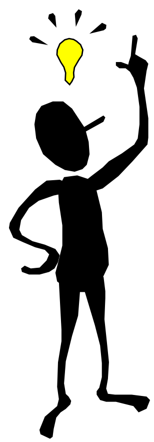
Class notes for ChE 4N04
Engineering Economics section



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.

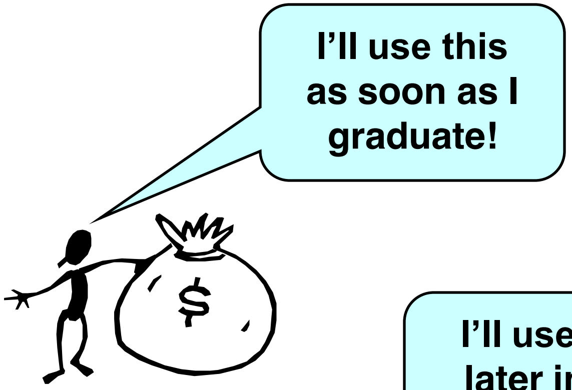
Course principles have many applications

Engineering Economics

- Evaluate profitability of alternative investments

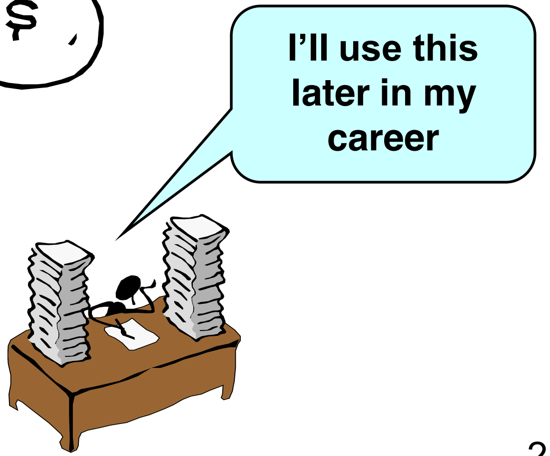
Personal Finance

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



Corporate Finance

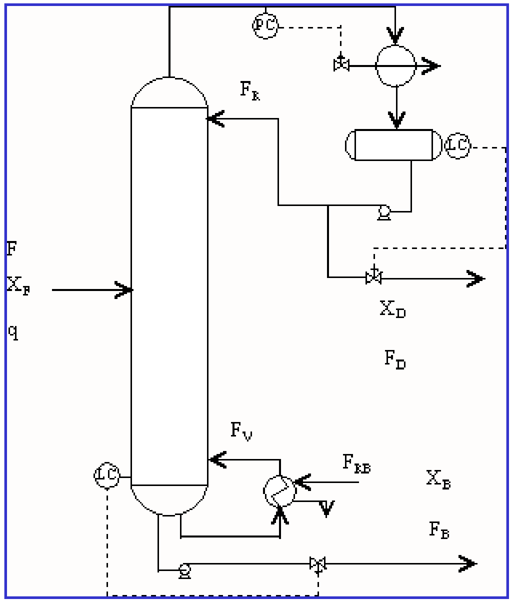
- Provide adequate cash reserves
- Determine minimum rate of return



Your first task at your new job

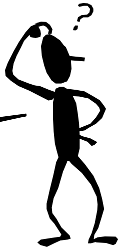
Supervisor to you: We want to increase our production rate by 35%, but the distillation tower is at its maximum capacity (liquid and vapour flows).

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



What is the best choice?

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?

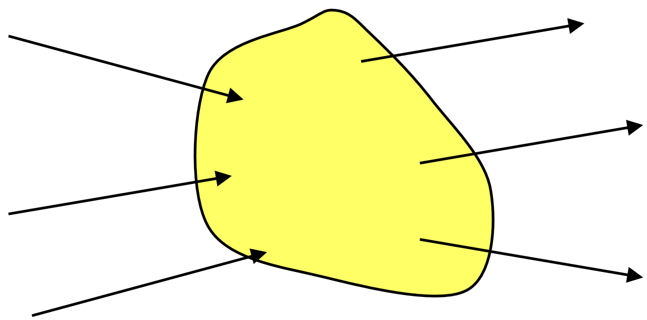
Time-value
Money

Time value of money

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

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

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



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

- **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

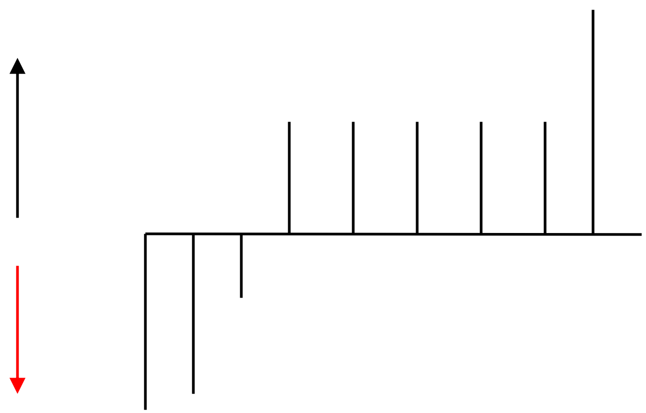
Cash flows occur over time.

