Engineering Economics
ECO 1192

Topic 1: Introduction

Claude Théoret
University of Ottawa

General Information

- Availability
  - Weekly office hours
    - Instructor & TAs: tba
    - Consult course website for locations and times.
- Final Grade
  - Two (2) mid-term examinations: 2 x 15% = 30%
  - Two (2) assignments: 2 x 15% = 30%
  - One (1) final examination: 1 x 40%
  - Please note that the assignments and the examinations (mid-term and final) are compulsory.

Recommended textbook

- Fraser and Jewkes, *Engineering Economics*, 6th edition, Pearson, Toronto, Ontario, 2017
  - Available at the Agora and University bookstores.
- Access to an "engineering economics" text is highly recommended.

Course website: ECO 1192

1. PowerPoint lecture notes.
2. Calendar of key events
   - Lectures and references
   - Review sessions: dates and location
   - Examinations: coverage, dates and location
3. Two typical “problem-and-solution” sets
   - Each set covers about 50% of the course.
4. Excel applications.

Engineering Economics (ECO 1192A; Fall 2016)

COURSE CALENDAR

Instructor: Claude Théoret

- **All references are to the recommended course textbook by N.M. Fraser, E.M. Jewkes and M.Pirnia, Engineering Economics, 6th edition, Pearson, Toronto, Ontario, 2017.**
- **Please consult ECO1192A website for TA/instructor office schedules.**

Date: August 11, 2016.

TOPICS	LECTURES, ASSIGNMENTS AND EXAMINATIONS	DATES
1	• Engineering Decision Making (Ch. 1)	September 13

First Assignment

- **Compulsory**
- **Availability: ECO 1192A Website from September 16**
- **Due date: October 18.**

1. **Each student will be randomly assigned ONE of THREE (3) colour-coded assignments (Blue; Pink; White).**
2. **Assignments and their random allocation will be posted on the course website in mid-September.**
3. **Students will use colour-coded Scantrons (answer sheets) to submit their answers.**
4. **The colour-coded Scantrons will be distributed and collected at the beginning of the October 18 lecture.**
5. **Absolutely no late assignments and email submissions.**

……………

Access to course website

- http://www.uottawa.ca
- Quick Picks
- Virtual Campus
- Provide student number & password
- Select *Engineering Economics* (ECO1192A) from drop-down menu.

Recommended reading

- Fraser et al. chapter 1
  - Newnan et al. chapter 1
  - Park chapter 1

Lecture objectives

1. Provide overview of economics.
2. Describe
   - science and engineering
   - engineer economic studies
3. Show the importance of time in decision-making.
4. Provide a first look at cash flows.
5. Project analyses.

Engineering Economics

- The science that deals with techniques of quantitative analysis useful for selecting the preferred alternative among competing alternatives.

Economics

- The study of
  1. the choices made by individuals, businesses, governments, and societies as they cope with **scarcity**.
  2. scarcity and efficiency.
- Scarcity
  - the **inability** to satisfy all of a society's wants (needs) at a point in time.
- Efficiency
  - Using available resources to satisfy the most needs (knowing that all needs cannot be satisfied).

Economic problem

- **Scarcity ➔ economic problem**
  - societal wants exceed resources available to produce goods and services to satisfy them
    - wants are satisfied from the consumption of goods and services
- Rich and poor alike face scarcity
  - no one can satisfy his or her wants or desires at a point in time.

Economic objective

- Satisfy as many societal wants as possible from available (although limited) productive resources (land, labour, capital and entrepreneurial spirit)
- Make the <u>best possible decisions</u> when confronted with several projects or investments
  - Avoid producing commodities which society does not value
  - Produce the commodities that society wants as efficiently as possible.

Economic way of thinking

- Scarcity involves making choices
- **Choices involve costs**
  - whatever we choose to do, we could have done something else instead
  - 7 to 10 pm: movies; theater, lecture; tennis …
- Choices are tradeoffs
  - give up something to get something else
  - highest valued alternative given up is the opportunity cost of the activity **chosen**
    - ✂But not the sum of all activities foregone

The Economic Problem

Inputs

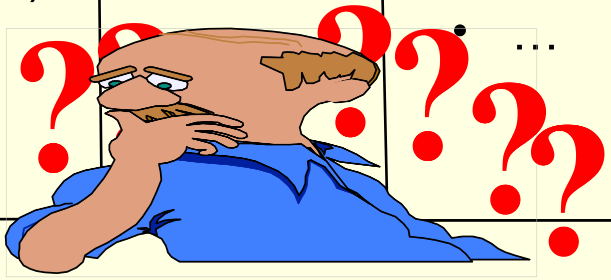
- Land
- Labour
- Capital
- Entrepreneurial spirit

(used to produce outputs)

Outputs

(Goods & services)

- Bread
- Books
- Computers
- …
- Health services
- Education
- …



The economic problem: Consumers want an unlimited quantity of goods and services to satisfy Their wants and desires. However, there is a limited quantity of inputs to produce goods and services.

The outcome: Decisions are required (choices must be made) by individuals, businesses and governments to ensure the largest number of wants will be satisfied (knowing that it is impossible to satisfy all wants).

Physical and economic efficiency

Physical efficiency (all points on PPF)

- measure of the success of engineering activity in the physical environment
- ratio of outputs to inputs
- maximum physical efficiency ratio is 1 (or 100%)
- physical units include BTUs, kw-hours, etc.

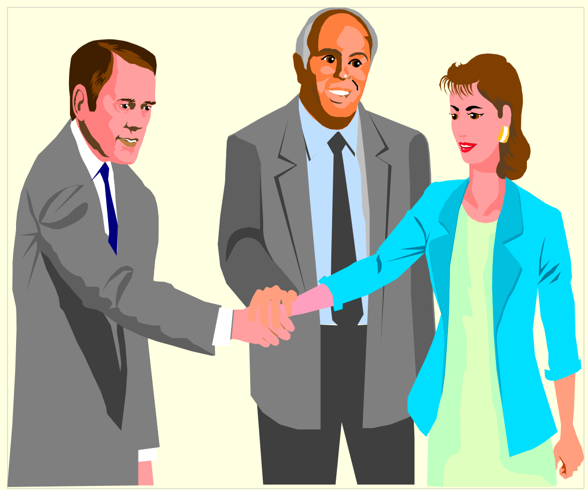
Economic efficiency (most-valued point on PPF)

- ratio of value or worth to cost.
- must exceed 1 (or 100%) to be successful.

