



Engineering Economics

Computer System Engineering, QUEST
Spring 2019

*“Economy is how to spend
money without enjoying it”*



Engineering & Economics

- Engineers apply science and technology to develop cost-effective solutions to practical problems. Cost-effective means economic.
- Economics is the study of how individuals and groups make decisions about the allocation of limited resources. Example: using principles of economics, a person might decide it is better to lease rather than purchase an automobile.
- Engineering Economics is the application of economic techniques to engineering decisions. Engineers often have to decide among alternatives. Which of several designs to use? Which of several projects to pursue? Engineering economics gives engineers the tools they need to make decisions that maximize the use of resources.



Why study Engineering Economics?

- The Accreditation Board for Engineering and Technology (ABET) defines Engineering as:

“The profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, ██████████ the materials and forces of nature for the benefit of mankind”

- Economically is an important qualifier in the definition of engineering.
- A successfully engineered solution is one that not only works from a technical perspective, but also from an economic one.
- An economical solution is one that makes efficient use of resources.



More reasons to study Engineering Economics

- Approximately 4% of the questions on the Fundamentals of Engineering (FE) exam deal with Engineering Economy. Passing the FE exam is one of the major hurdles to becoming a licensed Professional Engineering (PE).
- Engineering Economics was recently added to one of the 11 Knowledge Areas covered by the Certified Software Development Professional (CSDP) exam.
- Just as business people need a basic understanding of technology in order to make wise business decisions, Computer engineers need a basic understanding of economics in order to make wise technical decisions. Wise technical decisions, from an economics perspective, are ones that maximize available resources.

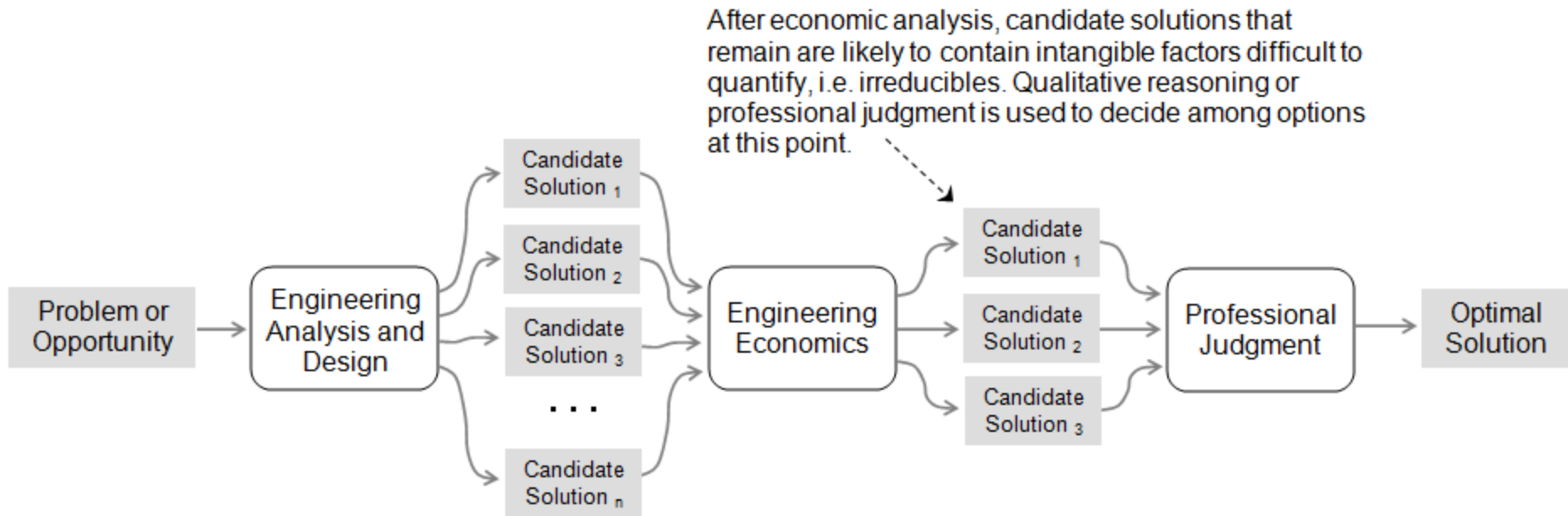


Economics

- Economics is the science of choice.
- We live in a resource-constrained world. Available resources are insufficient to satisfy all wants and needs.
- The resources that are available have alternative uses. You could purchase the latest smart phone, but if you did that means forgoing some other use for your money such as saving it or purchasing new cloths. Your decision is an economic one. You make it with the goal of maximizing your self-interest (Pursuing your self-interest doesn't necessarily mean being selfish. You might decide to forgo a smart phone in order to make a larger donation to your favorite charity. Your self-interest might be helping others.)
- Economics is the study of how countries (macroeconomics) and individuals (microeconomics) make decisions to allocate limited resources.
- Engineering economics is the application of microeconomics to engineering projects.

