A SunCam online continuing education course

Engineering Economics Made Easier with *MS Excel*

by

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Contents

Introduction

The preamble to the NSPE Code of Ethics for Engineers states that:

> *"the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare."*

When we submit engineering proposals, we know we often have to overcome a number of physical limitations in order to come up with the "best" way of solving a problem. But we should also ask ourselves, "Is this the most economical way of solving the problem?"

Part of our responsibility as professional engineers must include providing an unbiased and quantitative economic assessment of any idea that involves spending money. These ideas may come from small-business owners, managers of large companies, community leaders, government officials, or others. We may be asked to provide our input on proposed initiatives for a business plan. Questions may arise such as, "What is the return on investment for this?" or "How long will it take to pay back all the money I am spending?"

We must be able to speak both our "technical language" and the "language of managers" (paraphrasing slightly from quality guru Joseph Juran). Managers are concerned with the bottom line and want to ensure that resources are being used in the best way possible. As engineers, we too have a similar responsibility as we protect the welfare of the public.

The field of engineering economics, formerly known as engineering economy, estimates the costs and potential savings of proposals, and then determines if the proposal makes "money-sense". Because the value of money today is not the same as money in the future, we must account for the time value of money, and calculate the proposal's "net present value" based on a rate of return desired by the organization.

Unfortunately, the concepts of the time value of money and rate of return are not well understood by many. A friend of mine in the printing business was recently telling me about a buy versus lease decision he had to make. He could buy a digital printer for $100,000, use it for 4 years, and then recoup $5,000 by selling the printer. He would get a service contract for $3,000 a year. Or, he could lease the digital printer for $30,000 a year, service included. He said, "This is easy. If I buy, I am only spending $107,000. But if I lease, I am spending $120,000." I said, it depends on the rate of return you expect in your business. I could tell this was not a concept he was comfortable with.

Even engineers struggle with these concepts. Two of my colleagues are trying to decide whether they should draw their Social Security benefits before full retirement age, or wait until full retirement age, or wait until age 70. Both said to me in separate conversations, “I wish I had paid more attention back in engineering economy.”

Back in those engineering economy days, we often would have to go to tables of numbers and look up the correct “factors” to use to calculate present values and future values. We would have to “interpolate” from the tables if we were to use an interest rate of 7.5% (because the tables skipped from 7% to 8%). It was difficult to “back into” a rate of return for a proposal, or to estimate how long it may take to recoup an investment based on a desired rate of return. (Dare I mention slide rules?)

When you take this course, you will see that *MS Excel* has quite a few functions that will speed through calculations involving present value, future value, annuities, rates of return, and others. Woven through the course are engineering, business, and personal illustrations to help you better relate to the time value of money and the rate of return.

There will also be material devoted to understanding the different types of costs and benefits, including a discussion on intangible benefits. We will look at six different ways of evaluating the monetary value of proposals, and discuss the subtleties of what each measure tells us. We will use an *Excel* tool called *Data Table* to help us perform a type of sensitivity analysis of proposals.

Engineering economics is not easy. But after completing this course, you should be able to see how *Excel* can make it easier.

Course Objectives

In this course, "Engineering Economics Made Easier with *MS Excel"*, we plan to:

1. Define initial and on-going costs, monetary benefits, and intangible benefits.
2. Demonstrate the use of a cash-flow diagram, and how to depict costs and benefits.
3. Calculate three basic measures of a proposal, including net benefit, benefit-cost ratio, and ROI (return on investment).
4. Show how to calculate the above with simple *Excel* formulas.
5. Through illustrations, identify the subtleties of what each measure indicates, and explain which is the preferred one and why.
6. Identify the major weakness in each of the measures, i.e., their failure to account for the time value of money.
7. Illustrate the inaccuracy of a fourth proposal measure called payback period.
8. Through problems, practice using *Excel*'s *=PV*, *=FV*, *=PMT*, *=NPER*, and *=RATE* functions in a variety of engineering, business, and personal applications, illustrating the time value of money.
9. Open an *Excel* sample template for loan amortization, and make calculations.
10. Investigate the use of present value analysis and the concept of equivalency as it pertains to future cash flows.
11. Use the *Excel* function *=NPV* to calculate a fifth proposal measure called net present value, and apply it to a number of engineering, business, and personal applications.
12. Refer to guidance that suggests that the net present value is the preferred measure of a proposal's value.
13. Determine the appropriate interest rate (aka discount rate) to use when calculating the net present value, from the perspective of personal investments, private sector enterprises, and governments.
14. Use the *Excel* function *=IRR* to calculate the sixth measure called internal rate of return, when the choice of an interest rate or a discount rate is ambiguous.
15. Use the *Excel* tool *Data Table* to illustrate sensitivity analysis, working through problems involving differing interest rates and other proposal variables.

