Engineering Economic Analysis

Sam Labi

Purdue University School of Civil Engineering,
West Lafayette, IN

- Part 1: Introductory Concepts
- Part 2: Evaluation of Alternatives
- Part 3: Depreciation

- Cash Flow Illustrations
- The 5 Variables in any Cash Flow Diagram
- Equivalence Equations

The basis for engineering economics:

1. Economic efficiency is a key criterion for evaluation of a civil engineering system

2. The value of money changes over time ($1,000 today is not the same as $1,000 in 1993, and is not the same as $1,000 in 2013)

Simple Interest vs. Compound Interest

1. Simple Interest

Let's say in Dec 2003 you borrow $1000 with 5% simple interest

Year	Principal	Interest	Total Amount Owed at the End of The Year (=Principal + Interest)
Dec 2003	$1000		$1000
Dec 2004		$50	$1050
Dec 2005		$50	$1100
Dec 2006		$50	$1150
Dec 2007		$50	$1200

2. Compound Interest

Let's say in Dec 2003 you borrow $1000 with 5% compound interest

Year	Principal	Interest	Total Amount Owed at the End of The Year (=Principal + Interest)
Dec 2003	$1000	-	$1000
Dec 2004	$1000	$50	$1050
Dec 2005	$1050	$52.5	$1102.5
Dec 2006	$1102.5	$55.13	$1157.63
Dec 2007	$1157.63	$57.88	$1215.51

The Concept of Cash Flows

John's recent expenses:

Aug 5: John's Dad gives him $10,000

Aug 10: Car Rental, Chicago-Purdue $70

Aug 13: Pays Tuition Fees $6,000

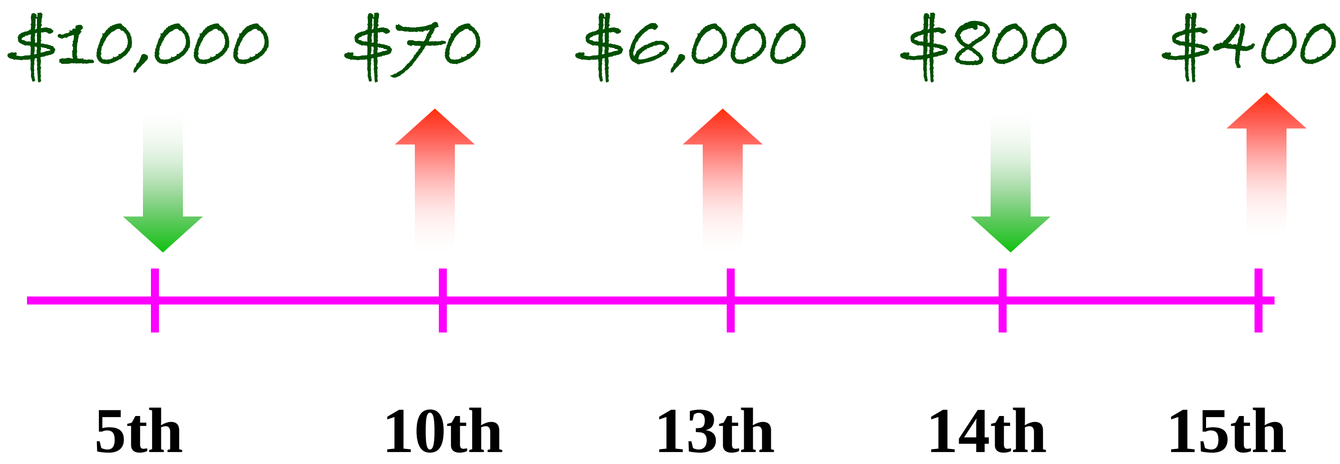
Aug 14: Receives $800 gift from Auntie

Aug 15: Pays rent $400

CASH FLOW TABLE

DATE	CASH FLOW ($)
Aug 5	+10,000
Aug 10	-70
Aug 13	-6,000
Aug 14	+800
Aug 15	-400

Cash Flow Diagram



Money spent (going out) : upward arrows

Money received (coming in): downward

Cash Flow Diagrams for Civil Engineering Projects

- Yearly intervals, typically, (not monthly, weekly, etc.)
- Amounts received or incurred during year are assumed to have happened …

  … at end of year, or

  … at beginning of year

  (choose only 1 of above conventions, and stick to it)

