

Production & Industrial Engineering

Industrial Engineering

Comprehensive Theory

with Solved Examples and Practice Questions



MADE EASY
Publications

**MADE EASY Publications Pvt. Ltd.**

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016

E-mail: infomep@madeeasy.in

Contact: 011-45124660, 8860378007

Visit us at: www.madeeasypublications.org

Industrial Engineering

© Copyright by MADE EASY Publications Pvt. Ltd.

All rights are reserved. No part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photo-copying, recording or otherwise), without the prior written permission of the above mentioned publisher of this book.

First Edition : 2020

Second Edition : 2021

Third Edition : 2022

Contents

Industrial Engineering

Chapter 1

Product Design and Development 1

1.1	Product Life Cycle.....	1
1.2	Product Policy of an Organization	4
1.3	Selection of Profitable Product	4
1.4	Product Development.....	5
1.5	Product Analysis	9
1.6	Principles of Product Development	11
1.7	Challenges for Product Development	17
1.8	Value Engineering.....	18
1.9	Concurrent Engineering	23
1.10	Production System	24
	<i>Student's Assignments</i>	29

Chapter 2

Work System Design.....32

2.1	Productivity	33
2.2	Classification of Work Study	36
2.3	Importance of Work Study	36
2.4	Advantages of Work Study	36
2.5	Work Study Procedure.....	37
2.6	Work Simplification and Work Study.....	37
2.7	Human Considerations in Work Study.....	38
2.8	Concept Work Content.....	38
2.9	Reasons for Excess Work Content.....	38
2.10	Techniques to Reduce Work Content.....	39

2.11	Method Study.....	40
2.12	Memo Motion Study.....	55
2.13	Cycle Graph and Chronocycle Graph.....	55
2.14	Work Measurement	59
2.15	Techniques of Work Measurement	60
2.16	Work Sampling.....	75
2.17	Job Evaluation.....	79
2.18	Merit Rating.....	84
2.19	Wage Administration and Incentive Systems	86
2.20	Sequencing	93
	<i>Student's Assignments</i>	111

Chapter 3

Facility Design 116

3.1	Need of Selecting Suitable Location	116
3.2	Plant Location Problem	117
3.3	Advantages and Limitations of Urban, Sub-Urban and Rural Locations	117
3.4	Factors influencing Plant Location	119
3.5	Analytical Methods of Location Planning.....	122
3.6	Facilities Layout Design and Facilities Location.....	125
3.7	Assembly Line Balancing	134
3.8	Material Handling System	144
	<i>Student's Assignments</i>	158



Product Design and Development

INTRODUCTION

A product is an article obtained by the transformation of raw material and is marketed/sold by the manufacturer, i.e. a product is a salable item. It may be

- (i) Consumer product, e.g. cigarettes, televisions or
- (ii) Industrial product, e.g. a lathe, an overhead bridge crane, etc.

Every organisation has to design, develop and introduce new products as a survival and growth strategy. Organisations objective of achieving growth of business is only through introduction of new products. Organisation's are required to design the new products for the following reasons:

- To be in business for a long time believing the fact that business is a long lasting institution.
- To satisfy unfulfilled needs of the customers.
- The company's existing product line becomes saturated and the sales is on the decline.
- To enter into new prospective businesses through diversification (related or unrelated).
- Too much competition in the existing product line.
- The profit margin is on the decline.

1.1 Product Life Cycle

The product once introduced into the market will undergo definite phases. The various phases of life-cycle of a product are represented in the figure given below.