Initial Costs, On-going Costs, and Residual Values

Initial costs are one-time costs that we incur to get the activity or proposal started. They would not occur again during the life of the project. In your prior engineering economy courses, these may have been described as "first costs" or "startup costs".

On-going costs. On-going costs consist of recurring costs (meaning re-occurring usually on an annual basis), and non-recurring costs, such as scheduled upgrades, expansions, or other costs that may not occur on an annual basis.

A **residual value**, sometimes called a salvage value, would be a cost credit, if we were able to get anything from an asset we purchased in our proposal.

The different types of costs are illustrated in the examples below.

<u>Example 1: Replacing a house heating system – the costs</u>

Let's say after a long, cold winter, you've become frustrated with your current heating system, a 15-year old heat pump, and this spring you will begin to investigate the purchase of a replacement heating system. Two options under consideration include 1) a newer, high-tech heat pump which promises better heat and lower energy costs; or 2) perhaps it is time to abandon the heat pump idea, and install a propane tank and furnace, and start to feel "real heat". A neighbor suggests heating with a wood stove or wood pellets, but your neighbor is a lot younger than you, and enjoys climbing trees and harvesting his own firewood. You rule out this alternative. You consider natural gas, but it is not available in your area, so this also is ruled out. For various reasons, you also rule out solar panels, coal, and systems powered by heating oil.

The initial costs for your replacement heat pump alternative may include:

- Removal and disposal of the current system
- Purchase price of the new system
- Programmable thermostat
- Installation costs of the heating system unit (labor and supplies)
- Extended warranties
- Electrical upgrades

For a new propane system, we would incur all of the above, and may have a few others:

- Purchase of a 500-gallon storage tank
- Installation of the tank
- Installation of gas lines, regulators, electrical grounds

On-going costs for either system include:

- Regular system maintenance (inspection, cleaning, etc.)
- Operating costs (electricity or propane)
- Renewal of warranties

More than likely there is some value to some of the old heat pump parts, but these will be part of the profit for the installer. Therefore, there is no residual value for your old system.

Example 2: A company-wide upgrade to a new computer system – the costs

In the case of a company-wide upgrade to a new computer system, the initial costs could take years, and would include:

- System Design
- Software development
- Hardware acquisition
- Training the employees on how to operate the new system
- Exchange of data from old system to new

For the system-wide upgrade to a new computer system, on-going costs could include:

- System "maintenance" and upgrades
- Help/support labor

Finally, there is likely no residual value from the system after its physical or technological life.

Benefits/Savings (Monetary and Intangible)

Back in our engineering economy courses, we used the term receipts to mean the income from an investment opportunity. (Similarly, the costs were described as disbursements.) In this course, we will refer to the receipts as the benefits of a proposal. The anticipated benefits are why we are considering doing a proposal, and they may be to increase profit, lower labor costs, improve customer service, reduce air pollution, and so forth. It is ultimately the engineer's job to forecast what those benefits might be, and then compare those benefits to the costs. An attractive proposal would be one where the benefits are higher than the costs. In the comparison of alternatives, we would likely choose the option that yielded the greatest benefits for the cost.

