Engineering Economics

Samundra Paudel

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Pokhara University

Course Objectives :

After completing this course students will be able to:

- Understand and describe the basic concept of economics, cost accounting and time value of money.
- Assist in the valuation of engineering projects in the public and private sectors to take decisions.
- Analyzes the project risk and relate the concept of ecological limit and economic development.
- Calculate depreciation, taxation and its application in analysis.
- Identify different financing options and use to a limited extent, general accounting procedures.

Text book and References:

Text Book:

- Chan S. Park, *Contemporary Engineering Economics,* PHI Learning Private Limited.

Refrences:

- E Paul De Garmo. William G Sullivan and James A. Bontadelli, *Engineering Economy,* MC Milan Publishing Company
- James L., Riggs, David D. Bedworth and Sabah U. Randhawa, Engineering Economics, Tata McGraw Hill Education Private Limited
- N. N. Borish and S. Kaplan, *Economics Analysis for Engineering and Managerial Decision Making*, MCGraw Hill Publishing Company
- Adhikari, D. *Principles of Engineering Economics Analysis,* Global Publication, Nepal
- Sen Gupta, Ramprasad, *Ecological Limits and Economic Development,* Oxford University Press.

Chapter 1: Basics of Engineering Economics

- Definition of Economics, Demand, the Law of Diminishing Utility, Marginal Utility, Supply, Law of Supply, Law of Supply and Demand
- Engineering Economics, Principles of Engineering Economy and its application

What is economics?

- *"Whenever six economists are gathered, there are seven opinions."*-Barbara Wootton.
- *"Economics is the science of wealth."*-Adam Smith (Father of economics, Leader of Classical Economics, 1776)
- *"Economics is on the one side, a study of wealth and on the other and more important side is a part of the study of man."*-Alfred Marshall (Leader of neo-classical economists).
- *"Economics is the science which studies human behavior as a relationship between ends and scarce means which have alternative uses."*-Lionel Robbins (British Economist,1932)

Economics

- Economics is a social science which deals with human wants and their satisfaction. It is mainly concerned with the way in which a society chooses to employ its scarce resources which have alternative uses, for the production of goods for present and future consumption.
- Human wants are unlimited. So scarcity is the fundamental fact of life. As all wants are not of equal importance, this leads to choice. Economics is the science of choice. As there is scarcity of goods, we have to pay a price for them. So, economics studies about the pricing process. And, as prices are paid in money, we study about the part played by money in the economic life of a society. We study how people get and spend money, how they earn a living and how it affects their way of life and so on.
- All the scarce goods which satisfy our wants are known as wealth. So, in economics, we study about the production of wealth, exchange of wealth, distribution of wealth and consumption of wealth. As wealth is produced to promote human welfare, we study the relationship between wealth and welfare.

Adam Smith's Definition (Wealth Definition)

- Adam Smith (1723-90) defined economics as follows : "*Economics is the science of wealth*". He is the author of the famous book "*Wealth of Nations*" (1776). He is known as the Father of Political Economy because he was the first person who put all the economic ideas in a systematic way. It is only after Adam Smith, we study economics as a systematic science.
- We study about consumption, production, exchange and distribution of wealth. J.S. Mill defined economics as "the practical science of the production and distribution of wealth".

Alfred Marshall's Definition (Welfare Definition)

- Alfred Marshall (1842-1924) wrote a book *Principles of Economics* in 1890. In it, he defined economics as "*a study of mankind in the ordinary business of life*". An altered form of this definition is: "*Economics is a study of man's actions in the ordinary business of life*".
- Marshall agrees that economics studies about wealth. But he does not accept the view that economics studies about wealth alone. In the words of Marshall, "Economics is on the one side a study of wealth, and on the other and more important side, a part of the study of man. Man is the centre of his study. According to him, the study of man is more important than the study of wealth.
- According to this definition, we may say that economics is the study of the causes of material welfare. Marshall's definition is known as material welfare definition of economics because of its emphasis on welfare.

Lionel Robbins' definition (Scarcity Definition)

- Lionel Robbins has defined economics as follows: "*Economics is the science which studies human behaviour as a relationship between ends and scarce means which have alternative uses*". Robbins has given the above definition in his book "*An Essay on the Nature and significance of Economic Science*".
- The definition of Robbins is based on the following basic assumptions
- 1. Ends are various. The term "ends" mean wants. Human wants are unlimited.
- 2. Means are limited. Means like time, money and resources are limited.
- 3. We can put time and money to alternative uses. For example, though time is limited, we can use it for different purposes. We can use time for earning money or we may enjoy it as leisure, and
- 4. All wants are not of equal importance.
- Choice between alternatives is the basic principle underlying all economic activity. This is applicable to all economic systems – capitalism, socialism and mixed economy.
- Lionel Robbins' definition is also known as scarcity definition of economics.

Samuelson's Definition (Modern Definition of Economics)

- Samuelson's definition is known as a modern definition of economics. According to Samuelson, "*Economics is a social science concerned chiefly with the way society chooses to employ its resources, which have alternative uses, to produce goods and services for present and future consumption*". The above definition is general in nature. There are many common points in the definitions of Robbins and Samuelson.
- Samuelson's definition tells us that economics is a social science and it is mainly concerned with the way how society employs its limited resources for alternative uses. All this we find in the definition of Robbins.
- But Samuelson goes a step further and discusses how a society uses limited resources for producing goods and services for present and future consumption of various people or groups.

Main Divisions of Economics

- There are four main divisions of economics.
- They are consumption, production, exchange and distribution.
- In modern times, economists add one more division and that is public finance. In public finance, we study about the economics of government. The economic functions of the modern State have increased to a great extent. So public finance has become an important branch of economics.
- All the above divisions are interrelated. And they are dependent on each other.

Micro-economics and Macro-economics

- Economic theory can be broadly divided into *micro economics* and *macroeconomics*. The term *micro* means small and *macro* means large.
- In microeconomics, we deal with problems such as the output of a single firm or industry, price of a single commodity and spending on goods by a single household.
- Macroeconomics studies the economic system as a whole. In it, we get a complete picture of the working of the economy. It is a study of the relations between broad economic aggregates such as total employment, saving and investment. We may also say that macro-economics is the theory of income, employment, prices and money.
- That is why macroeconomics is sometimes studied under the title "Income and Employment Analysis".

Basic Terminologies (Refer to EE notes (doc. file) for more detail)

Demand:

- Desire with ability to pay and willingness to pay.
- Various quantities of an item that a buyer is willing to buy at alternative prices, other things being equal.

Supply:

- Desire with ability to sell and willingness to sell.
- Various quantities of an item that a seller is willing to sell at alternative prices, other things being equal.

Basic Terminologies

Utility:

- The level/power of satisfaction to a consumer by consuming goods and services.

Marginal Utility:

- The change in total utility due to one more/additional unit of consumption.
- It is the utility derived by single unit of consumption.
- **$MU=TU_n - TU_{n-1}$**
- **MU=Change in Total Utility/Change in quantity consumption**

Law of Demand(Refer to EE notes (doc.) file for more detail)

- Law of demand states the relationship between quantity demanded and price of the commodity.
- It explain the inverse relationship between price and quantity demanded.
- It states: "*All other things being equal, demand varies inversely with price.*"
- It is defined as "*all other things remaining the same, the quantity demanded of commodity increases when its price decreases and vice versa.*"
- This law assumes all other factors are remained constant.

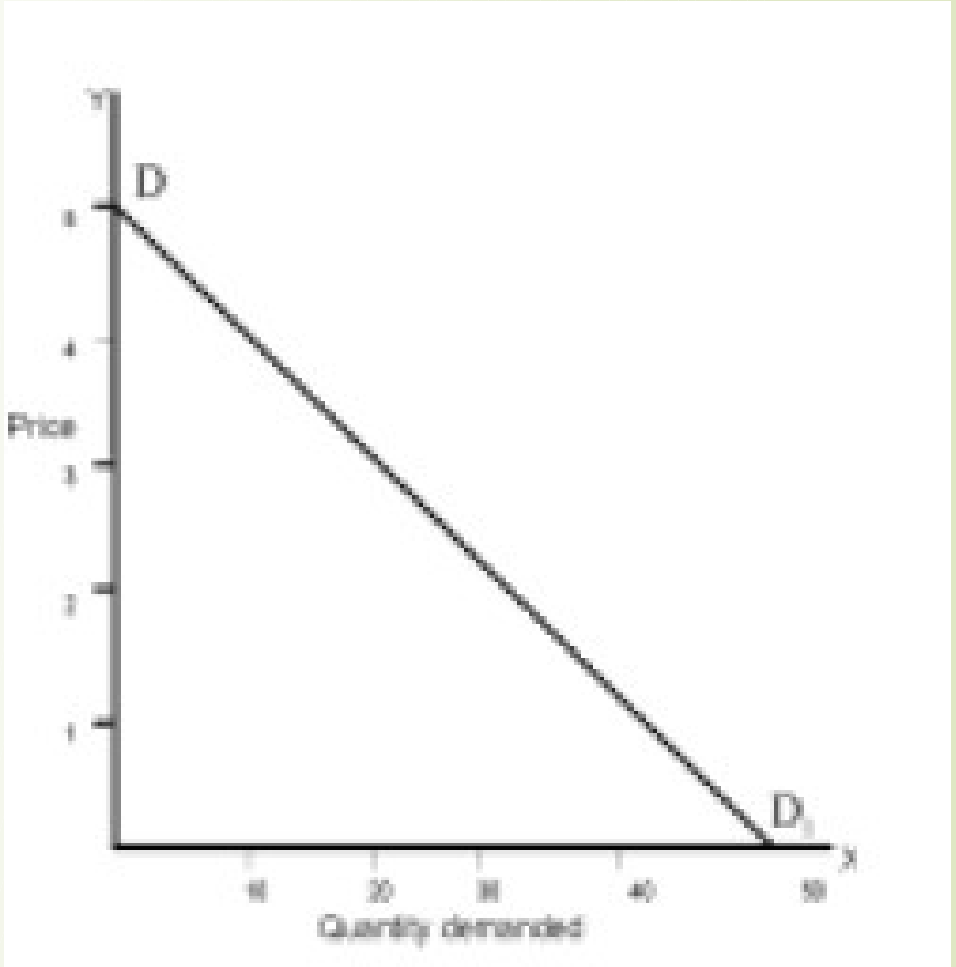
Demand Schedule

Price of Potato (Rs/Kg)	Quantity demand (Kg)
20	20
30	16
40	12
50	8
60	4

Demand Curve

Demand curve is graphical representation of demand schedule. Demand curve always slopes downwards.

Demand Curve



Factors influencing demand

1. Price of commodity
2. Income of consumer
3. Price of related goods (competitive or complimentary)
4. Weather
5. Custom and fashion
6. Size of population
7. Future expectation etc.

Law of Supply (Refer to EE notes (doc. file) for more detail)

- Law of supply states the relationship between quantity supplied and price of the commodity.
- It explain the positive relationship between price and quantity supplied.
- It states: "*All other things being equal, demand varies inversely with price.*"
- It is defined as "*all other things remaining the same, the quantity supplied of commodity increases when its price increases and vice versa.*"
- This law assumes all other factors are remained constant.

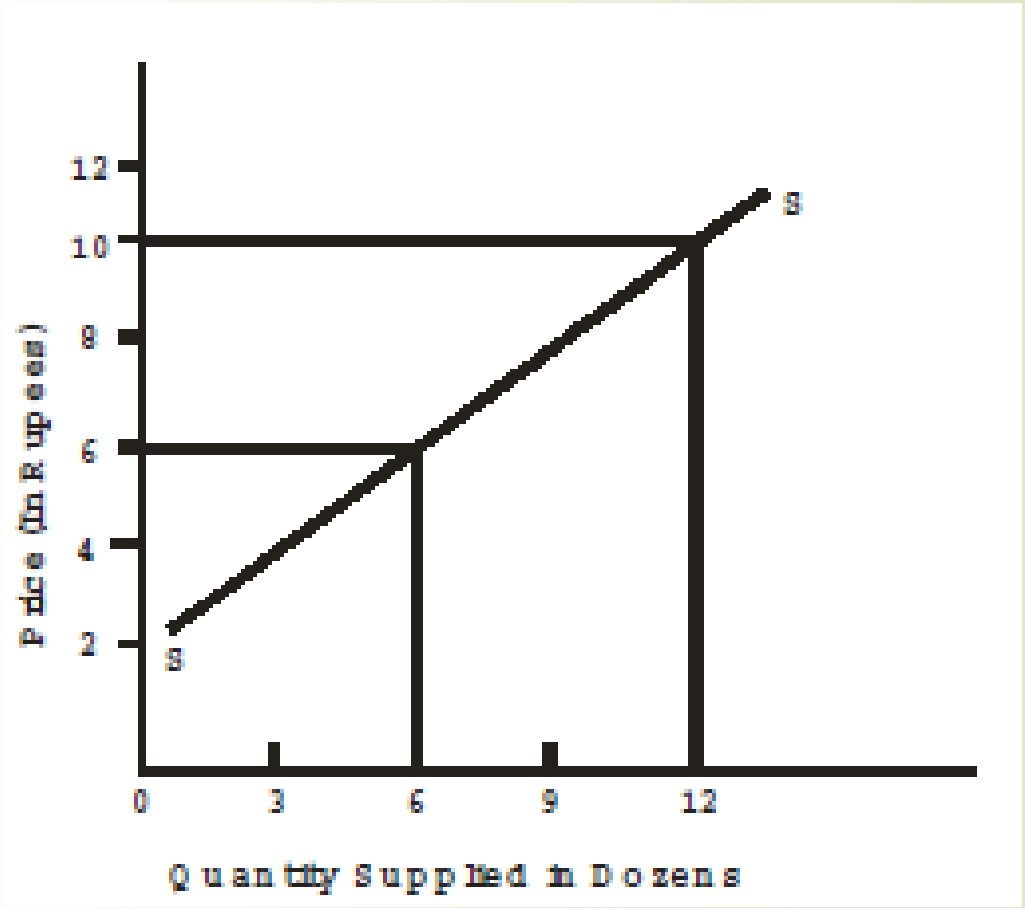
Supply Schedule

Price of Onion (Rs/Kg)	Quantity if Supply (Kg)
20	40
30	60
40	80
50	100
60	120

Supply Curve

Supply curve is graphical representation of supply schedule.
Supply curve always slopes upward.

Supply Curve



Factors influencing Supply

1. Price of commodity
2. Price of factor of production
3. Price of related goods (competitive/substitute or complimentary)
4. Production Technology
5. New inventions
6. Taxes and subsidies
7. Development of infrastructures
8. State of natural resources
9. Future expectation

Law of diminishing utility (Refer to EE notes (doc.) file for more detail)

- Also known as Law of diminishing marginal utility.
- It states that in the process of fulfilling human wants, when a consumer consumes additional units of commodity, the utility derived from each successive unit of the commodity goes decreasing.
- The law is based on certain assumptions:
  - Utility is measurable. The measurement unit is util.
  - Consumer taste and preferences unchanged.
  - Suitable and similar units of commodity.
  - Rational consumer.
  - Continuous consumption etc.