The Engineer’s Role

Engineers

Identify Societal Needs (Goods & Services)



Use Scientific Knowledge To Satisfy Needs

Impossible to satisfy all societal needs or wants → choices

Engineering and science

Engineers

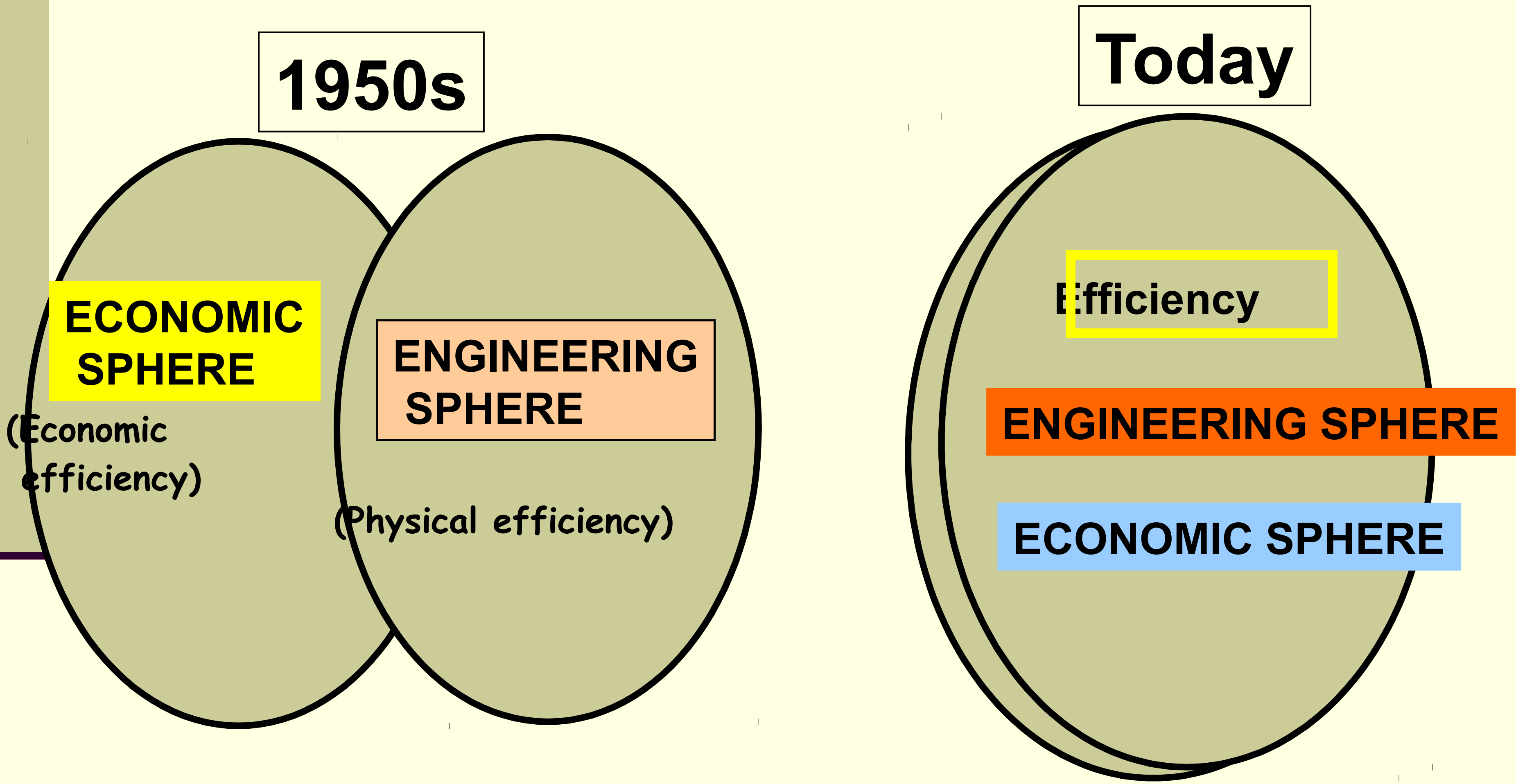
- apply science to satisfy human wants and desires
- have the dual task of determining
  - what society wants (its needs) and
  - the best combination of materials and forces etc. needed to produce the goods and services desired by society.

Scientists

  - discover laws of behaviour
  - expand the body of knowledge
- Science is the foundation upon which the engineer builds toward the advancement of mankind.
- The engineer applies this knowledge to produce products and services that satisfy more human wants and desires.

***Engineering activities are a means of satisfying human wants, and are not ends themselves*.**

Evolution of Economic and Physical Efficiency



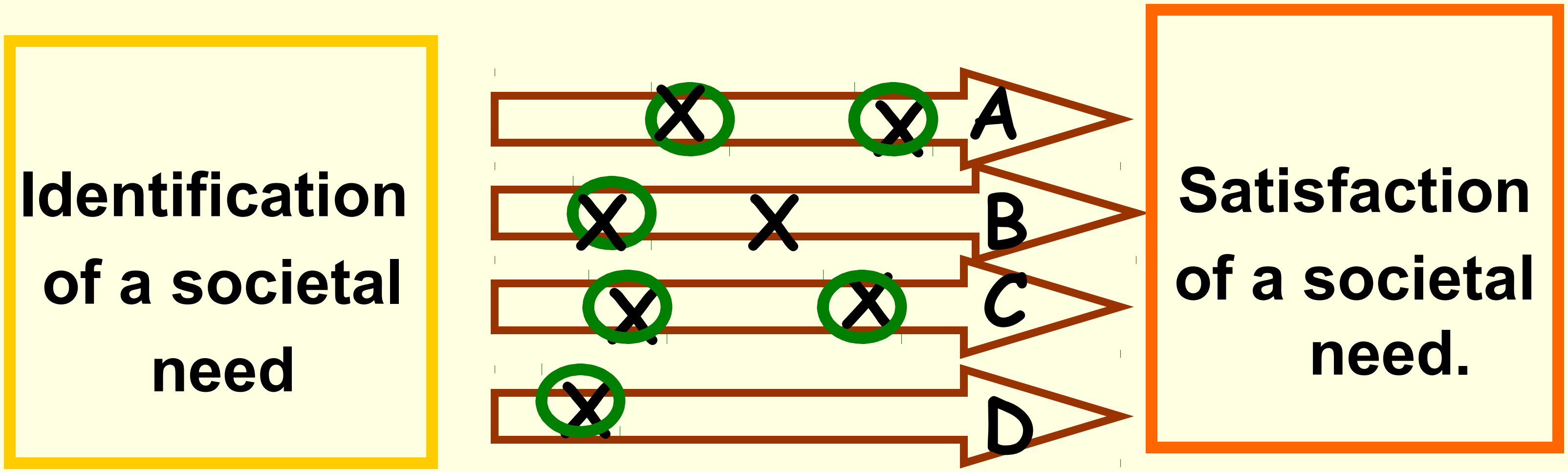
The engineering process

- Key steps by the engineering community to ensure that their activities will satisfy societal needs (wants).
  - Economic efficiency
- All activities (including engineering) not valued by society **WASTE** scarce (limited) resources.
  - Increase the gap between societal wants and the capacity to satisfy them.