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



time →

Periods are numbered from 0 to the end of analysis.

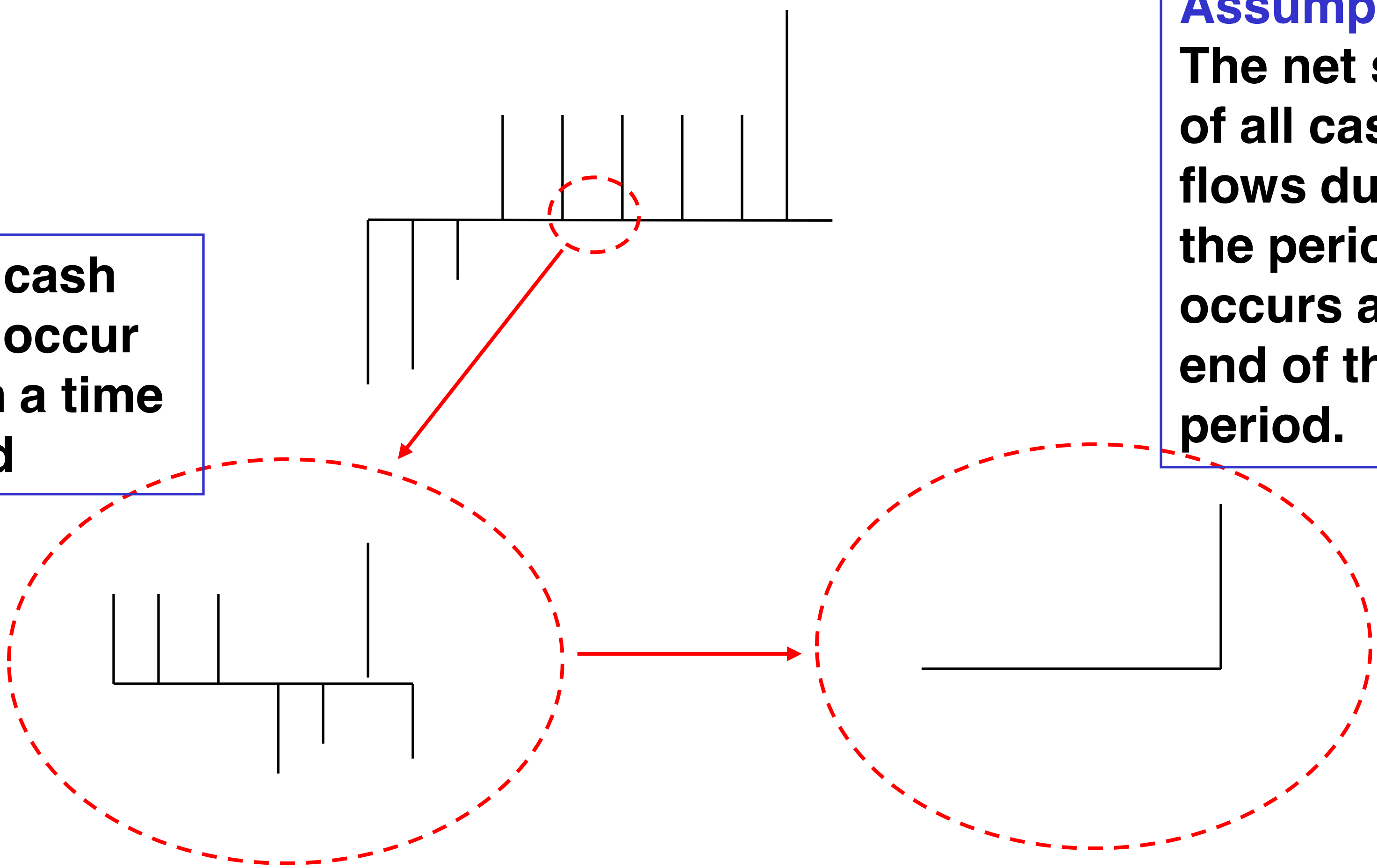
Period can be any time length; often one year for engineering projects

Cash flows in units of money ($)

Time value of money

Cash flow diagram and analysis

Many cash flows occur within a time period



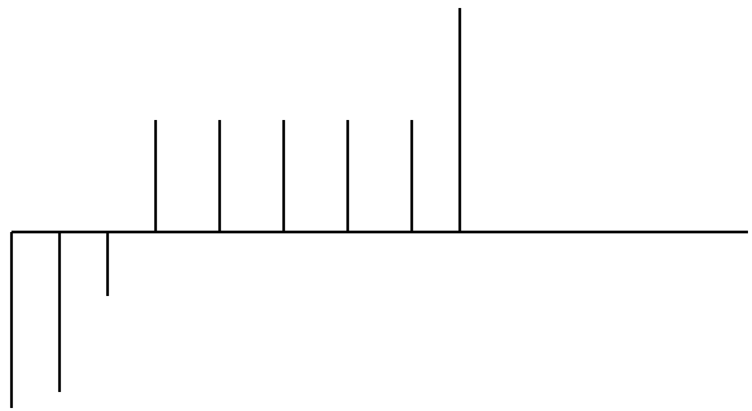
Assumption: The net sum of all cash flows during the period occurs at the end of the period.

