Class notes for ChE 4N04
Engineering Economics section

Ethics and Law

Safety and Environment

Engineering science

Process and Product Design

..

Economics

Risk and uncertainty

Chemistry and Biology

Project Management

..

We all must be able to apply basic concepts of economics because economics plays an important role in every engineering decision.

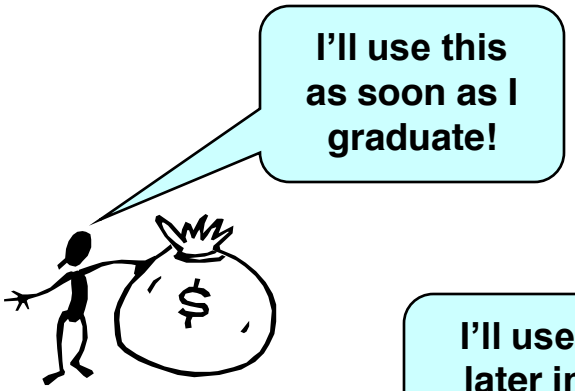
Course principles have many applications

Engineering Economics

- Evaluate profitability of alternative investments

Personal Finance

- When to buy that new car!
- Determine proper level of borrowing and saving
- Calculate income taxes



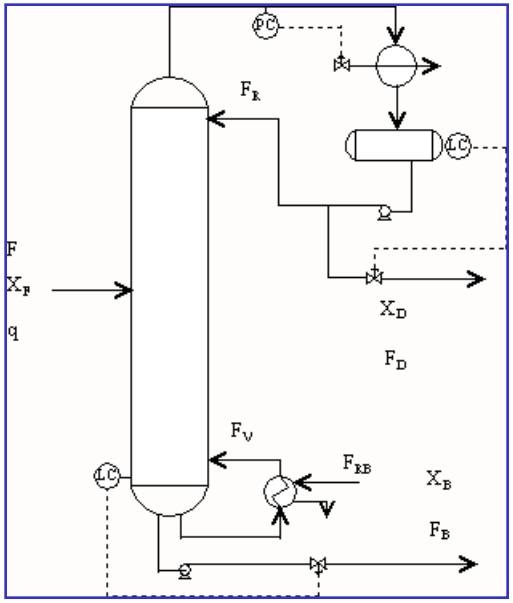
Corporate Finance

- Provide adequate cash reserves
- Determine minimum rate of return

Your first task at your new job

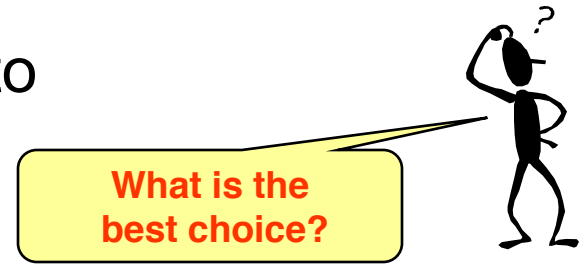
Supervisor to you: We want to increase our production rate by 35%, but the distillation tower is at its maximum capacity (liquid and vapour flows).

Evaluate the following feasible alternatives and determine the most financially attractive.



After some creative brainstorming …

1. Build a parallel distillation tower
2. Replace trays with packing
3. Increase the number of trays
4. Contract the extra production to another company
5. Change operating conditions



Roadmap for engineering economics topic

- **Four major topics**

  - Time value of money
  - Quantitative measures of profitability
  - Selecting from among alternatives
  - Cost estimating

  Able to evaluate potential projects and select the best

- **Lecture exercises and thought questions**
- **Class workshop**
- **Midterm (individual)**
- **Application in the SDL Project**

Four major topics in engineering economics

1. **Time value of money**

   - How do we compare $ at different times?

2. **Quantitative measures of profitability**

   - How do we determine the "profit" or "financial attractiveness" from an investment?

3. **Systematic comparison of alternatives**

   - How do we ensure that we select the "best" investment?

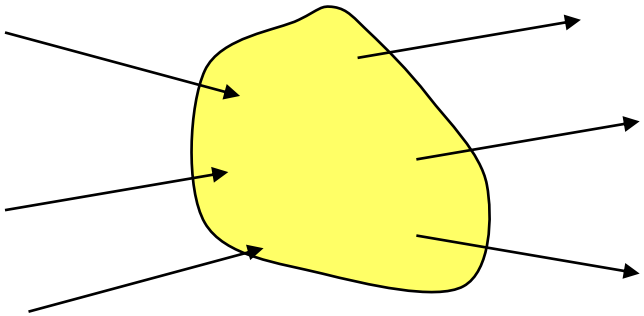
4. **Estimation of costs**

   - How do we determine the costs before we buy?

Time value of money

Let's use our modeling skills to determine a "*money balance*"

Revenues or incomes flow into the system, e.g.



Expenditures or costs flow out of the system, e.g.,

- **Product sales**
- **Equipment sales**
- **Licensing fees**

- **Feed costs**
- **Fuel and electricity**
- **Employee salaries**

Important definition: Cash flows are transfers of money that cross the system boundary. The system is typically a "project".

Time value of money

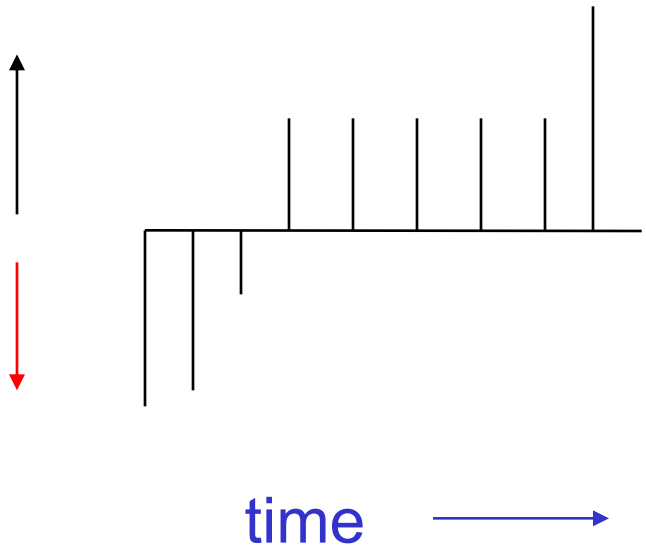
Cash flows occur over time.

We sum the revenues and expenditures within each time period to give the net cash flow at a time. We plot these in a cash flow diagram.

Cash flow diagram

Positive cash flow

Negative cash flow



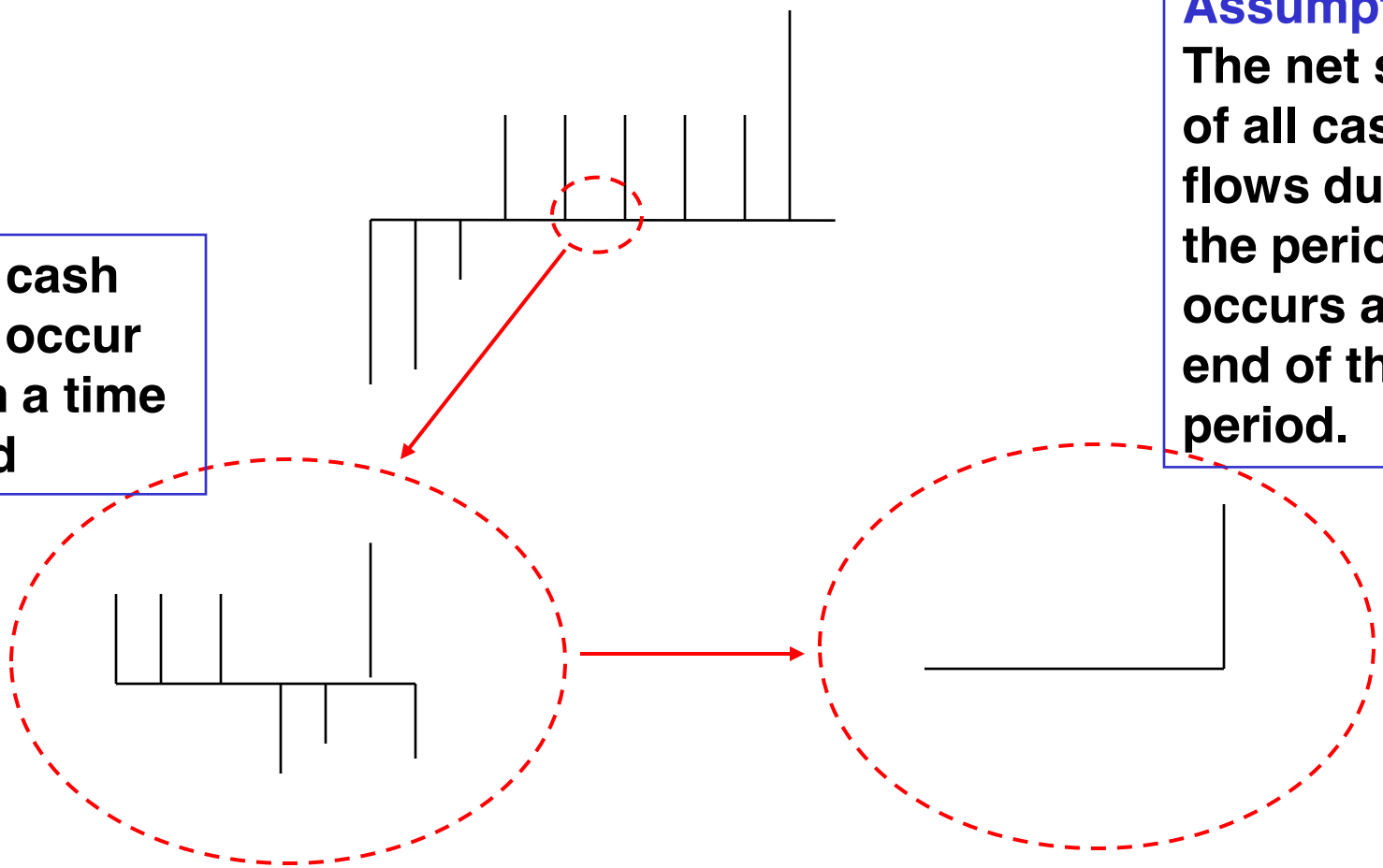
Periods are numbered from 0 to the end of analysis.

Period can be any time length; often one year for engineering projects

Cash flows in units of money ($)

Time value of money

Cash flow diagram and analysis



Many cash flows occur within a time period

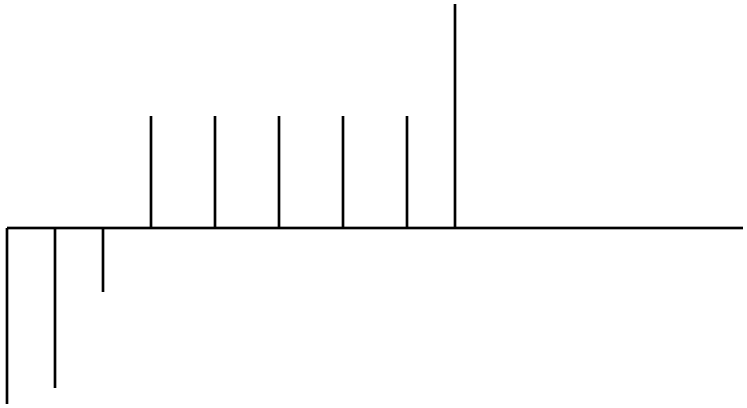
Assumption: The net sum of all cash flows during the period occurs at the end of the period.