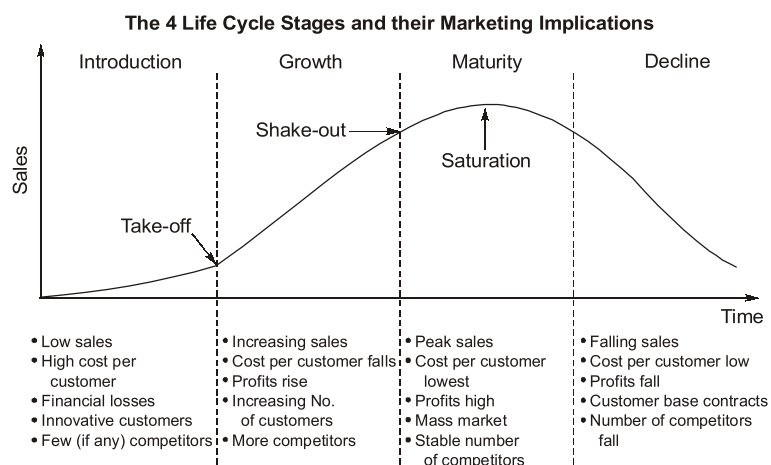


Fig. Product-Life Cycle

1.1.1 Introduction Stage

When a product is launched on the market, its sales will begin to grow slowly and profit, if any, will be rather small. This can be attributed to the lead time which is required for marketing efforts to take effect. At this stage, the product is new and untested, which implicates that potential customers may be unwilling or reluctant to purchase it. A second reason for rather low profitability at the introduction stage is that the company is unlikely to be making full use of its production capacity. As a result, it will be unable to benefit from the economies of scale that are associated with higher levels of production. The low profitability does also come from the need to recover development and launch costs. The main priority of the firm at the introduction stage is to generate widespread awareness of the product in its target segment and to stimulate trial. This is especially the case for new-to-the-world products, which are truly innovative by nature. In this case, primary demand will first have to be established. The company should focus its marketing activities on those buyers who are readiest to buy: innovators, which are usually to be found within the higher-income groups. This behavior was evident for instance when the manufacturers of the first smart phones targeted B2B customers when the products were first introduced to the market.

There are various marketing strategies that can be used for introducing a new product to the market. Two pricing strategies are available. The choice between the two strategies depends on the nature of the product and the level of competition:

- **Price skimming** involves charging a high initial price, before reducing the price gradually to “skim” each potential target group in the market as the market grows.
- **Price penetration** involves setting a low price to enter the market quickly and capturing market share, before adjusting the price to increase profits once the market has grown.

Actually, a significant share of new products fails to progress beyond the introduction stage of the PLC. This is often caused by a lack of understanding of the characteristics of the product life cycle stages and their implication on the required marketing strategies. At the introduction stage, this failure is worst: Customers who are dissatisfied with their first purchase of a product or a brand will be unlikely to make repeat purchases and recommendations, which are in turn essential for sales increases. Therefore, it is absolutely crucial to ensure that the products provide valuable benefits to the customer and superior customer value if survival and growth are to follow. The most important point is to get it right the first time.

1.1.2 Growth Stage

If the product meets existing market needs or stimulates previously untapped needs, it will enter the growth stage. In this stage, sales will usually lift off. This point is called the *take-off point*. Profits are generated as sales revenues increase faster than costs. But competitors will also have had time to assess the product, predict its impact on the market and potentially respond with a similar or improved version of the offering. As a result, the total size of the market tends to grow, and the new competitors can increase their sales by attracting new customers rather than undercutting each other on price. An increase in the number of distribution outlets tends to go in hand with this.

1.1.3 Maturity Stage

When a the sales growth of the product slows down, the maturity stage is reached. During this stage, there is a tendency for companies to capture customers from their competitors by undercutting each other on prices and increasing promotional efforts. As competitive rivalry intensifies, the weaker competitors are forced out of the market. This point is known as the *shake-out point*. Thus, only the strongest players remain to dominate the more stable market. The maturity stage does usually last longer than the previous stages, but also poses the strongest challenges to the marketing: the firm will try to prevent the sales to decline, while maintaining profitability. The problem at this stage is heavy price competition and resulting increased marketing expenditure from all competitors in order to retain brand loyalty.

Certainly, there are some famous brands and products that are still in the maturity stage after thirty years and more. For instance, consider Mars' bars or Coca-Cola. Although these products have changes only very little

since their launch, they are still highly successful or even more successful than ever. Other products survive by evolving to meet changing consumer needs

During the maturity stage, the firm can choose from a number of alternative strategies to ensure the future success of the product. These strategies range from innovating the market (market development) over modifying the product (product development) to altering the marketing mix (marketing innovation).

1.1.4 Decline Stage

If the characteristics of the product life cycle stages and their marketing implications are understood properly, the product may have made it to the final stage in the PLC: the decline stage. Usually, the firm will have tried to keep the product as long as possible in the maturity stage. However, once the sales of a product start to fall or profitability can no further be maintained, the decline stage is reached. This does often happen as a result of the market entry of substitute products which satisfy customer needs better than the previous product.

There are several alternative strategies available for handling the decline stage appropriately.