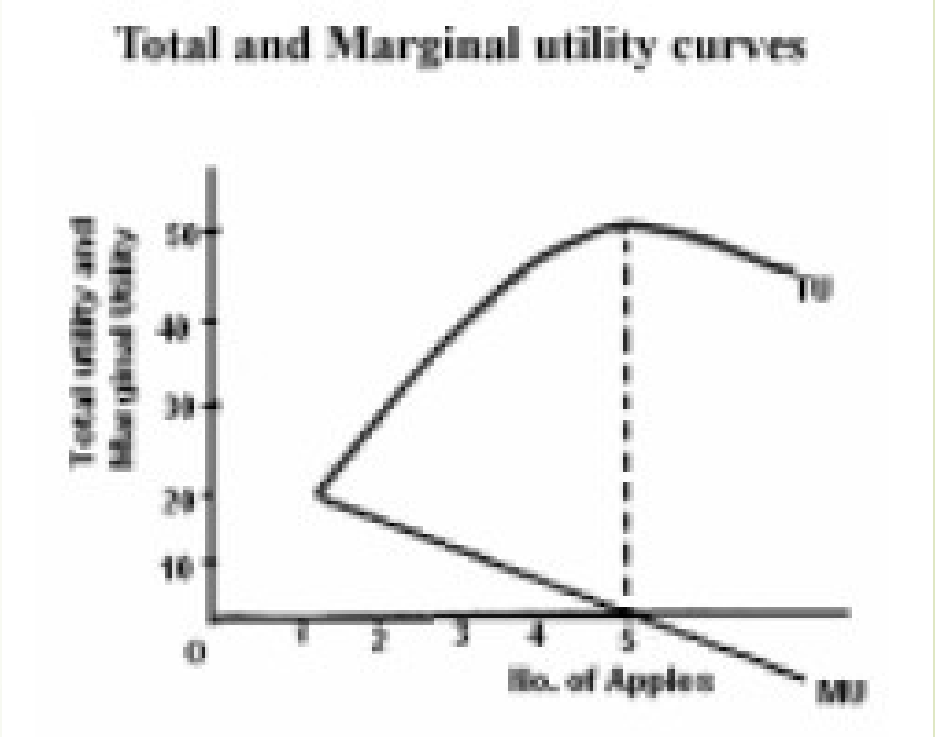
Law of diminishing utility

Units of Apple	Total Utility	Marginal Utility
1	10	10
2	18	8
3	24	6
4	28	4
5	30	2
6	30	0
7	28	-2

The relationship between TU and MU

	Marginal Utility	Total Utility
(i)	Declines	Increases
(ii)	Reaches zero	Reaches maximum
(iii)	Becomes negative	Declines

Law of Diminishing Marginal Utility



Engineering Economics

- ***Engineering Economics*** *is the applications of economic techniques to the evaluation of engineering alternatives. The role of engineering economics is to access the appropriateness of a given project, estimates its value and justify it from an engineering standpoint*. –John M. Watts.
- *The term* ***engineering economic decision*** *refers to any investment decision related to an engineering project. The facet of an economic decision that is of most interest from an engineer's point of view is the evaluation of costs and benefits associated with making a capital investment*.-- Chan S. Park

Engineering Economy

- It deals with the concepts and techniques of analysis useful in evaluating the worth of systems, products, and services in relation to their costs
- It is used to answer many different questions
  - Which engineering projects are worthwhile?
    - Has the mining or petroleum engineer shown that the mineral or oil deposits is worth developing?
  - Which engineering projects should have a higher priority?
    - Has the industrial engineer shown which factory improvement projects should be funded with the available dollars?
  - How should the engineering project be designed?
    - Has civil or mechanical engineer chosen the best thickness for insulation?

Applications of Engineering Economics/ Common Types of Engineering Economic Decisions

- Project ideas can originate from many different levels in an organization. Since some ideas will be good, while others will not, we need to establish procedures for screening projects.
- Many large companies have a specialized project analysis division that actively searches for new ideas, projects, and ventures. Once project ideas are identified, EE decisions are typically classified as:
  1. **equipment or process selection,**
  2. **equipment replacement,**
  3. **new product or product expansion,**
  4. **cost reduction, and**
  5. **service or quality improvement**

Applications of Engineering Economics/ Common Types of Engineering Economic Decisions

- The above classification scheme allows management to address key questions:
  - Can the existing plant, for example, be used to attain the new production levels?
  - Does the firm have the knowledge and skill to undertake the new investment?
  - Does the new proposal warrant the recruitment of new technical personnel?
- The answers to these questions help firms screen out proposals that are not feasible, given a company's resources.

1. Equipment or Process Selection

- This class of engineering decision problems involves selecting the best course of action out of several that meet a project's requirements.
- For example, which of several proposed items of equipment shall we purchase for a given purpose? The choice often hinges on which item is expected to generate the largest savings (or the largest return on the investment).
- For example, the choice of material will dictate the manufacturing process for the body panels in the automobile. Many factors will affect the ultimate choice of the material, and engineers should consider all major cost elements, such as the cost of machinery and equipment, tooling, labor, and material. Other factors may include press and assembly, production and engineered scrap, the number of dies and tools, and the cycle times for various processes.

2. Equipment Replacement

- This category of investment decisions involves considering the expenditure necessary to replace worn-out or obsolete equipment.
- For example, a company may purchase 10 large presses, expecting them to produce stamped metal parts for 10 years. After 5 years, however, it may become necessary to produce the parts in plastic, which would require retiring the presses early and purchasing plastic molding machines.
- Similarly, a company may find that, for competitive reasons, larger and more accurate parts are required, making the purchased machines become obsolete earlier than expected.

3. New Product or Product Expansion

- Investments in this category increase company revenues if output is increased.
- One common type of expansion decision includes decisions about expenditures aimed at increasing the output of existing production or distribution facilities.
- In these situations, we are basically asking, "Shall we build or otherwise acquire a new facility?" The expected future cash inflows in this investment category are the profits from the goods and services produced in the new facility.
- A second type of expenditure decision includes considering expenditures necessary to produce a new product or to expand into a new geographic area. These projects normally require large sums of money over long periods.

4. Cost Reduction

- A cost-reduction project is a project that attempts to lower a firm's operating costs.
- Typically, we need to consider whether a company should buy equipment to perform an operation currently done manually or spend money now in order to save more money later.
- The expected future cash inflows on this investment are savings resulting from lower operating costs.

5. Improvement in Service or Quality

- Most of the examples in the previous sections were related to economic decisions in the manufacturing sector.
- The decision techniques we develop in this book are also applicable to various economic decisions related to improving services or quality of product.

Principles of Engineering Economics
(According to Chan S. Park)

- Engineering Economics is focused on the principles and procedures engineers use to make sound economic decisions.
- To the first-time student of engineering economics, anything related to money matters may seem quite strange when compared to other engineering subjects.
- However, the decision logic involved in solving problems in this domain is quite similar to that employed in any other engineering subject.
- There are fundamental principles to follow in engineering economics that unite the concepts and techniques presented in any engineering economic book, thereby allowing us to focus on the logic underlying the practice of engineering economics.
- **According to Chan S. Park, there are four fundamental principles of Engineering Economic Decisions:**

(1) the time value of money,

(2) differential (incremental) cost and revenue,

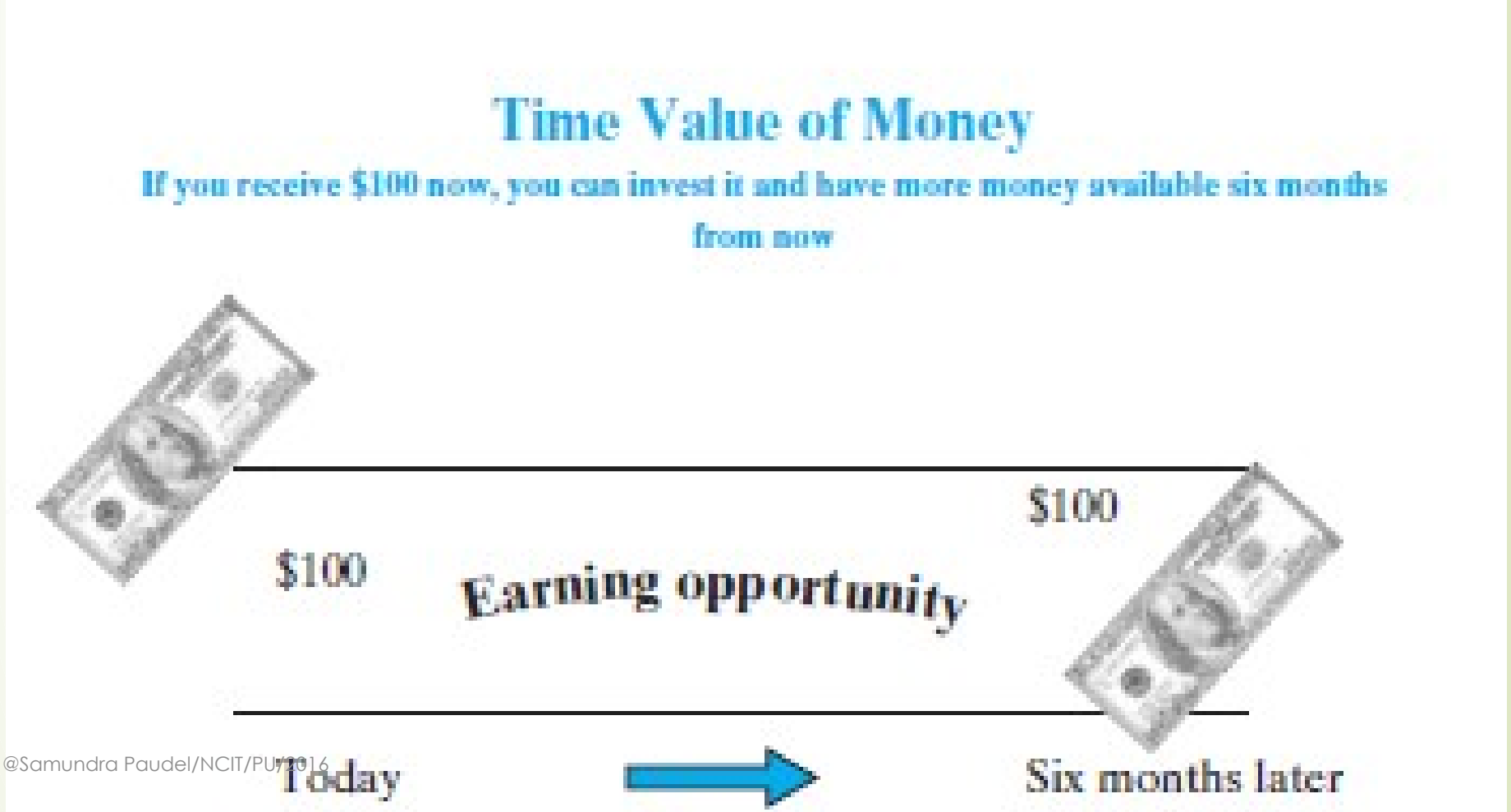
(3) marginal cost and revenue, and

(4) the trade-off between risk and reward.

Principle 1: A nearby penny is worth a distant dollar (Time value of money)

- A fundamental concept in engineering economics is that money has a time value associated with it.
- Because we can earn interest on money received today, it is better to receive money earlier than later.
- This concept will be the basic foundation for all engineering project evaluation.

Principle 1: A nearby penny is worth a distant dollar (Time value of money)



Principle 2: All that counts are the differences among alternatives (differential (incremental) cost and revenue)

- An economic decision should be based on the *differences* among the alternatives considered. All that is common is irrelevant to the decision.
- Certainly, any economic decision is no better than the alternatives being considered.
- Thus, an economic decision should be based on the objective of making the best use of limited resources.
- Whenever a choice is made, something is given up. The opportunity cost of a choice is the value of the best alternative given up.

Principle 2: All that counts are the differences among alternatives (differential (incremental) cost and revenue)

Comparing Buy versus Lease

Whatever you decide, you need to spend the same amount of money on fuel and maintenance

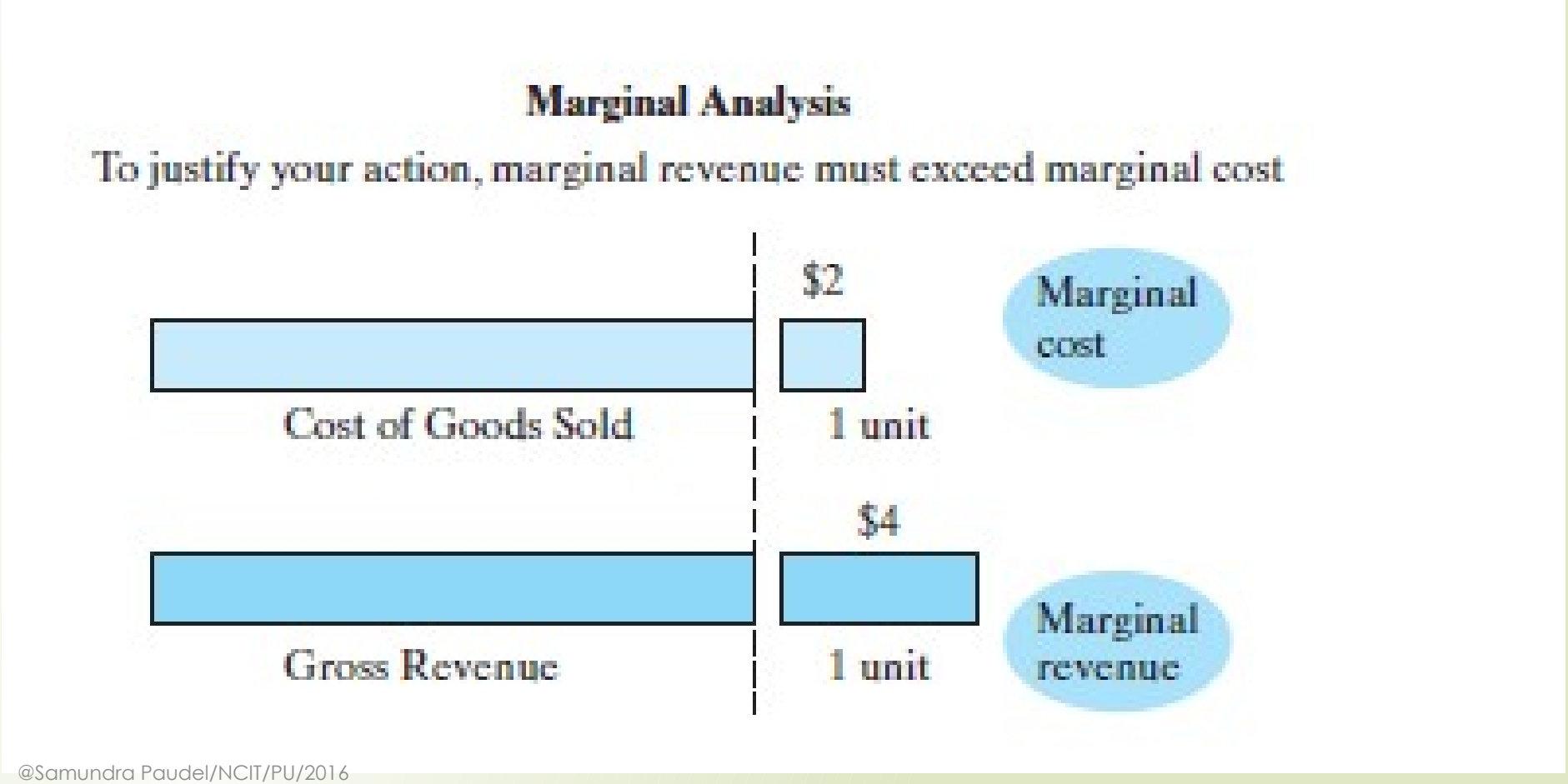
Option	Monthly Fuel Cost	Monthly Maintenance	Cash Outlay at Signing	Monthly Payment	Salvage Value at End of Year 3
Buy	$960	$550	$6,500	$350	$9,000
Lease	$960	$550	$2,400	$550	0

Irrelevant items in decision making

Principle 3: Marginal revenue must exceed marginal cost

- Effective decision making requires comparing the additional costs of alternatives with the additional benefits.
- Each decision alternative must be justified on its own economic merits before being compared with other alternatives.
- Any increased economic activity must be justified on the basis of the fundamental economic principle that marginal revenue must exceed marginal cost.
- Here, *marginal revenue* means the additional revenue made possible by increasing the activity by one unit (or small unit). *Marginal cost* has an analogous definition.
- Productive resources—the natural resources, human resources, and capital goods available to make goods and services—are limited.
- Therefore, people cannot have all the goods and services they want; as a result, they must choose some things and give up others.

Principle 3: Marginal revenue must exceed marginal cost



Principle 4: Additional risk is not taken without the expected additional return (the trade-off between risk and reward)

- For delaying consumption, investors demand a minimum return that must be greater than the anticipated rate of inflation or any perceived risk.
- If they didn't receive enough to compensate for anticipated inflation and the perceived investment risk, investors would purchase whatever goods they desired ahead of time or invest in assets that would provide a sufficient return to compensate for any loss from inflation or potential risk.