Time value of money

We plot the end-of-period, or the cumulative cash flows

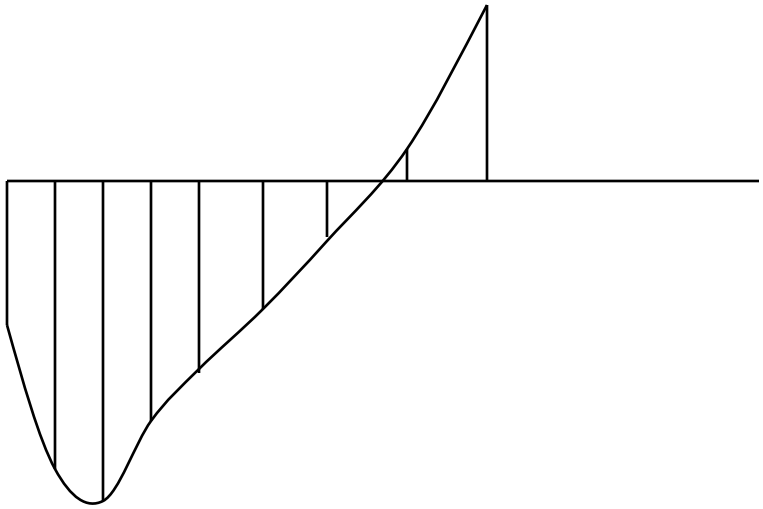
Cash flow diagram

(at each period)



Cumulative cash flow diagram

(just the cumulative sum of the above plot)



We'll use both, with the top plot used more often.

Time value of money

Draw a cash flow diagram for life from age 10 to age 40 with periods of 1 year

Time value of money

Key question: Why is there a "time value of money"?

Class exercise: A family member asks you to lend her $100. She promises to pay you exactly three years later. She will give you $100 then.

***Is this a good financial proposition*? Why?**

Time value of money

Why is there a “time value”?

- **The owner of money must defer its use**
- **The owner incurs risk**

Thus, money in the future is worth less than money now.

We must take this into account, as our employer’s money will almost always be spent over a long period of time.

Time value of money

How do we characterize time value?

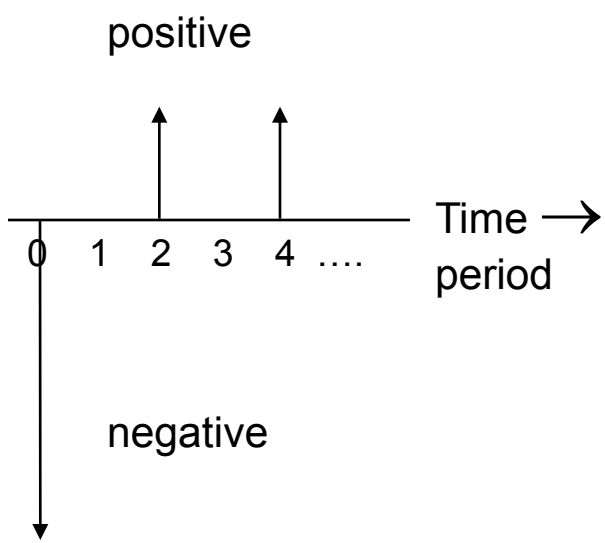
- **We use an interest rate, so that the effect of time is proportional to the total amount of money involved.**

Time value of money

We will use cash flow diagrams to summarize the behaviour of the system.

We need to calculate the value of all cash flows at the same time to make economic analyses.

Cash flow at each period ($)



P = present value (period = 0)

F = future value (period > 0)

i = interest rate

n = number of periods between present and future

Time value of money

Example 1:

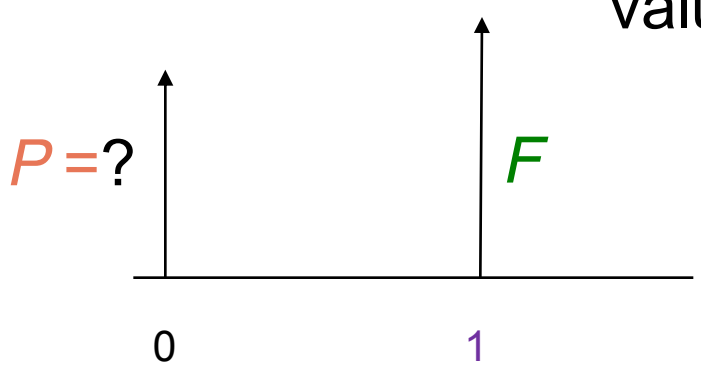
We would like a future amount $F = \$1000$
But we have only $P = \$800$ to invest now.

What interest rate is required to obtain F at $n = 1$ year from now?

Example 2:

We would like a future amount $F = \$1000$ at $n = 1$ year from now.

Given an interest rate $i=0.04$ [4%], how much should we invest today, called the present value, P ?



Time value of money

Determine the relationships between ***P*** and ***F*** for

n time periods, with compound interest rate *i*

$$F_n = P\,(1 + i)^n$$

What is the present value of a revenue of F = \$1000 at time n for each year n = 1, 2 … 10 at 10% per year time value of money?

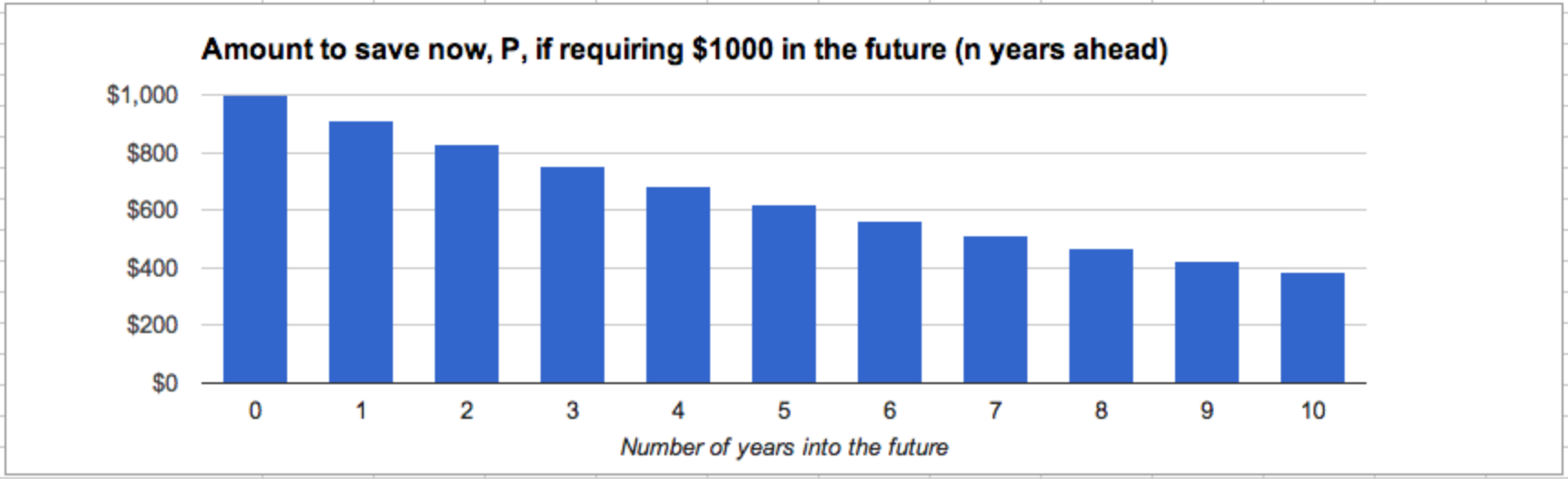
Asked another way …

If you want to have F=\$1000 in n = 1, 2, …10 years from now, how much do you have to invest right now, if interest rates remain at 10% per year?

Time-value Money

Time value of money

Amount in the future (F)	$1,000	(desired)									
Interest rate (i)	0.1										
Period, n	0	1	2	3	4	5	6	7	8	9	10
Present value required (P)	$1,000	$909	$826	$751	$683	$621	$564	$513	$467	$424	$386



Interpretation : $621 right now ($n$=0) has the equivalent worth of what $1000 will have 5 years ($n$=5) from now, at interest rates of 10%.

Time value of money

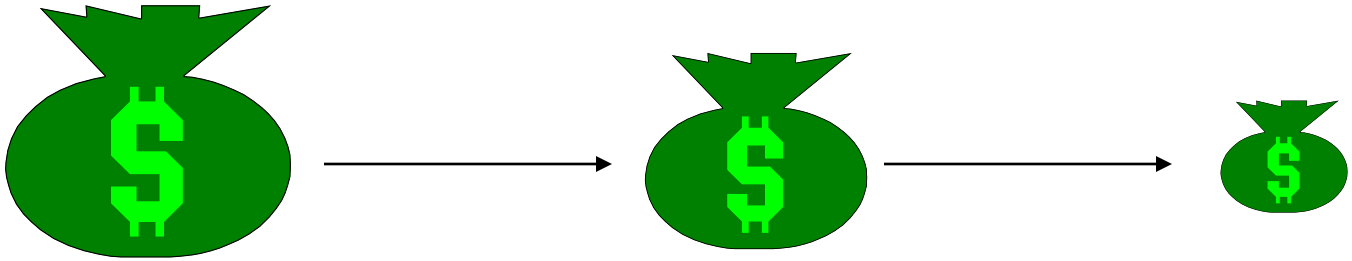
IGNORE

Time value of money

IGNORE

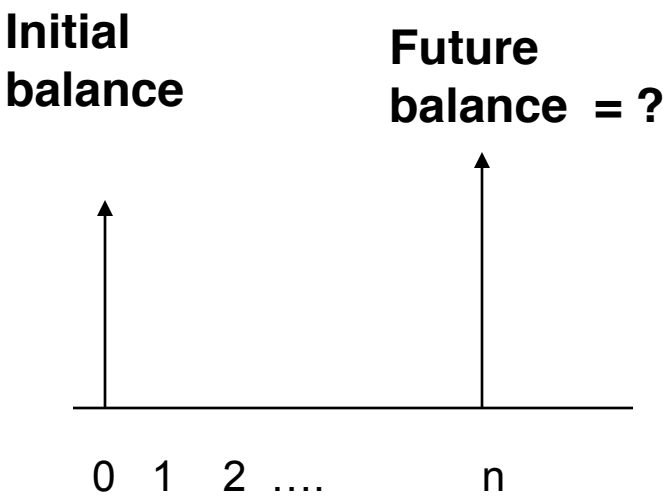
Time value of money

- Since money has a time value, money in the future has less value. We will characterize this decrease with the "time value of money".
- For a worthwhile investment, the net income in the future must be greater than the original expense.



Time value of money

Associated use of interest rates: When we place money in the bank, the bank increases the amount in our account according to an interest rate. This is payment for the bank using our money.



How do we calculate the future amount in our account?

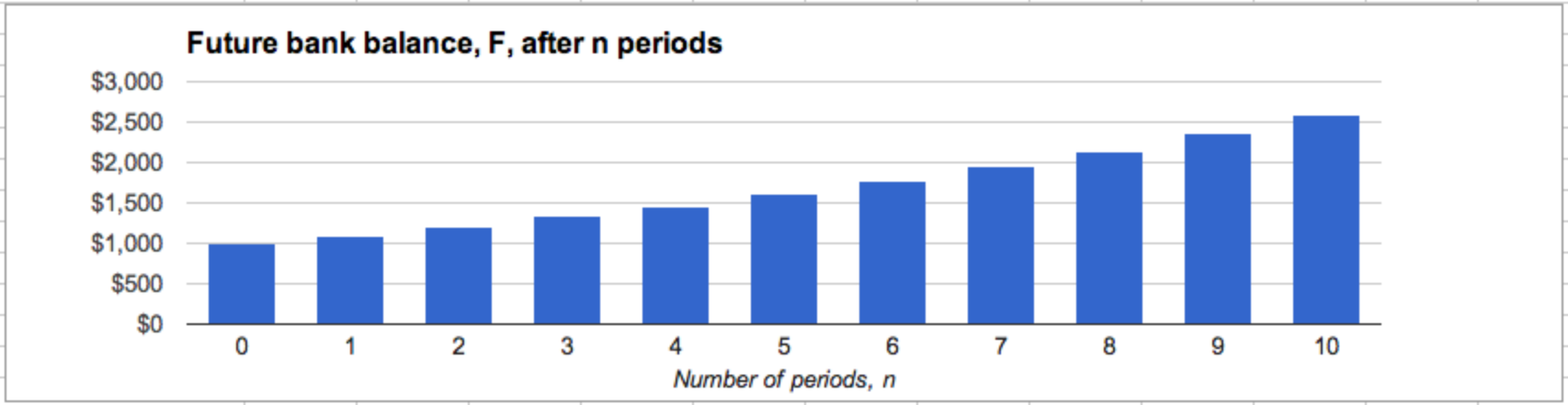
$$\textbf{Future balance} = P\ (1 + i)^n$$

What is the amount in your account ten years after depositing $1000 at 10% per year interest rate?

