



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF SCIENCE AND TECHNOLOGY EDUCATION
DEPARTMENT OF TECHNICAL AND ENGINEERING EDUCATION AND TRAINING
AUTOMATION AND ROBOTICS PTE6152

Main Examination Paper

NOVEMBER 2024

This Examination Paper consists of pages 3

Time Allowed: 3 hours

Total Marks: 100

Internal Examiner: Ms L Chimbani

External Examiner: Dr Mulolani

INSTRUCTIONS

1. The paper consists of seven (7) questions, nine (9) pages and an attachment of Automatic handling tables.
2. Answer any five questions in any order.
3. Each question carries 20 marks.
4. The use of calculators is permissible.
5. Show all workings.

MARK ALLOCATION

QUESTION	MARKS
1.	20
2.	20
3.	20
4.	20
5.	20
6.	20
7.	20
Total	100

Question 1

- a. Define the following terms:
 - i. Automation [2 Marks]
 - ii. Robotics [2 Marks]
- b. Describe factors to be considered before automating a plant. [6 Marks]
- c. Discuss the role of machine vision in the manufacturing systems. [10 Marks]

Question 2

- a. State the three classes of robots and gives 3 modern uses of robots. [6 Marks]
- b. Explain the difference between robot sensors and actuators. [4 Marks]
- c. Describe the use of sensors. [2 Marks]
- d. Briefly explain how the use of robots in the 21st century has improved production in the manufacturing industry giving examples. [8 Marks]

Question 3

- a. State the conditions of wedging. [2 Marks]
- b. Using a diagram explain how wedging can be avoided. [8 Marks]
- c. With the aid of a diagram explain the functions of a pneumatic actuator. [10 Marks]

Question 4

- a. Explain the following terms:
 - i. Repeatability [2 Marks]
 - ii. Forward Kinematics [2 Marks]
- b. Name any two sources of robotic accidents in a manufacturing plant and explain how these can be avoided. [4 Marks]
- c. Illustrate and label the work envelope of a Cartesian Robot [6 Marks]
- d. Briefly explain the application of cylindrical robots giving advantages and disadvantages. [6 Marks]

Questions 5

- Identify factors that affect orientation efficiency (E) and relative feeder cost (Cr). [2 Marks]
- State and explain giving relevant examples the USA principle. [9 Marks]
- Identify and explain the strategies for automation and production systems. [9 Marks]

Question 6

- What is machine vision? Give two applications of machine vision. [4 Mark]
- An end effector of a robot is translated by e units in x, f units in y and g units in z

$$\text{Given } A = \text{Translate } (e, f, g) = \begin{bmatrix} 1 & 0 & 0 & e \\ 0 & 1 & 0 & f \\ 0 & 0 & 1 & g \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

If $\vec{V} = 25\hat{i} + 10\hat{j} + 20\hat{k}$ determine

- Translation by 8 units in x, 5 units in y and 0 units in z. [4 Marks]
 - Rotation about Y through 30° . [4 Marks]
- Sketch and label an articulated robot showing the degrees of freedom. [8 Marks]

Question 7

- Explain the following control methods of robotic actuators or arms.
 - Point to point control [2 Marks]
 - Servo control [2 Marks]
 - Non servo control [2 Marks]
 - Continuous Path Controlled [2 Marks]
- Calculate the cost of orientation and feeding for the following parts: [12 Marks]

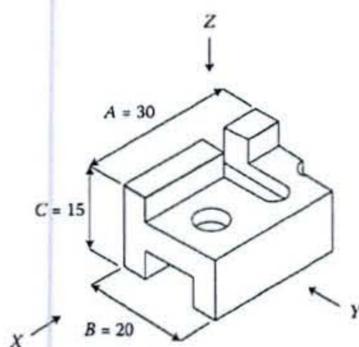


Fig Q7(b) i

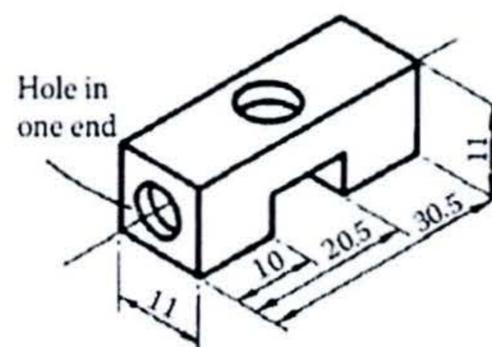


Fig Q7(b) ii

ATTACHMENT

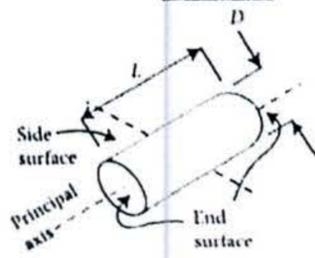
Rotational	Discs	$L/D < 0.8$	0
	Short cylinders	$0.8 \leq L/D \leq 1.5$	1
	Long cylinders	$L/D > 1.5$	2
Nonrotational	Flat	$A/B \leq 3$ $A/C > 4$	6
	Long	$A/B > 3$	7
	Cubic	$A/B \leq 3$ $A/C \leq 4$	8