Principle 4: Additional risk is not taken without the expected additional return (the trade-off between risk and reward)

Risk and Return Trade-Off

Expected returns from bonds and stocks are normally higher than the expected return from a savings account

Investment Class	Potential Risk	Expected Return
Savings account (cash)	Low/None	1.5%
Bond (debt)	Moderate	4.8%
Stock (equity)	High	11.5%

Principles of Engineering Economics
(According to W. Sullivan)

1. Develop Alternatives
2. Focus on the differences
3. Use a consistent viewpoint (Economic viewpoint)
4. Use common unit of measure
5. Consider all relevant criteria (Social and Environmental aspects)
6. Make uncertainty explicit
7. Revisit your decision (Self Evaluation)

If questions ask for principles of engineering economics, write detail from principles from earlier slides as given by Chan S. Park (quoting him) and also write above list only quoting W. Sullivan.

For More Detail: Refer William Sullivan (Engineering Economy) or Damodar Adhikari (Principles of Engineering Economics Analysis)

Why engineering students need to study engineering economics?

- In any organization, commonly, engineers are called upon to participate in a variety of strategic business decisions ranging from product design to marketing.
- In manufacturing, engineering is involved in every detail of a product's production, from conceptual design to shipping.
- Decisions made during the engineering design phase of product development determine the majority of the costs associated with the manufacturing of that product (some say that this value may be as high as 85%).
- With more increasing GDP (Gross Domestic Product) provided by the service sector worldwide, engineers work on various economic decision problems in the service sector as well.
- As design and manufacturing processes become more complex, engineers are making decisions that involve money more than ever before.

Why engineering students need to study engineering economics?

- The competent and successful engineer in the twenty-first century must have an improved understanding of the principles of science, engineering, and economics, coupled with relevant design experience.
- Engineers must consider the effective use of capital assets such as buildings and machinery.
- One of the engineer's primary tasks is to plan for the acquisition of equipment **(capital expenditure)** that will enable the firm to design and produce products economically.
- Engineers have to involve in different types of engineering economic decisions: **(1) equipment or process selection, (2) equipment replacement, (3) new product or product expansion, (4) cost reduction, and (5) improvement in service or quality.**
- Increasingly, in the new world economy, successful businesses will rely on engineers with such expertise.

Chapter 1: Assignments

- What do you mean by law of demand? Explain factors influencing demand.
- What do you mean by law of supply? Explain factors influencing supply.
- What do you mean by utility and marginal utility? State and explain the law of diminishing marginal utility with suitable example and figure.
- Define Engineering Economics. What are the basic principles of engineering economics?
- What is engineering economics? Why do you think studying this course is important for engineering students? Justify.
- "Engineering economics is all about decision making." Explain.
- Explain primary applications of engineering economics.

Chapter 2: Cost Concepts

- Cost Terminology: Manufacturing Cost and Non- Manufacturing Cost
- Cost of Business Decision: Differential Cost and revenue; Opportunity cost, Sunk Cost and Marginal Cost

Cost Concepts

- In engineering economics, the term **cost** is used in many different ways. Because there are many types of costs, each is classified differently according to the immediate needs of management.
- **Manufacturing Cost**
- **Non-manufacturing Cost**

Manufacturing Cost

- In converting raw materials into finished goods, a manufacturer incurs various costs associated with operating a factory.
- Most manufacturing companies divide manufacturing costs into three broad categories:
  - direct raw material costs,
  - direct labor costs, and
  - manufacturing overhead.

Direct Raw Materials

- Direct raw materials are any materials that are used in the final product and that can be easily traced to it. Some examples are wood in furniture, steel in bridge construction, paper in printing firms, and fabric for clothing manufacturers. It is important to note that the finished product of one company can become the raw materials of another company.
- For example, the computer chips produced by Intel are a raw material used by Dell in its personal computers.

Direct Labor

- Like direct raw materials, direct labor incurs costs that go into the production of a product.
- The labor costs of assembly-line workers, for example, would be direct labor costs, as would the labor costs of welders in metal-fabricating industries, carpenters or bricklayers in home building, and machine operators in various manufacturing operations.

Manufacturing (Direct) Overhead (Indirect labor and materials)

- Manufacturing overhead, the third element of manufacturing cost, includes all costs of manufacturing except the costs of direct materials and direct labor.
- In particular, manufacturing overhead includes such items as the costs of indirect materials; indirect labor; maintenance and repairs on production equipment; heat and light, property taxes, depreciation, and insurance on manufacturing facilities; and overtime premiums.
- The most important thing to note about manufacturing overhead is the fact that, unlike direct materials and direct labor, it is not easily traceable to specific units of output. In addition, many manufacturing overhead costs do not change as output changes, as long as the production volume stays within the capacity of the plant.
- For example, depreciation of factory buildings is unaffected by the amount of production during any particular period. If, however, a new building is required to meet any increased production, manufacturing overhead will certainly increase.

Non-Manufacturing Cost

- Two additional costs incurred in supporting any manufacturing operation are (1) marketing or selling costs and (2) administrative costs.
- Marketing or selling costs include all costs necessary to secure customer orders and get the finished product or service into the hands of the customer.
- Breakdowns of these types of costs provide data for control over selling and administrative functions in the same way that manufacturing cost breakdowns provide data for control over manufacturing functions.
- **Indirect Overhead.** Heat and light, property taxes, and depreciation or similar items associated with the company's selling and administrative functions.
- **Marketing.** Advertising, shipping, sales travel, sales commissions, and sales salaries. Marketing costs include all executive, organizational, and clerical costs associated with sales activities.
- **Administrative functions.** Executive compensation, general accounting, public relations, and secretarial support, associated with the general management of an organization.

Cost of Business Decisions:

- Differential cost
- Differential revenue
- Opportunity Cost
- Sunk Cost
- Marginal Cost

Differential Cost and Revenue

- As we have seen throughout the text, decisions involve choosing among alternatives.
- In business decisions, each alternative has certain costs and benefits that must be compared with the costs and benefits of the other available alternatives.
- A difference in cost between any two alternatives is known as a **differential cost**.
- Similarly, a difference in revenue between any two alternatives is known as **differential revenue**.
- A differential cost is also known as an incremental cost, although, technically, an incremental cost should refer only to an increase in cost from one alternative to another.

Differential Cost and Revenue

- Cost–volume relationships based on differential costs find many engineering applications.
- In particular, they are useful in making a variety of short-term operational decisions.
- Many short-run problems have the following characteristics:
  - The base case is the status quo (the current operation or existing method), and we propose an alternative to the base case. If we find the alternative to have lower costs than the base case, we accept the alternative, assuming that non-quantitative factors do not offset the cost advantage.
  - The **differential (incremental) cost** is the difference in total cost that results from selecting one alternative instead of another. If several alternatives are possible, we select the one with the maximum savings from the base.
  - Problems of this type are often called trade-off problems, because one type of cost is traded off for another.
  - New investments in physical assets are not required.
  - The planning horizon is relatively short (a week or a month—certainly less than a year).
  - Relatively few cost items are subject to change by management decision.
- Some common examples of short-run problems and decisions are:
  - method changes,
  - operations planning, and
  - make-or-buy decisions.

Example: Differential Cost

	Current Dies	Better Dies	Differential Cost
Variable costs:			
Materials	$150,000	$170,000	+$20,000
Machining labor	85,000	64,000	−21,000
Electricity	73,000	66,000	−7,000
Fixed costs:			
Supervision	25,000	25,000	0
Taxes	16,000	16,000	0
Depreciation	40,000	43,000	+3,000
Total	$392,000	$387,000	−$5,000

Opportunity Cost

- Opportunity cost may be defined as the potential benefit that is given up as you seek an alternative course of action. In fact, virtually every alternative has some opportunity cost associated with it.
- For example, suppose you have a part-time job while attending college that pays you Rs. 20,000 per month. You would like to spend 1 month Annapurna Trail during spring break, and your employer has agreed to give you the month off. What would be the opportunity cost of taking the time off to be at the Annapurna Trail?
- The Rs. 20,000 in lost wages would be an opportunity cost.
- In an economic sense, opportunity cost could mean the contribution to income that is forgone by not using a limited resource in the best way possible.
- Or we may view opportunity costs as cash flows that could be generated from an asset the firm already owns, provided that such flows are not used for the alternative in question.
- In general, *accountants do not post opportunity cost in the accounting records of an organization. However, this cost must be explicitly considered in every decision.*

Opportunity Cost

- In sum, an opportunity cost arises when a project uses a resource that may already have been paid for by the firm.
- When a resource that is already owned by a firm is being considered for use in a project, that resource has to be priced on its next-best alternative use, which may be

1. A sale of the asset, in which case the opportunity cost is the expected proceeds from the sale, net of any taxes on gains.

2. Renting or leasing the asset out, in which case the opportunity cost is the expected present value of the after-tax revenue from the rental or lease.

3. Some use elsewhere in the business, in which case the opportunity cost is the cost of replacing the resource.

4. That the asset has been abandoned or is of no use. Then the opportunity cost is zero.

Sunk Costs

- A sunk cost is a cost that has already been incurred by past actions.
- Sunk costs are not relevant to decisions, because they cannot be changed regardless of what decision is made now or in the future.
- The only costs relevant to a decision are costs that vary among the alternative courses of action being considered.
- To illustrate a sunk cost, suppose you have a very old motorcycle that requires frequent repairs. You want to sell the motorcycle, and you figure that the current market value would be about Rs.1,20,000 at best. While you are in the process of advertising the car, you find that the motorcycle's engine is leaking. You decided to have the engine repaired, which cost you Rs. 8,000. A friend of yours is interested in buying your car and has offered Rs. 1,30,000 for it. Would you take the offer, or would you decline it simply because you cannot recoup the repair cost with that offer?
- In this example, the Rs. 8,000 repair cost is a sunk cost.
- You cannot change this repair cost, regardless of whether you keep or sell the car. Since your friend's offer is Rs. 10,000 more than the best market value, it would be better to accept the offer.

Marginal Cost

- Another cost term useful in cost–volume analysis is marginal cost.
- We define **marginal cost** as the added cost that would result from increasing the rate of output by a single unit.
- The accountant's differential-cost concept can be compared to the economist's marginal cost concept.
- In speaking of changes in cost and revenue, the economist employs the terms *marginal cost* and *marginal revenue*.
- The revenue that can be obtained from selling one more unit of product is called **marginal revenue**.
- The cost involved in producing one more unit of product is called **marginal cost**.

Numerical Problem (PU, 2015)

- Following are the cost data for the production of a 100 badminton racquets.

  Labor rate: Rs. 40/hr.

  Leather:50m at Rs. 200/metre

  Gut: 300m at Rs. 50/metre

  Graphite: 100Kg at Rs. 200/Kg

  Total annual factory overhead: Rs. 5,00,000

  Total annual direct labor hours: 25,000 hrs.

  Labor hours needed: 200 hrs.

Show the cost breakdown and calculate the total cost for per racquet.

Numerical Problem (PU, 2015)

- Solution:

Cost		Amount
Manufacturing Cost		
Direct Material Cost		
Leather	(50metre*Rs.200)	Rs.10,000
Gut	(300metre *Rs.50)	Rs.15,000
Graphite	(100Kg*Rs. 200)	Rs. 10,000
Direct Labor Cost	(200hrs*Rs 40)	Rs. 8,000
Direct Overhead Cost		Rs. 5,00,000
Non-manufacturing Cost Marketing Administrative Indirect Overhead Cost		---
Total Cost (for 100 racquets)		**Rs. 543,000**
Per racquets cost (Rs. 543,000/100 racquets)		Rs. 5,430 per raquet

ABC Company manufactures a single product. Costs for the year 2018 for output levels of 1,000 and 2,000 units are as follows:

Units Produced	1000	2000
Direct Labor (Rs.)	30,000	30,000
Administrative Cost: Variable Portion (Rs.) Fixed Portion (Rs.)	 12,000 36,000	 24,000 36,000
Direct Materials (Rs.)	20,000	40,000
Manufacturing Overhead (Rs.)	10,000	20,000
Selling and Marketing Cost Variable Portion (Rs.) Fixed Portion (Rs.)	 5,000 22,000	 10,000 22,000

At 2000 units of output, compute the following:

- Total manufacturing cost and manufacturing cost per unit,
- Total non-manufacturing cost and non-manufacturing cost per unit,
- Total variable cost and total variable cost per unit,
- Total fixed cost and total fixed cost per unit,
- Total cost and total cost per unit.

Chapter 2: Assignments

- Explain concepts of manufacturing and non-manufacturing cost with suitable example.
- Explain the different types of cost involved in manufacturing of products with suitable example.
- Write short notes on:
  - Opportunity Cost
  - Marginal Cost
  - Sunk Cost
  - Differential Cost
  - Differential Revenue

Chapter 3: Time Value of Money

- Interest, Simple Interest, Compound Interest, Normal Rate of interest, Effective Rate of interest
- Economic Equivalence: Present Worth, Future Worth and Annual Worth
- Development of Formulas for Equivalence Calculation

Time value of money: Interest

- Most of us are familiar in a general way with the concept of interest.
- We know that money left in a savings account earns interest, so that the balance over time is greater than the sum of the deposits.
- We also know that borrowing to buy a car means repaying an amount over time, that that amount includes interest, and that it is therefore greater than the amount borrowed.
- The cost of money is established and measured by a **market interest rate**, a percentage that is periodically applied and added to an amount (or varying amounts) of money over a specified length of time.

Time value of money: Interest

- When money is borrowed, the **interest paid is the charge to the borrower for the use of the lender's property**; when money is lent or invested, the **interest earned is the lender's gain from providing a good to another**.
- **Interest**, then, may be **defined as the cost of having money available for use.**
- **Time value of money** is the idea that **a dollar today is worth more than a dollar in the future** because the dollar received today can earn interest.
- When lending or borrowing interest rates are quoted by financial institutions on the marketplace, those interest rates reflect the desired amounts to be earned, as well as any protection from loss in the future purchasing power of money because of inflation.

Elements of Transactions Involving Interest

- Many types of transactions (e.g., borrowing or investing money or purchasing machinery on credit) involve interest, but certain elements are common to all of these types of transactions:
- • An initial amount of money in transactions involving debt or investments is called the **principal**.
- • The **interest rate** measures the cost or price of money and is expressed as a percentage per period of time.
- • A period of time, called the **interest period**, determines how frequently interest is calculated. (Note that even though the length of time of an interest period can vary, interest rates are frequently quoted in terms of an annual percentage rate.)
- • A specified length of time marks the duration of the transaction and thereby establishes a certain **number of interest periods**.
- • A **plan for receipts or disbursements** yields a particular cash flow pattern over a specified length of time. (For example, we might have a series of equal monthly payments that repay a loan.)
- • A **future amount of money** results from the cumulative effects of the interest rate over a number of interest periods.

Methods of Calculating Interest

- Money can be lent and repaid in many ways, and, equally, money can earn interest in many different ways.
- Usually, however, at the end of each interest period, the interest earned on the principal amount is calculated according to a specified interest rate.
- The two computational schemes for calculating this earned interest are said to yield either **simple interest** or **compound interest**.
- ***Engineering economic analysis uses the compound-interest scheme almost exclusively***.

Simple Interest

- Simple interest is interest earned on only the principal amount during each interest period.
- In other words, with simple interest, the interest earned during each interest period does not earn additional interest in the remaining periods, *even though you do not withdraw it*.
- In general, for a deposit of *P* dollars at a simple interest rate of *i* for *N* periods, the total earned interest would be

  I = (i*P)*N

- The total amount available at the end of *N* periods thus would be

  F = P+I = P(1+i*N)

Compound Interest

- Under a compound-interest scheme, the interest earned in each period is calculated on the basis of the total amount at the end of the previous period.
- This total amount includes the original principal plus the accumulated interest that has been left in the account.
- In this case, you are, in effect, increasing the deposit amount by the amount of interest earned.
- Thus, **compound** means the ability of an asset to generate *earnings* that are then reinvested and generate their own earnings.
- This interest-earning process repeats, and after *N* periods the total accumulated value (balance) *F* will grow to

$$F = P(1 + i)^N.$$

Nominal Vs Effective Interest Rate

- In most of the examples, the implicit assumption was that payments are received *once a year*, or *annually*.
- However, some of the most familiar financial transactions, both personal and in engineering economic analysis, involve payments that are not based on one annual payment—for example, monthly mortgage payments and quarterly earnings on savings accounts.
- Thus, if we are to compare different cash flows with different compounding periods, we need to evaluate them on a common basis.
- This need has led to the development of the concepts of the **nominal interest rate** and the **effective interest rate**.