Engineering Process

Key steps by the engineering community to ensure that their activities will satisfy societal needs (removing barriers).

Alternatives (A, B ..D) for satisfying human needs



A, B, C and D are competing alternatives for satisfying needs

X ≡ Obstacle; X ≡ Obstacle overcome

The engineering process

1. Engineering community identifies societal wants
   - how can engineering contribute to the satisfaction of these wants?
2. Identification of all limiting factors (obstacles) and strategic factors (obstacles that can be overcome).
   - Some obstacles can be eliminated (overcome).
     - Financial requirements; zoning bylaws; environmental regulations
3. Determination of means or proposals
   - study and investigation of how to eliminate limiting factors
     - basically a set of engineering proposals

The engineering process

4. Evaluation of alternatives
   - a <u>conversion</u> step to bring all engineering proposals to common denominators
     - Decision criteria (e.g., Present Worth and Annuities)
5. Decision-making
   - select the best proposal (economically efficient)

<u>This course focuses on steps 4 and 5.</u>

Definitions of cost and profit

- **Accounting**
  - cost and profit mainly in terms of **cash flows**
    - **explicit (tangible) monetary transfers from one party to another.**
    - examples: wages paid, payment for goods purchased.
- **Economic**
  - cost = explicit cash flows + implicit cost
  - Implicit cost example: the wages and interest income not received by a firm's owner(s)

Accounting vs Economic Cost

- Paul
  - quits his public service employment to purchase and operate a convenience store (C-store).
  - earned $50,000 annually as a public servant.
  - rented the retail space which he owned while a public servant for $24,000 annually.
  - sets up his C-Store in the retail space which he owned.
- In the first year of operating the C-Store, Paul
  - had revenues of $100,000.
  - paid himself a salary of $40,000.
  - had other expenses totalling $25,000.

Accounting vs Economic Cost

- Paul's
  1. accounting cost = 40,000+25,000 = $65,000
  2. accounting profit
     - Revenues – accounting costs
     - 100,000 – 40,000 – 25,000 = $35,000
  3. economic cost = accounting cost + implicit cost (forgone revenues)

     = 65,000 + (50,000-40,000)+24,000 = $99,000
  4. economic profit = 100,000-99,000=$1,000

Time value mechanics: capturing the importance of time in decision-making

- Time is a critical factor in engineering economic studies.
  - Reflects the preference for consuming goods and services **sooner than later**
  - the stronger the preference for consuming now over consuming later, the more important is time in investment decisions
- The amount and timing of a project's cash flows (operating expenses; revenues/sales) are crucial to the value of a project's worth.

Time value mechanics: Rate of interest

- The importance of time in engineering economic studies is captured by the rate of interest
  - a cost to the borrower, a source of income to the lender.
- The market rate of interest has three components: real; inflation; risk of default.
- This course focuses mostly on applications of rates of interest in inflation- and risk-free environments.

Key project parameters

- First or initial cost (P); $
- Salvage value (SV); $
- Operating revenue (OR or AOR); $
- Operating cost (OC or AOC); $
- Rate of interest or MARR (i%)

The rate of interest will be known as the MARR -- an acronym which stands for <u>M</u>inimum <u>A</u>cceptable <u>R</u>ate of <u>R</u>eturn

Example 1: Importance of Time_

Project Parameters	Project A	Project B
First cost or initial cost (P)	$10,000	10,000
Salvage value (SV; $)	$0	0
Life (N; years)	5 years	5 years
Net end-of-year (EOY) cash flows		
Year 1 ($)	Revenues – operating costs = 3,000	5,000
Year 2 ($)	3,000	4,000
Year 3 ($)	3,000	3,000
Year 4 ($)	3,000	2,000
Year 5 ($)	3,000	1,000

Example 1: Importance of Time

- Elements common to projects A & B
  - first or initial costs (i.e., $10,000)
  - duration or life of projects (5 years)
  - cumulative cash flows over 5 years (i.e., $15,000).
- If i = 0%, projects A & B are equivalent
  - indifferent between projects A or B
- If i > 0%, project A is superior to project B (see next slide).
- Negative interest rates (i% < 0%) have no economic meaning or significance.

Interest Rates & Value Today

Rate of interest	Project A's current value	Project B's current value
0%	$5,000	$5,000
5%	638	-919
10%	- 876	-1,453
15%	-1,471	-4,743
20%	-3,238	-6,927

Example 2: Importance of Time

Goal: $1 million retirement fund after working 40 years

- **8% rate of interest compounded annually (interest paid on interest income)**
- **contributions to the retirement fund at the end of each year**
- **the initial contributions to the fund are paid at the of the first year of work.**

Option	Contributions at end of years 1 to 9 inclusively	Contributions at end of years 10 to 40 inclusively
Option 1 (Good Times Now)	$0	$7,368
Option 2 (Good Times Later)	$8,107	$0

Contributions in option 1 total about $228,000 compared to $73,000 for option 2. Interest income generated by early contributions is responsible for the difference in required contributions.

Types of project analyses

1. Financial
   - Considers project-generated cash flows only
   - Objective: maximize profit
2. Economic
   - Considers all project effects (both explicit and implicit) on society's economic well-being
   - Objective: maximize economic well-being

1. Financial analysis of projects

Exclusive focus: cash flows

- Cash outflows (outlays or expenses)
  - Initial investments
  - Annual costs
  - Salvage values if negative
- Cash inflows
  - Annual revenues
  - Salvage values if positive
- Find a project’s NPW, AEW …..