Engineering Economics in Context

- General workflow for engineering a solution:



Technical Analysis → Financial Analysis → Professional Judgment.



A systematic process for making business decisions

1. Understand the problem
2. Identify all technically-feasible candidate solutions.
3. Define the selection criteria (e.g. Return on investment, delivery date, performance, risk, etc.)
4. Evaluate each proposal against selection criteria. Since cost is always a consideration, this step will include the development of **cash flows** and the computation of **present value** (or equivalent) for each alternative. This step also includes consideration of intangible factors (irreducibles).
5. Use professional judgment to select the preferred solution.
6. Monitor performance of solution selected. Use feedback to calibrate decision making process.



Practical Questions Answered by Economics

- Here is a mix of engineering and non-engineering questions you should be able to answer at the end of this lesson. Note, the techniques described here will be personally valuable even if you don't apply them in an engineering context.
 - Does it cost less to rewrite a software system, which would lower your monthly maintenance costs, or continue paying a higher monthly maintenance cost but avoid the upfront cost of a rewrite?
 - Is it better to buy or lease an automobile/computer?



Practical Questions—2

- You are trying to decide between two projects. Project A would cost \$12K in staff salaries each month for 3 years and result in a one-time payment at the end for \$500K. Project B would cost \$10K a month for 3 years in staff salaries but result in yearend payments of \$150K. Which one has the greatest ROI?
- You and 3 classmates agree to share evenly the cost of renting a \$1000/month apartment for 3 years. One of your roommates, agrees to pay the \$2000 deposit (which he will get back at the end of the 3-year rental period). How much less should he pay each month?
- User interface A cost \$80,000. User interface B cost \$275,000 but is expected to save each user 10 minutes a day. Each user's time is worth \$20 hour. There are 60 users. The system is expected to be in production for 5 years. Which UI is the better value? (Assume a 6% interest rate.)
- A regular furnace cost \$x. A high-efficiency furnace cost \$y. The average monthly bill with the regular furnace is expected to be \$a. The average monthly bill with the high-efficiency furnace is expected to be \$b. How long until the high-efficiency furnace pays for itself?



Practical Questions—3

- You and a partner start a new business. You agree to make a \$24,000 down payment toward office equipment. Your partner agrees to pay the monthly expenses of \$2,000. At the end of 10 years your partner agrees to sell you his stake in the company. In order to value his stake in the company, you first have to calculate how much both of you have invested. How much have each of you invested?



Economic Fundamentals

- Cash flow and cash flow diagrams
- Time value of money
- Inflation and purchasing power
- Interest
 - Simple
 - Compound
- Interest Formulas
- Economic Equivalence