Time-value Money

Time value of money

Amount invested (P)	$1,000										
Interest rate (i)	0.1										
Period, n	0	1	2	3	4	5	6	7	8	9	10
Bank balance, F	$1,000	$1,100	$1,210	$1,331	$1,464	$1,611	$1,772	$1,949	$2,144	$2,358	$2,594

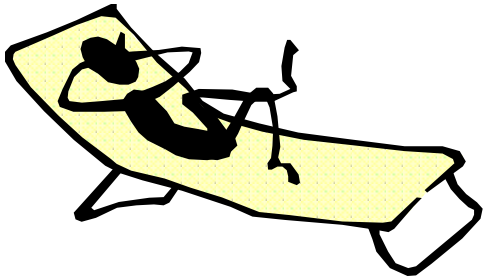


Time value of money

If you want to get rich, just invest and wait

Invest $10,000/yr at 5% is worth after 35 years: $ 948,000
after 40 years: $ 1,268,000
after 45 years: $ 1,677,000*

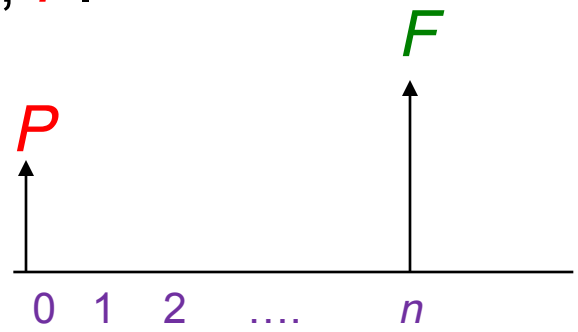
* This is close to the number we discussed at tutorial on Monday



*"Compound interest is the eighth wonder of the world. He who understands it, earns it ... he who doesn't ... **pays it**."* – Albert Einstein

Time value of money

We can consider inflation, i, in a similar way. An amount of money in the future (F), is worth less than in the present, P.



$$F_n = P\,(1 + i)^n$$

What is the present value of F=\$1000 at time = n

for each year (n= 1 to 10)

at 10% per year time value of money?

Asked another way …

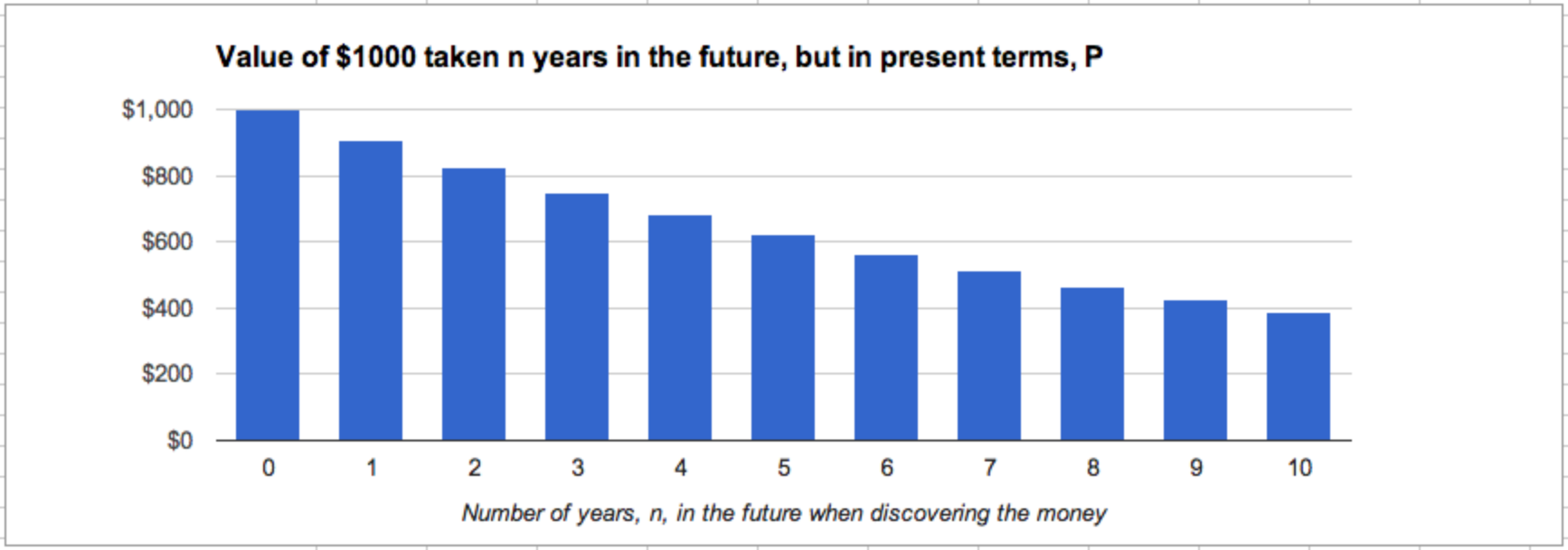
In n = 1, 2, …10 years from now you discover F = \$1000 under your mattress, and you can go buy goods with those dollars.

How much would those same goods have cost, in today's dollars if inflation was 10% per year?

Time-value Money

Time value of money

Amount discovered later (F)	$1,000										
Inflation rate (i)	0.1										
Period, n	0	1	2	3	4	5	6	7	8	9	10
Value in present terms (P)	$1,000	$909	$826	$751	$683	$621	$564	$513	$467	$424	$386



Interpretation : If TVM (inflation) = 10%, then consider that something worth $424 now is what you'll have to pay $1000 for in 9 years from now.

Time value of money

Interest rates

Economic and financial indicators — The Economist September 7th 2013

Economic data (2)

% change on year ago

	Current-account balance latest 12 months, $bn	Current-account balance % of GDP 2013†	Budget balance % of GDP 2013†	Interest rates, % 10-year gov't bonds, latest	Currency units, per $ Sep 4th	Currency units, per $ year ago
United States	-425.7 Q1	-2.7	-4.0	2.89	-	-
China	+211.6 Q2	+2.1	-2.1	3.94§§	6.12	6.35
Japan	+54.1 Jun	+1.2	-8.3	0.78	99.5	78.4
Britain	-96.7 Q1	-2.7	-7.6	2.95	0.64	0.63
Canada	-59.6 Q2	-3.1	-2.8	2.72	1.05	0.99
Euro area	+247.1 Jun	+1.8	-3.3	1.94	0.76	0.80
Austria	+9.7 Q1	+2.4	-3.0	2.37	0.76	0.80
Belgium	-8.7 Mar	-0.7	-3.1	2.82	0.76	0.80
France	-46.4 Jun	-2.1	-4.2	2.53	0.76	0.80
Germany	+244.5 Jun	+6.6	+0.3	1.94	0.76	0.80
Greece	-3.4 Jun	-0.8	-4.7	10.46	0.76	0.80
Italy	+5.9 Jun	+0.6	-3.5	4.42	0.76	0.80
Netherlands	+85.1 Q1	+8.1	-3.8	2.35	0.76	0.80
Spain	+8.7 Jun	+0.7	-7.2	4.43	0.76	0.80
Czech Republic	-3.8 Q2	-1.9	-2.9	2.58	19.5	19.8
Denmark	+18.2 Jun	+5.2	-2.6	2.13	5.65	5.93
Hungary	+3.0 Q1	+1.7	-3.0	6.59	228	227
Norway	+64.6 Q2	+12.9	+13.0	3.15	6.07	5.79
Poland	-9.3 Jun	-2.4	-3.9	4.80	3.24	3.34
Russia	+47.9 Q2	+2.5	-0.6	7.94	33.3	32.3
Sweden	+32.0 Q2	+7.1	-1.4	2.57	6.60	6.71
Switzerland	+77.6 Q1	+11.6	+0.2	1.18	0.94	0.96
Turkey	-53.6 Jun	-6.8	-2.2	10.02	2.06	1.82
Australia	-49.4 Q2	-3.1	-1.3	4.02	1.09	0.98
Hong Kong	+5.2 Q1	+0.9	+2.0	2.47	7.76	7.76
India	-87.8 Q1	-4.5	-5.1	8.39†††	67.0	55.6
Indonesia	-28.8 Q2	-2.4	-2.9	na	11,065	9,571
Malaysia	+14.2 Q2	+5.8	-4.3	3.98	3.28	3.11
Pakistan	-2.3 Q2	-1.0	-8.8	12.10†††	105	94.8
Singapore	+49.9 Q2	+18.3	+0.7	2.65	1.27	1.25
South Korea	+59.8 Jul	+3.5	+0.5	3.64	1,095	1,133
Taiwan	+52.8 Q2	+11.7	-1.9	1.73	29.8	29.9

Time value of money

Class exercise: Your bank account is the "system". You have an initial revenue of $4,000 and the following monthly revenues and expenditures, and the bank pays 5% interest per month.

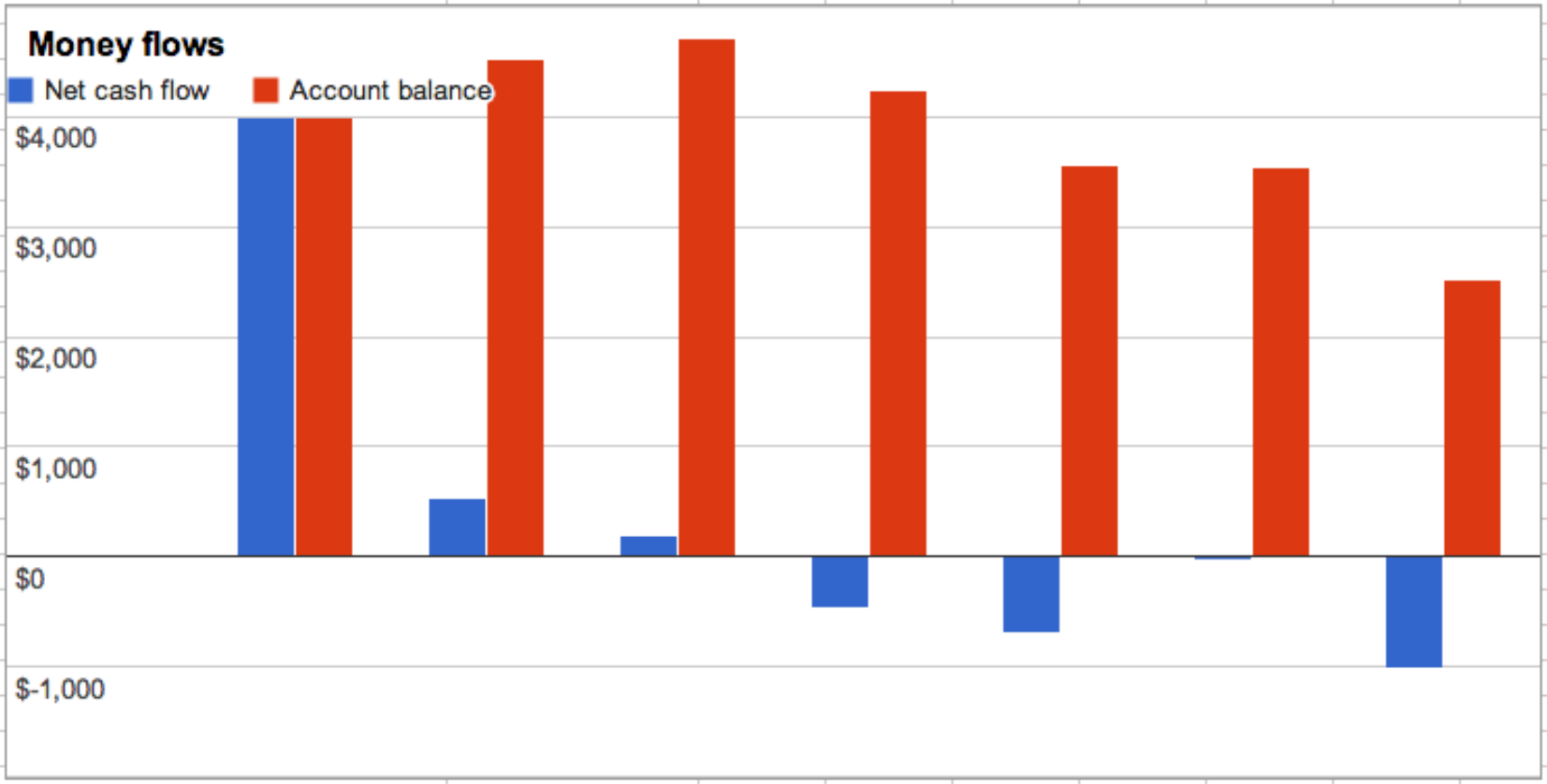
Plot the monthly balance *and* cash flow diagram for your bank account.