1. Financial analysis of projects

- Quantitative approach (tangible or explicit cash flows only)
  - NPW, AEW, IRR, ERR
- Qualitative considerations can be used to tweak (adjust) the quantitative results
  - based on the experience/judgment of the decision-makers
- Hence, cash flows have priority in the decision-making process

Example 1. Financial analysis of snow clearing public roads

Cost and benefits	How measured
1. Noise pollution; interferes with sleep of residents	Public complaints; hard to quantity
2. Snowplow damage to roads and to residential property	Observation of damage
3. Fewer accidents; reduced material damages	Difference in number by experiment
4. Visible demonstration of property tax use	Political benefit
5. Snow in driveways; cost of removal	Cost of removal

Considers cash flows only.

Example 2: Financial analysis of information kiosks along major highways

Cost and benefits	**How measured**
1. Cost of maps, etc.	Cost of purchase: price x quantity
2. Telephone costs	Telephone bills
3. Insurance costs	Insurance premiums
4. More tourists in territory; tourists may stay for longer periods	Survey information
5. Tourists may return more frequently	Survey information
6. Advertising for campsites, hotels, restaurants ….	Survey information
7.Healthy to stop and stretch	Difficult to measure

Focus exclusively on cash flows.

Example 3: Financial analysis of a community re-cycling proposal

Revenues and Costs	How measured
1. Cost: Need for specialized equipment for collecting, sorting and processing newspapers …	Obtain price estimates of equipment and building costs (if required).
2. Cost: purchase of recycling boxes and "composters" for each household (provided free of charge).	Total cost = number of households multiplied by cost of boxes and "composters".
3. Costs by households (time, smells) of sorting garbage weekly.	Cost = Time required multiplied by an appropriate wage.
4. Benefits: sale of newspapers, cardboard, metal cans …	Estimate quantity recycled per household multiplied by the number of households and sale price of recycled material.
5. Savings: Landfill site will have longer life→ longer land purchase and acquisition costs.	Estimates of yearly waste volumes saved.
6. Savings: Reduced tipping fees.	Forecast reduction in waste volume brought to landfill site.
7. Reduced air and water pollution.	Surveys

1. Financial analysis: Pros and Cons

<u>Advantages</u>

1. Single model (only one approach).
2. Cash flows are somewhat reliable and readily available.
3. Simple calculations.

<u>Disadvantages</u>

4. Risk of wrong decision by excluding intangible information (e.g., value of time savings)
5. More difficult to explain project selection (value judgments can bias conclusion).

2. Economic Analysis

- Measures a project's benefits and costs on a target population's well-being (compulsory headgear for cyclists).
- All tangible and intangible impacts on the value of
  - goods and services
  - resources (labour, physical capital …)

must be

  - Identified
  - Converted to equivalent monetary values.

Example 1: Economic analysis of snow clearing public roads

Cost and benefits	How measured
1. Noise pollution; interferes with sleep of residents	Public complaints; hard to quantity
2. Snowplow damage to roads and residential property	Observation of damage
3. Fewer accidents; reduced material damages	Difference in number by experiment
4. Visible demonstration of property tax use	Political benefit
5. Snow in driveways; cost of removal	Cost of removal

All explicit and implicit project impacts must be considered.

Example 2: Economic analysis of information kiosks along major highways

- Major benefits to visitors
  - Provision of maps and brochures
  - Campground and hotel reservations
- Major cost
  - Staffing, building (capital) and maintenance
- Are there other costs and benefits?
- How are these costs and benefits measured?

2. Economic analysis: Information kiosks at border crossings

Cost and benefits	How measured
1. Cost of maps, etc.	Cost of purchase: price x quantity
2. Telephone costs	Telephone bills
3. Insurance costs	Insurance premiums
4. More tourists in territory; tourists may stay for longer periods	Survey information
5. Tourists may return more frequently	Survey information
6. Advertising for campsites, hotels, restaurants ….	Survey information
7.Healthy to stop and stretch	Difficult to measure

Example 3: Economic analysis of a proposed re-cycling program

- A city is proposing a new recycling and composting program.
- City residents will be responsible for separating
  - newspaper, cardboard, and metallic cans from regular waste which will be recycled by the city
  - "compostable" waste from other waste which they will be responsible for composting
- The city will
  - provide residents with recycling bins and composting units.
  - Collect recycled material weekly which will be sorted and sold by the city.
- **<u>Your Task</u>**
  1. Identify program benefits and costs.
  2. Discuss how program benefits and costs will be measured?

Example 3: Economic analysis of a proposed re-cycling program

Revenues and Costs	**How measured**
1. Cost: Need for specialized equipment for collecting, sorting and processing newspapers …	Obtain price estimates of equipment and building costs (if required).
2. Cost: purchase of recycling boxes and “composters” for each household (provided free of charge).	Total cost = number of households multiplied by cost of boxes and “composters”.
3. Costs by households (time, smells) of sorting garbage weekly.	Cost = Time required multiplied by an appropriate wage.
4. Benefits: sale of newspapers, cardboard, metal cans …	Estimate quantity recycled per household multiplied by the number of households and sale price of recycled material.
5. Savings: Landfill site will have longer life➔ longer land purchase and acquisition costs.	Estimates of yearly waste volumes saved.
6. Savings: Reduced tipping fees.	Forecast reduction in waste volume brought to landfill site.
7. Reduced air and water pollution.	Surveys

Economic Analysis: Pros and Cons

Advantages

- Analysis MUST account for all project impacts (positive and negative) on the economic welfare of a target population.

Disadvantages

- Range of values for most intangible impacts (e.g., disagreement over the value of a life)
- Disagreement over the discount rate to be used for public projects.
- Major emphasis on economic efficiency ➔ little concern for distributional issues
  - Who benefits? The rich? The poor? The more influential political class?

Course overview

- Many sections of this course can be applied to personal financial decisions. For example,
  - mortgage payment calculations
  - bond yields
  - financial & real property investments
  - effective credit card or car payment interest rates
  - …

Sample personal applications

1. Mary paid $9,775 for a $10,000 Canada Bond which has a 10-year life and pays 5% annual interest.
   - Her broker stated that the investment would yield x% but was unable to provide calculation details.
   - Would you
     - calculate the rate yourself?
     - accept the broker's word?
2. You are planning a major vacation in five years which you expect to cost $30,000. What annual savings are needed if money earns 5% annually?
3. How much of this month's mortgage payment is
   - Equity (repayment of the mortgage)?
   - Interest on the outstanding (unpaid) mortgage?