Example:
Reconstruction of I-90 Toll Road

Dec 2000-- Initial Contract Cost: $8 mil

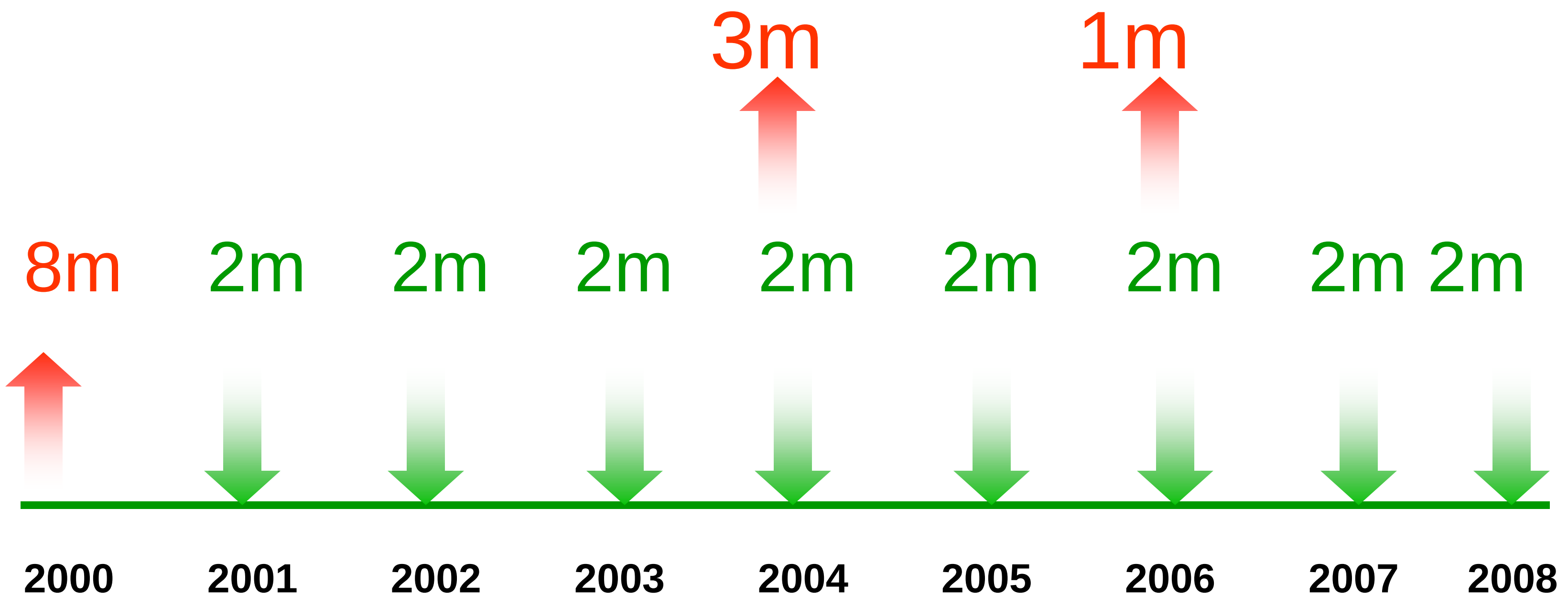
Dec Each year of 2001-2008-- Toll receipts: $2 million at end of every year

Dec 2004 -- Major Maintenance $3 mil

Dec 2006 --Minor Maintenance $1 mil

Draw the Cash Flow Diagram for this example.

Solution:


3m
1m
8m
2m
2m
2m
2m
2m
2m
2m 2m
2000
2001
2002
2003
2004
2005
2006
2007
2008

The 5 Variables in any Cash Flow Diagram

P - Present Amount

F - Future Amount

A - Annual Amount

i - Interest Rate

N - Analysis Period

Typically, we're given 4 of the above variables and we will need to calculate the 5^{th}, using equivalence equations.

Discussion of the 5 Variables

1. Present Amount, P

Amount received or incurred in Year 0. Typically a large amount, e.g., initial construction cost, initial money collected for car loan, etc.

2. Future Amount, F

A future amount that is equivalent to a given present amount (received or incurred).

Also called "discounted amount".

May be incurred (or paid) at end of analysis period or anytime within the analysis period.