Time value of money

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

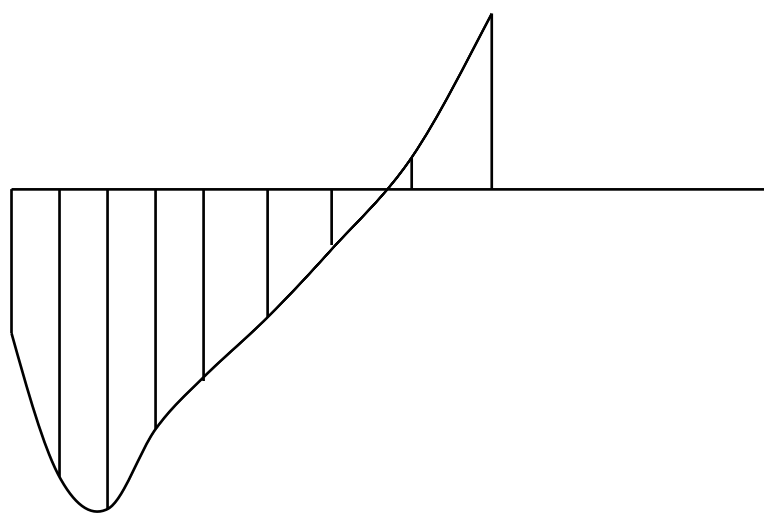
Cash flow diagram

(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?

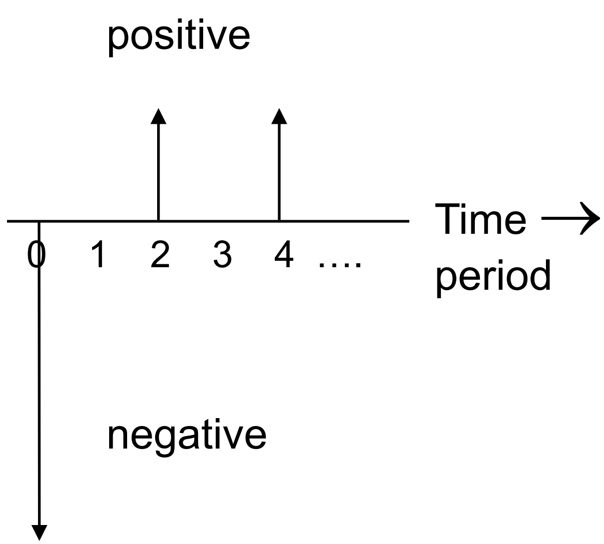
- **We use an interest rate, so that the effect of time is proportional to the total amount of money involved.**

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 $F = \$1000$

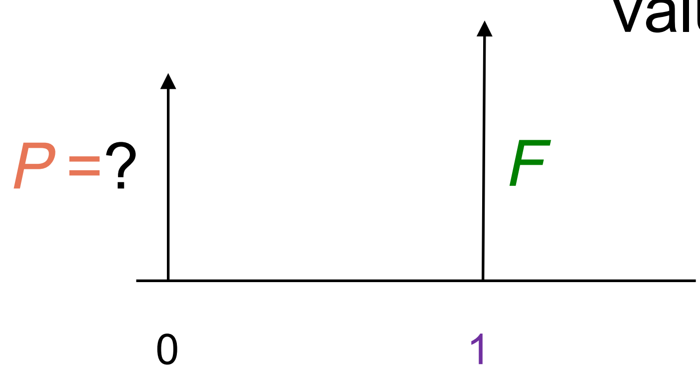
But we have only $P = \$800$ to invest now.

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?