Typical cash flow patterns

1. Single sums (PW & FW)
2. Uniform series (annuities)
3. Linear gradient (arithmetic) series
4. Geometric gradient series
5. Irregular series

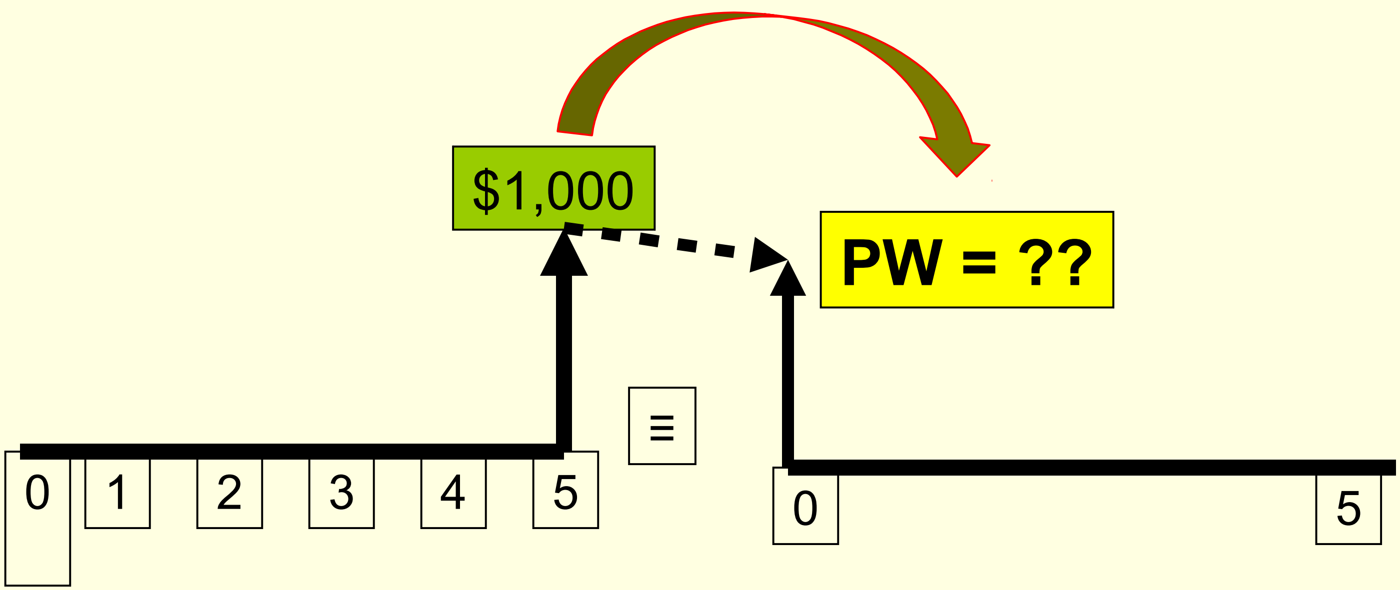
<u>Note</u>:

1. *Shortcuts for calculations of summary measures (e.g., NPW) are only possible for categories 1 to 4.*
2. *This section is irrelevant if NPW and other calculations are performed with a computer or financial calculator.*

Cash flow patterns

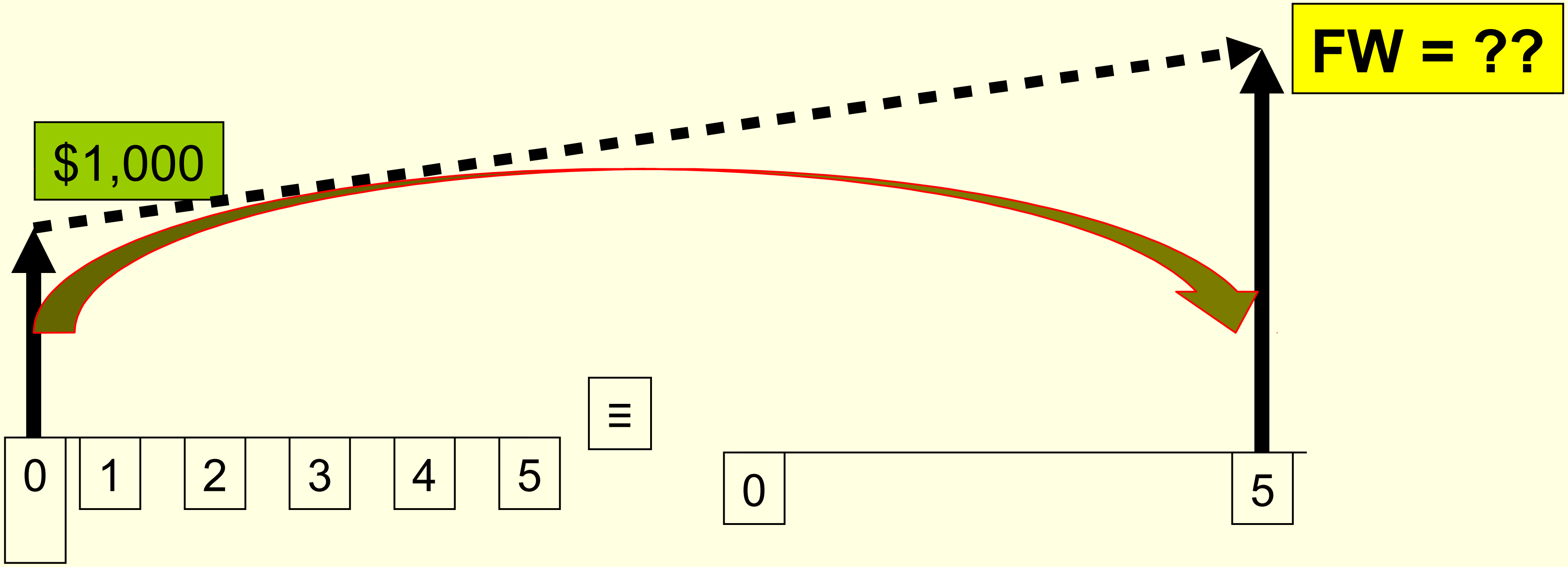
1. A single disbursement (money spent) or receipt (money received)
2. A set of equal disbursements or receipts over a sequence of periods, referred to as an **annuity**
3. A set of disbursements or receipts that change by a constant *amount* from one period to the next in a sequence of periods, referred to as an **arithmetic gradient series**
4. A set of disbursements or receipts that change by a constant *proportion* from one period to the next in a sequence of periods, referred to as a **geometric gradient series.**

Cash flow diagram
Present Worth (PW)