Nominal Interest Rates

- If you financed a new car recently, examine the loan contract. You will typically find the interest that the bank charges on your unpaid balance. Even if a financial institution uses a unit of time other than a year—say, a month or a quarter (e.g., when calculating interest payments)— the institution usually quotes the interest rate on an *annual basis*.
- Many banks, for example, state the interest arrangement for credit cards in this way: **18% compounded monthly.**
- This statement simply means that each month the bank will charge 1.5% interest on an unpaid balance. We say that 18% is the **nominal interest rate** or **annual percentage rate** (APR), and the compounding frequency is monthly (12). To obtain the interest rate per compounding period, we divide, 18% by 12, to get 1.5% per month.
- Although the annual percentage rate, or APR, is commonly used by financial institutions and is familiar to many customers, the APR does not explain precisely the amount of interest that will accumulate in a year.
- To explain the true effect of more frequent compounding on annual interest amounts, we will introduce the term *effective interest rate*, commonly known as *annual effective yield*, or *annual percentage yield* (APY).

Effective Interest Rates

- The **effective annual interest rate** is the one rate that truly represents the interest earned in a year.
- For instance, in our credit card example, the bank will charge 1.5% interest on any unpaid balance at the end of each month. Therefore, the 1.5% rate represents the effective interest rate per month.
- On a yearly basis, you are looking for a cumulative rate—1.5% each month for 12 months. This cumulative rate predicts the actual interest payment on your outstanding credit card balance.
- As you can see, depending on the frequency of compounding, the effective interest earned or paid by the borrower can differ significantly from the APR.
- Therefore, truth in- lending laws require that financial institutions quote both the nominal interest rate and the compounding frequency (i.e., the effective interest) when you deposit or borrow money.

Effective Interest Rates

- Certainly, more frequent compounding increases the amount of interest paid over a year at the same nominal interest rate.
- Assuming that the nominal interest rate is *r*, and *M* compounding periods occur during the year, we can calculate the effective annual interest rate

$$i_a = \left(1 + \frac{r}{M}\right)^M - 1.$$

- Calculate yearly effective interest rate, if nominal interest rate is 10% and compounded as follow :
  - Yearly
  - Semiannually
  - Quarterly
  - Monthly
  - Daily
  - Continuously (e^r)

Cash Flow

- Engineering projects generally have economic consequences that occur over an extended period of time
  - For example, if an expensive piece of machinery is installed in a plant were brought on credit, the simple process of paying for it may take several years
  - The resulting favorable consequences may last as long as the equipment performs its useful function
- Each project is described as cash receipts or disbursements (expenses) at different points in time

Categories of Cash Flows

- The expenses and receipts due to engineering projects usually fall into one of the following categories:
  - **First cost**: expense to build or to buy and install
  - **Operations and maintenance (O&M):** annual expense, such as electricity, labor, and minor repairs
  - **Salvage value:** receipt at project termination for sale or transfer of the equipment (can be a salvage cost)
  - **Revenues:** annual receipts due to sale of products or services
  - **Overhaul:** major capital expenditure that occurs during the asset's life

Cash Flow diagrams

- The costs and benefits of engineering projects over time are summarized on a cash flow diagram (CFD). Specifically, CFD illustrates the size, sign, and timing of individual cash flows, and forms the basis for engineering economic analysis
- A CFD is created by first drawing a segmented time-based horizontal line, divided into appropriate time unit. Each time when there is a cash flow, a vertical arrow is added – pointing down for costs and up for revenues or benefits. The cost flows are drawn to relative scale

Drawing a Cash Flow Diagram

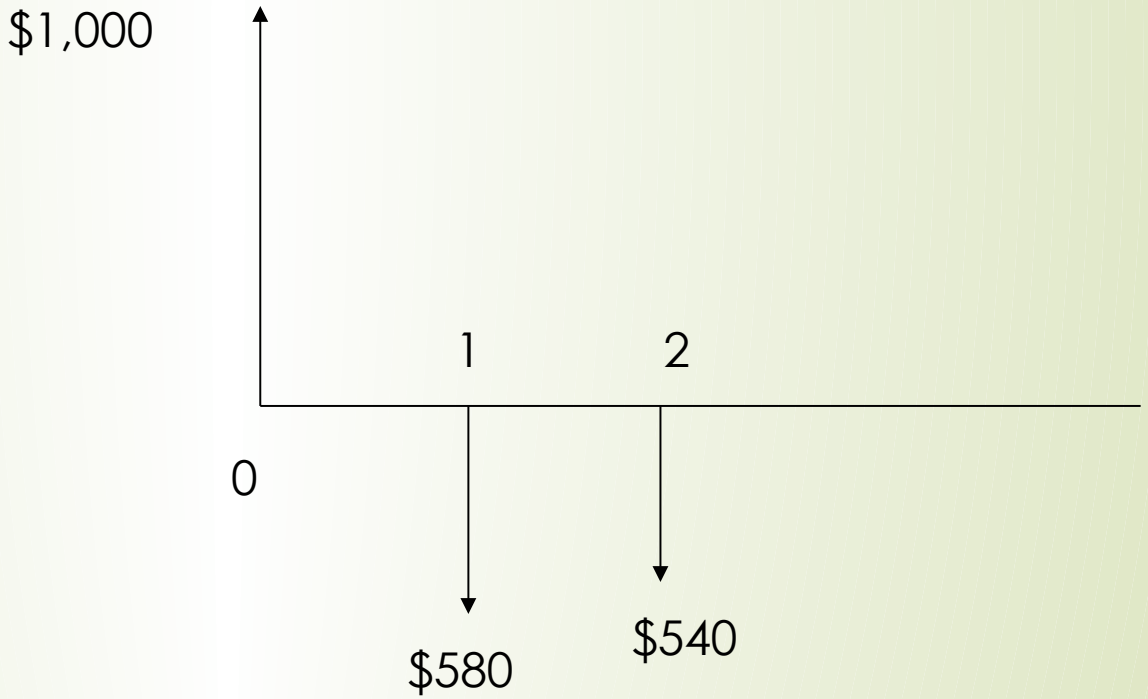
- In a cash flow diagram (CFD) the end of period t is the same as the beginning of period (t+1)
- **Beginning of period cash flows** are: rent, lease, and insurance payments
- **End-of-period cash flows** are: O&M, salvages, revenues, overhauls
- The choice of time 0 is arbitrary. It can be when a project is analyzed, when funding is approved, or when construction begins
- One person's cash outflow (represented as a negative value) is another person's inflow (represented as a positive value)
- It is better to show two or more cash flows occurring in the same year individually so that there is a clear connection from the problem statement to each cash flow in the diagram

An Example of Cash Flow Diagram

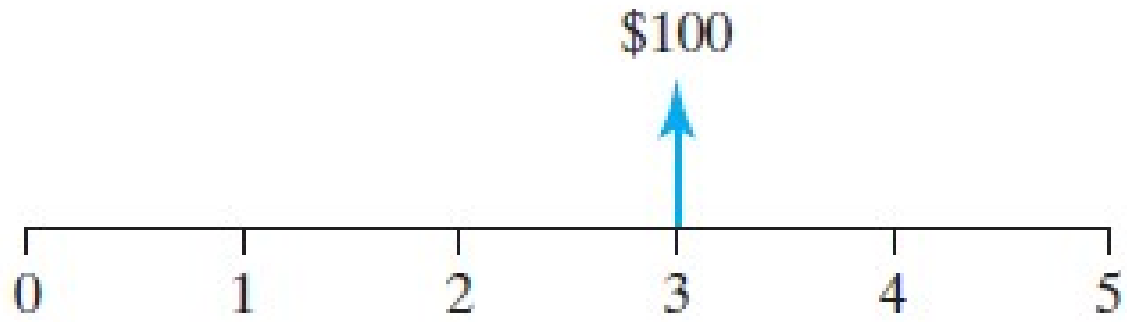
- A man borrowed $1,000 from a bank at 8% interest. Two end-of-year payments: at the end of the first year, he will repay half of the $1000 principal plus the interest that is due. At the end of the second year, he will repay the remaining half plus the interest for the second year.
- Develop cash flow diagram for this problem.

End of year	Cash flow
0	+$1000
1	-$580 (-$500 - $80)
2	-$540 (-$500 - $40)

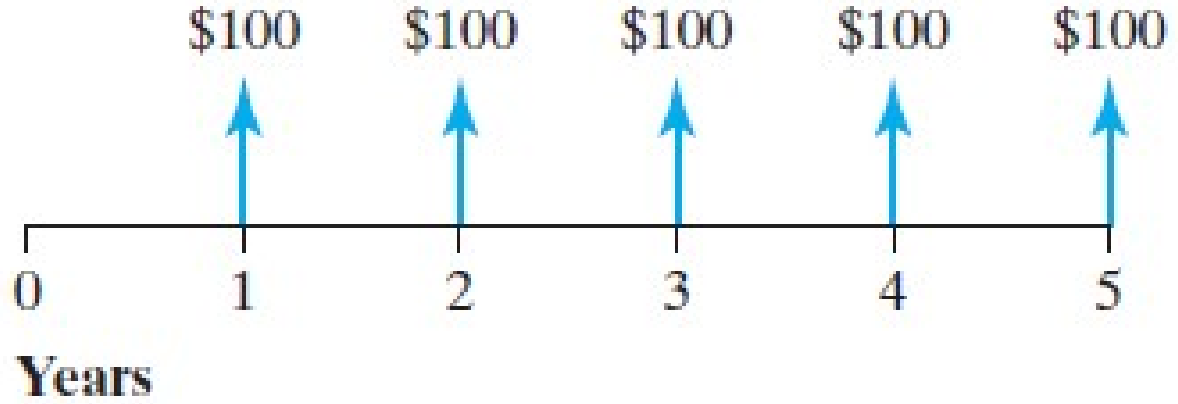
Cash Flow Diagram



Five Types of Cash Flows

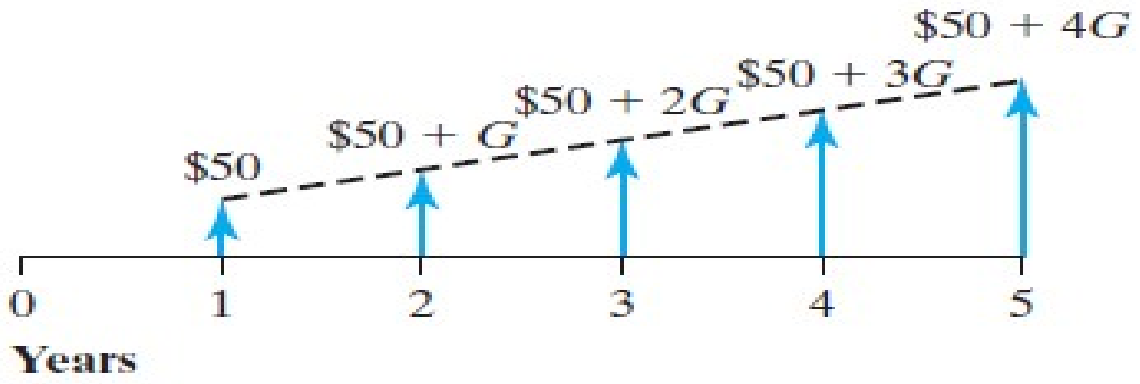


(a) Single cash flow

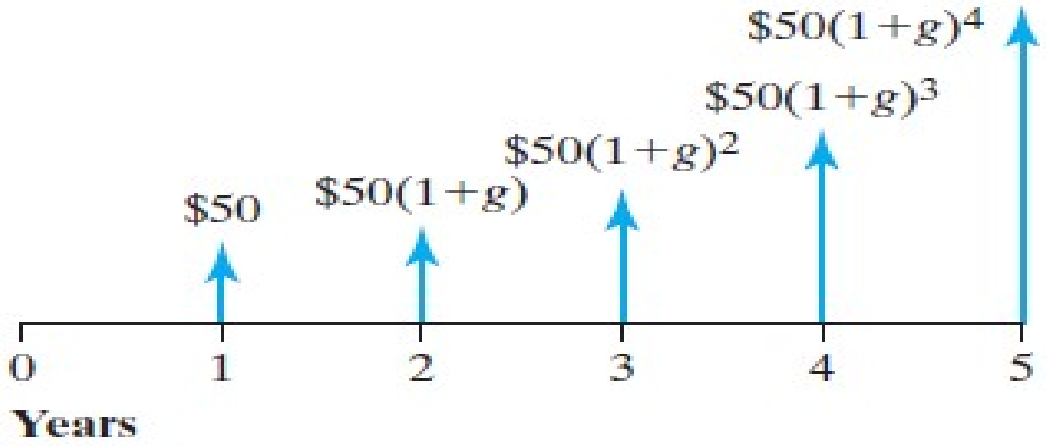


(b) Equal (uniform) payment series at regular intervals

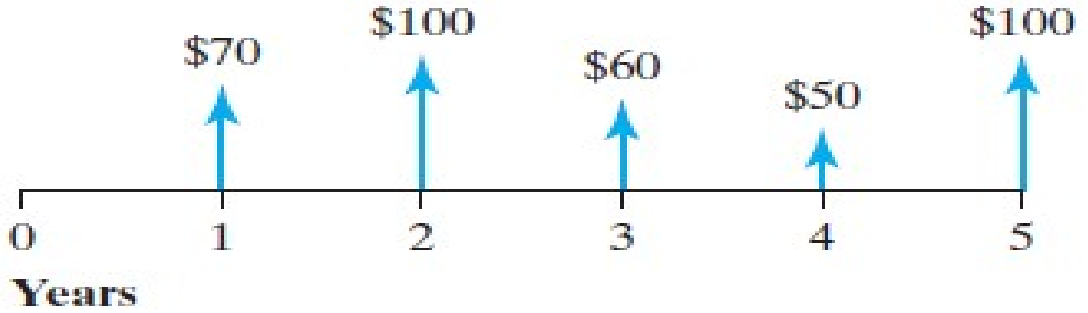
Five Types of Cash Flows



(c) Linear gradient series, where each cash flow in the series increases or decreases by a fixed amount G