3. Annual Amounts, A

- Amount received or incurred every year
- Also called "Annuities"
- Generally referred to as "uniform amounts" but only called "annual amounts" when the units of time is years.

4. Analysis Period, N

- Is the total time over which we are carrying out economic evaluation for a system.
- For CE systems, this is typically in years.
- Depends on system type and expected life of the system.
- Examples: 35 years for highway pavements 50 years for RC bridges, 70 years for steel bridges, 100 years for some dams.

5. Interest Rate, i

- Represents the extent to which money changes in value over time.

- May be (i) fixed (constant)
  (ii) variable. If variable, may be ...
  - compounded a finite number of times during each year
  - compounded an infinite number of times each year

- National interest rate is determined by the Central Bank (or Federal Reserve Board). Individual lenders also have their own rates, but are generally pegged to the federal rate.

Equivalence Equations …

What are they?

- Are equations used to calculate any 1 of the 5 major variables, given the other 4.
- Two main types of Equivalence Equations, mostly depending on the nature of the interest rate (how it changes).

- Equivalence Equations Type I

Used when interest rate is either…

- Compounded and Constant, or
- Compounded and changing a finite number of times

6 possible cases under Type I

Case 1:

Description: Finding the future amount (F) that would be yielded by an initial amount (P) at the end of a given period.

Example: Current car price is $20,000. Jim takes the car now (say, Dec 2009) and agrees with the dealer to pay nothing until Dec 2014 when he pays everything at a go.

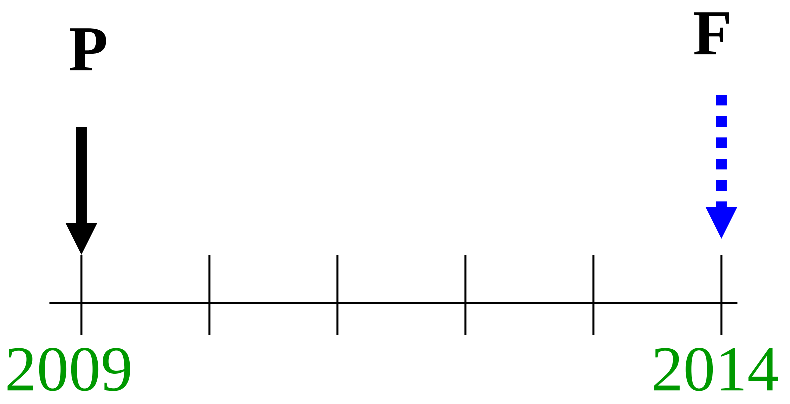
What price will he pay in 2014?

CASE 1 (cont'd)

Problem Definition:

This is a Single Payment Present Compound Amount Factor (SPCAF) problem

Cash Flow Diagram:



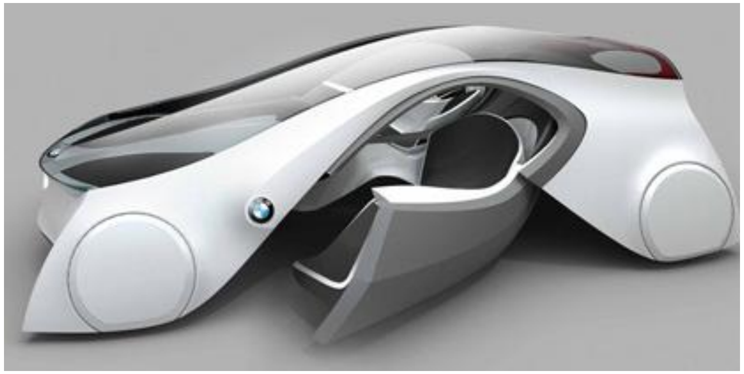
Computational Formula:

$$F = P*[(1+i)^n]$$

Case 2:

Description: Finding the initial amount (P) that would yield a future amount (F) at the end of a given period

Example: Jim has seen the 2014 model in a car magazine, and thinks it's cool. Wants to buy that model when it is released in 2014, at a price of $30,000 at that year.