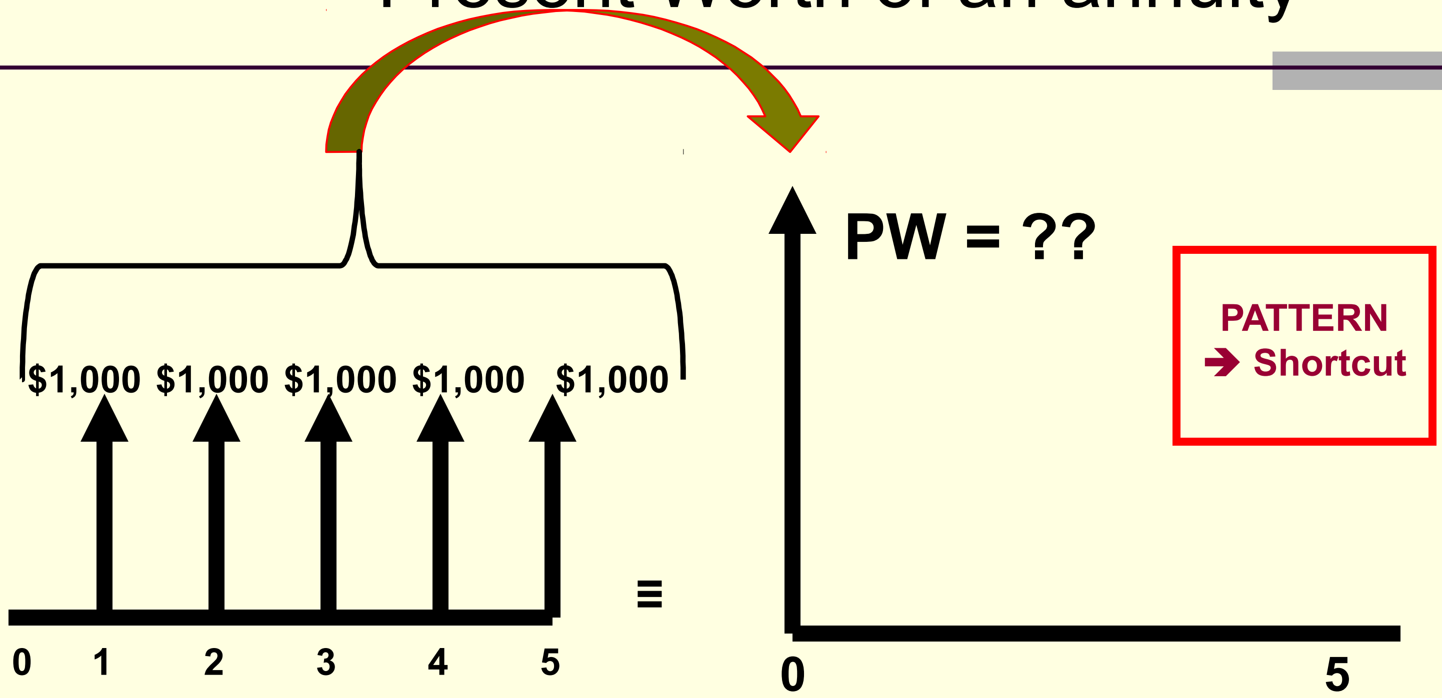
What is the value TODAY or NOW (time = 0) of $1,000 in five years for a given interest rate (e.g., 10%) compounded annually?

Cash flow diagram
Future Worth (FW)



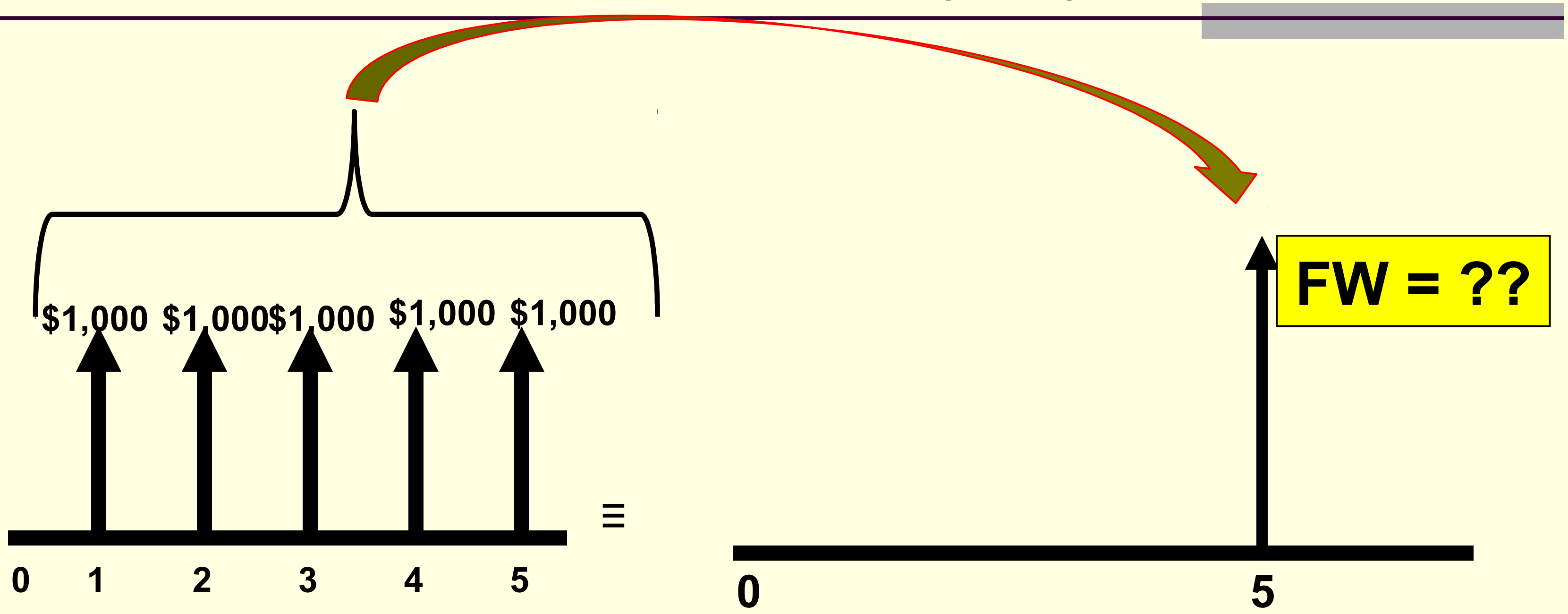
How much will $1,000 TODAY or NOW be worth in five years (t=5) for a given interest rate (e.g., 10% compounded annually)?