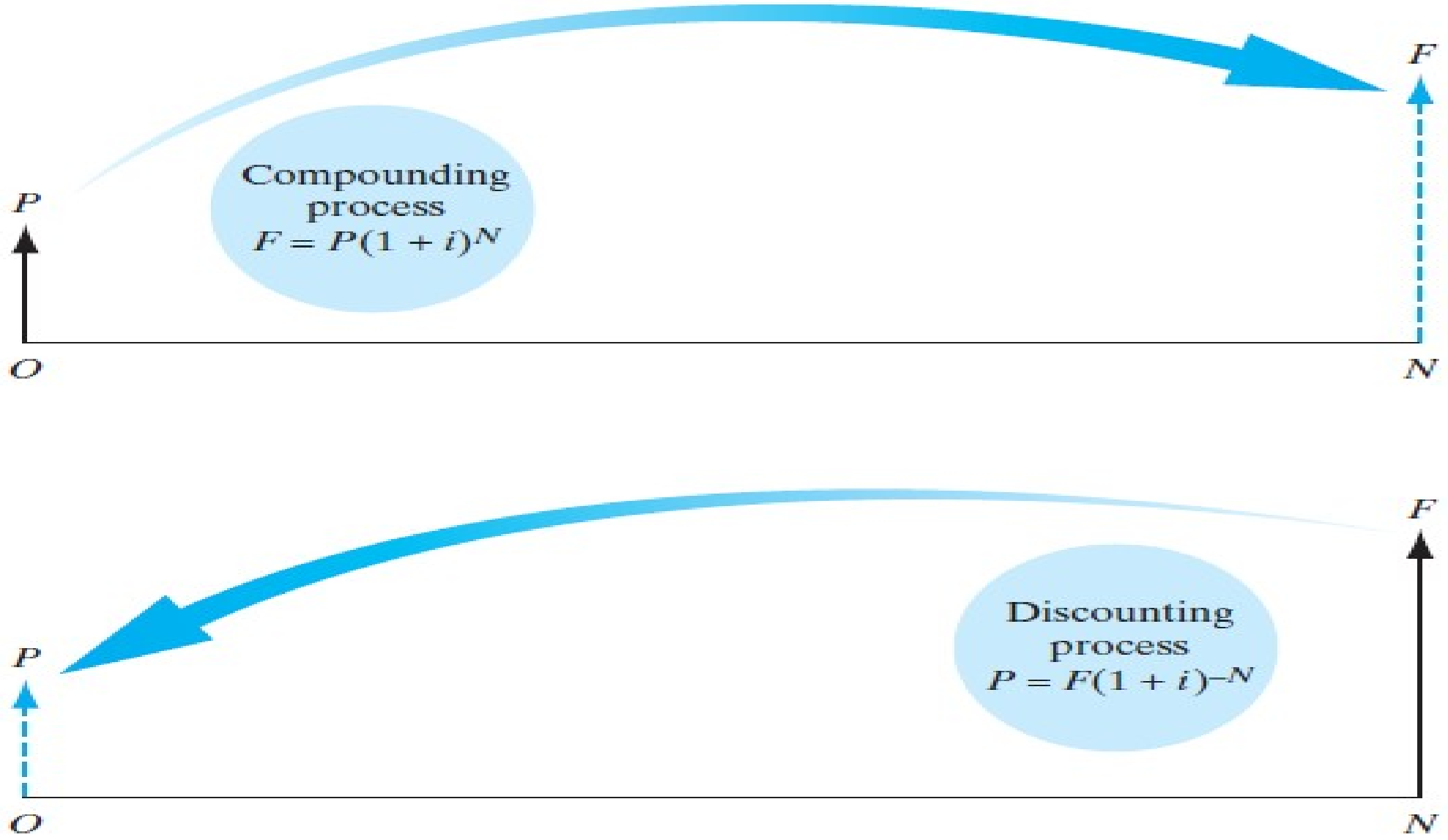


(d) Geometric gradient series, where each cash flow in the series increases or decreases by a fixed rate (percentage) g

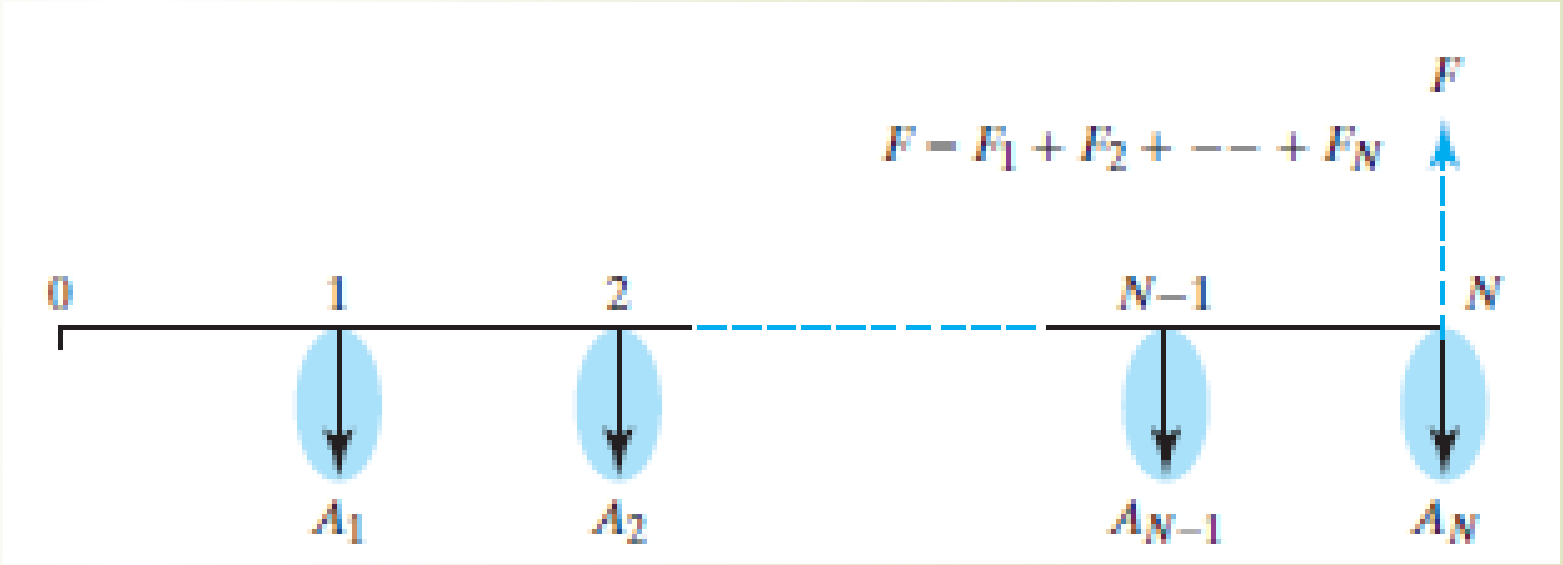


(e) Irregular payment series, which exhibits no regular overall pattern

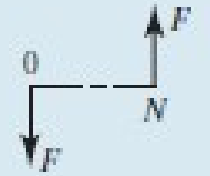
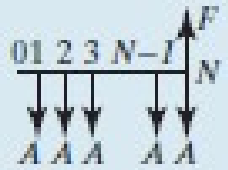
Economic Equivalence: Present Worth, Future Worth



Economic Equivalence: Annual Worth; Capital Recovery Fund/Annuity Factor (Given P) and Sinking Fund Factor (Given F)



Development of Formulas for Equivalence Calculation

Flow Type	Factor Notation	Formula	Excel Command	Cash Flow Diagram
SINGLE	Compound amount $(F/P, i, N)$	$F = P(1+i)^N$	=FV(i, N, P,, 0)	
SINGLE	Present worth $(P/F, i, N)$	$P = F(1+i)^{-N}$	=PV(i, N, F,, 0)	
EQUAL PAYMENT SERIES	Compound amount $(F/A, i, N)$	$F = A\left[\frac{(1+i)^N - 1}{i}\right]$	=PV(i, N, A,, 0)	
EQUAL PAYMENT SERIES	Sinking fund $(A/F, i, N)$	$A = F\left[\frac{i}{(1+i)^N - 1}\right]$	=PMT(i, N, P, F, 0)	
EQUAL PAYMENT SERIES	Present worth $(P/A, i, N)$	$P = A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right]$	=PV(i, N, A,, 0)	
EQUAL PAYMENT SERIES	Capital recovery $(A/P, i, N)$	$A = P\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right]$	=PMT(i, N,, P)	

Development of Formulas for Equivalence Calculation

GRADIENT

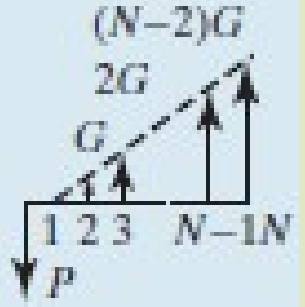
Linear gradient

Present worth $(P/G, i, N)$

$$P = G\left[\frac{(1+i)^N - iN - 1}{i^2(1+i)^N}\right]$$

Conversion factor $(A/G, i, N)$

$$A = G\left[\frac{(1+i)^N - iN - 1}{i[(1+i)^N - 1]}\right]$$

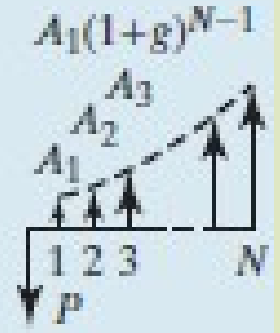


SERIES

Geometric gradient

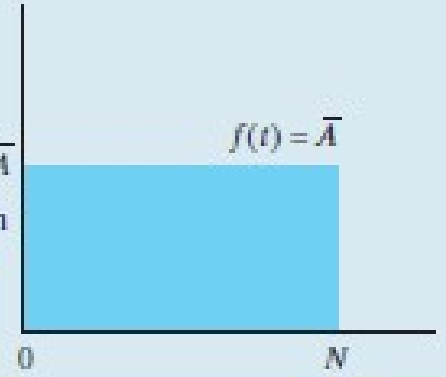
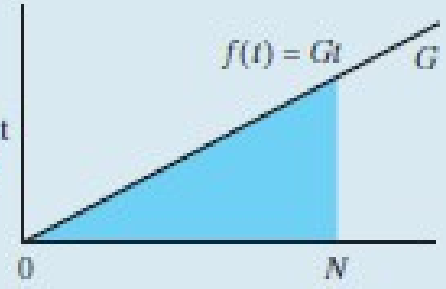
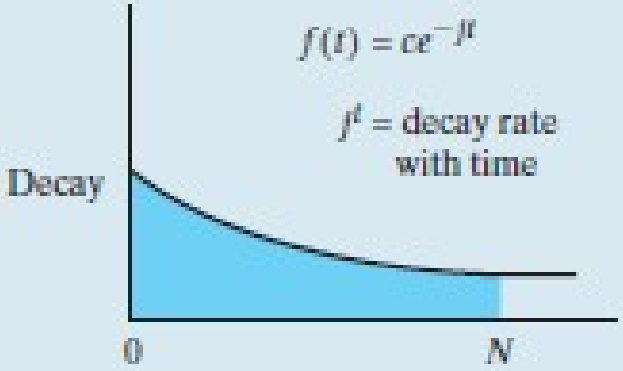
Present worth $(P/A_1, g, i, N)$

$$P = \begin{cases} A_1\left[\dfrac{1-(1+g)^N(1+i)^{-N}}{i-g}\right] \\ A_1\left(\dfrac{N}{1+i}\right) \text{(if } i = g\text{)} \end{cases}$$



Development of Formulas for Equivalence Calculation

TABLE 4.2 Summary of Interest Factors for Typical Continuous Cash Flows with Continuous Compounding

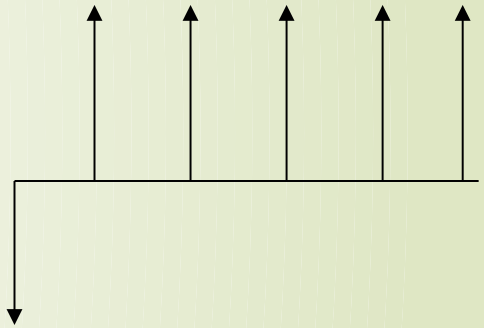
Type of Cash Flow	Cash Flow Function	Parameters Find	Parameters Given	Algebraic Notation	Factor Notation
Uniform (step)		P	$\bar{A}$	$\bar{A}\left[\frac{e^{rN}-1}{re^{rN}}\right]$	$(P/\bar{A}, r, N)$
		$\bar{A}$	P	$P\left[\frac{re^{rN}}{e^{rN}-1}\right]$	$(\bar{A}/P, r, N)$
		F	$\bar{A}$	$\bar{A}\left[\frac{e^{rN}-1}{r}\right]$	$(F/\bar{A}, r, N)$
		$\bar{A}$	F	$F\left[\frac{r}{e^{rN}-1}\right]$	$(\bar{A}/P, r, N)$
Gradient (ramp)		P	G	$\frac{G}{r^2}(1-e^{-rN}) - \frac{G}{r}(Ne^{-rN})$	
Decay		P	c, j	$\frac{c}{r+j}(1-e^{-(r+j)N})$	

Given the choice of these two plans which would you choose?

Year	Plan 1	Plan 2
0		$5,000
1	$1,000	
2	$1,000	
3	$1,000	
4	$1,000	
5	$1,000	
Total	$5,000	$5,000

Resolving Cash Flows to Equivalent Present Values

- P = $1,000(P|A,10%,5)
- P = $1,000(3.791) = $3,791



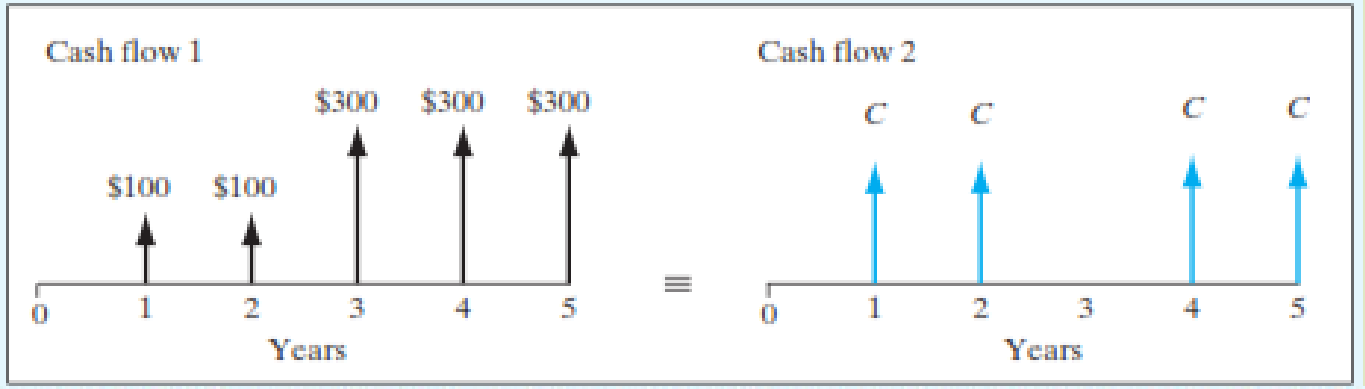
- P = $5,000
- Alternative 2 is better than alternative 1 since alternative 2 has a greater present value

An Example of Future Value

- Example: If $500 were deposited in a bank savings account, how much would be in the account three years hence if the bank paid 6% interest compounded annually?
- Given P = 500, i = 6%, n = 3,
- Then, use F = P(F/P,6%,3,) = 595.91

An Example of Present Value

- Example: If you wished to have $800 in a savings account at the end of four years, and 5% interest we paid annually, how much should you put into the savings account?
- n = 4, F = $800, i = 5%, P = ?
- P = F(P/F,5%,4,) = $658.16
- You should put P = $658.16



The two cash flows in Figure 3.38 are equivalent at an interest rate of 12% compounded annually. Determine the unknown value C.

SOLUTION

Given: Cash flows as in Figure 3.38; $i = 12\%$ per year.

Find: C.

- **Method 1.** Compute the present worth of each cash flow at time 0:

$$P_1 = \$100(P/A, 12\%, 2) + \$300(P/A, 12\%, 3)(P/F, 12\%, 2)$$
$$= \$743.42;$$

$$P_2 = C(P/A, 12\%, 5) - C(P/F, 12\%, 3)$$
$$= 2.8930C.$$

Since the two flows are equivalent, $P_1 = P_2$, and we have

$$743.42 = 2.8930C.$$

Solving for C, we obtain $C = \$256.97$.

- Sagar, a self-employed individual, is opening a retirement account at a bank. His goal is to have Rs.1,000,000 in his account in 20 years' time. He wishes to start with a deposit at the end of year 1 and increase the deposit at a rate of 6% each year thereafter. If bank is willing to pay 8% interest compounded annually throughout the 20 years, what should be the size of his first and last deposit. (Use formula of geometric gradient)

SOLUTION

Given: $F = \$1{,}000{,}000$, $g = 6\%$ per year, $i = 8\%$ per year, and $N = 20$ years.

Find: A_1 as in Figure 3.35.