	Month	0	1	2	3	4	5	6
Revenues		$4,000	$530	$530	$0	$0	$0	$0
Expenses		$0	-$200	-$570	-$700	-$900	-$200	-$1,200

Time-value Money

Time value of money

	Month	0	1	2	3	4	5	6
Revenues	A	$4,000	$530	$530	$0	$0	$0	$0
Expenses	B	$0	-$200	-$570	-$700	-$900	-$200	-$1,200
Interest earned at 5% per month	C = 0.05 x E(n-1)		$200	$227	$236	$213	$178	$177
Net cash flow	D = A + B + C	$4,000	$530	$187	-$464	-$687	-$22	-$1,023
Account balance	E = D + E(n-1)	$4,000	$4,530	$4,717	$4,252	$3,565	$3,543	$2,520



Time value of money

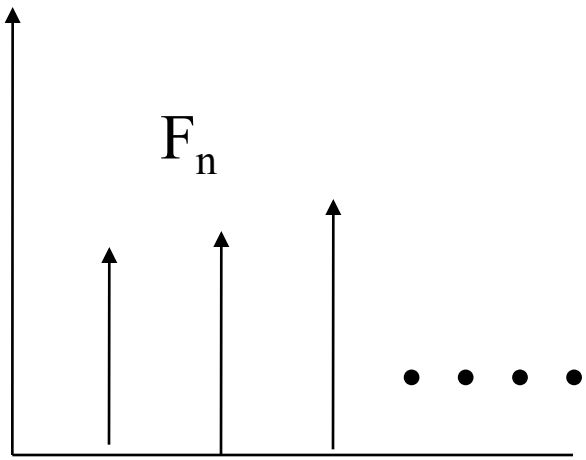
Now, let's relate the banking interest to the time value of money

Class exercise: You deposit \$5000 in a bank account with an annual compound interest rate i^*. The time value of money is described by an interest rate i' (inflation rate).

Calculate the present value of the bank account after n years.

Time value of money

$C_0 = 5000$



$$F_n = C_0(1+i^*)^n$$

Interest earned on the investment

$$P = \frac{F_n}{(1+i')^n}$$

Present value of the investment

$$P = C_0 \frac{(1+i^*)^n}{(1+i')^n}$$

What is the result if $i^* = i'$?

How do we use this result to interpret the time-value of money?

Time value of money

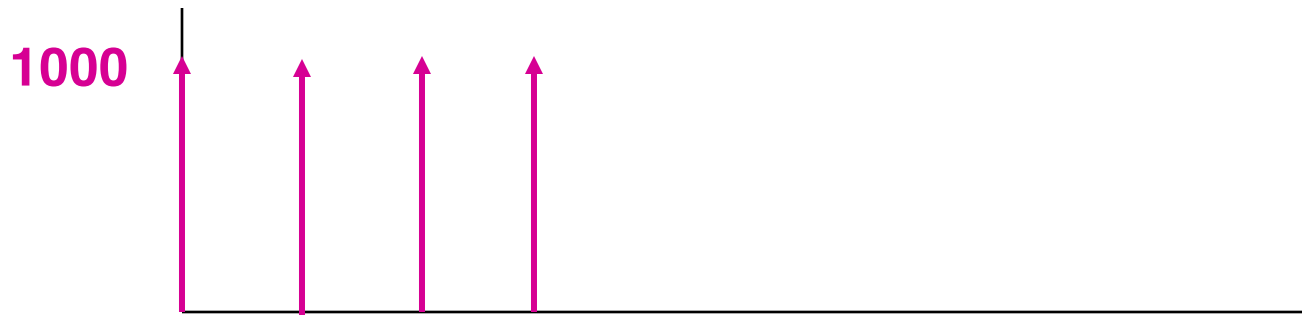
Class exercise

You have an income of $1000 per year for each of the 4 years of your undergraduate studies.

- Draw a cash flow diagram
- Determine the value for this income in the beginning of the first year when the inflation rate (time value of money) is 10%.

Time value of money

Class exercise

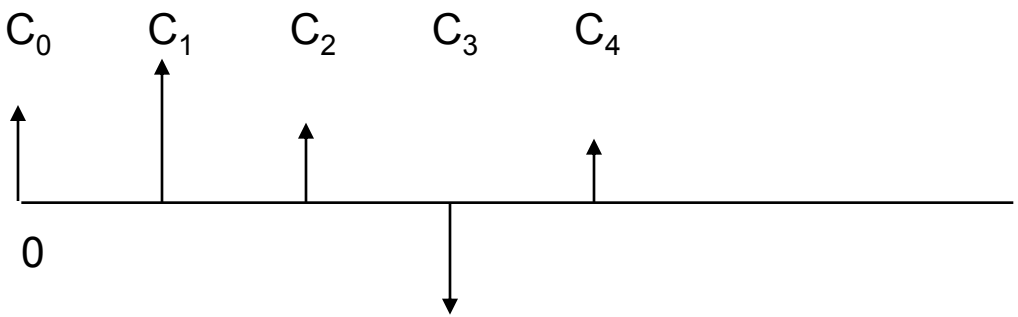


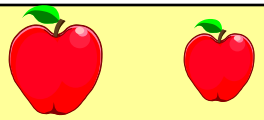
	Inflation rate, i =	0.1			
Period	n	**0**	**1**	**2**	**3**
Cash flow in the period	Fn	$1,000	$1,000	$1,000	$1,000
Cash flow in present value terms	P	$1,000	$909	$826	$751
Cumulate cash flow in present value terms		**$1,000**	**$1,909**	**$2,736**	**$3,487**

Interpretation: You could have replaced the cash flow with one revenue of $3487 at time period 0, that earned interest at 10%. Then make $1000 withdrawals in each year from the bank account. The balance will be $0 after the last withdrawal. Prove this interpretation for yourself in a spreadsheet.

Time value of money

Look ahead: We will be expressing values for different investments at the **same time** period for the purpose of comparison.





We need to compare apples and apples!

$$P = \frac{C_0}{(1+i)^0} + \frac{C_1}{(1+i)^1} + \frac{C_2}{(1+i)^2} + \frac{C_3}{(1+i)^3} + \frac{C_4}{(1+i)^4} + \cdots$$

with C_n = cash flow at period n with a TVM rate of i

Time value of money

Some thoughts

- **Interest factor tables:** Many tables are provided for relationships among *P*, *F* and annuity values for specified interest rates and periods
- **Calculations:** Many projects have unequal cash flows. The time-value calculations are easily performed using spreadsheets like Excel.
- **Life-long Applications:** These concepts are useful for personal finances (mortgage rate, credit card borrowing, and so forth).

Time value of money

Group learning / Self-directed learning

1. Determine the meanings of **simple**, **compound**, **nominal**, **effective** and **continuous** interest.
2. How would the equations used in this section be changed if the interest rate depended on the period?
3. You have a balance of $4,000 on your credit card which has an interest rate of 24% (nominal, **compounded monthly**). How much do you have to pay per month to maintain your balance at $4,000? How much do you have to pay per month to clear your debt in one year?
4. What is the meaning of the term "usury"? What is the history of charging interest for loans? Read up on Sharia compliant finance (finance without charging interest on loans).
5. Investigate the **`=PV( )`** and **`=FV( )`** functions in spreadsheet software

Measures of profitability

1. Time value of money
2. Quantitative measures of profitability
3. Systematic comparison of alternatives
4. Estimation of costs

- We need a systematic method for **comparing** expenses and incomes at different times using the time value of money
- We need to compare the project profitability with a **minimum acceptable performance**
- Many measures are in use; we'll look at four.

  - Two are useful and commonly used by engineers

  - Two are not recommended, but are used in practice. We should know these as well.

Measures of profitability

The following organizations and decisions are not “profit based”; do they need measures of profitability?

- Universities
- Charities
- Governments
- For-profit companies when involved in
  - safety projects
  - environmental projects

Measures of profitability

Examples for each category

- Universities – e.g. rent or purchase computers
- Charities - Invest in fund raising
- Governments - In-house or outsource tasks
- For-profit companies when involved in
  - safety projects
  - environmental projects

  } Find project that satisfies goals at the lowest cost

Measures of profitability

Example

We can invest money yielding a 15% annually compounded return.

Compared to that, would the following project be financially attractive?

i.e. should we invest, or just park our money and earn the 15%?

Period	Cash Flow ($)
0	-91,093
1	20,000
2	40,000
3	40,000
4	40,000
5	30,000

Don't know how to estimate the costs? Don't worry, we will cover the topic soon.

Measures of profitability

Payback time

- This measure is often used as a “quick and dirty” measure of profitability
- We use it in our daily lives: how long does it take to pay back for …(car, vacation, new cell phone, *etc*)
- Also called *Payout Time*
- Defined in units of time (e.g. months or years)

The time for the cumulative cash flow to achieve a value of $0

Usually (and in this course), payback time does not consider interest.

Measures of profitability

Class exercise: Payback time

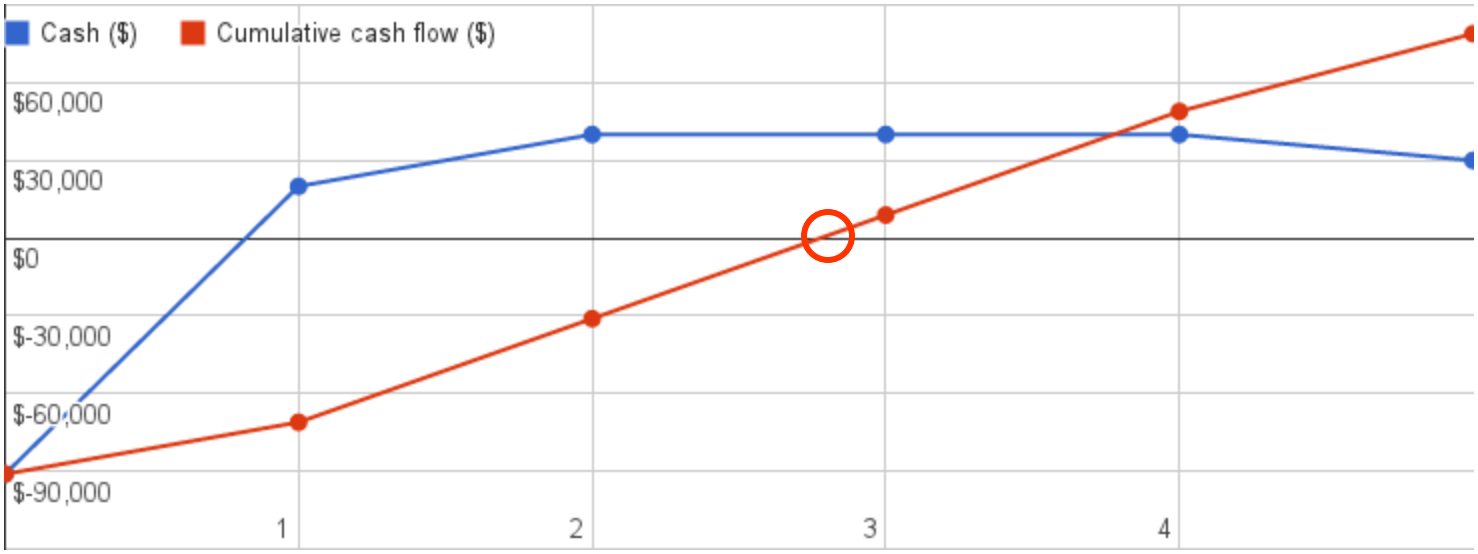
Determine the payback time for the cash flow defined in previous table

Period	Cash Flow ($)
0	-91,093
1	20,000
2	40,000
3	40,000
4	40,000
5	30,000

Profitability

Measures of profitability

A plot (visual interpolation) used to determine the payback time



Measures of profitability

- What is the Payback time for a project that involves an original investment of $91,000 and provides an annual profit (positive cash flow) of $34,000 per year over the first three years and no depreciation.