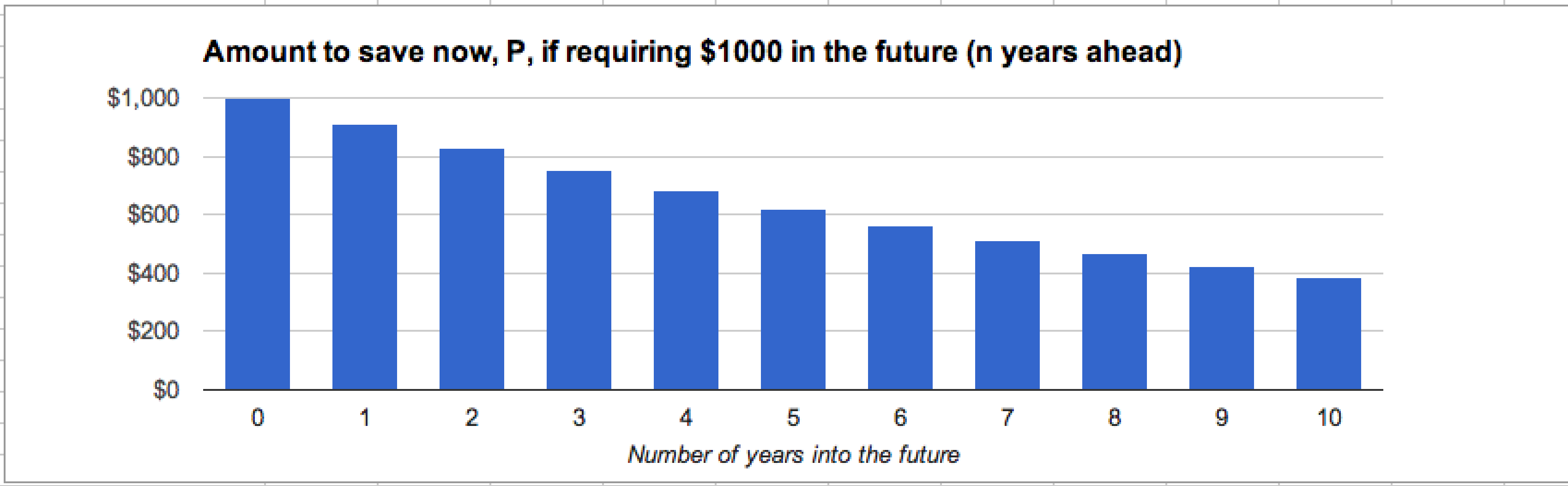
Asked another way …

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
Money

Time value of money

IGNORE

Time-value Money

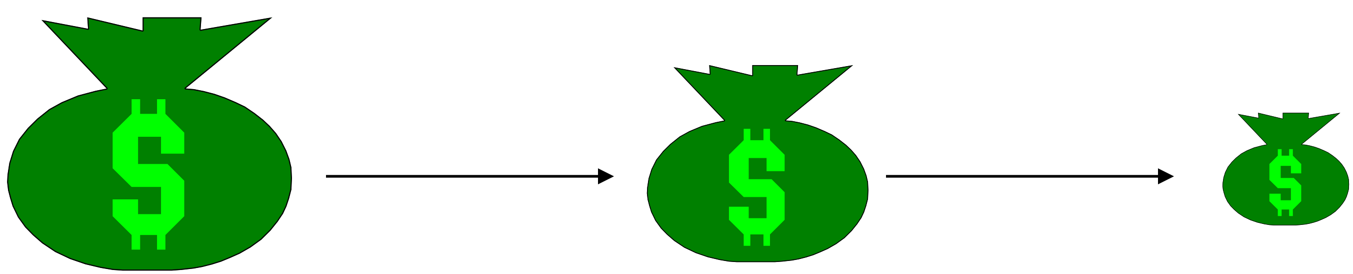
Time value of money

IGNORE

Time-value
Money

Time value of money

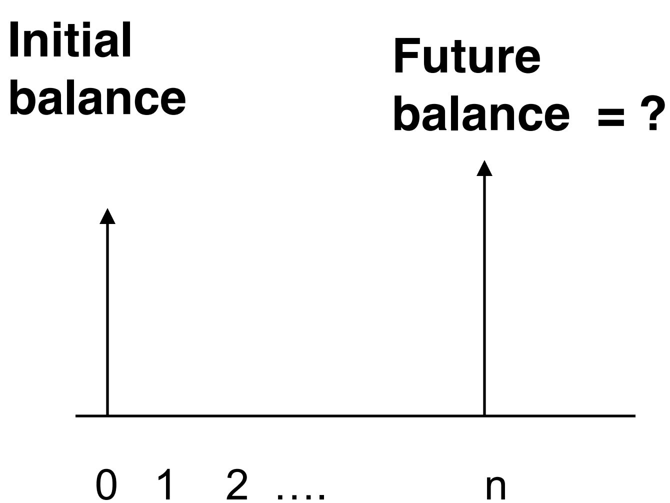
- Since money has a time value, money in the future has less value. We will characterize this decrease with the “time value of money”.
- For a worthwhile investment, the net income in the future must be greater than the original expense.



Time-value Money

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?