The benefits of a proposal that can have a dollar value assigned to them are defined as the **monetary benefits**. It is the monetary benefits that we capture onto the cash flow diagrams, and ultimately compare to the costs. In this course, we do not delve into the detail of how to calculate monetary benefits, but a simplified example of how this may be done is shown below:

1. A proposal to automate an operation may result in eliminating five positions.
2. A position's average annual salary is $50,000.
3. The fringe benefit rate is 20%.
4. The savings = 5 x $50,000/year x 1.20 = $300,000 annually.

As a general rule, the monetary benefit estimates from proposed projects are perceived as being more "nebulous", as compared to the cost estimates. Even though unexpected costs can arise, cost estimates can usually be documented by bids, market research, and standard cost data (used in construction). Because of this, it is the monetary benefits that are often "tweaked" to improve the financial attractiveness of a proposal.

For example, when I worked in manufacturing in the industrial engineering department, our plant management would give the cost estimating part of a proposal to what it termed the "real engineers" (civil, mechanical, electrical – CEs, MEs, EEs), and the savings estimation to the industrial engineers (IEs), who also had the moniker "imaginary engineers", which happened to also nicely fit the abbreviation "IE".

When management would "marry" the cost estimates and the savings estimates, often the proposal was not economically justified, and management's first stop in making the proposal more attractive was at the IE department, to try to coax more savings. I, the instigator, would say why don't you get the "real engineers" to lower their costs, but management would say that the costs were pretty solid, and that it needed the IEs – the imaginary engineers – to create more savings. So, if we had guessed there would be a 10-person labor reduction, management would ask us to "imagine" a 12-person reduction, perhaps. Obviously, this was not a great way to run a business.

Intangible benefits are those benefits that cannot be monetized, or at least they shouldn't be. Sometimes it is the intangibles that can justify the proposal, even if the monetary benefits alone are not enough to justify the costs – but usually not.

Because of this, since it is only the monetized benefits that are captured in a net present value or in a return on investment calculation (terms to be defined later), there is pressure exerted on the engineer to monetize intangible benefits. For example, if a proposed light rail extension could offer more workers a chance to get to work without the hassle of fighting traffic, the workers would likely be less fatigued and less stressed when they arrive at work. This is an intangible benefit and should be noted in an engineering justification, but it would not increase the monetary attractiveness of the proposal.

So, to get more savings, "imagine" the reduced stress could result in improved productivity. Suppose there were a 5% increase in productivity from a "less stressed" worker earning $70,000 a year (including fringe), and 1,000 workers took the light rail extension instead of driving to work. A monetized annual benefit of 5% x $70,000 x 1,000 = $3,500,000 could be estimated, for the life of the proposal. Over a 30-year proposal life, we could claim $105 million.

This would definitely drive up the monetized savings for the proposal, but I would not want to be the engineer who would have to defend this calculation. Shenanigans like this cast a "cloud" over all of the engineering calculations that went into the analysis. Now, let's return to our two examples.

<u>Example 1: Replacing a house heating system – monetary and intangible benefits</u>

For a heating system replacement, the monetary and intangible benefits are:

- Energy savings (monetary) realized by either system
- A warmer house (intangible) realized by either system, though propane feels warmer
- A "cleaner house" (intangible) especially if we were replacing a wood stove or an oil-fired furnace
- Higher resale value of our house (monetary)
- "Gadgets" (intangible), such as controlling our heat from a remote location

Example 2: A company-wide upgrade to a new computer system – monetary and intangible benefits

Dependent on the scope of the proposal, some typical benefits are:

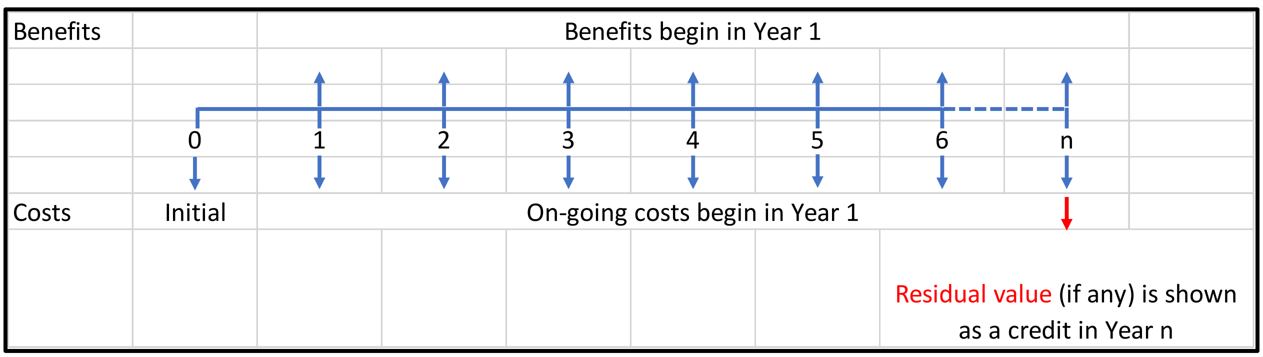
- Labor savings (monetary) from improved efficiency in processing
- Quality improvement (monetary)
- Faster customer response (mostly intangible)
- Improved protection of Personally Identifiable Information (intangible)
- Reduced backlog (monetary)
- Cost avoidance (monetary), such as not having to hire future workers
- Reduction of fraud (monetary)
- Keeping technologically "current" (intangible)

The Cash Flow Diagram

In this course, we will be using **cash flow diagrams** to visually depict costs and benefits for proposals. Costs will be shown as arrows pointing downward. The initial costs are placed onto a cash-flow diagram into what may be termed Year 0, or the "Present". They can be incurred in a matter of days (such as the new heating system), or months, or even years (such as the new computer system). Regardless of the length of time, they are claimed in Year 0.

On-going costs start as soon as the new project/system begins, and the convention is to place these costs into Years 1 – n on a cash flow diagram. The convention is to claim each cost at the end of the year.

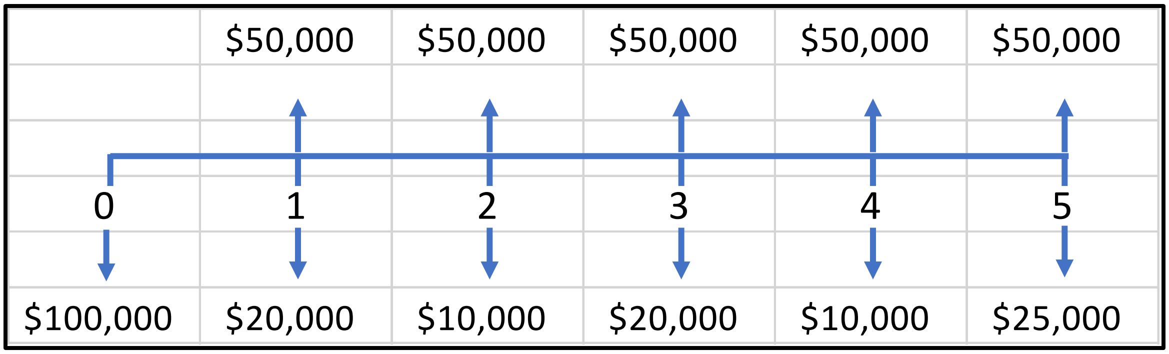
Any residual value would be shown as a cost credit in year "n".



Benefits or savings are shown as arrows pointing upwards. Similar to on-going costs, the convention is to put the benefits onto the cash flow diagram starting in year 1. As with costs, the convention is to claim the benefits at the end of each year.

Another convention we follow is that we forecast future benefits and costs as constant dollars. If we calculated a monetary benefit of $300,000/yr., based on current salaries, we use this same calculated benefit in Years 1 – n. A technical reason why we can do this is because we will later evaluate the future cash flows using interest rates that are "real" rates, meaning that inflation is not included. (For example, a 7% real interest rate would be the same as a 9.5% nominal interest rate, if annual inflation were 2.5%.) Therefore, we would not want to mix inflated benefits, with real rates, or vice-versa.