BMW XZ-6, Year 2014 model

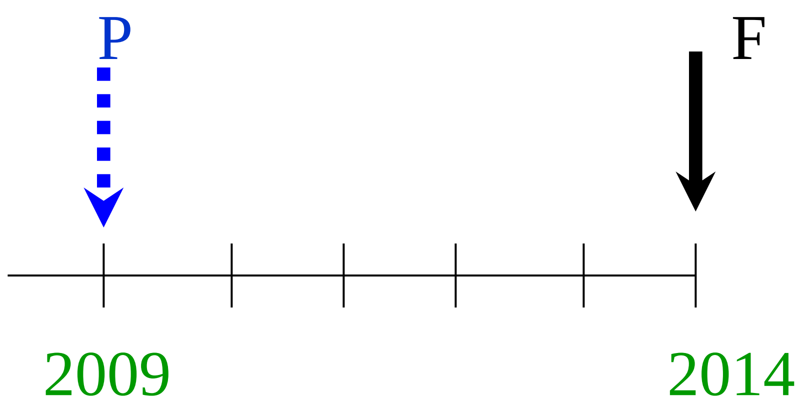
How much should Jim put away now in order to be able to pay for the car in 2014?

CASE 2 (cont'd)

Problem Definition:

This is a Single Payment Present Worth Factor (SPPWF) problem

Cash Flow Diagram:



Computational Formula:

$$P = \frac{F}{1[(1+i)^n]}$$

Case 3:

Description: Finding the amount of uniform annual payments (A) that would yield a certain future amount (F) at the end of a given period.

Example: Same as for Case 2 (Jim has seen the 2014 model in a car magazine. Wants to buy that model when it is released in 2014, at a price of $30,000 at that year.)

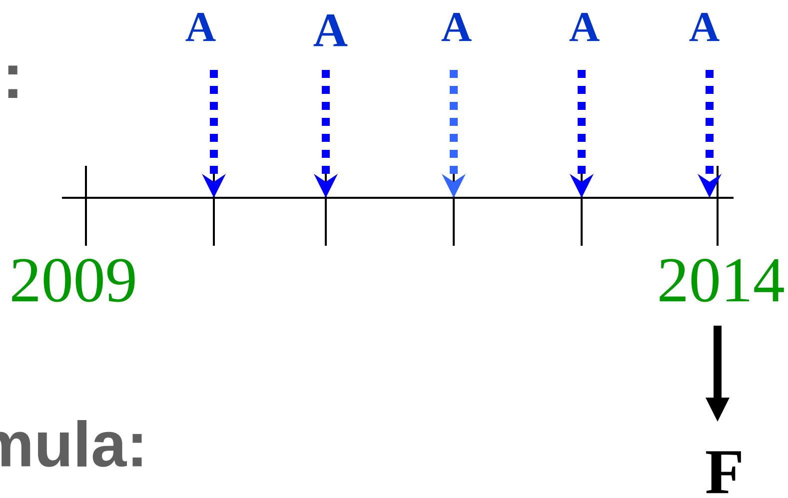
Jim agrees to pay 5 yearly amounts until December 2014, starting December 2009. How much should he pay in December every year?

CASE 3 (cont'd)

Problem Definition:

This is a Uniform Series Sinking Fund Deposit Factor (USSFDF) problem

Cash Flow Diagram:



Computational Formula:

$$A = F * \frac{i}{[(1+i)^n - 1]}$$

Case 4:

Description: Finding the final compounded amount (F) at the end of a given period due to uniform annual payments (A).

Example: Same as for Case 2 (Jim has seen the 2014 model in a car magazine. He thinks it's cool, and wants to buy that model when it is released in 2014 that year.)

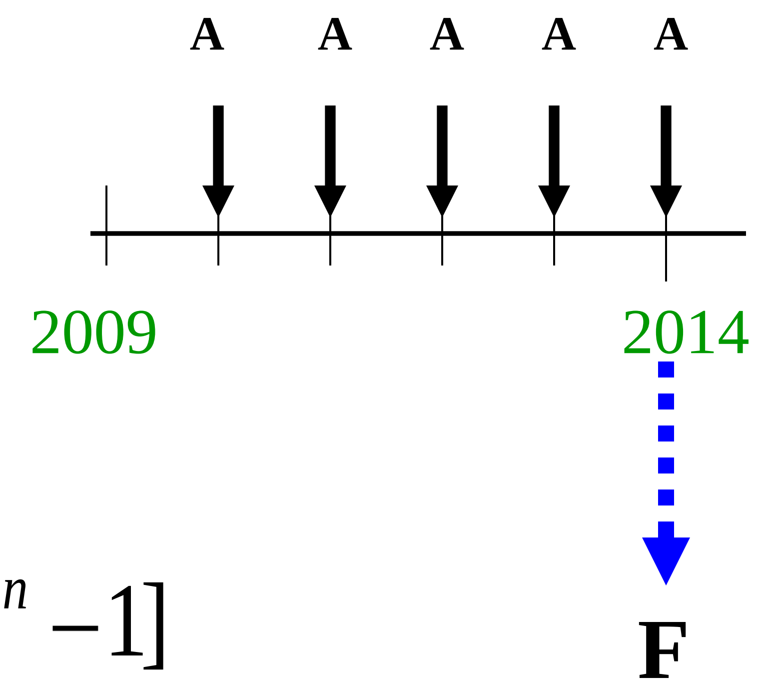
Jim agrees to pay $5,000 every year until 2014, starting December 2009. How much will he end up paying for the car by December 2014?