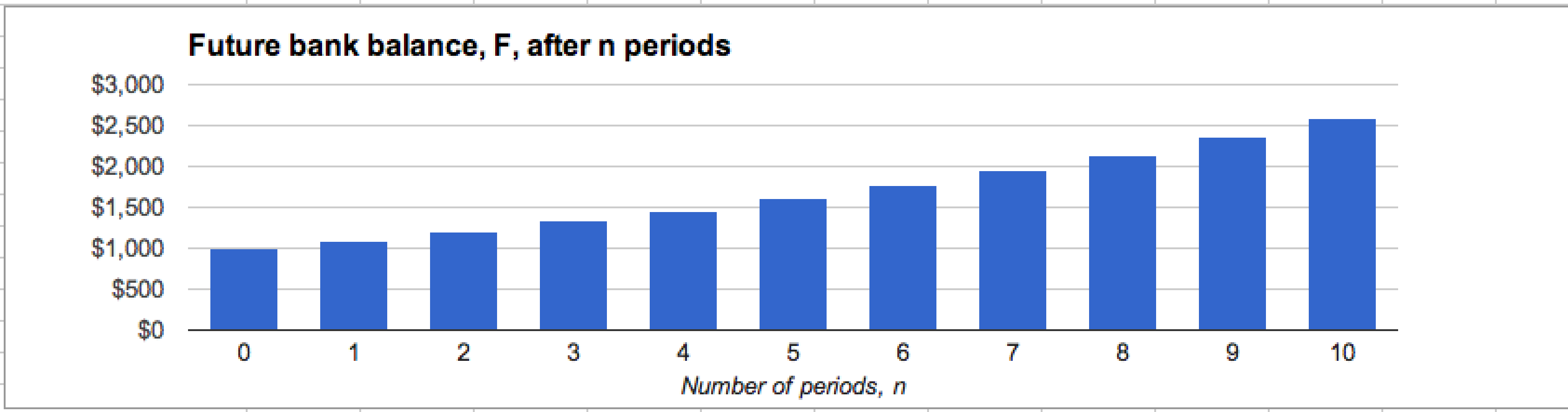
$$\boxed{\textbf{Future balance} = P\,(1 + i)^n}$$

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



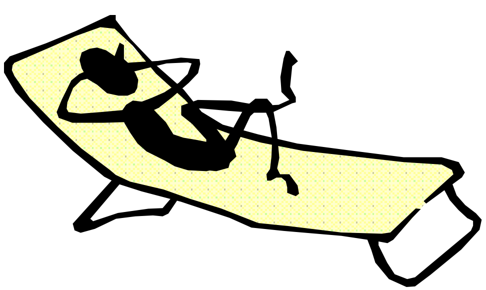
Time-value
Money

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 Money

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 …

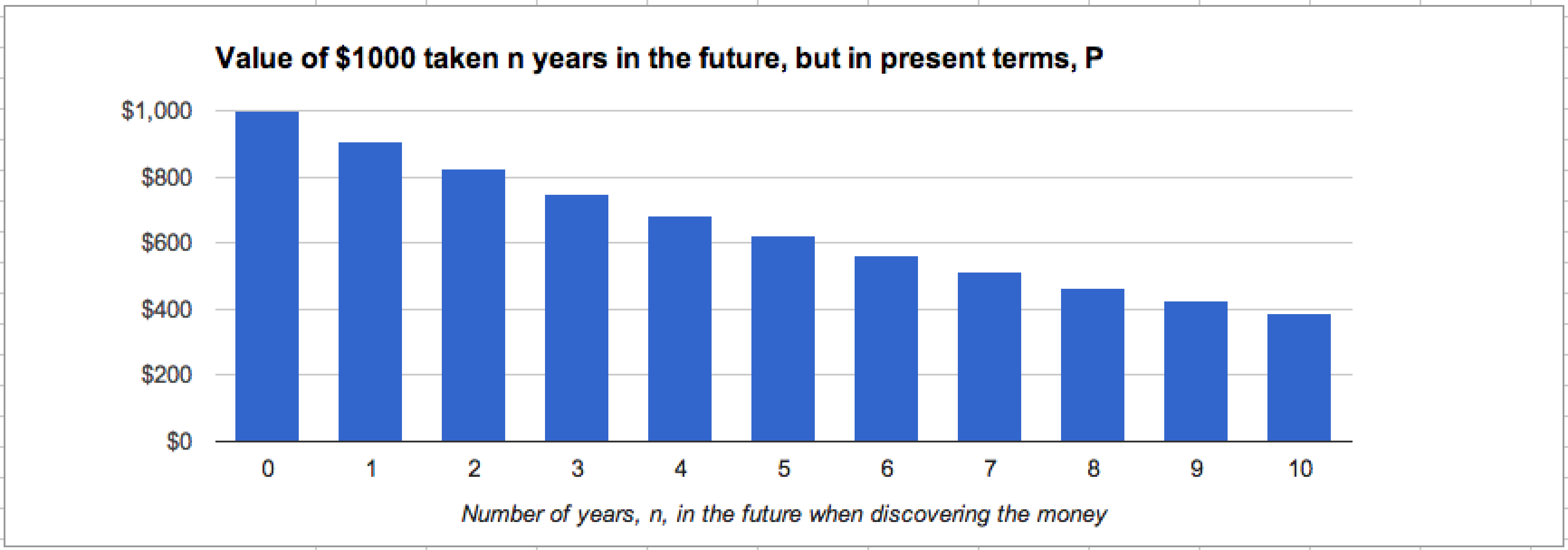
In n = 1, 2, …10 years from now you discover F = \$1000 under your mattress, and you can go buy goods with those dollars.

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 Money

Time value of money

Economic and financial indicators — **The Economist** September 7th 2013

Interest rates

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% month interest per month.