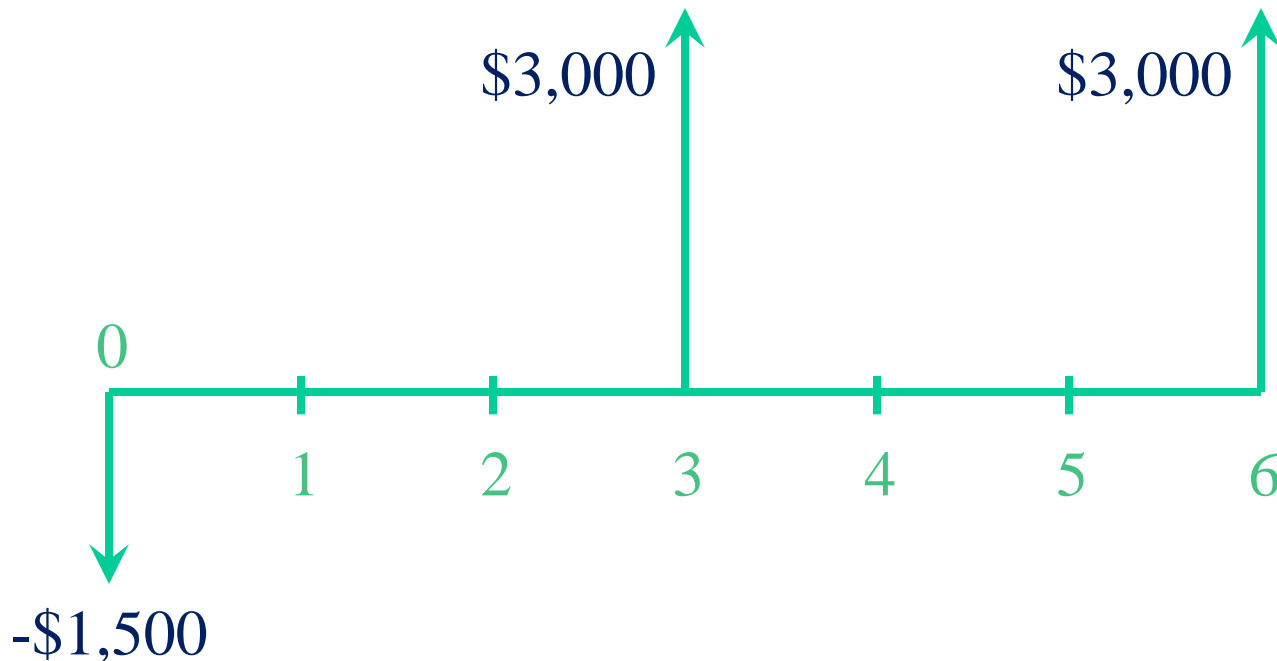
Cash-Flow

- Cash flow refers to the money entering or leaving a project or business during a specific period of time.
- When analyzing the economic feasibility of a project or design, you will compare its cash flow with the cash flow of other alternatives.
- The following table shows the cash flow for a simple 6-month project. The project starts on January 1 with a small initial investment and receives income in two installments.

Date	Amount
Jan 1	- 1,500
March 31	+ 3,000
June 30	+ 3,000

Cash-Flow Diagram

- A cash flow diagram shows a visual representation of a cash flow (receipts and disbursements).
- For instance, here is the cash flow diagram for the cash flow described in the table on the previous slide.

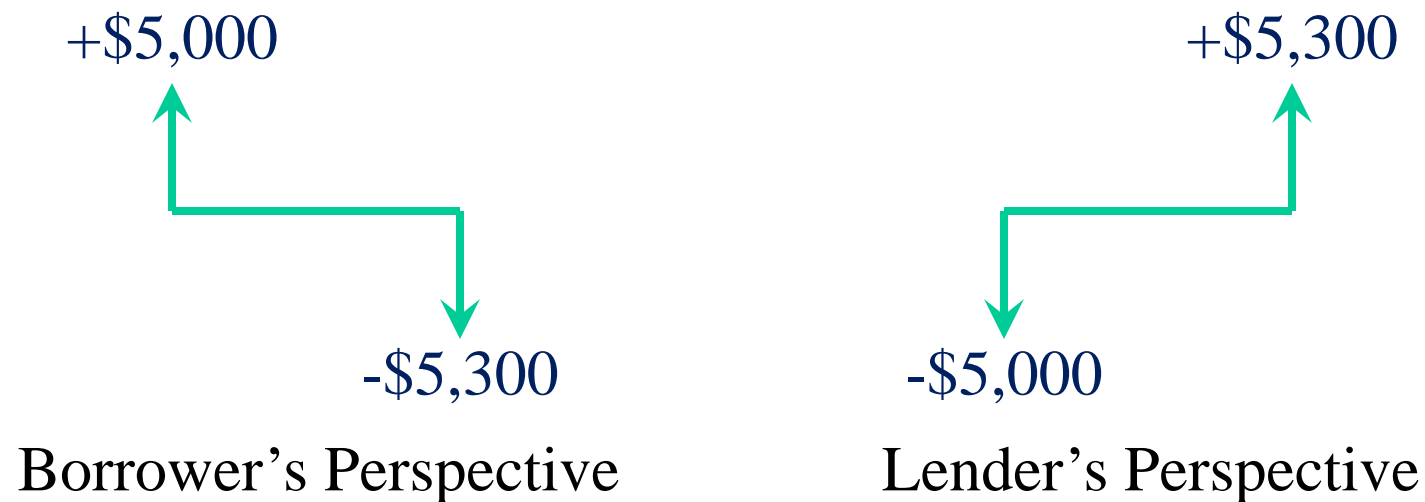


Cash-Flow Diagram—Details

- The horizontal axis represents time. It is divided into equal time periods (days, months, years, etc.) and stretches for the duration of the project.
- Cash inflows (income, withdraws, etc.) are represented by upward pointing arrows.
- Cash outflows (expenses, deposits, etc.) are represented by downward pointing arrows.
- Cash flows that occur within a time period (both inflows and outflows), are added together and represented with a single arrow at the end of the period.
- When space allows, arrow lengths are drawn proportional to the magnitude of the cash flow.
- Initial investments are show at time 0.