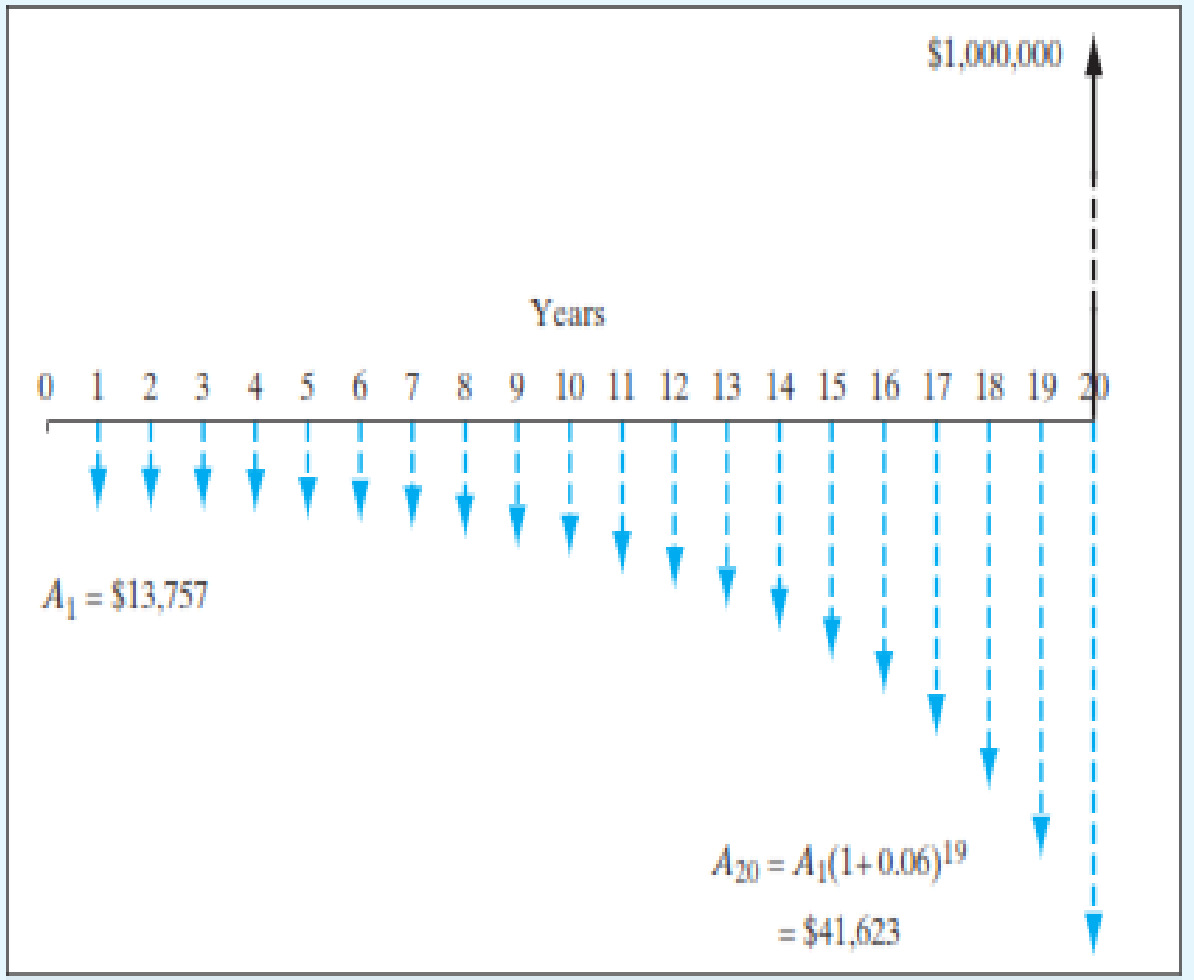
We have

$$F = A_1(P/A_1, 6\%, 8\%, 20)\,(F/P, 8\%, 20)$$

$$= A_1(72.6911).$$

Solving for A_1 yields

$$A_1 = \$1{,}000{,}000/72.6911 = \$13{,}757.$$



Example:

- Calculate effective rate of interest when nominal rate of interest is 7% and compounding is i) Monthly iii) Daily ii) Quarterly iv) Continuously
- Your sister needs Rs. 6,00,000 at the end of 10th year for the study of +2 level. How much money should be deposited in the bank account at the end of each year for 7 continuous years from this year if bank provides 6% rate of interest per year? Make also cash flow diagram.
- You deposited Rs. 50,000 the beginning of each for 7 years. How much money will be in your account at the end of 10th year when rate of interest is 6% compounded quarterly. Make also cash flow diagram.
- Suppose that you make a series of annual deposits into a bank account that pays 10% interest. The initial deposit at the end of the first year is Rs.1,200. The deposit amounts decline by Rs. 200 in each of the next four years. How much would you have immediately after the fifth deposit?
- BioGen Company has borrowed Rs. 25,00,000 to purchase lab equipments. The loan carries 8% interest per year compounding quarterly and is to be repaid in equal annual installments over the next six years. Compute the amount of the annual installment. If university wants to negotiate with the bank to defer the first loan repayment until the end of year 2 (but still desires to make six equal installments at 8% interest), what should be the annual installment?

Chapter 3: Assignments

- What do you mean by time value of money? Differentiate between simple and compound interest rate.
- Explain nominal and effective interest rate? How do you derive effective interest rate on the basis of nominal interest rate?
- Write short notes on:
  - Time Value of money
  - Nominal Vs Effective interest rate
  - Simple Vs Compound interest rate
  - Present Worth Vs Future Worth
  - Sinking Fund Vs Capital Recovery Fund
- ***Numerical Questions***

Chapter 4: Basic Methods of Engineering Economic Studies

- Minimum Attractive Rate of Return- MARR
- Payback Period Method
  - Simple Payback Method
  - Discounted Payback Method
- Equivalent Worth Method
  - Present Worth (PW)
  - Future Worth (FW)
  - Annual Worth (AW)
- Rate of Return Method
  - Internal Rate of Return (IRR)
  - Modified Internal Rate of Return (MIRR)/External Rate of Return (ERR)
- Benefit Cost Ratio Method
  - Conventional BC Ratio
  - Modified BC Ratio

Minimum Attractive Rate of Return- MARR

- A company may borrow funds to invest in profitable projects, or it may return to (invest in) its **investment pool** any unused funds until they are needed for other investment activities.
- Here, we may view the borrowing rate as a marginal cost of capital (*k*). Suppose that all available funds can be placed in investments yielding a return equal to *I*, the **lending rate**. We view these funds as an investment pool.
- The firm may withdraw funds from this pool for other investment purposes, but if left in the pool, the funds will earn at the rate *r* (which is thus the opportunity cost).
- The MARR is thus related to either the borrowing interest rate or the lending interest rate.
- Thus, the minimum attractive rate of return (MARR) is the interest rate at which a firm can always earn or borrow money under a normal operating environment.
- Usually, selection of the MARR is a policy decision made by top management.
- It is the rate at which NPW analysis should be conducted.

Payback Period Method ~ Simple and Discounted

- One of the primary concerns of most businesspeople is whether and when the money invested in a project can be recovered.
- The **payback method** screens projects on the basis of how long it takes for net receipts to equal investment outlays.
- This calculation can take one of two forms: either ignore time-value-of-money considerations or include them.
- The former case is usually designated the **conventional/ simple payback method**, the latter case the **discounted payback method**.

Payback Period Method ~ Simple and Discounted

- If a company makes investment decisions solely on the basis of the payback period, it considers only those projects with a payback period *shorter* than the maximum acceptable payback period.
- This time limit is determined largely by management policy. For example, a high-tech firm, such as a computer chip manufacturer, would set a short time limit for any new investment, because high-tech products rapidly become obsolete.
- If the payback period is within the acceptable range, a formal project evaluation (such as a present-worth analysis) may begin.
- It is important to remember that **payback screening** is not an *end* in itself, but rather a method of screening out certain obviously unacceptable investment alternatives before progressing to an analysis of potentially acceptable ones.

Present worth Method

- Until the 1950s, the payback method was widely used as a means of making investment decisions.
- As flaws in this method were recognized, however, businesspeople began to search for methods to improve project evaluations.
- The result was the development of **discounted cash flow techniques (**DCFs**)**, which take into account the time value of money.
- One of the DCFs is the net-present-worth, or net-present-value, method.
- Under the NPW criterion, the present worth of all cash inflows is compared against the present worth of all cash outflows associated with an investment project.
- The difference between the present worth of these cash flows, referred to as the **net present worth** (NPW), **net present value** (NPV) determines whether the project is an acceptable investment.
- When two or more projects are under consideration, NPW analysis further allows us to select the best project by comparing their NPW figures.

Present worth Method: Basic Procedure

- Present worth is an equivalence method of analysis in which a project's cash flows are discounted to a single present value. It is perhaps the most efficient analysis method we can use in determining the acceptability of a project on an economic basis.
- Determine the interest rate that the firm wishes to earn on its investments. The interest rate you determine represents the rate at which the firm can always invest the money in its **investment pool**. This interest rate is often referred to as either a **required rate of return** or a **minimum attractive rate of return** (MARR). Usually, selection of the MARR is a policy decision made by top management.
- Estimate the service life of the project.
- Estimate the cash inflow for each period over the service life.
- Estimate the cash outflow over each service period.
- Determine the net cash flows
- Find Present Worth (NPW)=Net Cash Flow=Net Cash Inflow-Net Cash Outflow

Present worth Method: Decision Criteria

- **Single Project Evaluation.** In this context, a positive NPW means that the equivalent worth of the inflows is greater than the equivalent worth of outflows, so the project makes a profit. Therefore, if the PW(*i*) is positive for a single project, the project should be accepted; if the PW(*i*) is negative, the project should be rejected. The decision rule is:
  - If PW(i) > 0, accept the investment.
  - If PW (i) = 0, remain indifferent.
  - If PW(i) < 0, reject the investment.

Future Worth Method

- Net present worth measures the surplus in an investment project at time 0. **Net future worth (NFW)** measures this surplus at a time other than 0.
- Net-future-worth analysis is particularly useful in an investment situation in which we need to compute the equivalent worth of a project at the end of its investment period, rather than at its beginning.
- As you might expect, the ***decision rule*** for the NFW criterion is the same as that for the NPW criterion: For a single project evaluation,
  - If FW(i)> 0, accept the investment
  - If FW(i) = 0, remain indifferent to the investment
  - If FW(i) < 0, reject the investment

Annual Worth Method

- The **annual equivalent worth (AE)** criterion provides a basis for measuring the worth of an investment by determining equal payments on an annual basis.
- Knowing that any lump-sum cash amount can be converted into a series of equal annual payments, we may first find the net present worth (NPW) of the original series and then multiply this amount by the capital recovery factor:

$$AE(i) = PW(i)(A>P, i, N)$$

- **Single-project evaluation:** The accept–reject selection rule for a single *revenue* project is as follows:

  If AE (i) > 0, accept the investment.

  If AE (i) = 0, remain indifferent to the investment.

  If AE (i) < 0, reject the investment.

Present Worth Analysis

- **Example:** A construction enterprise is investigating the purchase of a new dump truck. Interest rate is 9%. The cash flow for the dump truck are as follows:
- First cost = $50,000, annual operating cost = $2000, annual income = $9,000, salvage value is $10,000, life = 10 years. Is this investment worth undertaking?
- **Given:**
- P = $50,000, A = annual net income = $9,000 - $2,000 = $7,000, S = 10,000, n = 10.
- Evaluate net present worth = present worth of benefits – present worth of costs

Present Worth Analysis

- Present worth of benefits = $9,000(P|A,9%,10) = $9,000(6.418) = $57,762
- Present worth of costs = $50,000 + $2,000(P|A,9%,10) - $10,000(P|F,9%,10)= $50,000 + $2,000(6..418) - $10,000(.4224) = $58,612
- Net present worth = $57,762 - $58,612 < 0 ⇒ do not invest
- ***What should be the minimum annual benefit for making it a worthy of investment at 9% rate of return?***

Annual Worth Analysis

- Present worth of benefits = A(P|A,9%,10) = A(6.418)
- Present worth of costs = $50,000 + $2,000(P|A,9%,10) - $10,000(P|F,9%,10)= $50,000 + $2,000(6..418) - $10,000(.4224) = $58,612
- Thus, Annual Worth of the project:
- A(6.418) = $58,612 $\Rightarrow$ A = $58,612/6.418 = $9,312.44

Example:

From the given cashflow, find PW, AW & FW when MARR= 9%.

EOY	Cashflow
0	-5,00,000
1	80,000
2	1,00,000
3	60,000
4	1,20,000
5	90,000
6	90,000
7	90,000
8	1,00,000

Rate of Return Method: Interest Rate of Return (IRR) Method

- A project's return is referred to as the internal rate of return (IRR) or the **yield** promised by an **investment project** over its **useful life**.
- *The rate of return is the break-even interest rate i* that equates the present worth of a project's cash outflows to the present worth of its cash inflows, or*
  - PW(i*) = PW Cash inflows – PW Cash outflow
- *The internal rate of return is the interest rate charged on the unrecovered project balance of the investment such that, when the project terminates, the unrecovered project balance will be zero.*

Internal Rate of Return: Trial and Error Method

- The first step in the trial-and-error method is to make an estimated ***guess*** at the value of i*.
- For a simple investment, we use the "guessed" interest rate to compute the present worth of net cash flows and observe whether it is positive, negative, or zero.
- Whenever we reach the point where PW(*i*) is bounded by one negative and one positive value, we use **linear interpolation** to approximate i*.
- i*= LI+(HI-LI)*(Amount at LI-0)/(Amount at LI- (-Amount at HI))
- If the IRR exceeds this MARR, we are assured that the company will more than break even.
- The decision rule for a pure project is as follows:
  - If IRR > MARR, accept the project.
  - If IRR = MARR, remain indifferent.
  - If IRR < MARR, reject the project.

Internal Rate of Return

- **Benefits of using IRR**
  - Considers the time value of money
  - Consistent with shareholder wealth maximization
  - Intuitive appeal (rate feels better than absolute number because it is readily comparable with other rates)
  - Doesn't require advance specification of the discount rate

- **Disadvantages**
  - Reinvestment rate assumption (i.e. cash inflows are reinvested at the IRR) may be unreasonable
  - Multiple IRRs possible where sign reversals occur in cash flow
  - Requires detailed cash flow predictions over the entire life of the project.
  - Only as accurate as the cash flow predictions.
  - When scale differences exist, there can be a ranking conflict with the NPV method.

External / Modified Internal Rate of Return (ERR/MIRR) Method

- The **modified internal rate of return** (MIRR) is a financial measure of an investment's attractiveness.
- As the name implies, MIRR is a **modification** of the internal **rate of return** (IRR) and as such aims to resolve some problems with the IRR.
- Modified internal rate of return (MIRR) uses explicit reinvestment assumptions.
- The discount rate which equates the present value of the cash *outflows* (calculated on the basis of the finance rate or MARR) with the present value of the project's **terminal value**. Where the **terminal value** is the sum of the future values of the project's cash *inflows* compounded to the project's termination (at the reinvestment rate or MARR).
- **Decision Rules**
  - Accept projects with MIRR ≥ MARR
  - Reject projects with MIRR < MARR
  - Where two projects are mutually exclusive, do not rank on MIRR values, accept the one with the higher **NPV**.

External / Modified Rate of Return (ERR/ MIRR) Method

$$PV_{outflows} = PV_{inflows}$$

$$\sum_{t=0}^{n} \frac{ACOF_t}{(1+k)^t} = \frac{\sum_{t=0}^{n} ACIF_t \quad (1+k)^{n-t}}{(1+MIRR)^n} = \frac{TV}{(1+MIRR)^n}$$

where

$ACIF_t$ = Annual net cash *inflow* in time period t
$ACOF_t$ = Annual net cash *outflow* in time period t
TV = the Terminal Value of all the cash inflows compounded at the discount rate
k = the appropriate discount rate
$MIRR$ = the Modified Internal Rate of Return
n = the project's expected life

External / Modified Rate of Return (ERR/ MIRR) Method

- **Benefits of using MIRR**
- Considers the time value of money
- Consistent with shareholder wealth maximisation
- Intuitive appeal (rate feels better than absolute number because it is readily comparable with other rates)
- Overcomes the reinvestment rate problem of IRR by allowing the reinvestment rate to be specified.

Disadvantages

- Requires detailed cash flow predictions over the entire life of the project.
- Only as accurate as the cash flow and reinvestment rate predictions.
- When scale differences exist, there can still be a ranking conflict with the NPV method.
- Multiple MIRRs possible where sign reversals occur in cash flow.