Notes:

1. A part whose basic shape is a cylinder or regular prism whose cross section is a regular polygon of five or more sides is called a rotational part. In addition, triangular or square parts that repeat their orientation when rotated about their principal axis through angles of 120° or 90° , respectively, are rotational parts.
2. L is the length and D is the diameter of the smallest cylinder that can completely enclose the part.
3. A is the length of the longest side, C is the length of the shortest side and B is the length of the intermediate side of the smallest rectangular prism that can completely enclose the part.

FIGURE 5.3
 First digit of geometrical classification of parts for automatic handling. (From Boothroyd, G and Dewhurst, P. *Product Design for Assembly Handbook*, Boothroyd Dewhurst Inc., Wakefield, RI, 1986. With permission.)

First digit	KEY	
	E	C ₁
0	0.1	1
1	0.15	1.5
2	0.15	1.5



AUTOMATIC HANDLING-DATA FOR ROTATIONAL PARTS (first digit 0, 1 or 2)																	
Part is symmetrical about its principal axis (BETA symmetric) (see note 2)	Part is not BETA symmetric (code the main feature or features requiring orientation about the principal axis)																
	BETA asymmetric projections, steps, or chamfers (can be seen in silhouette)				BETA asymmetric grooves or flats (can be seen in silhouette)			Slightly asymmetric or small features less than $D/10$ and $L/10$ or holes or recesses which cannot be seen in outer shape of silhouette									
	On side surface only	On end surface(s) only	On both side and end surface(s)	Through groove or flat can be seen in end view	Through groove can be seen in side view												
					On end surface	On side surface											
0	2	3	4	5	6	7	8										
Part is ALPHA symmetric (see note 1)	0	1	0.1	1	0.5	1	0.1	1	0.35	1	0.2	1	0.5	1			
	0	1	0.15	1	0.2	1	0.15	1	0.2	1	0.2	1	0.2	1			
Part is not ALPHA symmetric (code the main feature or features requiring end-to-end orientation) (see note 1)	Part can be fed in a slot supported by large end or protruding flange	1	0.4	1	0.2	1	0.25	1	0.2	1	0.2	1	0.1	1	0.25	1	
		1	0.1	1	0.1	1	0.1	1	0.1	1	0.1	1	0.1	1	0.1	1	
	BETA symmetric steps or chamfers on external surfaces (see note 3)	2	0.4	1	0.15	1	0.25	1	0.15	1	0.15	1	0.15	1	0.15	1	
		2	0.3	1	0.1	1.5	0.1	1.5	0.1	1.5	0.2	1.5	0.05	1.5	0.1	1.5	
	BETA symmetric grooves holes or recesses (see note 3)	On both side and end surface(s)	3	0.5	1	0.15	1	0.25	3	0.37	2.5	0.5	1	0.5	3	0.25	1
			3	0.2	1	0.1	1.5	0.1	1.5	0.1	1.5	0.05	1.5	0.1	1.5	0.1	1.5
		On side surface only	4	0.1	1	0.15	1	0.25	2	0.33	1.5	0.5	1	0.5	2	0.5	2
	On end surface(s) only	5	0.1	1	0.15	1	0.25	1	0.15	1	0.2	1	0.1	1	0.25	1	
		5	0.2	1	0.1	1.5	0.1	1.5	0.1	1.5	0.05	1.5	0.1	1.5	0.1	1.5	
	BETA symmetric hidden features with no corresponding exposed features (see note 4)	6	0.6	1	0.27	1.5	0.25	2	0.27	1.5	0.45	1	0.45	2	0.45	2	
6		0.6	1	0.27	1.5	0.25	2	0.27	1.5	0.45	1	0.45	2	0.45	2		
BETA asymmetric features on side or end surface(s)	7	0.27	2	0.25	1	0.1	1	0.1	1	0.1	1	0.25	1				
	7	0.27	2	0.25	1	0.1	1.5	0.05	1.5	0.1	3	0.05	1.5	0.1	1.5		
Slightly asymmetric or small features amount of asymmetry or feature size less than $D/10$ and $L/10$	8	MANUAL HANDLING REQUIRED															

Notes:

1. A rotational part is alpha symmetric if it does not require orienting end-to-end. If a part can only be inserted into the assembly in one direction then it is referred to as "not alpha symmetric."
2. A beta-symmetric part has rotational symmetry and therefore does not require orienting about its principal axis.
3. A beta-symmetric step, chamfer or groove is a concentric reduction or increase in diameter; its cross section can be circular or any regular polygon. Less significant features should be ignored.
4. Parts in this category have an alpha-symmetric external shape, but the internal surface (composed perhaps of cavities, counterbores, grooves, etc.) requires that the part be oriented end to end.