  Payback time = 91/34 ≈ 2.7 years [rough calc.]

  Same payback time as previous example, but different cash flows

Notes

- No time value of money taken into account
- Doesn't consider what happens after payback

Not recommended!

Can be an effective screening tool though

Measures of profitability

Return on original investment (ROI)

- Simple calculation
- ROI = $\dfrac{\text{average annual profit}}{\text{fixed capital} + \text{working capital}}$
- Expressed in units of percent per year

What is fixed capital?
What is working capital?

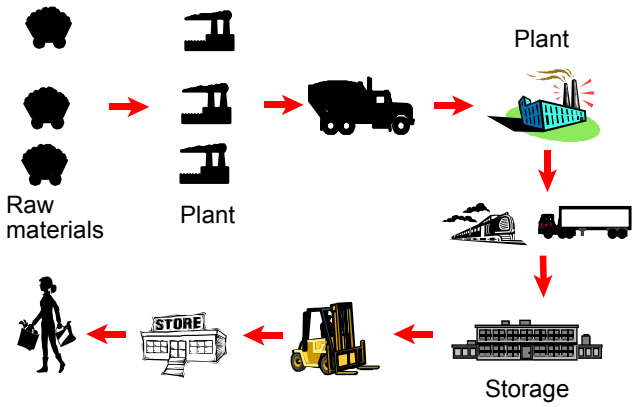
Profitability

Measures of profitability

Working Capital

Working capital is the difference between current assets and current liabilities. (Estimation given later in course.) Examples include:

- Raw materials
- Work in progress (WIP), which is material part way through the production
- Supplies stored for manufacturing, e.g., catalyst
- Finished products in storage and transport that we still own
- Cash on hand to cover short-term expenses



A key feature of working capital is that it can be recovered when the plant is shutdown.

Measures of profitability

- Calculate the ROI for a project with fixed capital of $91,000, no working capital, and an average annual profit of $34,000.

$$ROI = 34/91 \times 100 \approx 34\%$$

Does not consider time value of money

Not recommended!

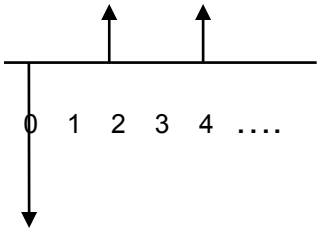
Measures of profitability

Net Present Value (NPV) (NP worth)

- Explicitly expressed as a **specific value of money**
- Defined as present value of all cash flows
- Sum up these present values (i.e. “net” them up)
- For N compounding periods in the life of the project, with a net cash flow in each period of C_n

recommended

$$\mathrm{NPV} = \sum_{n=0}^{N} C_n (1+i)^{-n}$$



What does NPV=$0 imply?

Measures of profitability

Class exercise: Net Present Value (NPV)

Period	Cash Flow ($)	PV of cash flow ($)
0	-91,093	
1	20,000	
2	40,000	
3	40,000	
4	40,000	
5	30,000	

Calculate the NPV for this project at 15% time value of money

Measures of profitability

Class exercise: Net Present Value (NPV)

See the calculations below and *on the course website*

Payback time	Period	Cash ($)	Present value ($)	Cumulative sum of PV ($)	Cumulative cash flow ($)
	0	-$91,093	-$91,093	-$91,093	-$91,093
	1	$20,000	$17,391	-$73,702	-$71,093
Interest rate	2	$40,000	$30,246	-$43,456	-$31,093
0.15	3	$40,000	$26,301	-$17,155	$8,907
	4	$40,000	$22,870	$5,715	$48,907
	5	$30,000	$14,915	$20,630	$78,907

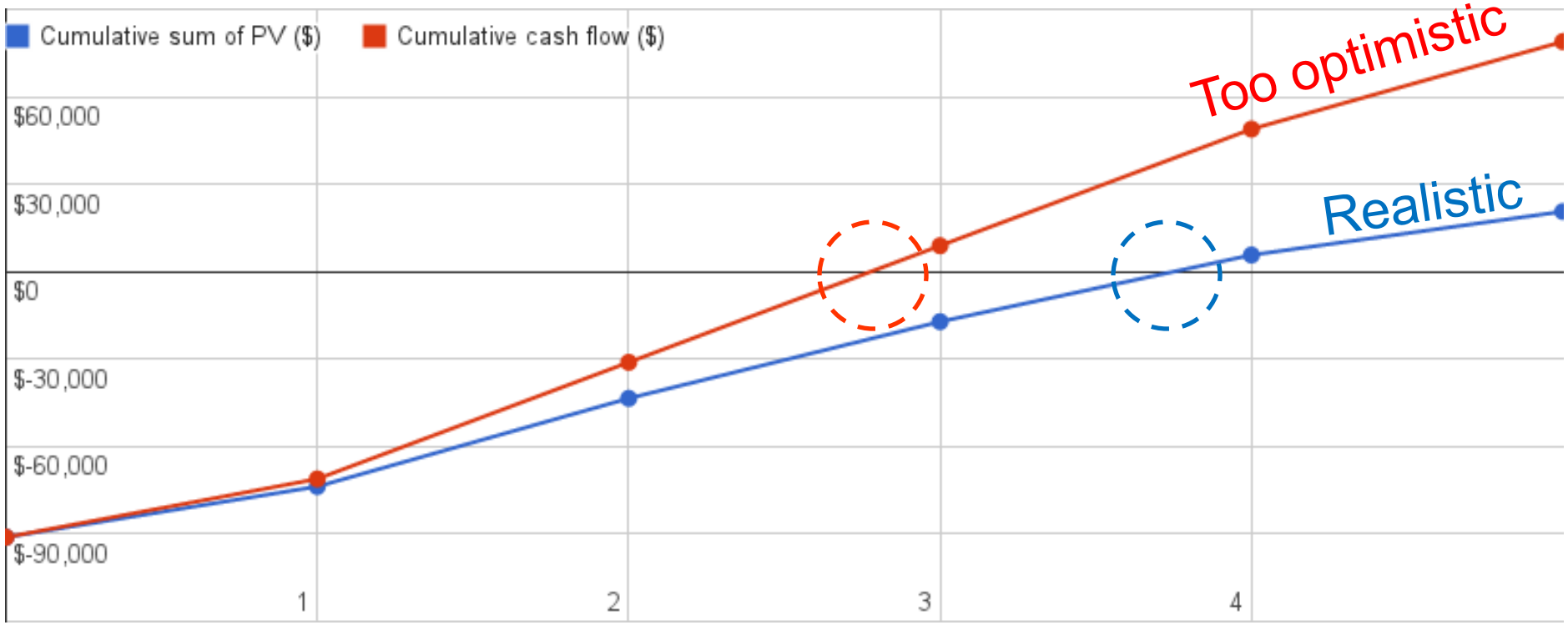
What does this value mean?

From prior exercise

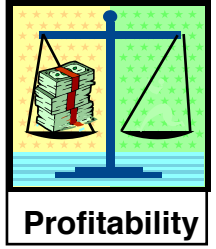
This approach considers time value of money explicitly. Important for projects of long duration, and in high deflationary environments.

Measures of profitability

Class exercise: Net Present Value (NPV)



Payback time **not** taking time value of money into account is too optimistic.

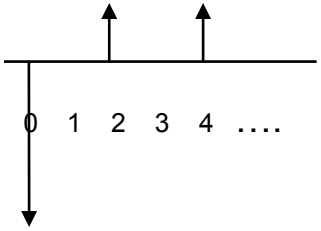


Measures of profitability

Discounted Cash Flow Rate Of Return (DCFRR)

- **Also called,** Discounted Cash Flow (DCF)
  Internal Rate of Return (IRR)
- Defined as **the interest rate** that results in a NPV of $0

$$\text{NPV} = \sum_{n=0}^{N} C_n (1+i)^{-n} = 0$$



recommended

Measures of profitability

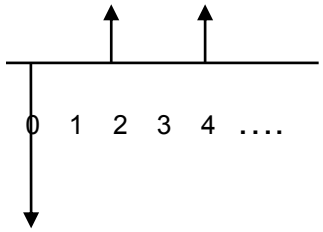
Internal Rate of Return (IRR)

- Why *internal*? It is the NPV from this project's (internal) cash flows. NOT dependent on other project's.

- Simplest example: you invest $100 now and wish to have $108 next year. What is the rate of return, i.e. the IRR, required to achieve this?

Now use the equation below.

$$\text{NPV} = \sum_{n=0}^{N} C_n (1+i)^{-n} = 0$$



Measures of profitability

Class exercise: Discounted cash flow rate of return (DCFRR)

Period	Cash Flow ($)
0	-91,093
1	20,000
2	40,000
3	40,000
4	40,000
5	30,000

Calculate the DCFRR for this project (you'll need a computer for this)

Profitability

Measures of profitability

Calculate the DCFRR for this project

DCFRR = $i = 0.236$ **or 23.6% (By trial and error, use "goal seek")**

Payback time	Period	Cash ($)	Present value ($)	Cumulative sum of PV ($)
	0	-$91,093	-$91,093	-$91,093
	1	$20,000	$16,182	-$74,911
Interest rate	2	$40,000	$26,184	-$48,727
0.23597	3	$40,000	$21,185	-$27,542
Adjust this value to get cumulative	4	$40,000	$17,141	-$10,401
sum of PV, i.e. NPV = 0	5	$30,000	$10,401	$0

So the DCFRR is 23.6% in this example over the 6 periods of the project's life.

What does this value mean?

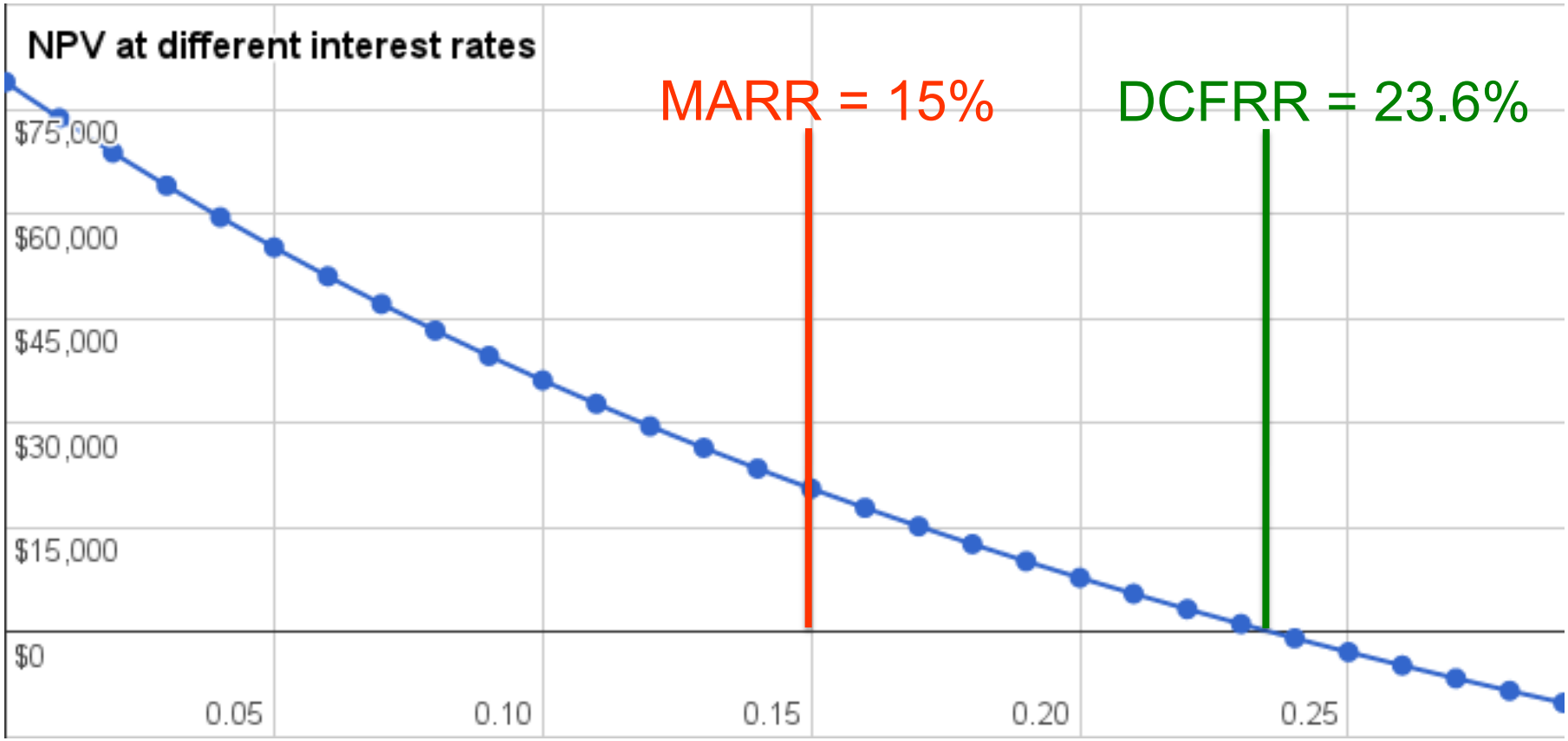
Considers time value of money explicitly

