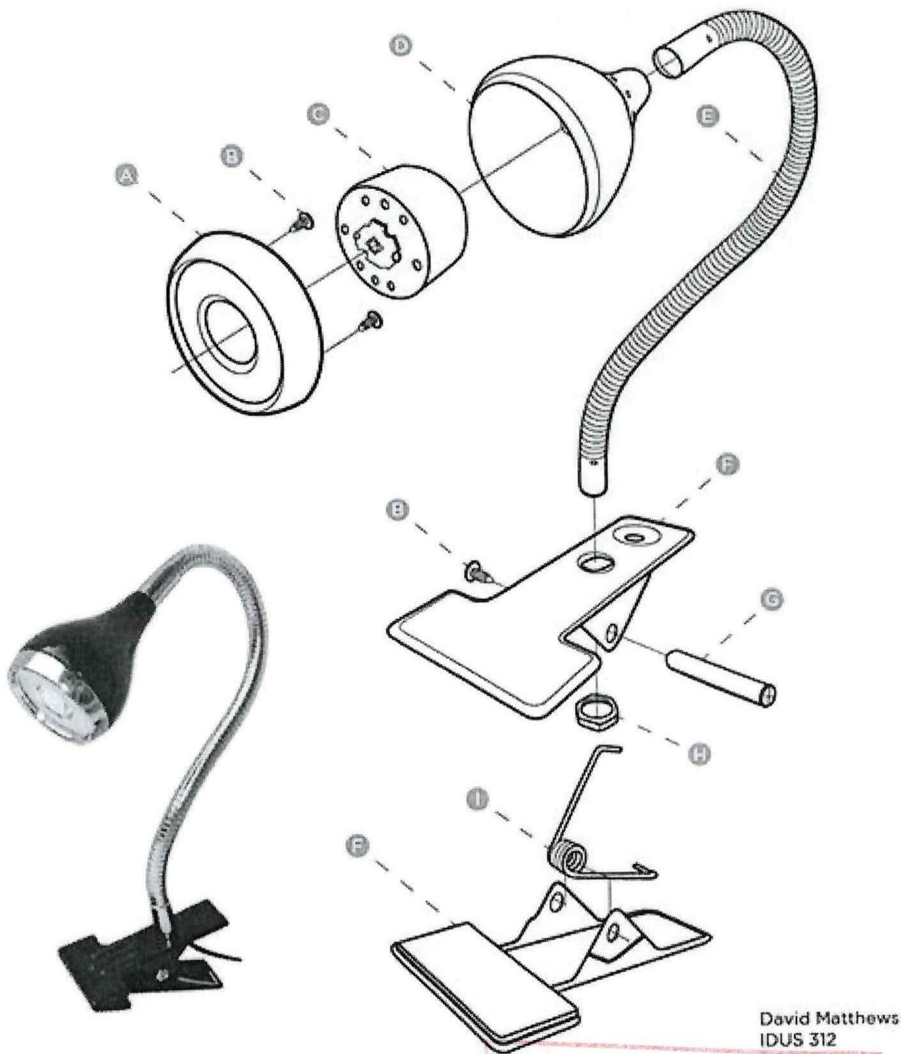

Figure Q5

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Table Q5 (a)

MANUAL HANDLING – ESTIMATED TIMES (seconds)

Key: ONE HAND

			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
parts can be grasped and manipulated by one hand without the aid of grasping tools	$(\alpha+\beta) < 360°$	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
	$360° \le (\alpha+\beta) < 540°$	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
	$540° \le (\alpha+\beta) < 720°$	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
	$(\alpha+\beta) = 720°$	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 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
parts can be grasped and manipulated by one hand but only with the use of grasping tools	$\alpha \le 180°$	$0 \le \beta \le 180°$	4	3.6	6.85	4.35	7.6	5.6	8.35	6.35	8.6	7	7
		$\beta = 360°$	5	4	7.25	4.75	8	6	8.75	6.75	9	8	8
	$\alpha = 360°$	$0 \le \beta \le 180°$	6	4.8	8.05	5.55	8.8	6.8	9.55	7.55	9.8	8	9
		$\beta = 360°$	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)				
		$\alpha \le 180°$			$\alpha = 360°$		$\alpha \le 180°$			$\alpha = 360°$	
		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 need special tools for grasping and manipulation
		parts do not severely nest or tangle and are not flexible								parts severely nest or tangle or are flexible (2)	
		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)			
		$\alpha \le 180°$	$\alpha = 360°$	$\alpha \le 180°$	$\alpha = 360°$	$\alpha \le 180°$	$\alpha = 360°$	$\alpha \le 180°$	$\alpha = 360°$		
		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