FIGURE 5.4

Second and third digits of geometrical classification for rotational parts. (From Boothroyd, G. and Dewhurst, P. *Product Design for Assembly Handbook*, Boothroyd Dewhurst Inc., Wakefield, RI, 1986. With permission.)

AUTOMATIC INSERTION - RELATIVE WORKHEAD COST, W_r

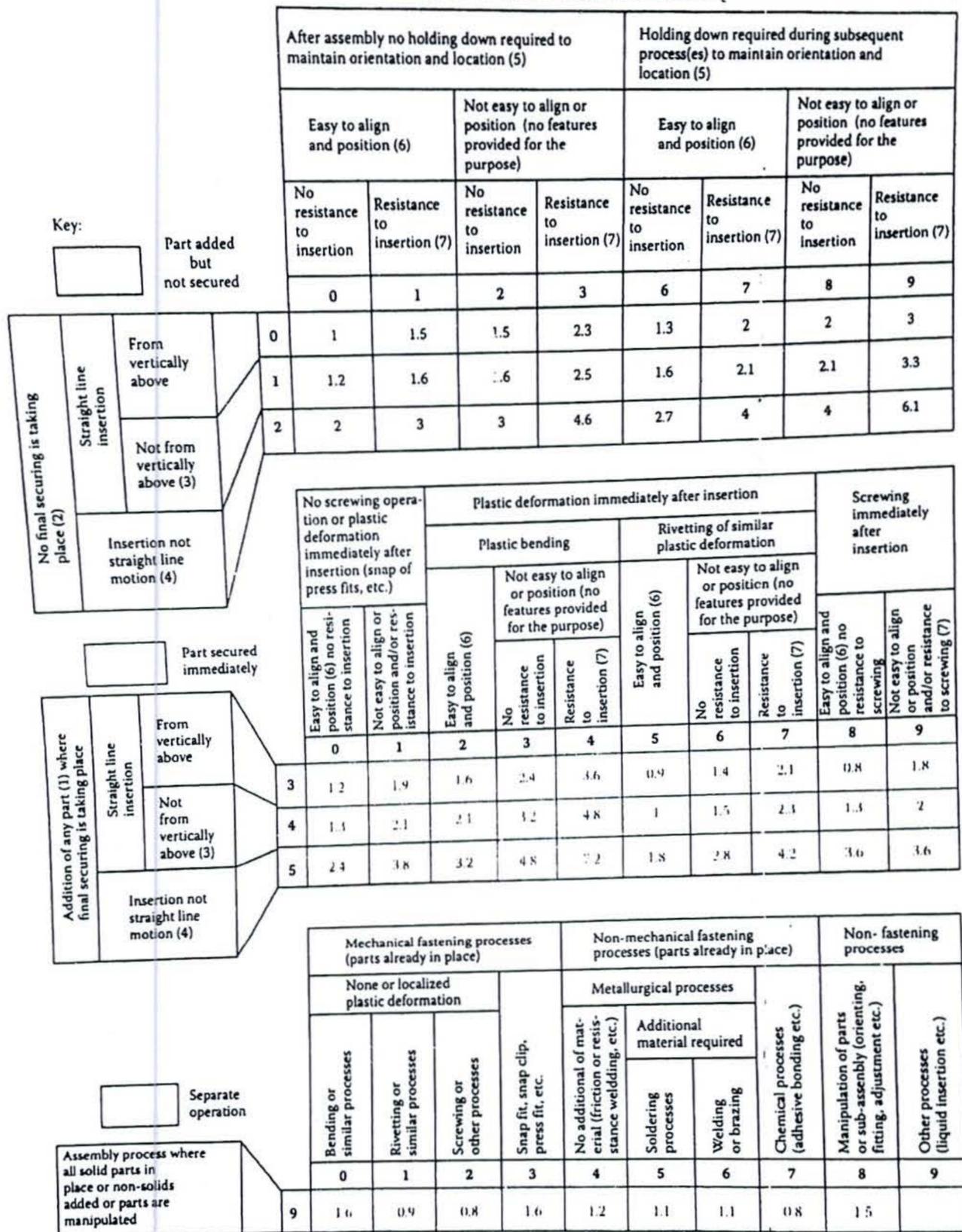


FIGURE 5.9 Relative workhead costs W_r for a selection of automatic insertion situations. (From Boothroyd, G. and Dewhurst, P. *Product Design for Assembly Handbook*, Boothroyd Dewhurst Inc., Wakefield, RI, 1986. With permission.)