Profitability

Measures of profitability

This is a fixed value that the company chooses

A profitable investment has DCFRR > MARR



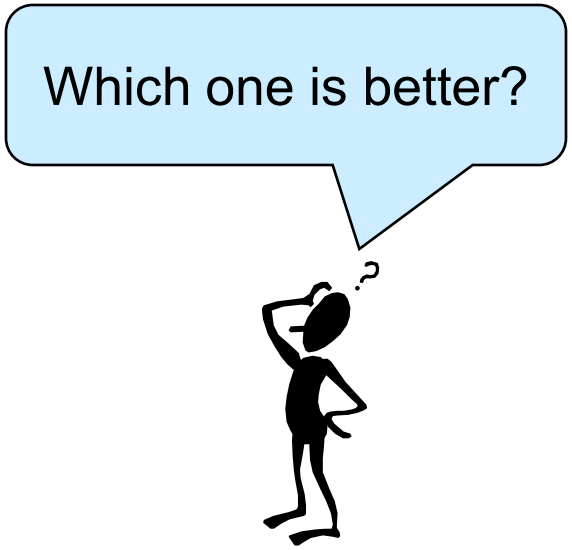
i **= interest rate**

Profitability

Measures of profitability

Calculate the DCFRR for the following cash flows

year		0	1	2	3
Cash flows	A	-1000	750	390	180
	B	-1000	350	470	660
	C	-1000	533	467	400



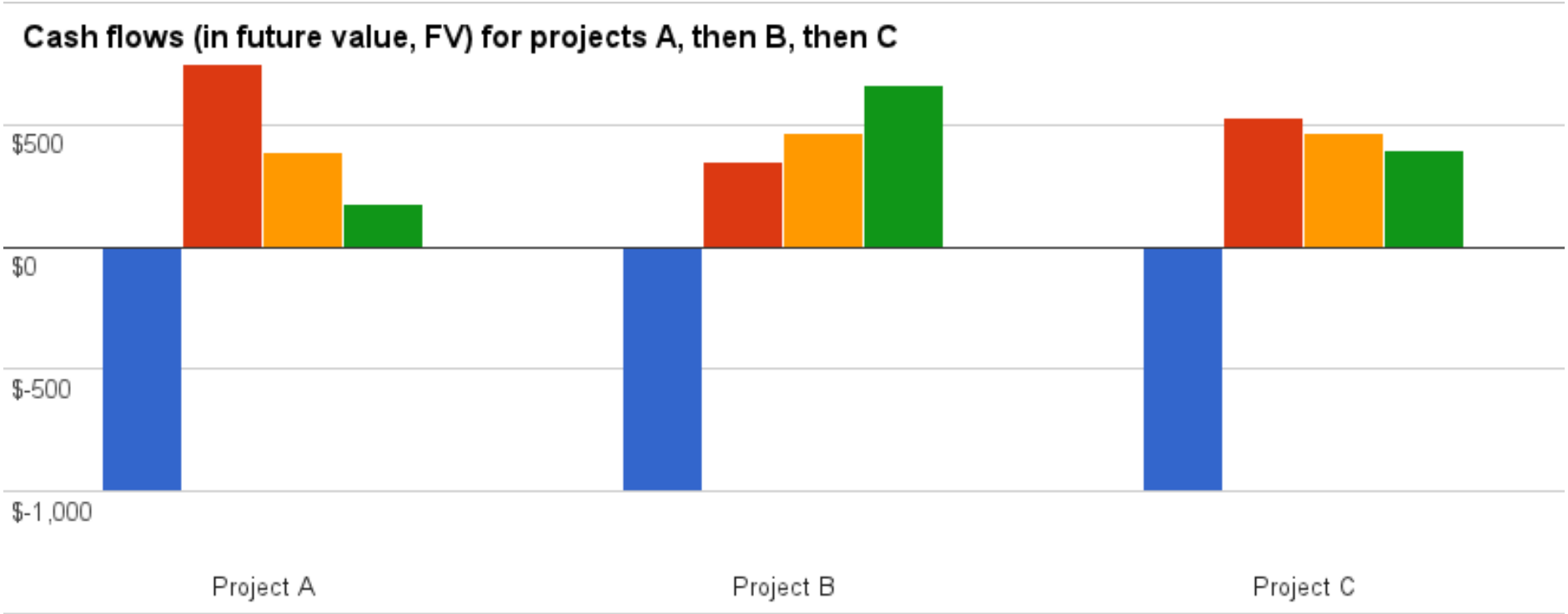
From Humphreys, Jelen's Cost and Optimization Engineering, page 117

Profitability

Measures of profitability

Calculate the DCFRR for the following cash flows

Cash flow diagrams



Profitability

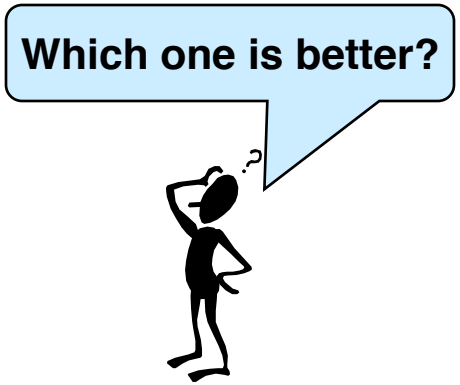
Measures of profitability

Calculate the DCFRR for the following cash flows

Period	Project A	Project B	Project C		Period	Cuml PV A	Cuml PV B	Cuml PV C
0	-$1,000	-$1,000	-$1,000		0	-$1,000	-$1,000	-$1,000
1	$750	$350	$533		1	-$375	-$708	-$556
2	$390	$470	$467		2	-$104	-$382	-$231
3	$180	$660	$400		3	$0	$0	$0
DCFRR	0.2000	0.2000	0.2000	*calculated with the =IRR(...) function*				

Different cash flows with the same DCFRR.

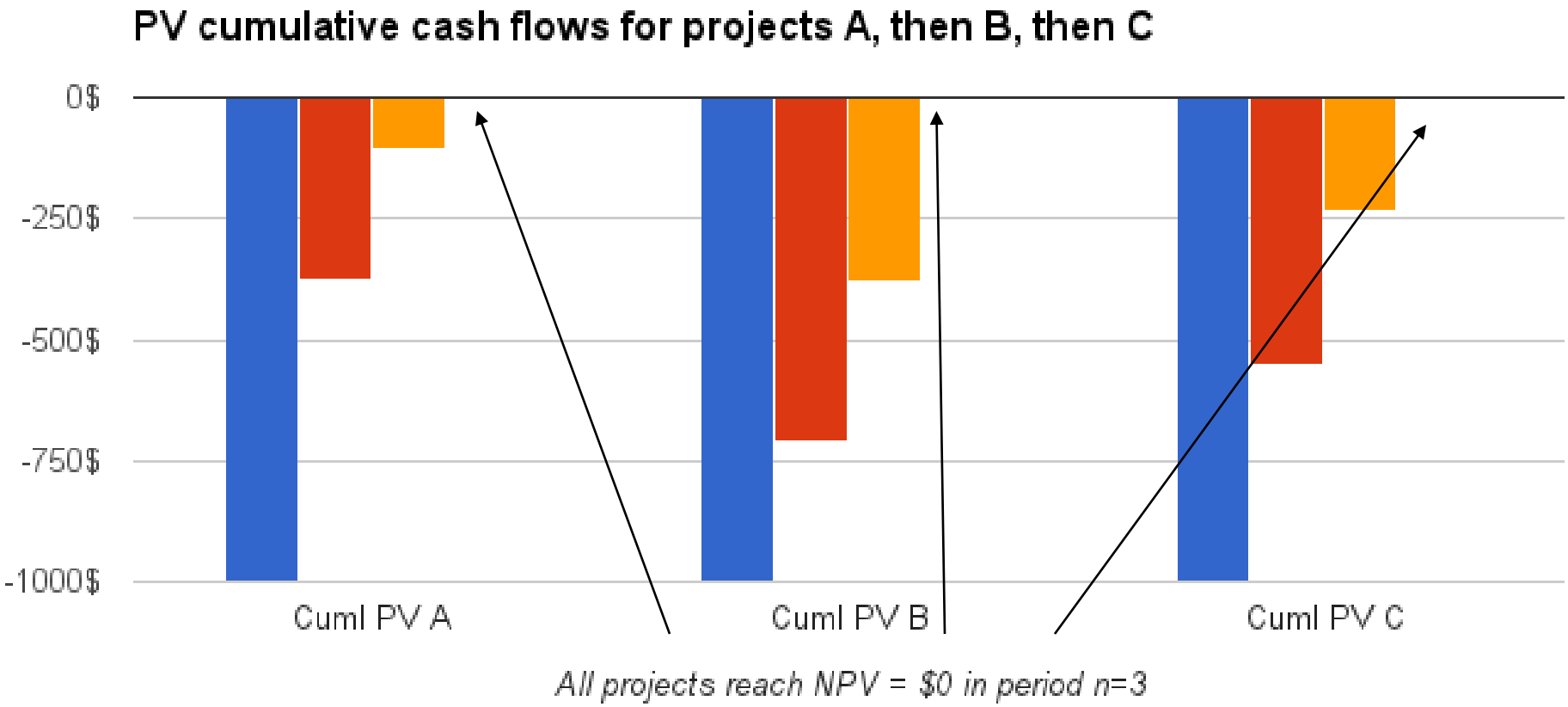
How do we interpret this?

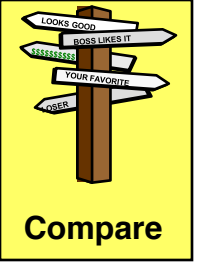


Measures of profitability

Calculate the DCFRR for the following cash flows

Cumulative NPV using $i_{\mathrm{TVM}}=20\%$





We will come back to this topic again

Detour: Comparison of alternatives

We will need to know the following term

MARR = Minimum Acceptable (compound) Rate of Return

Desired return, considering risk

Weighted average cost of capital

Depends on debt and equity capital and percentage return to achieve breakeven.

MARR →

High risk

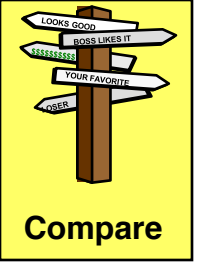
Venture capital

Historic return of investments

Bank loan interest

Bank deposit interest

0 Put money under your mattress



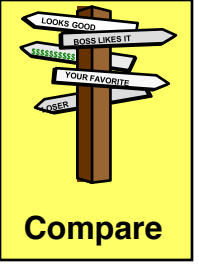
Detour: Comparison of alternatives

MARR = Minimum Acceptable Rate of Return

Sample values from Peters *et al*. Table 8-1.*

Description	Level of risk	Typical MARR (%)
Very low risk, hold capital short-term	Safe	4-8
New production capacity where company has established position in market	Low	8-16
New product or process technology, company has established market position	Medium	16-24
New process or product in new market	High	24-32
High R&D and marketing development	Very High	32-48

* Descriptions modified slightly



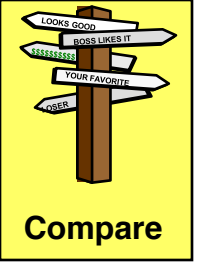
Detour: Comparison of alternatives

The analysis depends on the scenario

- Alternatives are: "project" *or* "do nothing"
- Independent alternatives

- Mutually exclusive alternatives
- Contingency dependent alternatives

We cover these later



Detour: Comparison of alternatives

Comparing one alternative with "Do nothing"

- The "do nothing" alternative in a large company implies the that the money can be invested with a return rate = **MARR**.
- We always have the (***independent***) alternative of placing the money in an interest bearing bank account. This defines a lower limit on MARR.
- Therefore, we always compare alternatives.