- **Milking or Harvesting** : When this strategy is used, the product receives only little or no marketing support. The firm aims to maximize the life of the product while generating the cash and the time required to establish new products. In addition, the slow decline of the product provides the firm with sufficient time to adjust to the declining cash flow and to find alternative means of generating income.
- **Phased Withdrawal** : Unlike under the milking approach, where the product could in theory continue indefinitely, phased withdrawal involves setting a hard cut-off date for the product. Before the cut-off date, there may be interim stages at which the product is either pulled from certain channels of distribution or certain geographic areas. Phased withdrawal provides the advantage of enabling the firm to plan the introduction of replacement products. However, it can be a source of dissatisfaction to customers, who may not like the sudden disappearance of their favoured product. A typical example of the phased withdrawal strategy can be found in the automotive industry: car manufacturers normally set hard cut-off dates to existing products, so that both dealers and the public are notified of product withdrawals and new product launches.
- **Contracting out or Selling** : Loyal users of a product can be retained when the brand or the rights to produce and sell the product are handed on to a niche operator or by subcontracting. Many smaller firms use this strategy since they are flexible enough to offer the product's market a satisfactory return. Each party involved in this strategy benefits from the deal: the originating firm can dispose profitably of a product it no longer wants, consumers can keep buying products they desire, and the subcontractor or buyer can gain the benefits of a brand they could never have established on their own.

Management have to consider few things before dropping the product :

- (a) Effects on customers who expect service and replacement parts.
- (b) Effects on employees if you fire the workers who are involved in making the product.
- (c) Effect on other related products in the product line.

Table. Characteristics of Phases of PLC

Particulars	Introduction	Growth	Maturity	Decline
1. Product Variety	High Variety	Increasing Standardisation	Dominant Design feature of product	High standard commodity
2. Volume	Low Volume	Increasing Volume Consolidation	High Volume	Decreasing Volume
3. Industry Structure	Small Competition	Beginning of Competition	Few large companies	Survivors
4. Form of Competition	Product Characteristics	Product Quality and availability	Price and dependability	Price

1.2 Product Policy of an Organization

Product policy is the top management(Strategic) decision. Every organization has its own product strategies or policies which form the basis of competing in the market and they become the Unique Selling Proposition(USP) of the company. The various product policies are :

1. **Lowest Price** : The company will be the price leader and the company is going to offer the product at the cheapest price than its competitors. Price becomes the criteria used to compete in the market. Though the profit per unit is less, the company is going to make the substantial profit by the large volume.
2. **Highest Quality** : Some organisations offer highest quality products irrespective of the cost. They are catering to the needs of special class of customers who value quality as the only criteria to purchase the product.
3. **Compromise between Cost and Quality** : Some organisations in order to capture the larger sections of the customers, offer products with the optimum blend of quality and cost. The products are reasonably of good quality in proportion to its price. These organisations try to give good value to the customers for his money.
4. **Safety** : Some organisations give maximum importance to safety. Safety is the criteria on which they compete in the market. For example, all home appliances, electrical gadgets, etc.

Thus, organisations have to choose the policies suitable for them. This policy is going to Influence the design to the large extent.

1.3 Selection of Profitable Product

It is the product that makes or mar the fortune of the company. So utmost care should be taken in the identification of the product.

Before selecting a product, organisations have to carryout SWOT analysis in order to know their strength areas, weaknesses or limitations, opportunities before the organisation and the perceived threat. The organisations have to explore the opportunities (products) which fall under their strength areas so that they are able to cash on the opportunities. Product selection is a team effort.

Following are the methods to identify the profitable product :

1. **By chance** : It is impossible to ignore the effects of chance. A meeting in a train with a stranger, sight of a new device, an attendance at a social gathering can create the idea which may lead to a successful product.
2. **Desire to utilise idle resources** : Many organisations have idle resources like excess cash, unused plant and equipment, unutilised management talent, surplus distribution channels and the management may conceive an idea of putting these resources to productive use which gives rise to new product.
3. **Demand supply gap** : If the gap between demand and supply is big, then the products are selected to bridge this gap.
4. Need to support existing range.
5. Forward and/or backward integration.
6. By spreading the risk.
7. To supplement a declining income.
8. To keep pace with changing fashion and customer preferences and tastes.
9. To exploit special skills.
10. To attract prestige.
11. To exploit special assets.

No project should be undertaken until it is viewed objectively from all aspects and a detailed feasibility study is carried out. The personal preference and immediate excitement should not be given any room.