Cash Flow Diagram: Present Worth of an annuity



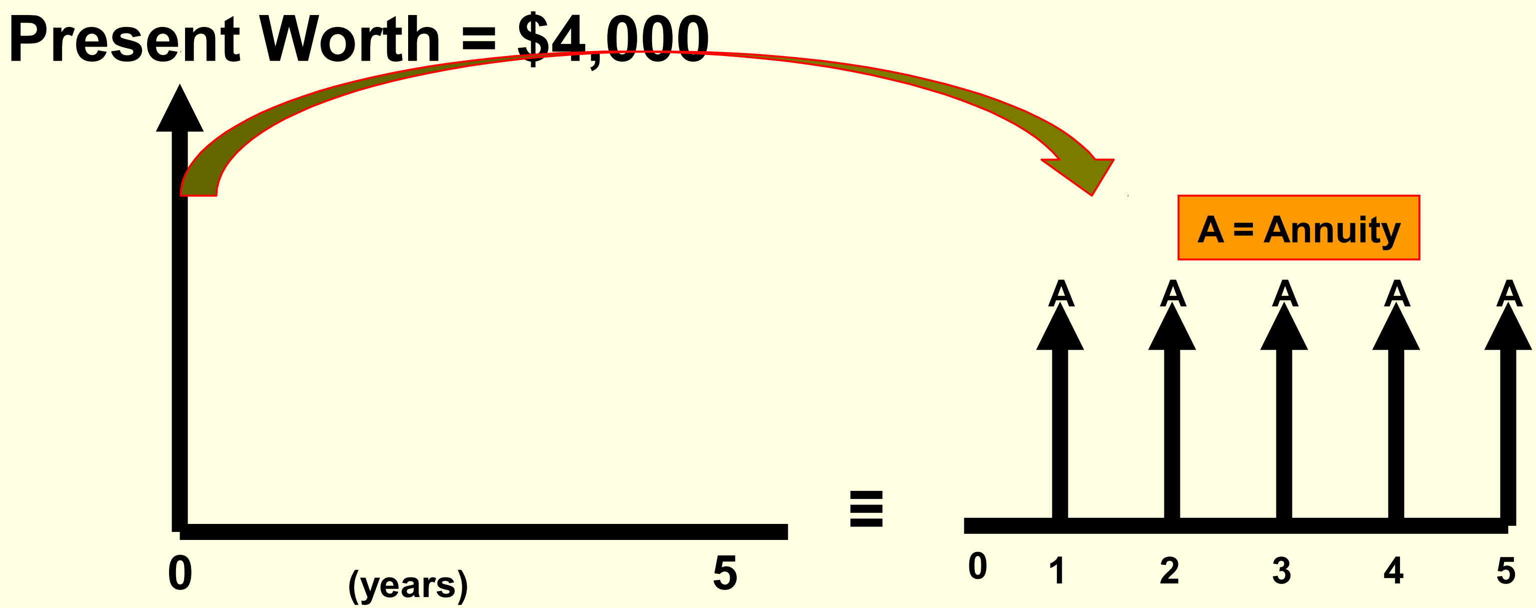
What is the value today (t=0) of five yearend deposits of $1,000 for a given rate of interest (e.g., 10% compounded annually)?

Cash Flow Diagram: Future Worth (FW)



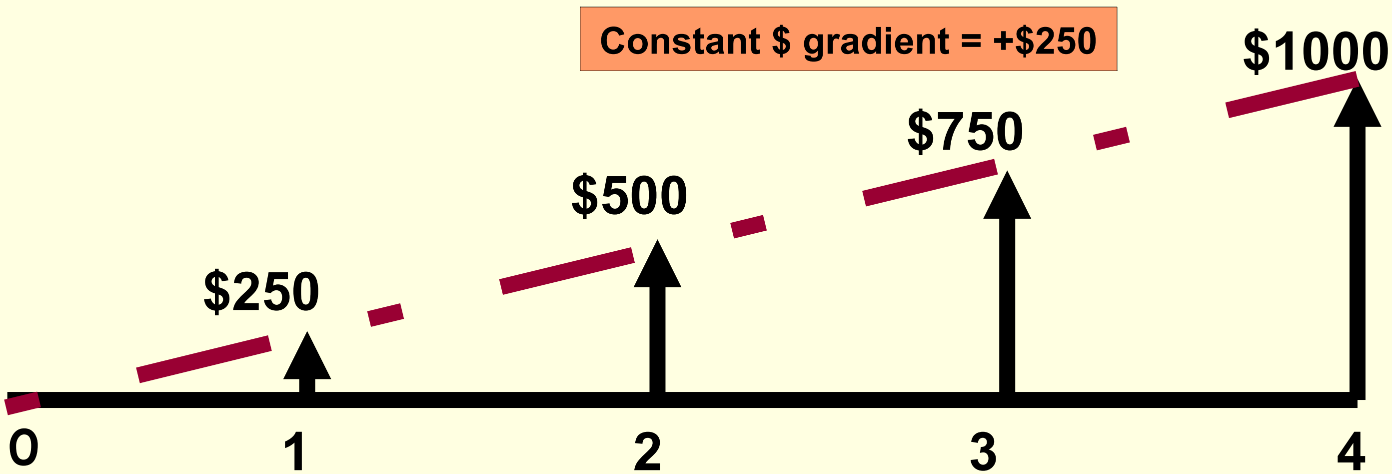
What will be the value in five years of five yearend deposits of $1,000 for a given compound interest rate (e.g., 10% compounded annually)?

Cash Flow Diagram: Converting a present value to an annuity



What annual cash flow over five years can be generated by $4,000 today at a given interest rate?