ROBOT ASSEMBLY DATA FOR A MULTI-STATION SYSTEM

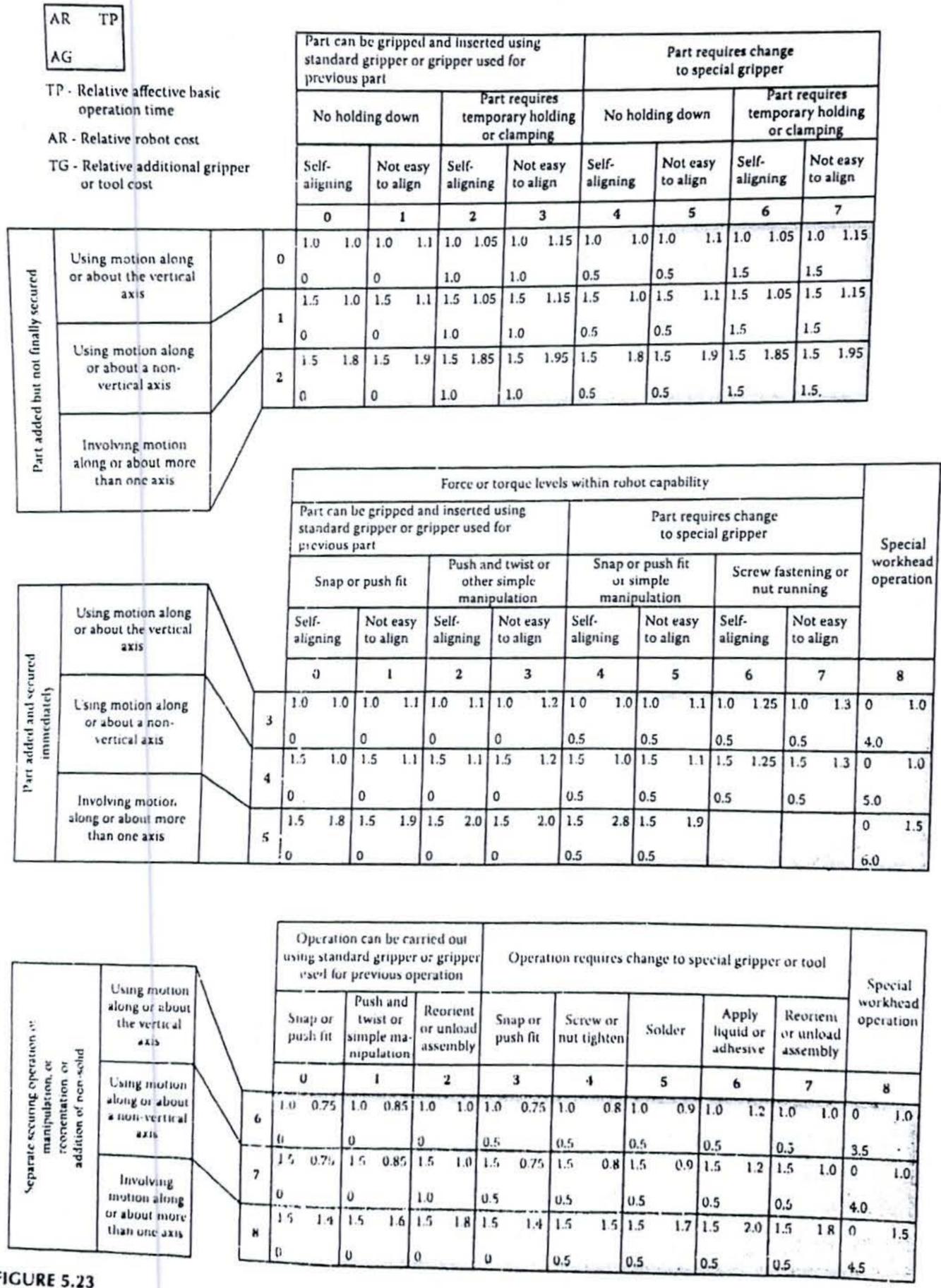


FIGURE 5.23 Classification system and database for a single-station one-arm robot assembly system. (From Boothroyd, G. and Dewhurst, P. *Product Design for Assembly Handbook*, Boothroyd Dewhurst Inc., Wakefield, RI, 1986. With permission.)

END OF EXAMINATION PAPER