External / Modified Rate of Return (ERR/ MIRR) Method

Calculation

For example, if an initial investment of 10000 produces net cash flows of 4000 for 4 years and the discount rate is taken as 10%, the MIRR of this investment is:

Time	Net cash flows	$PV_{outflows}$	TV (of inflows)
Initial cash outlay (time 0)	-10000	(Step 1) 10000	
Year 1	4000	→	5324
Year 2	4000	→	4840
Year 3	4000	→	4400
Year 4	4000	→	4000
		Total	(Step 2) 18584

Calculation

Step 1 (previous slide): calculate $PV_{outflows}$

Step 2 (previous slide): calculate TV of inflows

Step 3: $PV_{outflows} = \frac{TV}{(1 + MIRR)^4}$

$$10000 = \frac{18584}{(1 + MIRR)^4}$$

MIRR = 16,7%

Benefit Cost Ratio Method

- Benefit cost ratio is defined as the ratio of the equivalent worth of benefits to the equivalent worth of costs. This is the ratio of discounted benefits to discounted costs of the projects. It is also known as investment ratio.
- This ratio consider the time value of money while evaluating the project.
- Two commonly used B/C ratio:
  - Conventional B/C Ratio
  - Modified B/C Ratio

Benefit Cost Ratio: Conventional Method

- With PW Formulation:
  - B/C Ratio= PW (B)/(PW(I)-PW(S)+PW(O&M))
- With FW Formulation:
  - B/C Ratio= FW (B)/(FW(I)-FW(S)+FW(O&M))
- With AW Formulation:
  - B/C Ratio= AW (B)/(AW(I)-AW(S)+AW(O&M))=AW(B)/(CR+AW(O&M))
  - Where, B=Benefit of the proposed projects
  - O&M=Operation and Maintenance Cost
  - S=Salvage Value
  - I=Initial Investment
  - CR=Capital Recovery Amount

Benefit Cost Ratio: Modified B/C Ratio

- With PW Formulation:
  - B/C Ratio=(PW (B)-PW(O&M))/(PW(I)-PW(S))
- With FW Formulation:
  - B/C Ratio=(FW (B)-FW(O&M))/(FW(I)-FW(S))
- With AW Formulation:
  - B/C Ratio= (AW (B)-AW(O&M))/((AW(I)-AW(S))=(AW(B)-AW(O&M))/CR
- **The decision rule for a pure project is as follows:**
  - If B/C ratio >1, accept the project.
  - If B/C ratio = 1, remain indifferent.
  - If B/C ratio < 1, reject the project.

Problems on Benefit Cost Ratio

- A project is viable and worth taking up when the BC ratio is more than 1. The main problem here is that BCR can be manipulated easily as its value is sensitive to the treatment and aggregation of costs and benefits.
- For example, taking benefit in the numerator net of a few cost items, which would have been otherwise accounted in the denominator, a different value for BCR may be obtained. Precisely for this reason, it becomes difficult to compare different projects unless a uniform method of aggregating benefits and costs is followed.
- Similarly, the ratio is also sensitive to the time span considered for project evaluation and comparing projects of different durations becomes untenable.
- Another problem is in its interpretation when applied to projects like watersheds where public funding and private benefits, non-correspondence between those who incur costs and those who benefit are the contentious issues.

Example: Basic Methods of EE (NEC, 2015)

- Cosmos College is considering to purchase a new photocopy machine costing Rs. 1,00,000 having salvage value of Rs. 25,000 at 10th year that needs Rs. 5,000 electricity cost per year where MARR 10% per year.
  - a) Find PW, AW& FW
  - b) Find IRR & Decide investment on photocopy
  - c) Find both types of B/C ratio by PW formulation
  - d) Find simple & discounted payback period
  - e) MIRR, if reinvestment rate is 20%

Example: Basic Methods of EE (NEC, 2015)

- Nepal Engineering College (NEC) is considering to purchase a new generator costing of Rs. 4,00,000 having salvage value Rs. 1,00,000 at the end of 5th year. The use of generator will increase Rs. 1,50,000 that needs fuel cost of Rs. 30,000 per year. Find the following when MARR = 10%.
  - i. PW, AW & FW
  - ii. IRR. Also develop investment balance diagram and table.
  - iii. B\C ratio by PW formulation (Both Methods)
  - iv. Simple & discounted payback period
  - v. MIRR, if reinvestment rate is 20%

Solution:

- i) **PW (10%)** = -4,00,000 + (,50,000-30,000) (P/A, 10%, 5)+1,00,000 (P/F,10%,5)=1,16,986

  AW (10%) = -4,00,000 (A/P,10%,5)+ (,50,000-30,000) +1,00,000 (A/F,10%,5)=30,860

  FW (10%) = -4,00,000 (F/P, 10%, 5) + (,50,000-30,000) (F/A, 10%, 5)+1,00,000=1,88,412

ii) **For IRR; Setting equation PW Formulation**

PW (10%) = -4,00,000 + (,50,000-30,000) (P/A, i%, 5)+1,00,000 (P/F,i%,5)

Using Trial and Error Method,

Try at, i=10%; PW (10%) = -4,00,000 + (,50,000-30,000) (P/A, 10%, 5)+1,00,000 (P/F,10%,5)=1,16,986

Try at, i=18%; PW (18%) = -4,00,000 + (,50,000-30,000) (P/A, 18%, 5)+1,00,000 (P/F,18%,5)=26,844

Try at i=20%; PW (20%) = -4,00,000 + (,50,000-30,000) (P/A, 20%, 5)+1,00,000 (P/F,20%,5)=-938

Interpolation;

IRR=18% + 26,844/(26,844+938) * 2% = 19.93%; As MARR is 10%and IRR is 19.93%, accept the project.

Solution:

iv) Investment balance table

End of Year	Net Cash Flow	Interest Factor @ 19.93%	Unrecovered Amount (Beginning of the year)	Unrecovered Investment (End of the year)	Cumulative (E-B)
0	-4,00,000		-4,00,000	-4,00,000	-400,000
1	1,20,000	1.1993	-4,00,000	-479,720	-359,720
2	1,20,000	1.1993	-359,720	-431,412	-311,412
3	1,20,000	1.1993	-311,412	-373,477	-253,477
4	1,20,000	1.1993	-253,476	-303,994	-183,994
5	2,20,000	1.1993	-183,994	220,000	0

Solution:

iii) B/C ratio using PW formulation

We have, Conventional B/C Ratio= PW (B)/(PW(I)-PW(S)+PW(O&M))

Modified B/C Ratio=(PW (B)-PW(O&M))/(PW(I)-PW(S))

Then, PW(B)=5,68,620

PW(I)= 4,00,000

PW(S)=62,090

PW(O&M)=1,13,724

Then, Conventional B/C ratio=568,620/(4,00,000-62090+1,13,724)=1.259>1, So accept the project.

Modified B/C ratio= (568,620-1,13724)/(4,00,000-62090)=1.346>1, So accept the project.

Solution:

iv) Using Simple and Discounted Payback Period

End of Year	Net Cash Flow	Cumulative Cash Flow	Interest Factor @ 10%	Discounted Cash Flow	Cumulative Cash Flow
0	-4,00,000	-4,00,000	1	-4,00,000	-400,000
1	1,20,000	-280,000	0.9091	1,09,090.9	-2,90,909.09
2	1,20,000	-1,60,000	0.8264	99,173.55	-191,735.5
3	1,20,000	-40,000	0.7513	90,157.776	-1,01,577.7
4	1,20,000	80,000	0.6830	81,961.614	-19,616.08
5	2,20,000	3,00,000	0.6209	1,36,602.69	1,16,986.6

Solution:

- Simple Payback Period=3+40,000/1,20,000 = 3.333 years
- Discounted Payback Period=4+19,616/1,36,602=4.1435 years

v) **Using MIRR Method**:

PV of outflow=4,00,000

FV of inflow=$1,20,000*(1.2)^4$ +$1,20,000*(1.2)^3$ +$1,20,000*(1.2)^2$ +$1,20,000*(1.2)^1$ +$2,20,000*(1.2)^0$ = 992,992

Then, For MIRR;

PV of cash outflow=FV of cash inflow/ $(1+MIRR)^N$

$(1+MIRR)^5$=992,992/4,00,000; or 5Log(1+MIRR)= log 2.48; or MIRR=19.94%,

As MIRR(19.94%)>MARR (10%, we accept the project.

Example: Basic Methods of EE (NEC, 2015)

- Your college is considering to purchase a new machine costing Rs. 3,00,000 that will have salvage value of Rs. 20,000 at the end of 8th year generates annual income of Rs. 80, 000 that needs Rs. 20,000 operating cost for each year where MARR= 10%. Find,
- i) PW,AW, & FW
- Ii) IRR & interpret your result
- iii) Both types of B/C ratio by AW & FW formulation
- iv) Both types of payback period
- v) MIRR, if reinvestment rate is 20%

IRR (PU, 2009)

- Consider an investment project with the following cash flow. Compute the IRR for this investment and determine its acceptability at MARR=10% and draw also an investment balance diagram.

End of Year	Net cash flows
0	-22,000
1	-1,000
2	0
3	8,000
4	3,000
5	15.000

IRR (PU, 2016)

- Evaluate IRR of the following project and identify whether the project is feasible or not.
  - Initial investment =Rs. 5,00,000
  - Annual revenue =Rs. 2,30,000
  - Annual cost =Rs. 45,000
  - Useful life =8 yrs
  - Repair and maintenance cost at 4^{th} and 6^{th} year =Rs. 30,000
  - MARR =10% per year
- Also draw investment balance diagram.

Chapter 4: Assignments

- What do you mean by pay back period? Discuss simple and discounted payback period.
- Discuss PW, FW and AW method of project evaluation.
- What is IRR? Why MIRR is better than IRR for project evaluation?
- What do you mean by BC Ratio. Discuss conventional and modified method of B/C.
- ***Numerical Questions for each methods***

Chapter 5: Comparative Analysis of Alternatives

- Comparing Mutually Exclusive Alternatives having same useful life by Payback Period Method Equivalent Worth Method ;Rate of Return Method and Benefit Cost Ratio Method
- Comparing Mutually Exclusive Alternatives having different useful lives by Repeatability Assumption, Co-terminated Assumption, Capitalized Worth Method
- Comparing Mutually Exclusive, Contingent and Independent Project in Combination

Meaning of Independent Project

- Most firms have a number of unrelated investment opportunities available.
- An **independent project** is a project that may be accepted or rejected without influencing the accept–reject decision of another independent project. For example, the purchase of a milling machine, office furniture, and a forklift truck constitutes three independent projects.
- Only projects that are economically independent of one another can be evaluated separately.
- In other words, the decision regarding any one project has no effect on the decision to accept or reject another project. Such projects are said to be **independent**.
- **For a single project**, we have two investment alternatives: to accept or reject the project.
- **For two independent projects**, we can have four investment alternatives: (1) to accept both projects, (2) to reject both projects, (3) to accept only the first project, and (4) to accept only the second project.

Meaning of Dependent Project

- In many decision problems, several investment projects are related to one another such that the acceptance or rejection of one project influences the acceptance or rejection of others.
- Two such types of dependencies are **mutually exclusive** projects and **contingent** projects.

Meaning of Contingent Project

- We say that two or more projects are **contingent** if the acceptance of one requires the acceptance of the other.
- For example, the purchase of a computer printer is dependent upon the purchase of a computer, but the computer may be purchased without purchasing the printer.
- Suppose the acceptance of C is contingent on the acceptance of both A and B, and the acceptance of B is contingent on the acceptance of A. Then the number of decision alternatives can be formulated as follows:

Alternative	X_A	X_B	X_C
1	0	0	0
2	1	0	0
3	1	1	0
4	1	1	1

Meaning of Mutually Exclusive Project

- Many engineering situations we face are with selecting the most economically attractive project from a number of alternative projects, all of which solve the same problem or meet the same need.
- It is unnecessary to choose more than one project in this situation, and the acceptance of one automatically entails the rejection of all of the others. Such projects are said to be **mutually exclusive**.
- Several alternatives are **mutually exclusive** when any one of them will fulfill the same need and the selection of one of them implies that the others will be excluded.
- Take, for example, buying versus leasing an automobile for business use; when one alternative is accepted, the other is excluded.

Comparing Mutually Exclusive Alternatives having same useful life: PW, AW, FW and B/C Ratio

- Compute the PW(*i*) for each alternative and select the one with the largest PW(*i*).
- When you compare mutually exclusive alternatives with the *same revenues*, they are compared on a *cost-only basis*. In this situation (because you are minimizing costs, rather than maximizing profits), you should accept the project that results in the *smallest*, or *least negative*, NPW.
- Similarly, use same decision criteria for AW, FW, and B/C Ratio method while comparing and selecting between multiple alternatives.

Comparing Mutually Exclusive Alternatives having different useful lives by Repeatability Assumption

- Two projects will have two different useful life, so comparing is difficult for them, Thus;
  - Assume that projects will be repeated for certain times so both projects will have same useful life
  - Times to be repeated for any project can be accessed by computing LCM of useful life of both projects
  - Their overall PW/FW will be accessed (including their repeated project cycle assuming they are repeated at the end of each cycle, till their useful life becomes same)
  - Compare PW/FW with each other and select best one.

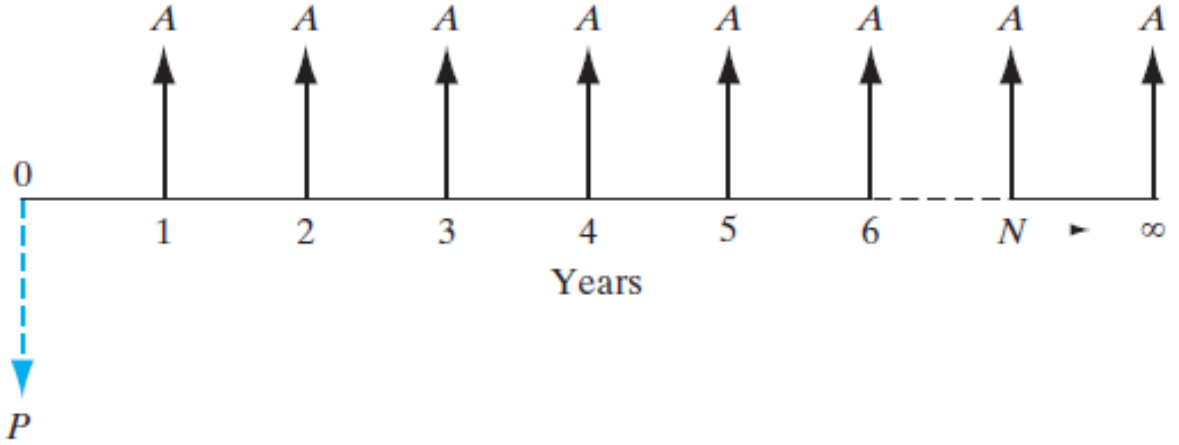
Comparing Mutually Exclusive Alternatives having different useful lives by Co-terminated Assumption

- Two projects will have two different useful life, so comparing is difficult for them, Thus;
  - Access shorter project's PW/FW (Project A)
  - For projects with longer useful life (Project B), assume this project will be terminated on shorter projects useful life, Thus;
    1. Find CR of initial investment and salvage value of Project B
    2. Find PW of CR (computed on above step) for remaining useful life of Project B beyond short project (Project A)
    3. Find PW/FW of overall project including PW of CR (accessed in step 2)
    4. Compare PW/FW with each other and select best one.

Comparing Mutually Exclusive Alternatives having perpetual lives by Capitalized Equivalent Method

- Another special case of the PW criterion is useful when the life of a proposed project is **perpetual** or the planning horizon is extremely long (say, 40 years or more).
- Many public projects, such as bridges, waterway structures, irrigation systems, and hydroelectric dams, are expected to generate benefits over an extended period (or forever).
- We will use the **capitalized equivalent** (CE(*i*)) method for evaluating such projects.

$$\mathrm{PW}(i) = A(P/A, i, N \to \infty) = \frac{A}{i}.$$



Example: Use FW/PW/AW Formulation

Compare following projects by using repeatability & Co-terminated assumption when MARR = 12% per year.