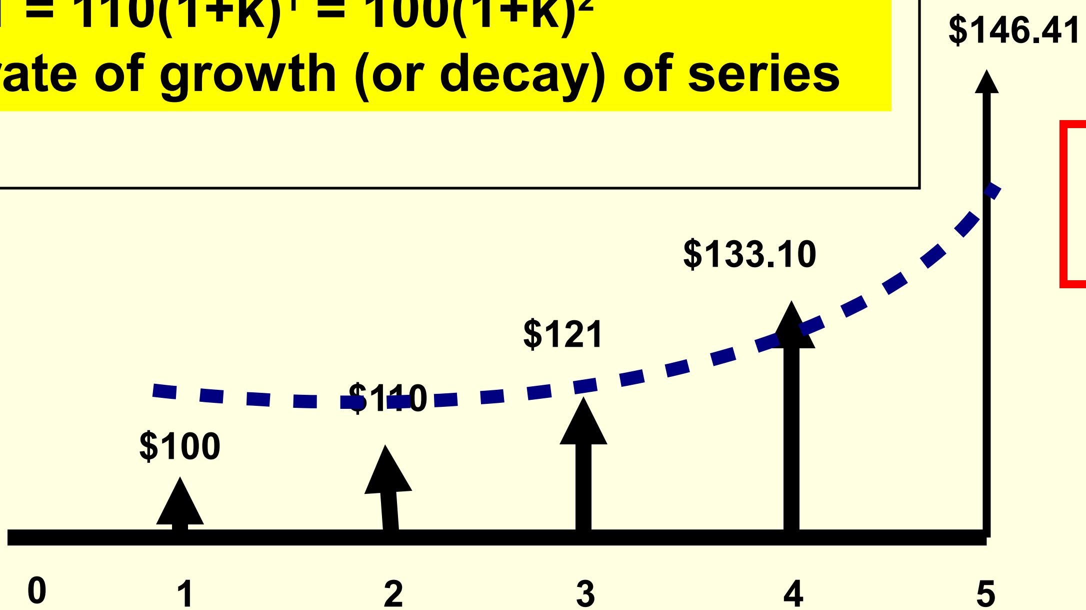
Cash Flow Diagram: Linear Gradient Series (Arithmetic Series)



- **An arithmetic (or gradient) series can be increasing (as shown) or decreasing**
- **The dollar difference between any two adjacent members must be the same.**

Cash Flow Diagram: Geometric Series

- **10% rate of growth (increase).**
- **$\$110 = 100(1+k)^1$**
- **$\$121 = 110(1+k)^1 = 100(1+k)^2$**
- **k ≡ rate of growth (or decay) of series**

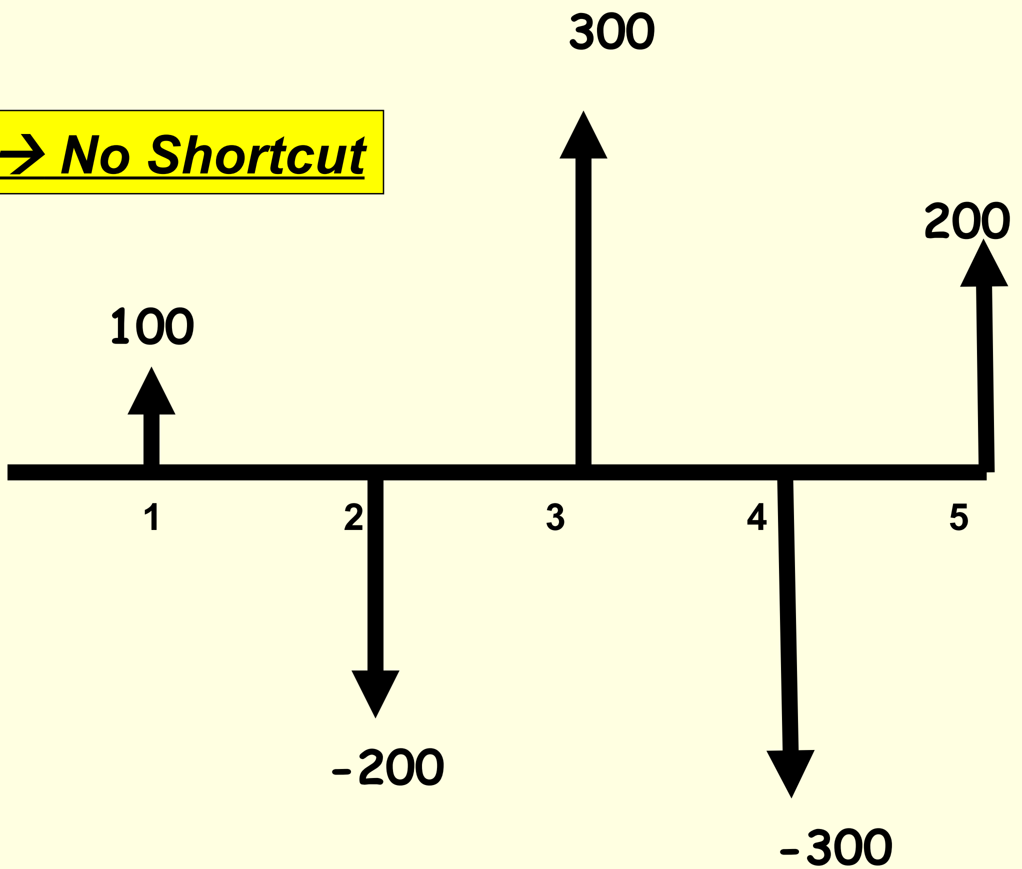


PATTERN
➔ Shortcut

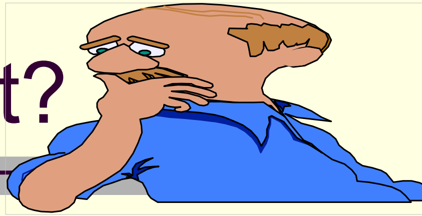
A series that increases (shown) or decreases at a given rate (e.g., 5% or -20%).

Cash Flow Diagram: Irregular Series (No pattern)

No Pattern → No Shortcut



Which projects are valid?
Which project (if any) is best?



Project parameters	Project A	Project B	Project C
First cost ($)	3,000	5,000	8,000
Annual cost ($)	600	900	1300
Annual revenues ($)	1500	1750	2000
Salvage value ($)	0	-200	1000
Duration (years)	5	10	20
Interest rate (10%)	10	10	10

- Difficult task because the projects have different parameters (identifiers)
  - Except for the interest rate
- A project conversion process is required (i.e., to summary measures) to reduce the projects to a common denominator such as a single sum (present or future worth).

Our objective for lectures 1 to 4

- Define interest rates
- Develop **major summary measures** of project evaluation **(decision criteria)**
  - single sums (present and future worth)
  - annual or periodic equivalent
  - internal rate of return
  - external rate of return
  - payback (simple and discounted)

Working Assumptions

1. No uncertainty, no risk
2. No government (no tax-deductible depreciation charges; no income taxes)
3. No debt capital (only equity capital)
4. No price changes (no inflation/deflation)
5. Single business objective
   - Maximise profits
   - Minimise costs

Next week: Topic 2

Time-Value Mechanics

Engineering Economics
ECO 1192

Topic 1: Introduction

Claude Théoret
University of Ottawa