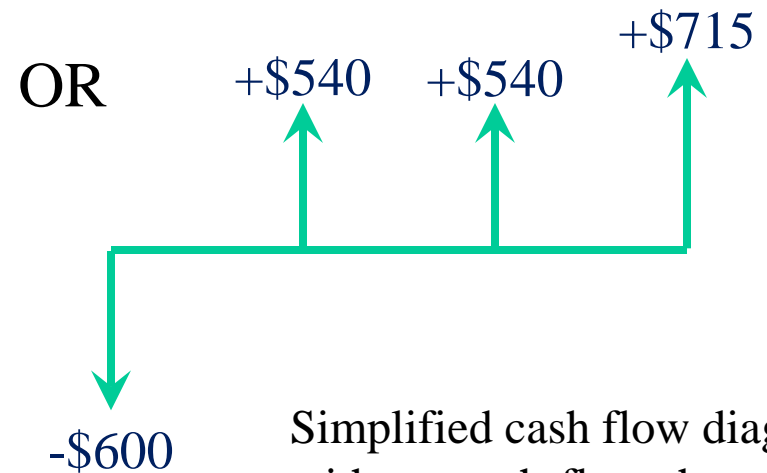
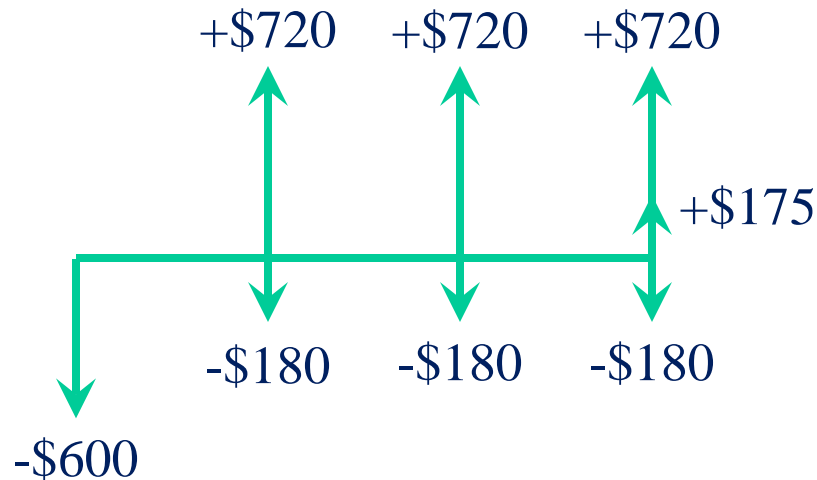
Cash-Flow Diagram—Perspective

- Cash flow diagrams are always from some perspective.
- A transfer of money will be an inflow or outflow depending on your perspective.
- Consider a borrower that takes out a loan for \$5,000 at 6% interest. From the borrower's perspective, the amount borrowed is an inflow. From the lender's perspective, it is an outflow.



Cash-Flow Diagram—Example

- A lawn mower will cost \$600. Maintenance costs are expected to be \$180 per year. Income from mowing lawns is expected to be \$720 a year. The salvage value after 3 years is expected to be \$175.



Simplified cash flow diagram with net cash-flow shown at the end of each time period.



Time Value of Money

- \$100 received today is worth more than \$100 received one year from now.
- If you don't believe this, give me \$100 and I will gladly give you back \$100 in one year.
- That would be a bad deal for you because:
 - I could invest the money and keep the interest earned on your money.
 - If there was inflation in the economy during the time I was holding onto your money, the purchasing power of the \$100 I give back will be less than the \$100 you gave me.
 - There is a risk I won't return the money.
- For all these reasons, when discussing cash flows over time you have to take into account the time value of money.

Interest

- Because of the time value of money, whenever money is loaned, the lender expects to get back the money loaned plus interest.
- Interest is the price paid for the use of borrowed money. As with any financial transaction, interest is either something you pay (a disbursement) or something you earn (a receipt) depending on whether you are doing the borrowing or the lending.
- Interest earned/paid is a certain percentage of the amount loaned/borrowed.

Simple Interest

- With simple interest, interest accrues only on the principle amount invested.
- Example. What is the value of \$100 after 3 years when invested at a simple interest rate of 10% per year?

$$\$100 * 10\% = \$10$$

$$\$100 * 10\% = \$10$$

$$\$100 * 10\% = \$10$$

$$\$30$$

$$\$100 + \$30 = \$130$$

Compound Interest

- With compound interest, interest is earned on interest.
- Example. What is the value of \$100 after 3 years when invested at a compound interest rate of 10% per year?

$$\$100.00 * 10\% = \$10.00$$

$$\$110.00 * 10\% = \$11.00$$

$$\$121.00 * 10\% = \$12.10$$

$$\$33.10$$

$$\$100.00 + \$33.10 = \$133.10$$

- Or,

$$\$100 * 1.10 * 1.10 * 1.10$$

Compound Interest—Formula

- The general compound interest formula is:

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

Where,

F = Future value (how much P will be worth in the future)

P = Present value (money invested today)

i = interest rate

N = number of interest periods

- The standard symbol for the above formula is:

$$F = P(F/P, i, N)$$

Interest Factor: P to F

- Notice that the compound interest formula:

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

includes the factor $(1+i)^N$. Present value P (how much money you have today) multiplied by this factor yields future value F (how much you will have in the future).