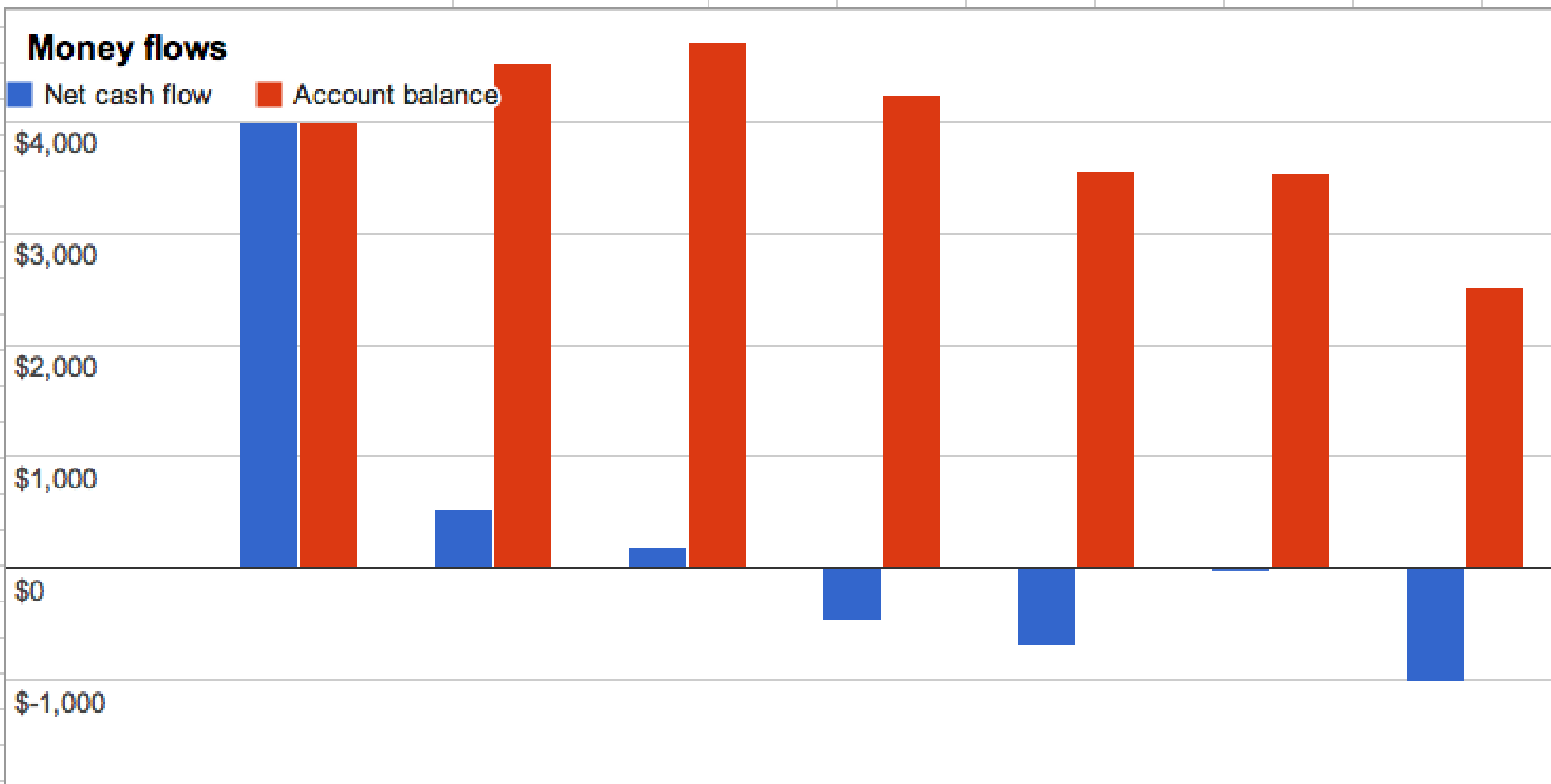
Plot the monthly balance *and* cash flow diagram for your bank account.

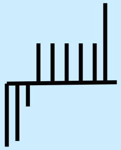
	Month	0	1	2	3	4	5	6
Revenues		$4,000	$530	$530	$0	$0	$0	$0
Expenses		$0	-$200	-$570	-$700	-$900	-$200	-$1,200

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

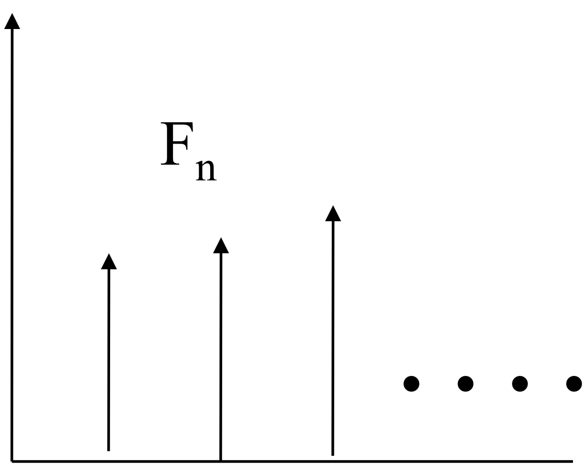
Class exercise: You deposit \$5000 in a bank account with an annual compound interest rate i^*. The time value of money is described by an interest rate i' (inflation rate).