Three Basic Proposal Measures



Consider a proposal with the cash flow diagram shown above, as we calculate three basic measures of the proposal's value.

1. Net Benefit

The **net benefit** of a proposal is the difference between the benefits of a proposal and its costs. In the example shown in the cash flow diagram, the benefits equal $250,000 and the costs equal $185,000. Therefore, the net benefit is calculated as shown below:

Benefits	$250,000
Costs	$185,000
Net Benefit = Benefits – Costs	= $65,000

If the net benefit is greater than $0, then the proposal is considered monetarily attractive. $0 is a breakeven. Less than $0 indicates an unattractive proposal. You can think of the net benefit as measuring a proposal's "impact". A proposal with a $65,000 net benefit has more of impact than one with only a $10,000 net benefit.

2. Benefit-Cost Ratio

The **benefit-cost ratio** (often referred to as the B/C ratio) is a ratio in which the numerator is the benefits and the denominator is the costs. Whenever a proposal shows a positive net benefit (gains outweigh losses), its benefit-cost ratio will be greater than one. For the same proposal, the benefit-cost ratio is calculated as shown below:

Benefits	$250,000
Costs	$185,000
Benefit-Cost Ratio = Benefits ÷ Costs	= 1.35

You can think of the benefit-cost ratio as a way to measure dollar efficiency. In this case, for every $1 spent, the proposal will return $1.35. A benefit-cost ratio greater than 1.0 would indicate an attractive proposal; equal to 1, breakeven; and less than 1, unattractive.

3. Return on Investment (ROI)

The **return on investment**, or **ROI**, takes the benefit-cost ratio and subtracts one. The resulting number is then converted to a percentage. For the example proposal, the return on investment is 35%, as shown below:

Benefit-Cost Ratio	1.35
- 1	-1
= ROI	= .35 or 35%

A breakeven ROI is 0%. A monetarily attractive proposal would have an ROI greater than 0%. A proposal with a negative ROI is one that is monetarily unattractive. ROI is essentially another way to measure dollar efficiency.

As you research this topic, you may also find the ROI calculation presented in a different formula:

$$ROI = \frac{(Benefits - Costs)}{Costs}$$

But this can be simplified to:

$$ROI = \frac{Benefits}{Costs} - \frac{Costs}{Costs} = \frac{Benefits}{Costs} - 1$$

which is simply the benefit-cost ratio minus 1.

Calculations of the Measures Using *MS Excel*

Now, let's calculate the three measures using *Excel*. Open the provided *Excel* file and go to the *Excel* worksheet named "Measures 1", and follow the steps shown below.

	A	B	C	D	E	F	G
1	Year	Benefits	Costs				
2	0		$100,000		Net Benefit		
3	1	$50,000	$20,000		Benefit-cost ratio		
4	2	$50,000	$10,000		ROI		
5	3	$50,000	$20,000				
6	4	$50,000	$10,000				
7	5	$50,000	$25,000		Complete the cells shown in yellow		
8							
9	Total						
10							

Step 1: Sum the benefits and the costs. A cool *Excel* shortcut is to highlight cells *B2:C9*, then use the keyboard shortcut "*Alt* + =" (meaning while depressing the *Alt* key, type the = key). This will place sums into cells *B9* and *C9*.

Step 2: To calculate the net benefit, go to cell *F2* and type *=B9-C9*, and then press *Enter*. (You can avoid a lot of typing and errors by simply typing "=", then click on cell *B9*, type the character "-", then click on cell *C9*, then press *Enter*.)

Step 3: To calculate the benefit-cost ratio, go to cell *F3* and type *=B9/C9* and then press *Enter*.

Step 4: To calculate the ROI, go to cell *F4* and type *=F3-1* and then press *Enter*.