- For example, if the interest rate is 6% and the number of periods is 4, the interest factor is:

$$(1+.06)^4 = 1.4185$$

- So, the future value of \$500 when invested at 6% interest for 4 years is:

$$\$500 * 1.4185 = \$709.26$$

- The future value of \$900 when invested at 6% interest for 4 years is:

$$\$900 * 1.4185 = \$1,276.65$$

Interest Factor: F to P

- Solving for P in the compound interest formula yields a formula for going the other direction: converting future value F to present value P:

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

$$P = F * (1+i)^{-N}$$

- For example, you make a bet with someone, the outcome of which won't be known for 4 years. If you lose, you owe \$500. How much do you need to set aside today to cover your \$500 bet assuming the prevailing interest rate is 6%?

$$(1+.06)^{-4} = .7921$$

$$\$500 * .7921 = \$396.05$$

Interest Formulas

- The P to F factor, $F = P * (1+i)^N$, is called Single-Payment Compound-Amount and is written:

$$F = P(F/P,i,N)$$

- The F to P factor, $P = F * (1+i)^{-N}$, is called Single-Payment Present-Worth and is written:

$$P = F(P/F,i,N)$$

- These are just 2 of 6 interest formulas we will study.
- All are used to convert the value of money at one point in time to an equivalent value at another point in time.



Name	Symbol	Cash Flow Diagram	What question does it answer?
Single-Payment Compound-Amount	$F = P(F/P, i, n)$		If you invest \$P at i% interest. How much will you have after n years?
Single-Payment Present-Worth	$P = F(P/F, i, n)$		How much do you need to invest today if you want \$F after n years, assuming an interest rate of i%?
Equal-Payment-Series Compound-Amount	$F = A(F/A, i, n)$		If you invest \$A every year for n years, how much will you have after n years, assuming an interest rate of i%?
Equal-Payment-Series Sinking-Fund	$A = F(A/F, i, n)$		If you want to have \$F in n years, how much do you need to set aside each year, assuming an interest rate of i%?
Equal-Payment-Series Capital-Recovery	$A = P(A/P, i, n)$		What are the yearly payments on \$P borrowed assuming n payments and an interest rate of i%?
Equal-Payment-Series Present-Worth	$P = A(P/A, i, n)$		How much is a series of n \$A payments worth today, assuming an interest rate of i%?

Six Interest Formulas

Definition of symbols used on previous page...

P = Present Worth (Present sum of money)

F = Future Worth (Future sum of money)

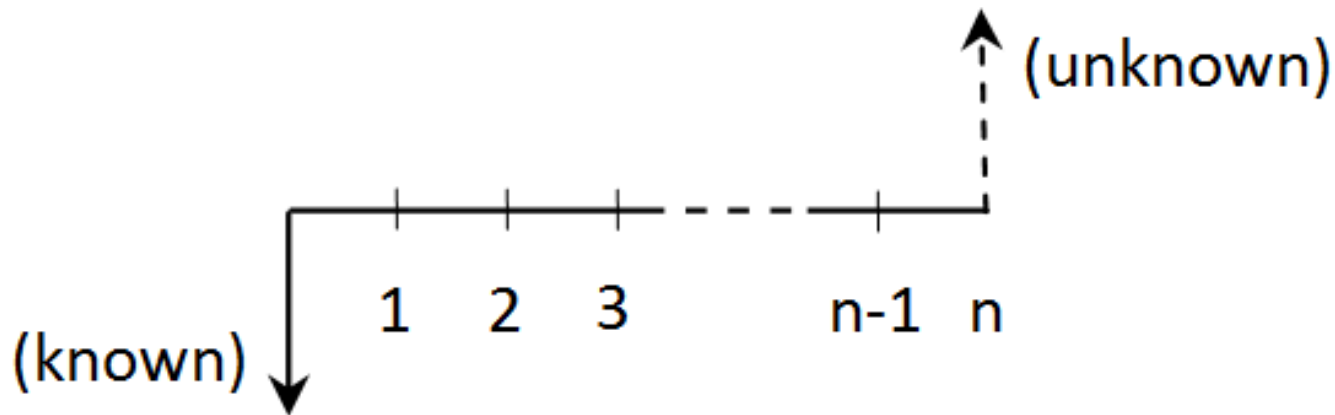
n = Number of interest periods

i = Interest rate per period

A = Amount of a regular end-of-period payment

Single-Payment Compound-Amount

- Formula: $F = P(F/P, i, n)$
- This formula can be used to calculate the compounded interest on a single payment. It tells how much a certain investment earning compound interest will be worth in the future.
- Cash flow diagram:



Example

You are considering a project that will require a \$300,000 investment. A viable alternative that must be considered is to “do nothing” and bank the money that would have been invested in the project. What is the value of \$300,000 after 8 years assuming an interest rate of 6%? In shorthand notation:

$$F = \$300,000 * (F/P, 6\%, 8)$$

Using the formula derived earlier:

$$F = \$300,000 * (1+.06)^8$$

$$F = \$478,154$$

Using the interest table at the right:

$$F = \$300,000 * 1.5938$$

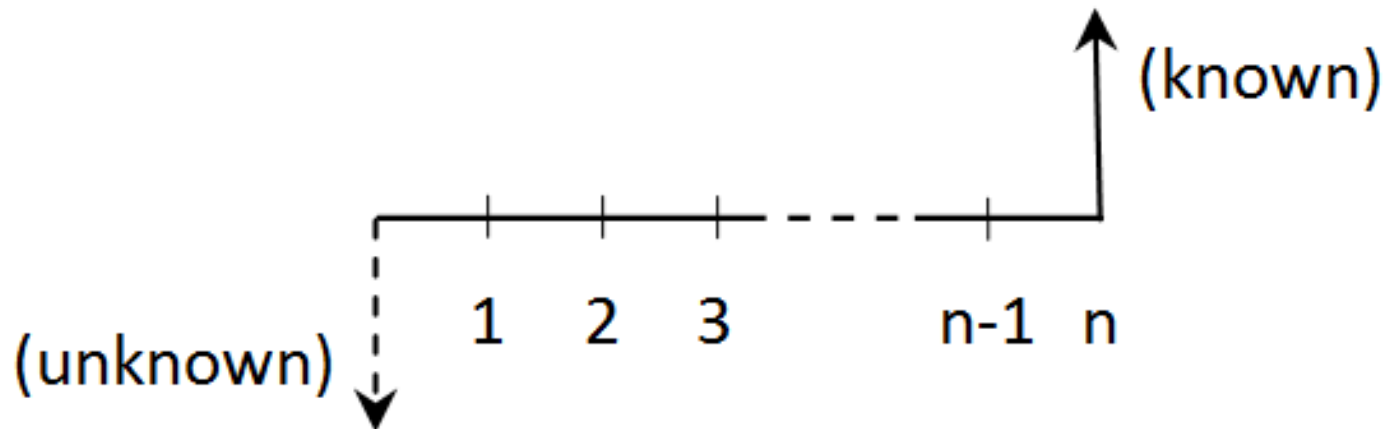
$$F = \$478,140$$

Table B.10. 6% Interest Factors for Discrete Compounding

n	Single-Payment	
	Compound-Amount	Present-Worth
	Find F Given P (F/P,i,n)	Find P Given F (P/F,i,n)
1	1.0600	0.9434
2	1.1236	0.8900
3	1.1910	0.8396
4	1.2625	0.7921
5	1.3382	0.7473
6	1.4185	0.7050
7	1.5036	0.6651
8	1.5938	0.6274
9	1.6895	0.5919

Single-Payment Present-Worth

- Formula: $P = F(P/F, i, n)$
- The previous formula computed F given P . This formula computes P given F . It tells the present value of some future amount. In English, it tells how much needs to be invested today order to have a certain sum in the future.
- Cash flow diagram:



Example

You are writing a proposal for a science experiment that will be launched into space in 6 years. The cost of the launch is expected to be \$500,000. How much do you need to set aside today, in order to have \$500,000 in 6 years assuming an interest rate of 5%?

$$P = \$500,000 * (P/F, 5\%, 6)$$

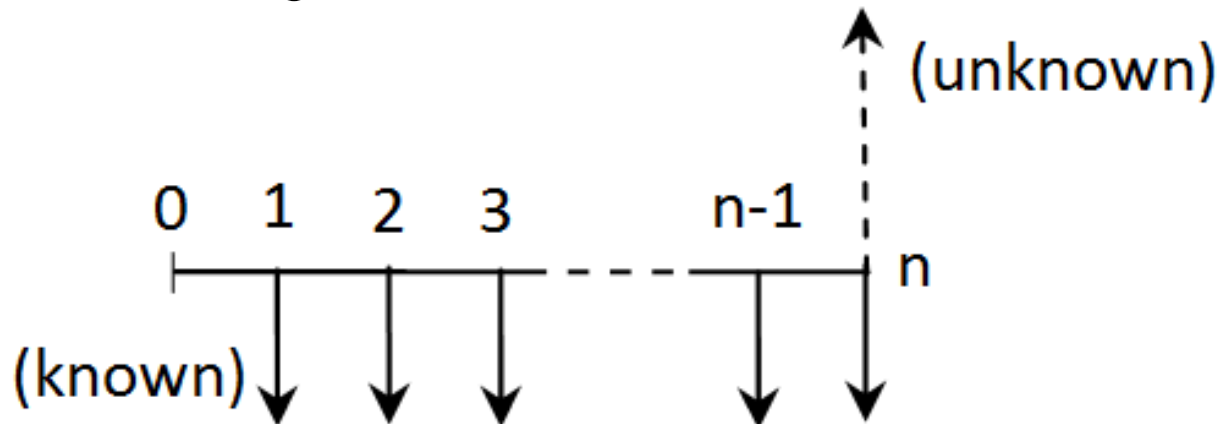
Using the formula derived earlier:

$$P = \$500,000 * (1+.05)^{-6}$$

$$P = \$373,108$$

Equal-Payment-Series Compound-Amount

- Formula: $F = A(F/A, i, n)$
- The previous 2 formulas dealt with the time value of one-time payments. The next 4 formulas deal with the time value of a series of equal payments.
- This formula can be used to calculate the future value of a number of equal payments.
- Cash flow diagram:





Example

You do a budget after starting a new job and calculate you have \$230 left over each month after paying expenses. How much will you have after 3 years if you invest \$230 each month assuming a yearly interest rate of 4%?