1.10.1 Classification of Production System

Production systems can be classified as

1. Job Shop,
2. Batch,
3. Mass and
4. Continuous Production systems.

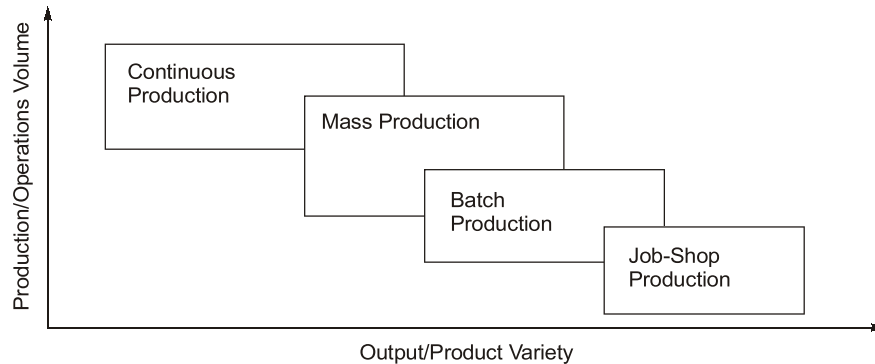


Fig. Classification of production systems

1. Job Shop Production

Job shop production are characterized by manufacturing of one or few quantity of products designed and produced as per the specification of customers within prefixed time and cost. The distinguishing feature of this is low volume and high variety of products.

A job shop comprises of general purpose machines arranged into different departments. Each job demands unique technological requirements, demands processing on machines in a certain sequence.

Characteristics :

The Job-shop production system is followed when there is :

1. High variety of products and low volume.
2. Use of general purpose machines and facilities.
3. Highly skilled operators who can take up each job as a challenge because of uniqueness.
4. Large inventory of materials, tools, parts.
5. Detailed planning is essential for sequencing the requirements of each product, capacities for each work centre and order priorities.

Advantages :

Following are the advantages of job shop production:

1. Because of general purpose machines and facilities variety of products can be produced.
2. Operators will become more skilled and competent, as each job gives them learning opportunities.
3. Full potential of operators can be utilised.
4. Opportunity exists for creative methods and innovative ideas.

Limitations :

Following are the limitations of job shop production:

1. Higher cost due to frequent set up changes.
2. Higher level of inventory at all levels and hence higher inventory cost.
3. Production planning is complicated.
4. Larger space requirements.

Advantages :

Following are the advantages of mass production:

1. Higher rate of production with reduced cycle time.
2. Higher capacity utilisation due to line balancing.
3. Less skilled operators are required.
4. Low process inventory.
5. Manufacturing cost per unit is low.

Limitations :

Following are the limitations of mass production:

1. Breakdown of one machine will stop an entire production line.
2. Line layout needs major change with the changes in the product design.
3. High investment in production facilities.
4. The cycle time is determined by the slowest operation.

4. Continuous Production

Production facilities are arranged as per the sequence of production operations from the first operations to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc.

Characteristics :

Continuous production is used under the following circumstances:

1. Dedicated plant and equipment with zero flexibility.
2. Material handling is fully automated.
3. Process follows a predetermined sequence of operations.
4. Component materials cannot be readily identified with final product.
5. Planning and scheduling is a routine action.

Advantages :

Following are the advantages of continuous production:

1. Standardisation of product and process sequence.
2. Higher rate of production with reduced cycle time.
3. Higher capacity utilisation due to line balancing.
4. Manpower is not required for material handling as it is completely automatic.
5. Person with limited skills can be used on the production line.
6. Unit cost is lower due to high volume of production.

Limitations :

Following are the limitations of continuous production:

1. Flexibility to accommodate and process number of products does not exist.
2. Very high investment for setting flow lines.
3. Product differentiation is limited.

1.10.2 Comparison between Different Types of Production System

Different systems of production can be compared in terms of following characteristics :

1. **Manufacturing Costs :** Per unit cost is maximum in Job production and minimum in process production. The four methods of production in increasing order of costs can be arranged as process, mass, batch and job.