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

Time-value Money

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

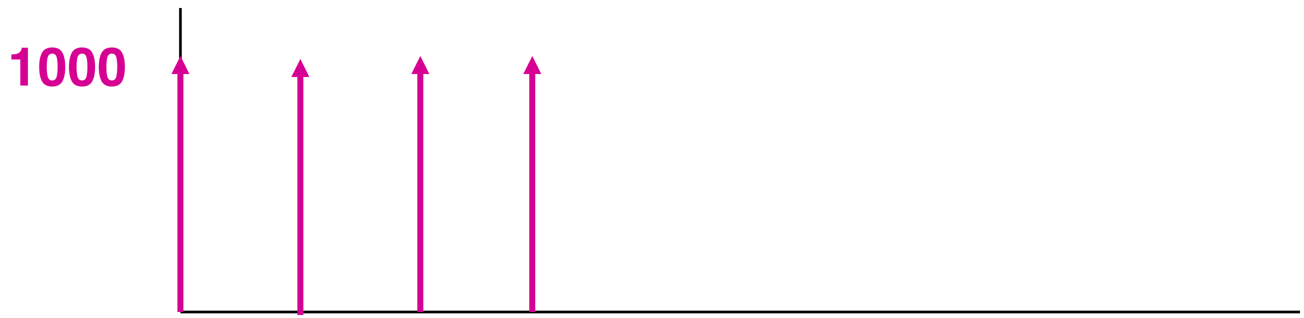
You have an income of $1000 per year for each of the 4 years of your undergraduate studies.

- 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 Money

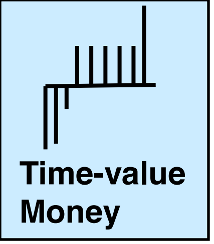
Time value of money

Class exercise



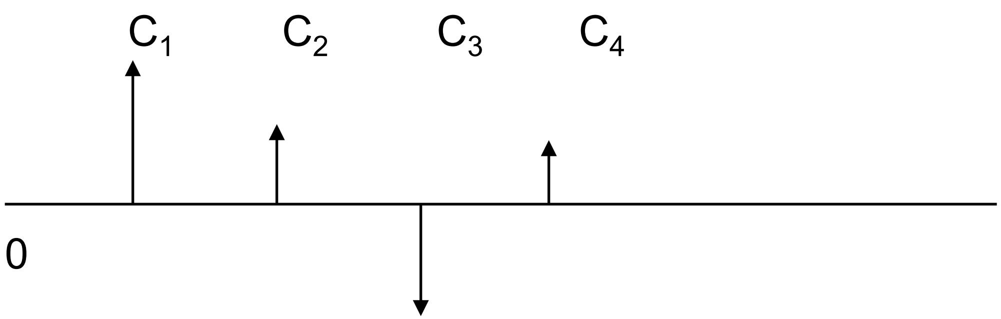
	Inflation rate, i =	0.1			
Period	n	**0**	**1**	**2**	**3**
Cash flow in the period	Fn	$1,000	$1,000	$1,000	$1,000
Cash flow in present value terms	P	$1,000	$909	$826	$751
Cumulate cash flow in present value terms		**$1,000**	**$1,909**	**$2,736**	**$3,487**

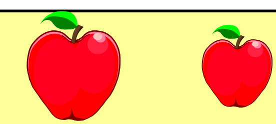
Interpretation: You could replace the cash flow with one revenue of $3487 at time period 0, that earned interest at 10%.



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!

$$\mathbf{P = C_1/(1+i) + C_2/(1+i)^2 + C_3/(1+i)^3 + C_4/(1+i)^4}$$

with C_i = cash flow at period i

Time value of money

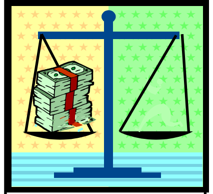
Some thoughts

- **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 $4000 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 $4000? 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).



Profitability

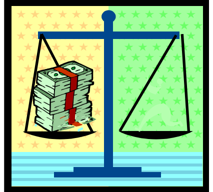
Measures of profitability

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.

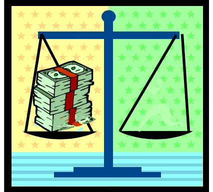


Profitability

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

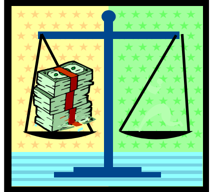


Measures of profitability

Examples for each category

- Universities - 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



Profitability

Measures of profitability

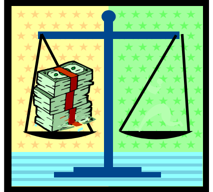
We can invest money yielding a 15% annually compounded return.

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.