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Table Q5 (b) 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
	part and associated tool (including hands) cannot easily reach the desired location: 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					
						not easy to align or position during assembly			not easy to align or position during assembly				
			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)	no resistance to insertion	resistance to insertion (5)	easy to align and position during assembly (4)	no resistance to insertion	resistance to insertion (5)	easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (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
	part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily: 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					
							additional material required				
		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.)	soldering processes	weld/braze processes	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.)
		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

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Table Q5 (c) DESIGN FOR MANUAL ASSEMBLY - WORKSHEET

1	2	3	4	5	6	7	8	9	Name of Assembly
Part No	Operations	Handling Code	Handling Time	Insertion Code	Insertion Time	Operation Time	Operation Cost	Minimum No Parts	
									Design Efficiency = $\frac{3 \times NM}{TM}$ =
						TM	CM	NM	

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Table Q6 (a) Processing Data for Selected Polymers

Thermoplastic	Specific gravity	Thermal diffusivity (mm^2/s)	Injection temp. (°C)	Mold temp. (°C)	Ejection temp. (°C)	Injection pressure (bars)
High-density polyethylene	0.95	0.11	232	27	52	965
High-impact polystyrene	1.59	0.09	218	27	77	965
Acrylonitrile-butadiene-styrene (ABS)	1.05	0.13	260	54	82	1000
Acetal (homopolymer)	1.42	0.09	216	93	129	1172
Polyamide (6/6 nylon)	1.13	0.10	291	91	129	1103
Polycarbonate	1.20	0.13	302	91	127	1172
Polycarbonate (30% glass)	1.43	0.13	329	102	141	1310
Modified polyphenylene oxide (PPO)	1.06	0.12	232	82	102	1034
Modified PPO (30% glass)	1.27	0.14	232	91	121	1034
Polypropylene (40% talc)	1.22	0.08	218	38	88	965
Polyester teraphthalate (30% glass)	1.56	0.17	293	104	143	1172

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Table Q6 (b) Runner Volumes (Du Pont)

Part volume (cm^3)	Shot size (cm^3)	Runner %
16	22	37
32	41	28
64	76	19
128	146	14
256	282	10
512	548	7
1024	1075	5

Table Q6 (c) Injection Molding Machines

Clamping force (kN)	Shot size (cc)	Operating cost ($/h)	Dry cycle times (s)	Maximum clamp stroke (cm)	Driving power (kW)
300	34	28	1.7	20	5.5
500	85	30	1.9	23	7.5
800	201	33	3.3	32	18.5
1100	286	36	3.9	37	22.0
1600	286	41	3.6	42	22.0
5000	2290	74	6.1	70	63.0
8500	3636	108	8.6	85	90.0

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LIST OF FORMULA;

$$EM = \frac{3 \times NM}{TM}$$

$$C_{ds} = 120 + 0.36A_u$$

$$t_m = \frac{d_m}{2fn_w}$$

$$X_p = \frac{P^2}{LW}$$

$$v_{\max} = \pi n_w d_m$$

$$M_p = M_{po} f_{lw} f_d$$

$$Z_{w_{\max}} = \pi f a_p n_w d_m$$

$$\text{Total Die Cost} = C_{ds} + \left(M_{po} + M_{pc} + M_{ps}\right)R$$

$$M_{po} = 23 + 0.03LW$$

F (kN) = A (m^2) x P_{max} (kN/m^2)

$$t_f = \frac{V}{Q_{av}} = \frac{2V_s p_j}{P_j}$$

t = -70 ln (c) –f (chamfer) + 3.7 L + 0.75 d

$$M_{pc} = 8 + 0.6P + 3N_p$$