$$F = \$230 * (F/A, 4\%/12, 3*12)$$

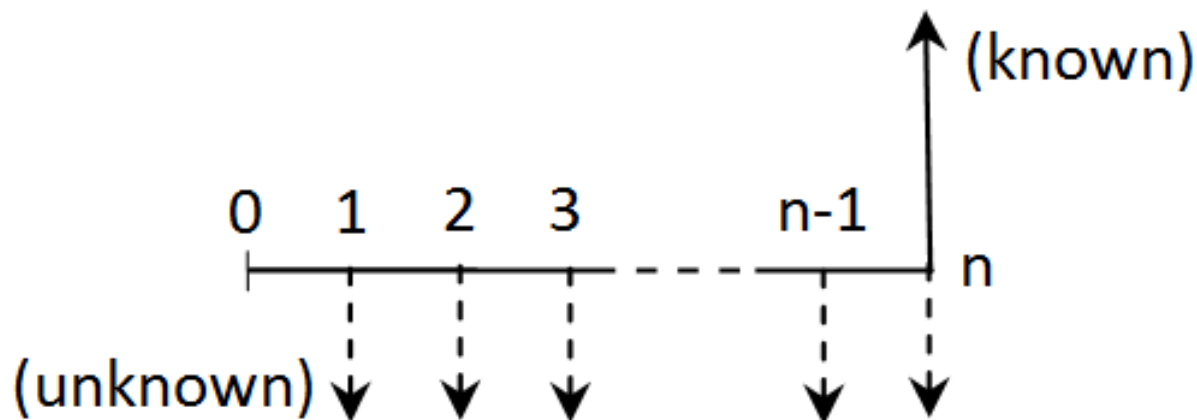
Using Excel:

$$F = FV(4\%/12, 3*12, 230)$$

$$F = \$8,781$$

Equal-Payment-Series Sinking-Fund

- Formula: $A = F(A/F, i, n)$
- This formula calculates the inverse of the previous. This formula tell you how much you need to set aside each year/month/etc in order to have a certain amount of money at the end of the equal payments.
- Cash flow diagram:



Example

- You just got a new job and are trying to decide whether to begin saving for retirement now or in a few years. You are 25 years old and expect to retire when you are 65. You feel you can save \$300 a month toward retirement. Using the previous formula and assuming an interest rate of 6%, you calculate that if you start saving today, you will have \$597,447 when you are ready to retire.

$$F = \$300 * (F/A, 6\%/12, 40*12)$$

Using Excel:

$$F = FV(6\%/12, 40*12, 300)$$

$$F = \$597,447$$

The question is, how much will you have to save each month if you wait 2 years before you start saving for retirement?

$$A = \$597,447 * (A/F, 6\%/12, 38*12)$$

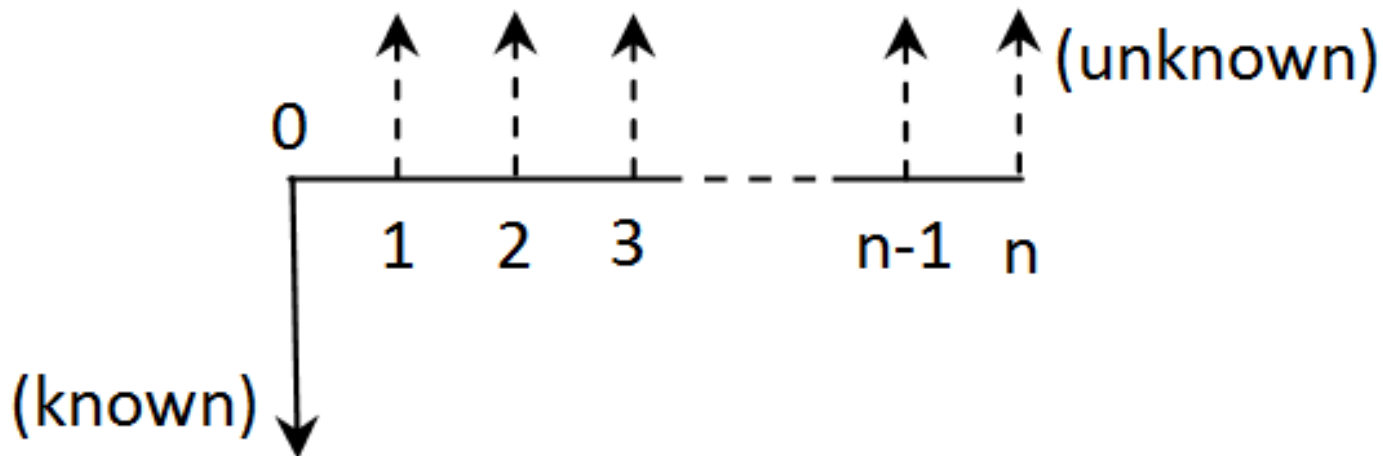
Using Excel:

$$A = =PMT(6\%/12, 38*12, , 597447)$$

$$A = \$343$$

Equal-Payment-Series Capital-Recovery

- Formula: $A = P(A/P, i, n)$
- This is the standard formula for calculating the payments on a loan. It tells the amount of equal payments needed to recover an initial amount of capital.
- Cash flow diagram:



Example

- You borrow \$50,000 to purchase a rack mounted server which you plan to pay off in 7 years. What are the yearly payments assuming a compound interest rate of 8%?

$$A = \$50,000 * (A/P, 8\%, 7)$$

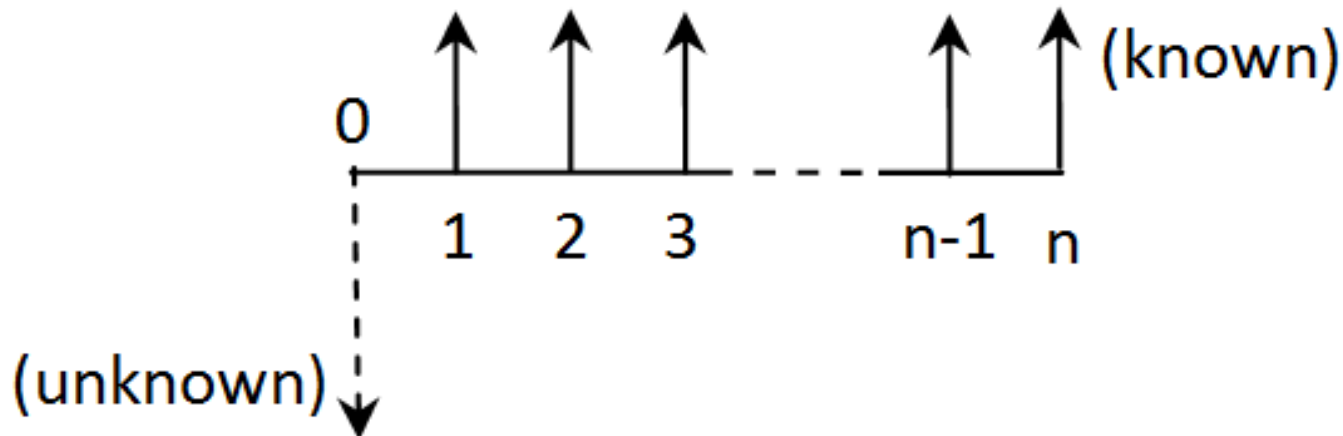
Using Excel:

$$A = \text{PMT}(8\%, 7, 50000)$$

$$A = \$9,604$$

Equal-Payment-Series Present-Worth

- Formula: $P = A(P/A, i, n)$
- This formula is the inverse of the previous. It gives the current value of a series of future equal payments.
- Cash flow diagram:



Example

- You are currently paying \$800 a month in rent. What amount of money borrowed would equal \$800 a month for 30 years at 5.5% interest?

$$P = \$800 * (P/A, 5.5\%/12, 30*12)$$

Using Excel:

$$P = PV(5.5\%/12, 30*12, 800)$$

$$P = \$140,897$$



Economic Equivalence

- The above formulas can be used to solve simple problems such as “how much will I have after 3 years if I save \$100 each month assuming a 3% interest rate”.
- They can also be used to answer more complex economic equivalence problems, such as “In an environment where the interest rate is 7%, which of the following is worth more?”
 - a. \$21,000 5 years from now
 - b. \$3,500 each year for 5 years
 - c. \$15,000 now
- To solve a problem like this you convert each option to a single cash flow that occurs at a common point in time (almost always present or future worth).

Solution

- Using Excel we convert each amount into present value. (Converting each option into future worth would have been an equally valid option.)
- Of the three, the most profitable option is option #3: take \$15,000 now.

	A	B	C	D	E
1					
2		\$21,000.00	5 years from now	\$14,972.71	=PV(7%,5,, -B2)
3		\$3,500.00	each year for 5 years	\$14,350.69	=PV(7%,5,-B3)
4		\$15,000.00	now	\$15,000.00	=B4



Engineering Example

User interface A cost \$80,000. User interface B cost \$275,000 but is expected to save each user 10 minutes a day. Each user's time is worth \$20 hour. There are 60 users. The system is expected to be in production for 5 years. Which UI is the better value? (Assume a 6% interest rate.)

\$48,000 is saved each year (see calculation in notes section)

The cost of UI B is \$275,000 – present value of \$48,000 equal payments over 5 years.

$$P = \$48,000 * (P/A, 6\%, 5)$$

$$P = \$202,193$$

$$\$275,000 - \$202,193 = \$72,807$$

The \$275,000 UI is a better value.



Advanced Economic Topics Not Covered

- Inflation
- Depreciation
- Taxes
- Sensitivity Analysis
- Uncertainty



References

- Steve Tockey. Return on Software: Maximizing the Return on Your Software Investment, Addison-Wesley, 2005.