CASE 4 (cont'd)

Problem Definition:

This is a Uniform Series Compounded Amount Factor (USCAF) problem

Cash Flow Diagram:



Computational Formula:

$$F = A * \frac{[(1+i)^n - 1]}{i}$$

Case 5:

Description: Finding the initial amount (P) that would yield specified uniform future amounts (A) over a given period.

Example: Jim takes the 2009 model now (in 2009). He has enough money to pay for it, but rather decides to pay in annual installments of $5,000 over a 5-year period (starting in Dec 2009 till Dec 2014).

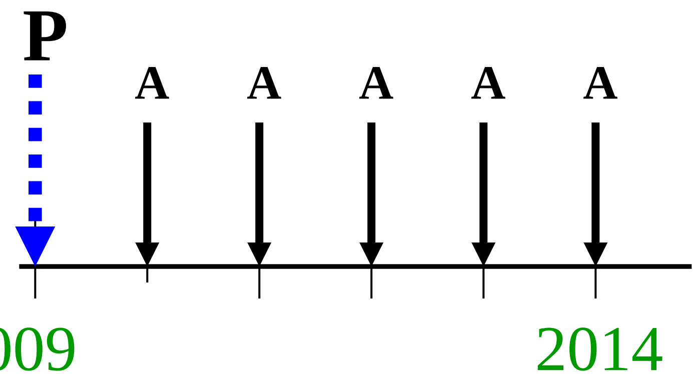
How much should he set aside now so that he can make such annual payments?

CASE 5 (cont'd)

Problem Definition:

This is a Uniform Series Present Worth Factor (USPWF) problem

Cash Flow Diagram:



Computational Formula:

$$P = A * \frac{[(1+i)^n - 1]}{i(1+i)^n}$$

Case 6:

Description: Finding the amount uniform annual payments (A) over a given period, that would completely recover an initial amount (P). e.g., car loan or credit card monthly payments

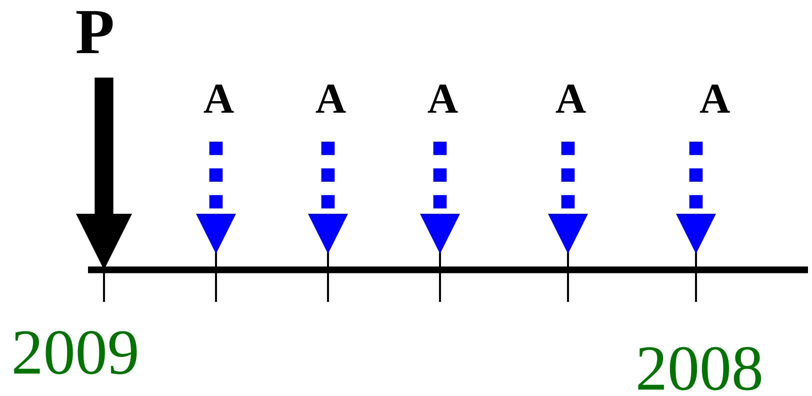
Example: Jim receives a loan of $25,000 from PEFCU to pay for the 2009 model and take it right now. How much will he have to pay back to the bank every year (starting Dec 2009) until Dec 2014?

CASE 6 (cont'd)

Problem Definition:

This is a Capital Recovery Factor (CRF) problem. (that is, the bank seeks to "recover its capital" from Jim).

Cash Flow Diagram:



Computational Formula:

$$A = P \times \frac{i(1+i)^n}{(1+i)^n - 1}$$