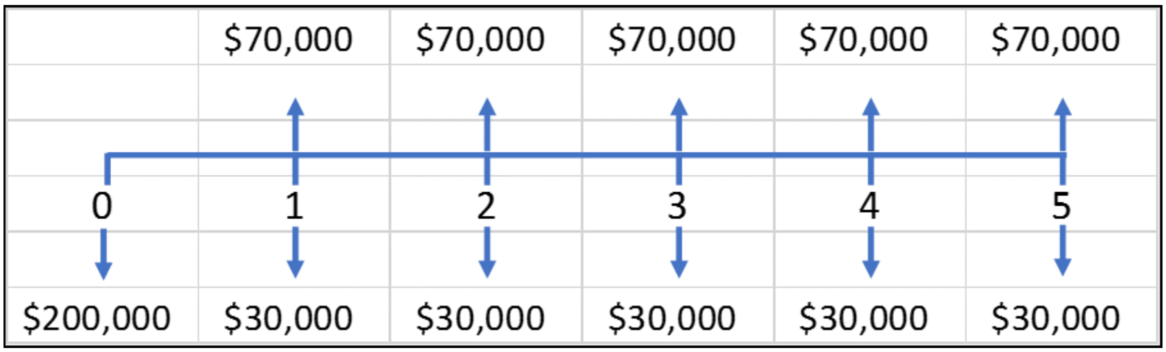
Net Benefit	=B9-C9
Benefit-cost ratio	=B9/C9
ROI	=F3-1

Net Benefit	$65,000
Benefit-cost ratio	1.35
ROI	35%

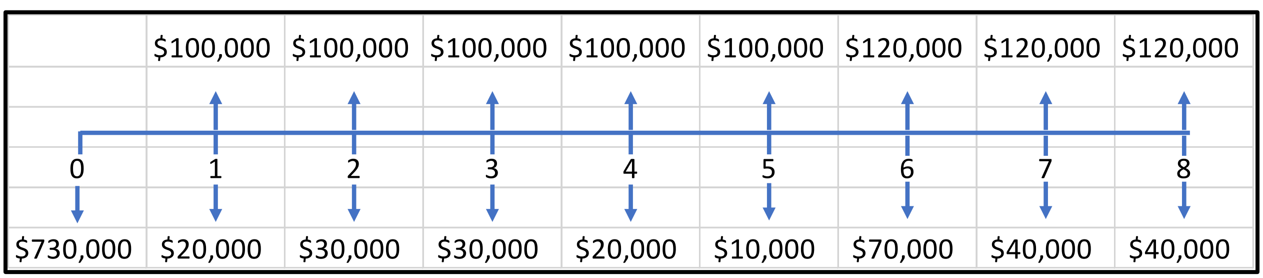
A view of the formulas and values are shown above. Note that formatting was pre-applied to the yellow cells. An *Excel* shortcut you can use to apply a currency format is *Shift+Ctrl+4* (which means depress and hold both *Shift* and *Ctrl*, then press "*4*" from the keyboard – not the "*4*" from the number pad). To apply a percentage format, use *Shift+Ctrl+5*.

For practice, go to the worksheets named "Measures 2" and "Measures 3", and calculate the measures for the two cash flow diagrams shown below. So that you can check your work, the answers are shown on the spreadsheets.

From the Measures 2 worksheet:



And from the Measures 3 worksheet:



These three illustrations show three proposals that are (respectively) monetarily attractive, break-even, and monetarily unattractive. As a reminder, the last two may still be acceptable if the intangible benefits are substantial.

Which Measure to Use

Sometimes the measures may point the engineer to different decisions. Consider the following:

	Proposal A	Proposal B
Benefits	$15,000,000	$65,000,000
Costs	$10,000,000	$50,000,000
Net Benefit	$5,000,000	$15,000,000
Benefit-cost ratio	1.50	1.30
ROI	50%	30%

The net benefit indicates that Proposal B is preferred over Proposal A. The benefit-cost ratio and the ROI indicate Proposal A is preferred over Proposal B. So, which is the correct measure to use?

Before completing this course, you will see that the correct answer is none of the above. But for now, the correct choice is the net benefit[1]. The engineer must recommend the proposal with the greatest impact – the net benefit – since Proposal B's "receipts" will exceed its "disbursements" by $15,000,000, whereas Proposal A's is only $5,000,000.