2. **Capital Investment** : The requirement of capital varies according to the nature of the product and the input needs. The systems in ascending order of capital investment can be arranged as job, batch, mass and process.
3. **Size of Plant** : In job and batch system same equipment/machine can perform a number of operations to manufacture different type of items. So the size of the plant is likely to be smaller than those for mass and process system where whole production process is to be strictly arranged in a predetermined sequence of operations.
4. **Technical Requirements** : Highly skilled labor is required in job and batch production to operate and carry out specialized work on machines. In the case of mass and process systems semi-skilled persons can also operate the machines. But due to large scale of production, more managerial skill is required in continuous systems.
5. **Organizational Structure** : In job and batch production generally functional organizational approach is adopted whereas divisional organization pattern is used in mass and process systems. There is decentralization concept in organization of job and batch whereas centralization is prominent in mass and process systems.
6. **Flexibility in Production** : Job-batch systems can easily adjust to changes in the requirement of the consumer with incurring any heavy expenditure. But in the case of mass and process systems we can produce one single product and with change in demand of products the systems cannot be adjusted easily. Thus job-batch system using general purpose machines is more flexible than mass-process system using single purpose machines.
7. **Type of Products Produced** : Job system can be used in buildings, bridges, specific machines, production etc. and batch system can be used in producing machine tools, garments, shoes etc. Mass production is helpful for producing electrical items like switches, plugs, refrigerators etc., cars, trucks, tractors etc. Process production is suitable to manufacture, petroleum, dairy and chemical products.
8. **Security of Job** : Job and batch systems produce items only when orders are received. During slack periods when there is no or very little demand workers are likely to be sacked. Thus, there is less job security in Job-batch production systems. In mass and process system, items are manufactured for stock and so production is continuous. Due to this there is more job-security for workers.



**Student's
Assignments****1**

- Q.1** The following is the preliminary stage of Production planning
(a) Capacity planning
(b) Material requirements planning
(c) Scheduling
(d) Product development and design
- Q.2** The following is the source(s) for developing new or improved product
(a) Research and Development department of the enterprise
(b) Consumer suggestions and Complaints
(c) Other competitive products in the market
(d) All of the above
- Q.3** Product cost can be reduced by considering the following aspect(s) at the design stage
(a) Minimum number of operations
(b) Unnecessary tight tolerance should not be provided
(c) Design should consist of standard parts
(d) All of the above
- Q.4** The ultimate objective of the product is
(a) To provide a new look
(b) Utilizing existing manpower
(c) To monopolize the market
(d) All of the above
- Q.5** Based on their field of application, manufactured goods can be classified as
(a) Primary, Secondary and Tertiary
(b) Consumer, Capital and Defense
(c) Essential, Market and Standard
(d) Primary, Luxury and Consumer
- Q.6** The following aspect of product is concerned with the ease and efficiency of the product performance
(a) Functional aspect (b) Operational aspect
(c) Durability aspect (d) Aesthetic aspect
- Q.7** The “simplicity to operate and easy to understand” of product is concerned with its following aspect
(a) Functional aspect (b) Operational aspect
(c) Durability aspect (d) Aesthetic aspect
- Q.8** _____ helps in establishing the interchangeability of products
(a) Standardization (b) Simplification
(c) Diversification (d) Specialization
- Q.9** In which of the following type the manufacturing cost may go up
(a) Standardization (b) Simplification
(c) Diversification (d) All of the above
- Q.10** Product _____ is the ultimate objective of variety reduction
(a) Simplification (b) Standardization
(c) Specialization (d) All of the above
- Q.11** The following eases the process of stock control
(a) Standardization (b) Simplification
(c) Both ‘A’ and ‘B’ (d) None of the above
- Q.12** The following is the Durability aspect(s) of a product
(a) Efficiency of the product
(b) Easy to understand
(c) Ease with which a product can be maintained
(d) All of the above
- Q.13** First step in process of developing new product must be
(a) idea generation
(b) idea screening
(c) concept development and testing
(d) business analysis
- Q.14** In product life cycle introductory stage, marketing objective is to
(a) maximize the market share
(b) create product awareness
(c) defend market share and profits
(d) reduce expenditure
- Q.15** The following is/are the source(s) for developing new or improved product.
(a) Research and Development department of enterprise.
(b) Consumer suggestions and complaints.
(c) Other competitive products in the market.
(d) All of the above

Q.16 Which of the following aspects can be considered at design stage to reduce the product cost?

- (a) Minimum number of operations.
- (b) Unnecessary tight tolerances should not be provided.
- (c) Design should consists of standard parts.
- (d) All of the above

Q.17 In which of the following type, manufacturing cost may go up?

- (a) Standardization (b) Simplification
- (c) Diversification (d) All of the above

Q.18 The 'simplicity to operate and easy to understand' of product is concerned with its following aspect.