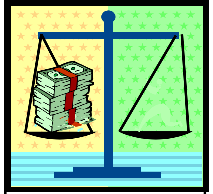


Profitability

Measures of profitability

Payback time

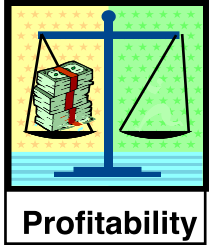
- This measure is often used as a “quick and dirty” measure of profitability
- Also called *Payout Time*
- Defined in units of time (months or years)
  - The time for the cumulative cash flow to achieve a value of 0.0.
  - Usually (and in this course), payback time does not consider interest.


Profitability

Measures of profitability

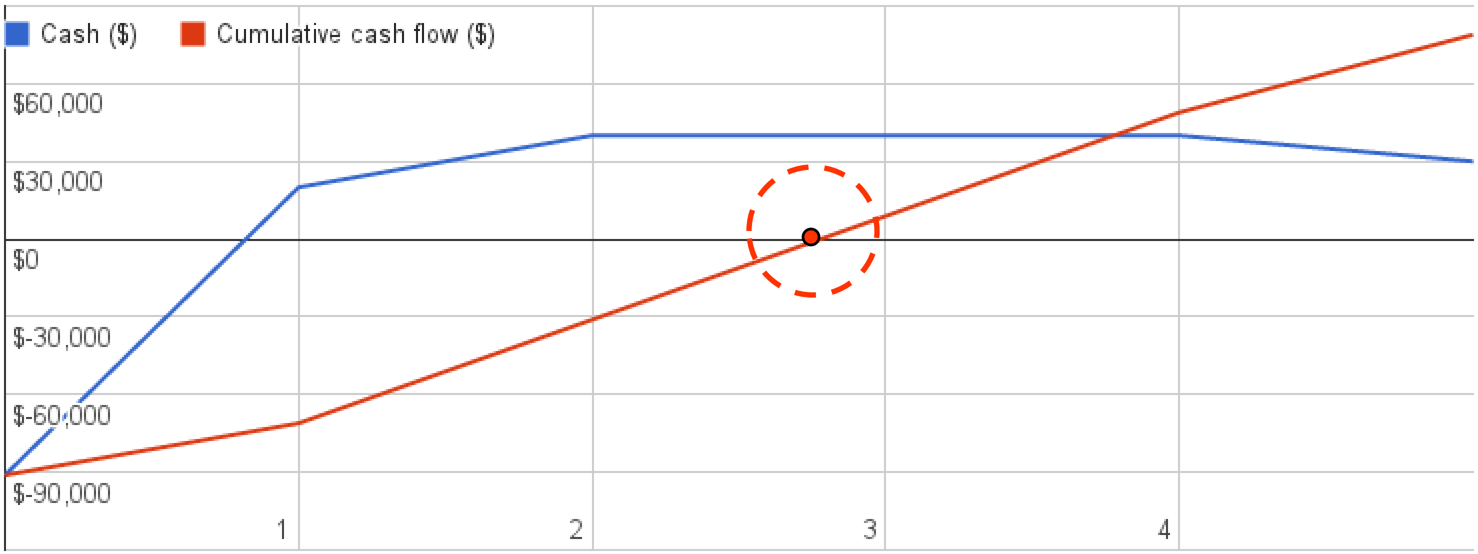
Class exercise: Payback time

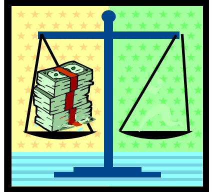
Determine the payback time for the cash flow defined in previous table



Measures of profitability

Plot used to determine the payback time





Profitability

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.

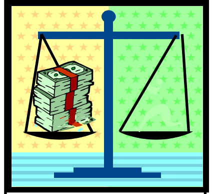
  Payback time = 91/34 ≈ 2.7 years [rough calc.]

- **Notes**

- No time value of money

- Zero investment gives instantaneous payback!

Not recommended!



Profitability

Measures of profitability

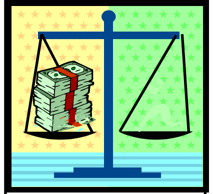
Return on original investment (ROI)

- 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?



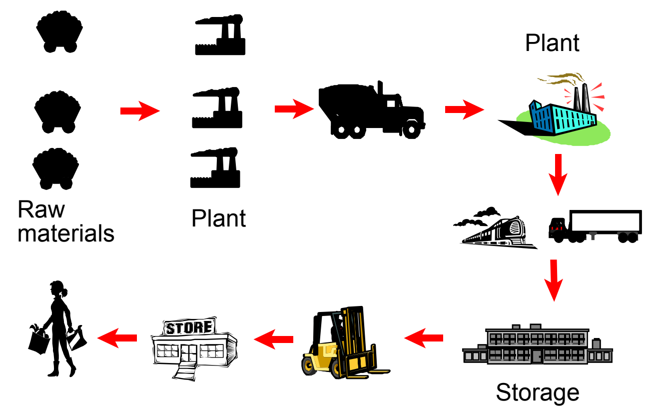
Profitability

Measures of profitability

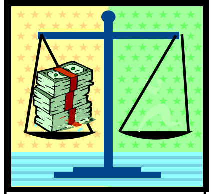
Working Capital

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.



Profitability

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!