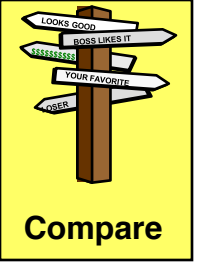
Profitability

Measures of profitability

Can you have an investment with DCFRR **>** MARR, but NPV **<** \$0 (calculating NPV with i_{TVM}=MARR)?

Can you have an investment with DCFRR **<** MARR, but NPV **>** \$0 (calculating NPV with i_{TVM}=MARR)?

Can you have an investment with DCFRR **<** MARR, and NPV **<** \$0 (calculating NPV with i_{TVM}=MARR)?



Detour: Comparison of alternatives

Independent alternatives

- Compare each alternative with the MARR
- Pick all combinations of investments for which:
  NPV > \$0 using i_{TVM} = MARR
  DCFRR > MARR
- Since they are independent, sufficient funds exist for all acceptable alternatives

Analysis for independent alternatives compares each project's DCFRR to the MARR

Measures of profitability

We have learned four measures of profitability

- **Payback time**
- **ROI**

Not recommended!

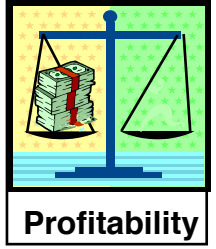
Unfortunately, both are used in everyday settings, so managers will often request these values. Just recognize their limitations.

- **NPV**
- **DCFRR**

Recommended

Note: both NPV and DCFRR require an estimate of *N* (project lifetime)

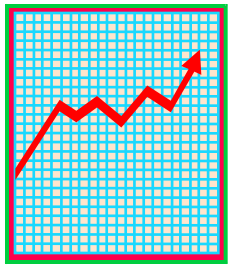
Which will you use in your course project and engineering practice?



Measures of profitability

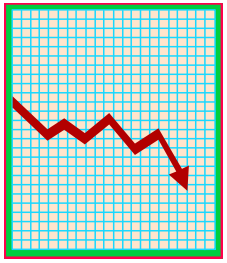
In summary, we have learned four methods

- What are they?
- Why did we learn more than one method?
- Which are recommended?
- Which will you use in your course projects?
- Which will you use in profession practice?



Is the project

profitable or unprofitable?



Measures of profitability

Self-directed learning: Covering the topic, extending beyond these visual aids.

1. For all four methods determine typical threshold values that define the boundary between attractive and unattractive projects Find the MARR for a company/sector you are interested in.
2. Investigate a fifth method, annual worth, define its threshold value, and explain when this method is most often used.
3. Determine how inflation affects the calculations of profitability measures.
4. Describe a mathematical method that you could use to calculate the DCFRR (IRR). How could you calculate the DCFRR (IRR) with the use of an Excel spreadsheet?

Measures of profitability

Extending profitability coverage

Depreciation and Taxes

must be taken into account

Corporate taxes and depreciation

- To this point, we have considered cash flows without tax. This is called Cash Flow Before Tax (CFBT). However, companies have to pay income taxes.
- Governments and non-profit organizations do not have to pay income tax.
- Tax rates generally depend on income level, but we will consider cases with high enough income that the tax rate will be considered constant.
- We will take a tax rate of 25% unless otherwise stated. Confirm that this is reasonable (CRA website).

Profitability

Corporate taxes and depreciation

Drive that new car off the car agent's lot …

- Depreciation means a decrease in worth. This could be due to wear and tear, technology changes (obsolescence), depletion, inflation, or failures.
- Companies must replace capital. *The government allows companies to lower their taxes through depreciation allowances – this helps to provide resources for (re)investment*.
- Is this "fair"?
- Can you depreciate your personal car ?

Corporate taxes and depreciation

Capital goods that can be depreciated are defined by the government. Typical properties of goods that can be depreciated are the following:

1. It must be used for the production of income.
2. It must have a determinable life longer than 1 year.
3. It must lose value over time.

Exercise: Which of the following can be depreciated by Suncor?

Laptop computers; printer paper; distillation columns; pumps; employee salaries; office buildings; land for the office buildings; company travel; CEO jet/vehicle; company travel; internet connection fees.

Corporate taxes and depreciation

- The government defines what and how goods can be depreciated (Canada Revenue Agency, CRA). We will cover the basic concepts in this course, not the detailed tax laws of Canada or another country.
- The company can reduce its taxable income by a loss in value of its equipment, i.e., by the depreciation. This reduces the taxes, not the company's actual income.

Tax paid = (tax rate) x (income – eligible expenses – depreciation)

Corporate taxes and depreciation

The following are “expensed”, i.e., the **full cost is deducted** from income in the year of the cash flow. These are “eligible expenses”:

- Startup costs
- Repair and maintenance

The following are “capital investments” and depreciated according to rules to be presented. **These are non-eligible expenses.**

- Improvements in equipment and processes
- Design engineering
- Equipment shipping and installation
- Land improvements, site preparation (roads, sewers etc.)

* The value of land is never depreciated, but it is expensed.

Profitability

Corporate taxes and depreciation

Canada Revenue Agency, CRA term for **depreciation** is

Capital Cost Allowance (CCA)

Class 8 (20%)
Class 8 with a CCA **rate of 20%** includes certain property that is not included in another class. Examples include furniture, appliances, tools costing $500 or more per tool, some fixtures, machinery, outdoor advertising signs, refrigeration equipment, and other equipment you use in business.

Class 52 (100%)
Include in Class 52 with a CCA rate of 100% (with no half year rule) general-purpose electronic data processing equipment … …. if they were acquired after January 27, 2009, and before February 2011, but not including …

Class 10 (30%)
Include in Class 10 with a **CCA rate of 30%** general-purpose electronic data-processing equipment (commonly called computer hardware) and systems software for that equipment, including ancillary data-processing equipment, if you acquired them before March 23, 2004, or after March 22, 2004, and before 2005, and you made an election.

Also include in Class 10 motor vehicles as well as some passenger vehicles as defined in Type of vehicle

etc, etc
etc, etc

Profitability

Corporate taxes and depreciation

Depreciation in a time period is calculated as a ***percentage of the initial investment*** or remaining book value in that time period.

- Starts when equipment is "put in service". The length of time that the depreciation will take place is defined by the government in some cases.
- The remaining value at the end of each period is termed the "book value".
- The initial book value is the purchase (installed) price.

includes engineering, transportation, installation, and site preparation costs. We'll see more in "Cost Estimation".

Corporate taxes and depreciation

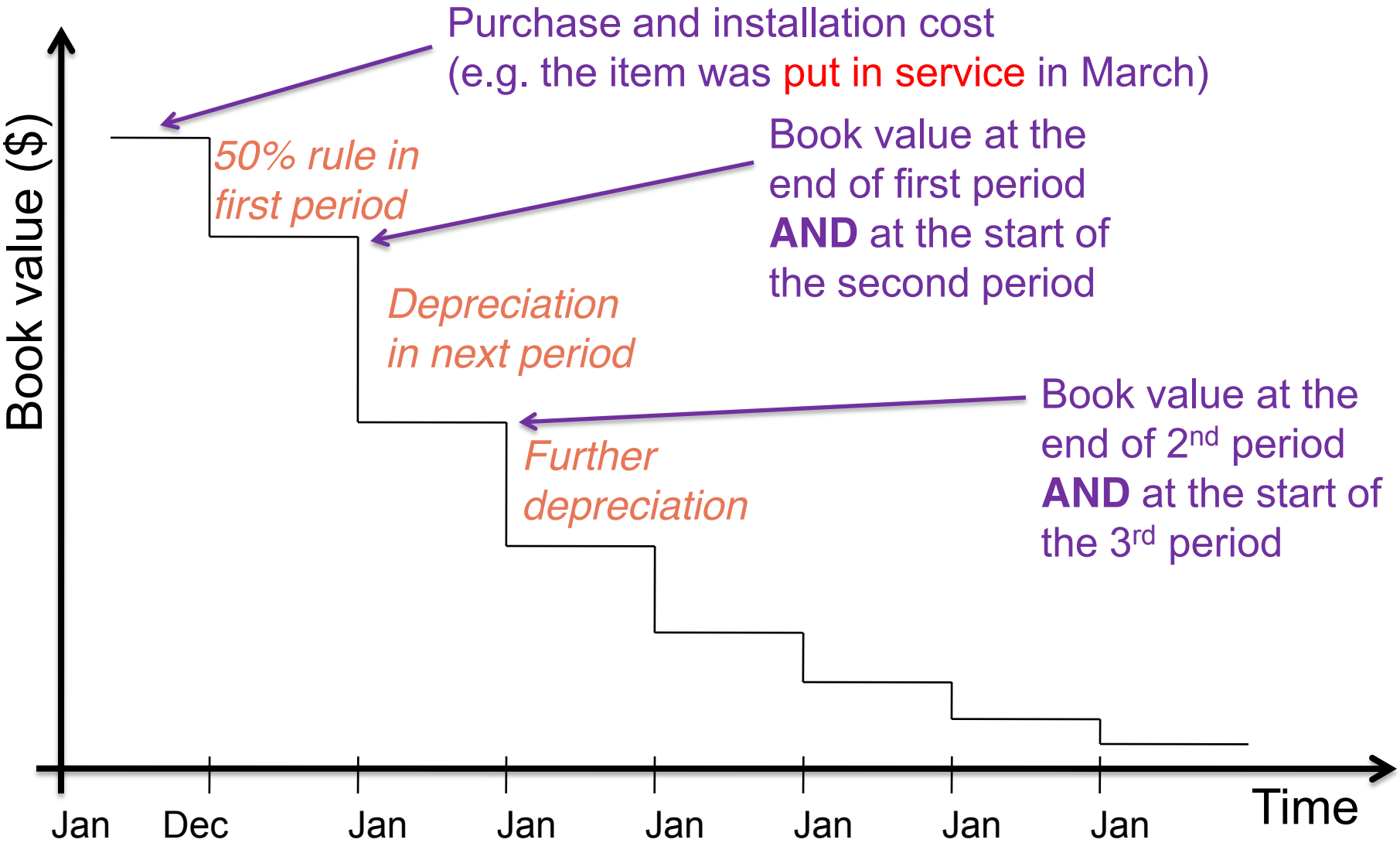
Let's look at ONE major depreciation method only.

But first, we recall that the typical time period is one year. When in the year does the company invest, January 1 or December 31?

50% Rule : The government sets the rules. It assumes that the investment is made in the middle of the year, and it allows only 50% of the depreciation for the first year.

We must abide by this rule!