- (a) Functional aspect
- (b) Operational aspect
- (c) Durability aspect
- (d) Aesthetic aspect

Q.19 Select the different tools used for product development

- 1. Standardization
- 2. Simplification
- 3. Selection of material
- 4. Specialization
- (a) 1 and 2 only (b) 1, 2 and 3 only
- (c) 1, 2 and 4 only (d) 1, 2, 3 and 4

Q.20 Procedure of value engineering :

- (a) Blast - Refine - Create
- (b) Blast - Create - Refine
- (c) Create - Blast - Refine
- (d) None of these

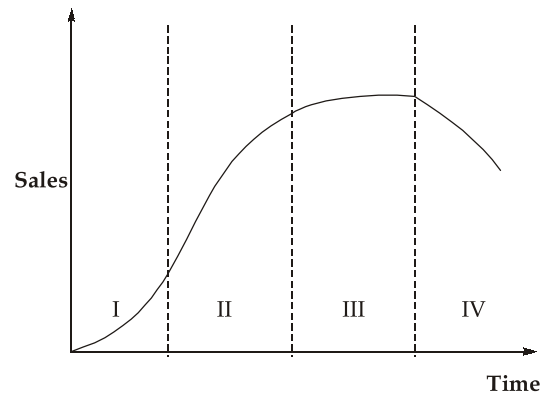
Q.21 For a particular product current year price is ₹10 and base year price is ₹11, then the value of deflator is _____.

Q.22 The process which is concerned with reduction of product range, assemblies, parts, materials and design is known as

- (a) Standardization (b) Diversification
- (c) Simplification (d) All of the above

Q.23 A company is selling 1320 beds in year. The cost of bed is ₹1950. After applying value engineering in the manufacturing of bed the cost reduces to ₹1660. The annual saving of company after value engineering (in ₹) is _____.

Q.24 Match List-I with List-II and select the correct answer using the codes given below the lists:



List-I

- A. I
- B. II
- C. III
- D. IV

List-II

- 1. Growth
- 2. Maturity
- 3. Introduction
- 4. Decline

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	2	1	4
(c)	2	1	3	4
(d)	3	1	2	4



**Student's
Assignments**

2

Q.25 Arrange the following product design process in logical sequence.

- 1. Preliminary Ideas 2. Problem identification
- 3. Analysis 4. Design refinement
- 5. Documentation 6. Optimization
- (a) 1-2-3-4-6-5 (b) 2-1-4-3-6-5
- (c) 2-1-3-4-5-6 (d) 1-2-4-3-6-5

Q.26 What is the correct sequence of different stages involved in selection and development of the product?

- 1. Screaming of ideas
- 2. Product analysis
- 3. Concept development
- 4. Test marketing
- 5. Product design and development programme
- 6. Commercialisation

- (a) 1 - 2 - 3 - 5 - 4 - 6 (b) 1 - 3 - 2 - 4 - 5 - 6
(c) 1 - 3 - 2 - 5 - 4 - 6 (d) 1 - 2 - 3 - 4 - 5 - 6

Q.27 What is concurrent design process.

- (a) The process includes only engineers.
(b) The process includes only the business part of the design.
(c) The process includes all disciplines involved in designing a product.
(d) None of the above

ANSWERS

1. (d) 2. (d) 3. (d) 4. (c) 5. (b)
6. (a) 7. (a) 8. (a) 9. (c) 10. (c)
11. (c) 12. (c) 13. (a) 14. (b) 15. (d)
16. (d) 17. (c) 18. (a) 19. (c) 20. (b)
21. (0.909) 22. (c) 23. (382800) 24. (d)
25. (b) 26. (c) 27. (c)

HINTS

- 13. (a)**
Idea Generation-Idea Screening-Concept development and testing-Marketing Strategy-Business analysis-Product development-Test marketing.
- 14. (b)**
Introductory stage our aim to:
establish a clear brand identity
connect with the right partners to promote your products
set up consumer tests, or provide samples or trials to key target markets

- 15. (d)**
All of the above are sources for developing new or improved product.

21. (0.909) (0.90 to 0.92)

$$\begin{aligned}\text{Deflator} &= \frac{\text{Current year price}}{\text{Base year price}} \\ &= \frac{10}{11} = 0.909\end{aligned}$$

23. (382800)

$$\begin{aligned}\text{Cost saving after Value engineering} \\ &= 1950 - 1660 = 290 \\ \text{Annual saving} &= 1320 \times 290 = 382800\end{aligned}$$

24. (d)

I - Introduction
II - Growth
III - Maturity
IV - Decline

25. (b)

Logical sequence is – problem identification → Preliminary Ideas → Design refinement → Analysis → Optimization → Documentation.

27. (c)

The process includes all disciplines involved in designing a product.