Items	Project A	Project B
I	1,50,000	2,00,000
AR	90,000	1,00,000
AE	20,000	22,000
S	50,000	1,00,000
N	2 years	4 years

Solution: Repeatability Assumption

- LCM of 2 and 4 years= 4 years

For Project A

- PW for 4 years=-150,000-150,000(P/F,10%,2)+(90,000-20,000)(P/A,10%,4)+ 50,000(P/F,10%,2)+ 50,000(P/F,10%,4)=-150,000-150,000*0.8264+70,000*3.1699+50,000*0.8264+50,000*0.6830
- =23,403

For Project B

- PW for 4 years=-200,000+(100,000-22,000) (P/A, 10%, 4)+100,000(P/F,10%,4)
- PW=-2,00,000+78,000*3.1699+1,00,000*0.6830=1,15,552

Then, PW of B > PW of A, So Select B.

Solution: Co-terminated Assumption

- For Project A
- PW of A=-1,50,000+70,000(P/A,10%,2)+50,000(P/F,10%,2)

  =-150,000+70,000*1.7355+50,000*0.8264 = 12,805

PW of B (Project B should be terminated at the end of 2nd year.)

CR for Project B=2,00(A/P,10%,4)-100,000(A/F,10%,4)

=200,000*(0.3155)-100,000*0.2155=41,550

PW of CR at the end of 2nd year

PW of CR (10%)=41550 (P/A,10%,2)=72110

PW of Project B terminating at the end of 2nd year

PW(10%)=-200,000+78,000(P/A,10%,2)+72,110(P/F,10%,2)

=-200,000+78,000*1.7355+72,110*0.8264

=-5,039

Thus, PW of A> PW of B, So select Project A.

Chapter 5: Assignments

- What do you mean by mutually exclusive, independent and contingent projects, describe with suitable example.
- Write short notes on:
  - Co-terminated assumption for comparing alternatives
  - Repeatability assumption for comparing alternatives
- ***Numerical Questions for each methods***

Chapter 6:Risk Analysis

- Origin/Sources of Project Risks.
- Method of Describing Project Risks; Sensitivity Analysis, Breakeven Analysis, Scenario Analysis.

Origin/Sources of Project Risks

- In previous chapters, cash flows from projects were assumed to be known with complete certainty; our analysis was concerned with measuring the economic worth of projects and selecting the best ones to invest in.
- Although that type of analysis can provide a reasonable basis for decision making in many investment situations, we should certainly consider the more usual *un*certainty.
- In this type of situation, management rarely has precise expectations about the future cash flows to be derived from a particular project.
- In fact, the best that a firm can reasonably expect to do is to estimate the range of possible future costs and benefits and the relative chances of achieving a reasonable return on the investment.

Origin/Sources of Project Risks

- The decision to make a major capital investment such as introducing a new product requires information about cash flow over the life of a project. The profitability estimate of an investment depends on cash flow estimations, which are generally uncertain.
- The factors to be estimated include the total market for the product; the market share that the firm can attain; the growth in the market; the cost of producing the product, including labor and materials; the selling price; the life of the product; the cost and life of the equipment needed; and the effective tax rates. Many of these factors are subject to substantial uncertainty.
- We use the term **risk** to describe an investment project whose cash flow is not known in advance with absolute certainty, but for which an array of alternative outcomes and their probabilities (odds) are known.

Origin/Sources of Project Risks

- We will also use the term **project risk** to refer to variability in a project's NPW.
- A greater project risk usually means a greater variability in a project's NPW, or simply that the *risk is the potential for loss.* This chapter begins by exploring the origins of project risk.
- In particular, managers have no way of determining either the probability that a project will lose money or the probability that it will generate large profits.
- Because cash flows can be so difficult to estimate accurately, project managers frequently consider a range of possible values for cash flow elements.
- If a range of values **Risk:** The chance that an investment's actual return will be different than expected.

Origin/Sources of Project Risks

- Boston Metal Company (BMC), a small manufacturer of fabricated metal parts, must decide whether to enter the competition to become the supplier of transmission housings for Gulf Electric, a company that produces the housings in its own in-house manufacturing facility, but that has almost reached its maximum production capacity. Therefore, Gulf is looking for an outside supplier. To compete, BMC must design a new fixture for individual cash flows is possible, it follows that a range of values for the NPW of a given project is also possible. Clearly, the analyst will want to gauge the probability and reliability of individual cash flows and, consequently, the level of certainty about the overall project worth
- A common approach is to make single-number "best estimates" for each of the uncertain factors and then to calculate measures of profitability, such as the NPW or rate of return for the project.
- This approach, however, has two drawbacks:
  - **1.** No guarantee can ever ensure that the "best estimates" will match actual values.
  - **2.** No provision is made to measure the risk associated with an investment, or the project risk.

Method of Describing Project Risks; Sensitivity Analysis, Breakeven Analysis, Scenario Analysis

- We may begin analyzing project risk by first determining the uncertainty inherent in a project's cash flows. We can do this analysis in a number of ways, which range from making informal judgments to calculating complex economic and statistical quantities.
- In this section, we will introduce three methods of describing project risk:
- **(1) sensitivity analysis,**
- **(2) break-even analysis, and**
- **(3) scenario analysis.**

Method of Describing Project Risks; Sensitivity Analysis

- One way to glean a sense of the possible outcomes of an investment is to perform a sensitivity analysis.
- This kind of analysis determines the effect on the NPW of variations in the input variables (such as revenues, operating cost, and salvage value) used to estimate after-tax cash flows.
- A **sensitivity analysis** reveals how much the NPW will change in response to a given change in an input variable.
- In calculating cash flows, some items have a greater influence on the final result than others. In some problems, the most significant item may be easily identified.
- For example, the estimate of sales volume is often a major factor in a problem in which the quantity sold varies with the alternatives. In other problems, we may want to locate the items that have an important influence on the final results so that they can be subjected to special scrutiny.

Method of Describing Project Risks; Sensitivity Analysis

- Sensitivity analysis is sometimes called "what-if" analysis, because it answers questions such as "What if incremental sales are only 1,000 units, rather than 2,000 units? Then what will the NPW be?"
- Sensitivity analysis begins with a base-case situation, which is developed by using the most likely values for each input. We then change the specific variable of interest by several specified percentage points above and below the most likely value, while holding other variables constant.
- Next, we calculate a new NPW for each of the values we obtained.
- A convenient and useful way to present the results of a sensitivity analysis is to plot **sensitivity graphs**.
- The slopes of the lines show how sensitive the NPW is to changes in each of the inputs: The steeper the slope, the more sensitive the NPW is to a change in a particular variable.
- Sensitivity graphs identify the crucial variables that affect the final outcome most.

Method of Describing Project Risks; Sensitivity Analysis

- Graphic displays provide a useful means to communicate the relative sensitivities of the different variables to the corresponding NPW value.
- However, **sensitivity graphs** do not explain any interactions among the variables or the likelihood of realizing any specific deviation from the base case.
- Certainly, it is conceivable that an answer might not be very sensitive to changes in either of two items, but very sensitive to combined changes in them.

Example: Sensitivity Analysis (PU, 2015)

- Perform sensitivity analysis over the range of ±40% by the parameters: i) Initial investment ii) Annual revenue iii) Useful life
- If I = 11,500; AR = 3,000; N = 6 years; S = 1,000; MARR = 10%

Solution:

PW(10%)=-11,500+3,000(P/A, 10%,6)+1,000(P/F, 10%,6)

=-11,500+3,000(4.3552)+1000(0.5644)=2,130.

a. When initial investment varies ±40% , the PW would be:

PW(10%)=-11,500+3,000(P/A, 10%,6)+1,000(P/F, 10%,6)

At I =+40%, PW=-11,500(1.4)+3,000(4.3552)+1000(0.5644)=-2,470.

At I =-40%, PW=-11,500(0.6)+3,000(4.3552)+1000(0.5644)=6730.

b. When Annual Revenue varies ±40% , the PW would be:

At AR =+40%, PW=-11,500+3,000(1.4)(4.3552)+1000(0.5644)=7,356

At AR =-40%, PW=-11,500+3,000(1.4)(4.3552)+1000(0.5644)=-3,096.

c. . When Useful life varies ±40% , the PW would be:

At N=+40%, PW(10%)=-11,500+3,000(P/A, 10%,8.4)+1,000(P/F, 10%,8.4)

At N =-40%, PW(10%)=-11,500+3,000(P/A, 10%,3.6)+1,000(P/F, 10%,3.6)

Example: Sensitivity Analysis

Sensitivity Analysis Table

PW (10%) with sensitivity of ±40%

Parameters	-40%	0%	+40%
Investment (I)	6,730	2,130	-2,470
Annual Revenue (AR)	-3,096	2,130	7,356
Useful life (N)	-2,077	2,130	5,476

Method of Describing Project Risks; Breakeven Analysis

- When we perform a sensitivity analysis of a project, we are asking how serious the effect of lower revenues or higher costs will be on the project's profitability.
- Managers sometimes prefer to ask instead how much sales can decrease below forecasts before the project begins to lose money. This type of analysis is known as **break-even analysis**.
- In other words, break-even analysis is a technique for studying the effect of variations in output on a firm's NPW (or other measures). We will present an approach to break-even analysis based on the project's cash flows.
- In this approach, the value of cash inflow equals to the cash outflow and this point is called as breakeven point and analysis is called as BEP Analysis.

Method of Describing Project Risks; Breakeven Analysis

- To illustrate the procedure of break-even analysis based on NPW, we use the generalized cash flow approach.
- We compute the PW of cash inflows as a function of an unknown variable (say, x), perhaps annual sales. For example,
  - PW of cash inflows = $f(x)_1$.
  - Next, we compute the PW of cash outflows as a function of x:
  - PW of cash outflows = $f(x)_2$
- NPW is, of course, the difference between these two numbers. Accordingly, we look for the break-even value of x that makes Note that this break-even value is similar to that used to calculate the internal rate of return when we want to find the interest rate that makes

$$F(x)_1 = f(x)_2 .$$

- the NPW equal zero. The break-even value is also used to calculate many other similar "cutoff values" at which a choice changes.

Breakeven Analysis for a Single Project

- The cost of producing a good can be split into two main parts:
  - Fixed Cost (FC)
  - Variable Cost (VC)=Variable cost per unit* Total no. of units (VCPU*X)

  Total cost is the sum of fixed cost and variable cost

  TC=FC+VC or, TC=FC+VCPU*X

  Again, Total Sales Revenue =Selling Price Per Unit* No of Units

  TR=SPPU*X

  For BEP, TC=TR; Net profit=0.

  Then, BEP units, X=FC/(SPPU-VCPU)

Example: Breakeven Analysis for a Single Project

- Find BEP (volume) and BEP (amount) from following information. Also what would be the output if company wishes profit of Rs. 5,00,00.
- Fixed cost=Rs. 5,00,000
- Variable Cost Per Unit=Rs. 20,000
- Selling Price Per Unit=Rs. 30,000

Solution:

BEP(volume)=FC/(SPPU-VCPU)=5,00,000/(30,000-20,000)=50 Units

BEP (amount)=SPPU*BEP (volume)=30,000*50=Rs.15,00,000

For Profit 5,00,000,

Net Profit=TR-TC; Net Profit=SPPU*X-(FC+VCPU*X)

Rs. 500,000=Rs. 30,000*X-(Rs. 5,00,000+Rs. 20,000*X); or 500,000+500,000=10,000X;

Or X= 100. Thus, for generating Rs, 5,00,000 profit, we need to sell 100 units of product.

Example: Breakeven Analysis for comparing two Alternatives (PU, 2011)

- From the following information, find that how many hours/year would the motors have to be operated at full load for annual costs to be equal if MARR is 15%?

	Motor A	Motor B
Purchase cost	Rs. 125000	Rs. 160,000
Efficiency	74%	92%
Life	10 yrs	10 yrs
Maintenance Cost	Rs. 5,000/year	Rs. 2500/year

Annual tax and insurance: 1.5% of investment for both motors and electricity cost Rs. 5/KW hr. Power of both motors =100hp.

Solution: For Motor A,

Calculating annual equivalent cost:

1. Capital recovery cost=125,000(A/P,15%,10)=Rs. 24,906.5
2. Maintenance cost= Rs. 5,000

- Mike, an industrial engineer at Energy Conservation Service has found that the anticipated profitability of a newly developed water-heater temperature control device can be measured by present worth with the formula

  NPW = 4.028V(2X - $11) - 77,860,

  where *V is the number of units produced and sold and X is the sales price per unit.* Mike also has found that the value of the parameter *V could occur anywhere over* the range from 1,000 to 6,000 units and that of the parameter *X anywhere between* $20 and $45 per unit. Develop a sensitivity graph as a function of the number of units produced and the sales price per unit.

Example: Breakeven Analysis

3. Tax and insurance=1.5% of 125,000=Rs. 1,875

4. Operating expenses for power (electricity cost),

We know that, Efficiency= Output/Input or Input=Output/Efficiency

Let X be the number of hours of operation per year.

Operating Expenses =Input*Rate*Hours of operation

=Output/Efficiency*Rate*Hours of Operation

=((100*0.746)/0.74) *5*X=504.05X (Note: 1HP=0.746KW)

Total annual cost for motor A (AW of A)

=Rs. 24,906.5+Rs. 5,000+Rs. 1,875+504.05X

=Rs. 31,781.5+504.05X----------(i)

For Motor B,

Calculating annual equivalent cost:

1. Capital recovery cost=160,000(A/P,15%,10)=Rs. 31,880.32
2. Maintenance cost= Rs. 2,500
3. Tax and insurance=1.5% of 160,000=Rs. 2,400

Example: Breakeven Analysis

4. Operating expenses for power (electricity cost),

Operating Expenses =Input*Rate*Hours of operation

=Output/Efficiency*Rate*Hours of Operation

=((100*0.746)/0.92) *5*X=405.43X (Note: 1HP=0.746KW)

Total annual cost for motor B (AW of B)

=Rs. 31,880.32+Rs. 2,500+Rs. 2,400+405.43X

=Rs. 36,780.32+405.43X----------(ii)

To get break even point,

AW of A=AW of B

Or, Rs. 31781.5+504.05X=Rs. 36,780.32+405.43X

Thus, X=51 hours per year (break even hour)

If annual operation hour is more than 51 hours, motor B is selected and if it is less than 51 hours then motor A is selected.

Method of Describing Project Risks; Scenario Analysis

- Although both sensitivity and break-even analyses are useful, they have limitations. Often, it is difficult to specify precisely the relationship between a particular variable and the NPW. The relationship is further complicated by interdependencies among the variables.
- Holding operating costs constant while varying unit sales may ease the analysis, but in reality, operating costs do not behave in this manner. Yet, it may complicate the analysis too much to permit movement in more than one variable at a time.
- **Scenario analysis** is a technique that considers the sensitivity of NPW both to changes in key variables and to the range of likely values of those variables. For example, the decision maker may examine two extreme cases: a "worst-case" scenario (low unit sales, low unit price, high variable cost per unit, high fixed cost, and so on) and a "best-case" scenario.

Method of Describing Project Risks; Scenario Analysis

- The NPWs under the worst and the best conditions are then calculated and compared with the expected, or base-case, NPW.
- The need to estimate probabilities leads us directly to our next step: developing a probability distribution (or, put another way, the probability that the variable in question takes on a certain value).
- If we can predict the effects on the NPW of variations in the parameters, why should we not assign a probability distribution to the possible outcomes of each parameter and combine these distributions in some way to produce a probability distribution for the possible outcomes of the NPW?

Example: Scenario Analysis

- Calculate PW of Worst case, most likely case and best case based on following information. I=$1,25,000, MARR=15%, N=5 years **(CS Park, Example 12.3, Page: 595)**

Variable Considered	Worst-Case Scenario	Most-Likely-Case Scenario	Best-Case Scenario
Unit demand	1,600	2,000	2,400
Unit price ($)	48	50	53
Variable cost ($)	17	15	12
Fixed cost ($)	11,000	10,000	8,000
Salvage value ($)	30,000	40,000	50,000
PW(15%)	−$5,856	$40,169	$104,295

Chapter 6: Assignments

- Describe project risk. Explain sensitivity analysis method of describing project risk.
- What do you mean by breakeven analysis? Why do we need to use breakeven analysis in engineering field?
- Write short notes on:
  - Project risk
  - Sensitivity analysis
  - Breakeven analysis
  - Scenario analysis
- ***Numerical Questions for each analysis***