Corporate taxes and depreciation



Profitability

Corporate taxes and depreciation

Declining balance depreciation

In this method, a percentage of the book value in each year is depreciated, so that the depreciated amount each year is not constant.

$$D_n = d \times B_n$$

$$B_n = B_{n-1} - D_n$$

$$D_0^{\text{actual}} = 0.5 D_0$$

B_0 = initial cost (installed price) of equipment

B_n = book value at time t

d = depreciation rate (government class)

D_n = **amount** depreciated each year

50% rule applies in first period

Corporate taxes and depreciation

Example

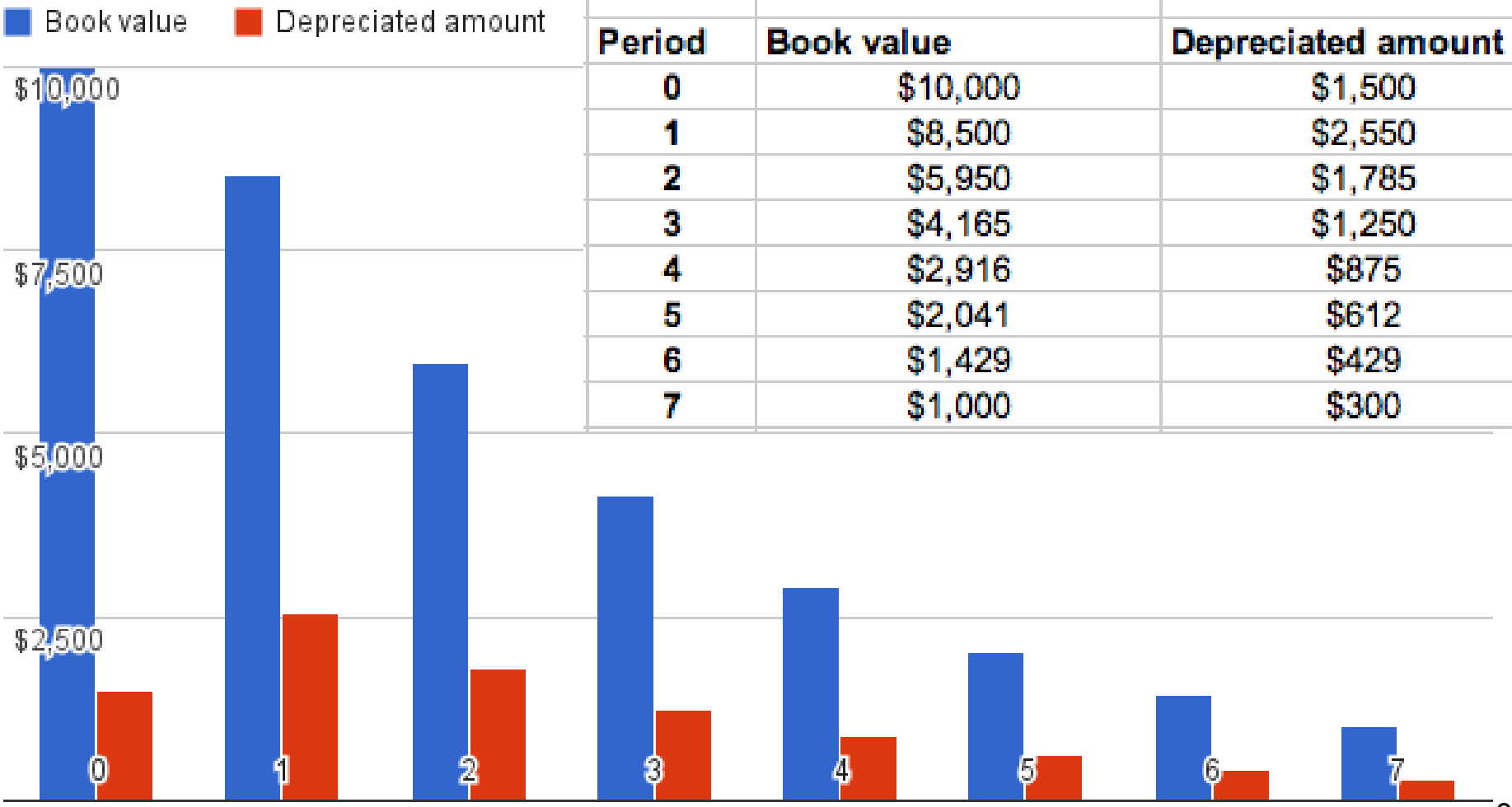
Suncor is purchasing a new reboiler for $10,000,000. The **CRA class is 43, with a rate of 30%**. Calculate and plot the book value (B_n) and depreciated amount (D_n) for 8 years.

Work in rounded $1000's.

Profitability

Corporate taxes and depreciation

	Depreciation rate =	0.3
Period	**Book value**	**Depreciated amount**
0	$10,000	$1,500
1	$8,500	$2,550
2	$5,950	$1,785
3	$4,165	$1,250
4	$2,916	$875
5	$2,041	$612
6	$1,429	$429
7	$1,000	$300



Profitability

Corporate taxes and depreciation

	Depreciation rate =	0.3
Period	**Book value**	**Depreciated amount**
0	$10,000	$1,500
1	$8,500	$2,550
2	$5,950	$1,785
3	$4,165	$1,250
4	$2,916	$875
5	$2,041	$612
6	$1,429	$429
7	$1,000	$300

What happens with these depreciated amounts?

Is it an income?
Is it an expense?
Does it exist as cash in the company's bank account?

Note: those depreciated amounts are not deflated for TVM, so their true value is actually less in PV terms.

Profitability

Corporate taxes and depreciation

What's the main advantage of depreciation for the company?

The company pays lower taxes! They can *reduce* their taxable income in a year by the amount of depreciation during the year. The company can, in **each** period:

A = sum all income and revenues

B = sum all ***eligible*** expenses (use –ve's for expenses)

C = all non-eligible expenses (use –ve's; equipment, shipping, installation, *etc*)

D = calculate the book value (at start of the period; update it from previous)

E = calculate the depreciation, and **sum all depreciations up** [always +ve]

F = taxable income = **A** + **B** *minus* **E** (note that **B** must have negative sign)

G = **tax paid** = (taxable income) * (tax rate) [can be a +ve or –ve result]

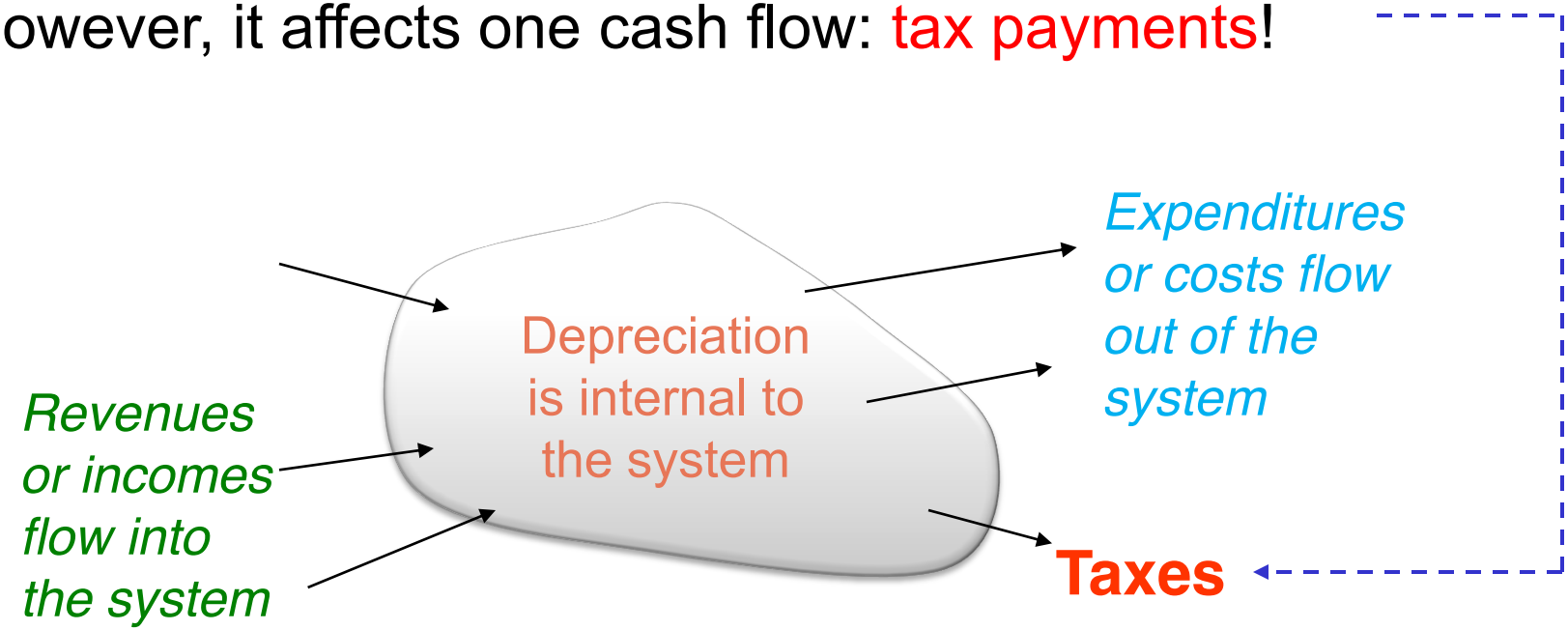
H = net cash flow for period = **A** + **B** + **C** *minus* **G**; then adjust **H** for TVM

Corporate taxes and depreciation

Point of frequent misunderstanding:

Depreciation is not a cash flow!

However, it affects one cash flow: tax payments!



Profitability

Corporate taxes and depreciation

Evaluate the **profitability** for installing an automated, online pulp quality analyzer (Kappa number) on a Kraft digester.

Analyzer capital cost including installation = $75,000
Analyzer maintenance cost = $5,000/year (except for first year)
Increased profit due to improved pulp quality = $20,000/year

Depreciate the analyzer using the declining balance method. The analyzer has an expected life of 5 years. The salvage value is $0.

Assume it is January 2014. Your company's year end is 31 December. Assume the equipment can be installed and put in service in January 2014.

Calculate the **payback time**, **cash flows** in each period, **NPV** (using a TVM of 8%), and **DCFRR**. The company's MARR is 10%.

In class: set up the problem and calculate for *n=0*, *n=1*. Do the rest at home.

Profitability

Corporate taxes and depreciation

	Depreciation rate =	**0.3**				
	TVM rate =	**0.08**				
	Corporate tax rate	**0.25**				
Period	**Revenue [A]**	**Eligible Exp [B]**	**Non-eligible exp [C]**	**Book value [D]**	**Depreciation [E]**	**Taxable income [F]**
0	$20,000	$0	-$75,000	$75,000	$11,250	$8,750
1	$20,000	-$5,000	$0	$63,750	$19,125	-$4,125
2	$20,000	-$5,000	$0	$44,625	$13,388	$1,613
3	$20,000	-$5,000	$0	$31,238	$9,371	$5,629
4	$20,000	-$5,000	$0	$21,866	$6,560	$8,440

Period	**Tax paid [G]**	**Net cash flow [H]**	**Cumulative CF**	**TVM cash flow**	**Cuml TVM cash**
0	$2,188	-$57,188	-$57,188	-$57,188	-$57,188
1	-$1,031	$16,031	-$41,156	$14,844	-$42,344
2	$403	$14,597	-$26,559	$12,514	-$29,829
3	$1,407	$13,593	-$12,967	$10,790	-$19,039
4	$2,110	$12,890	-$77	$9,475	-$9,564
			SUM	-$9,564	
			DCFRR	0.00	
			i.e.	0%	

Payback time is in period *n*=5 (around 5.1 years, although the life of the equipment is 5 years, we may never reach payback). Cash flows are shown above; NPV's are as shown; DCFRR=0% *in the 5 year period*.

Corporate taxes and depreciation

Straight line depreciation

The CRA allows straight line depreciation in certain classes.

Example: $10,000 over a 4 year (CRA specifies this) period, allows for

- $2,500/2 in year 1 (BV = $8,750)
- $2,500 in year 2 (BV = $6,250)
- $2,500 in year 3 (BV = $3,750)
- $2,500 in year 4 (BV = $1,250)
- $1,250 in year 5 (BV = $0)

Profitability

Corporate taxes and depreciation

Group learning / Self-learning:

1. Determine the typical corporate tax rate in several countries.
2. What is the effect on cash flow after tax when a depreciated good is sold for a price different from its book value?
3. What is the (approximate) relationship between the MARR before and after taxes?
4. The company purchases and installs new equipment on January. How much can be depreciated during the first year?

   More generally, when can a company begin depreciating a capital expense?

Profitability

Corporate taxes and depreciation

Group learning / Self-learning:

5. What is more beneficial to a profitable company? Why?
   a. Rapid depreciation
   b. Slow depreciation
6. How can a government encourage investment in a specific technology via the tax laws? (for example, information technology, sustainability, or environmental protection)
7. What is the effect of a negative income taxes, which can occur when depreciation in greater in magnitude than net income?