Another perspective is that the engineer's goal, and in turn an organization's goal, is to maximize benefits to society. Even though Proposal B has five times the cost of Proposal A, its total return is greater. Still not convinced? Suppose the "$" was replaced by "saved lives". Would you rather save 15,000,000 lives or only 5,000,000 lives?

However, if a group of managers, both private and public sector, were asked which of the two proposals should be selected, the vast majority would say Proposal A because its ROI is higher. I say this because in my training classes, it is very rare to have engineers or cost analysts choose Proposal B, in part because they are so accustomed to hearing their managers use jargon like ROI.

[1] As will be shown, the preferred measure is the net present value, which is the net benefit using benefits and costs that are "discounted", i.e. have had a present-value calculation made on them.

As noted earlier, the ROI (and its counterpart benefit-cost ratio) each measure dollar efficiency. For each dollar spent on Proposal A we get a $1.50 return, whereas with Proposal B we get only a $1.30 return. The problem with using the benefit-cost ratio or the ROI is that these measures are very sensitive to correctly classifying disbursements as costs, and negative benefits as a drawdown on a proposal's overall benefits. It is now time for a discussion of negative benefits, and to illustrate the impact that an incorrect distinction would have on our three proposal measures.

Positive vs. Negative Benefits

A result of any undertaking is what we call a benefit, but these results can be favorable or unfavorable. Those favorable ones are what we call **positive benefits**, and would reflect the reasons why we are considering the proposal. But there will also be the downsides, which we call the **negative benefits**. Later, when we refer to the monetary "benefits" of a proposal, we will infer that the negative benefits have been subtracted from the positive benefits.

For our heating system replacement, there are going to be some days when we will have no heat. There will be a learning curve as we learn to work the new controls. Maybe we will suffer from buyer's remorse, or wonder what else we could have done with the money we spent on the new system (a cruise, a bass boat, an investment that returns 6% a year, etc.) These are examples of negative benefits.

In some cases, we may actually be able to assign a monetary value to the negative benefit. (For example, having to spend a night or two in a hotel that has heat, because we took on this project during a cold snap in March.) But it is important that the monetary values of negative benefits not be labeled as costs in our proposal. Such a mis-classification can result in calculation errors in two of our three proposal measures, as demonstrated below:

Here in the Washington, DC area, the Metro – a light rail system – is used to transport commuters from the outlying suburbs into the DC metropolitan area. Let's say that a proposal to extend the Metro system farther out into an area of Maryland is met by some resistance from groups now in the commuting business, e.g. van pools, bus services, toll road operators, and a heavy rail commuter train that now operates in the area. Let's say these groups estimate that they would suffer losses of $20 million annually should this proposal be approved. And just for the mathematics, let's say the proposal is viewed on a 30-year basis, and therefore there would be a $20 million x 30 years = $600 million loss.

For illustrative purposes, let's say we have $2 billion in positive benefits, and $1 billion in costs, and let's say that our engineer correctly noted that this $600 million is a negative benefit, and not a cost. The three proposal measures (net benefit, benefit-cost ratio, and ROI) would calculate to be:

	Correct classification
Positive benefits	$2,000,000,000
Negative benefits	$600,000,000
Benefits	$1,400,000,000
Costs	$1,000,000,000
Net Benefit	$400,000,000
Benefit-cost ratio	1.40
ROI	40%

Now let's say a different engineer looked at the numbers and decided that the $600 million loss to the businesses impacted by the proposal should be called a cost (shown in highlight). These calculations are shown in the table below next to the "correct classification":

	Correct classification	Incorrect classification
Positive benefits	$2,000,000,000	$2,000,000,000
Negative benefits	$600,000,000	$0
Benefits	$1,400,000,000	$2,000,000,000
Costs	$1,000,000,000	$1,600,000,000
Net Benefit	$400,000,000	$400,000,000
Benefit-cost ratio	1.40	1.25
ROI	40%	25%

Notice the impact that the incorrect classification had on the benefit-cost ratio and the ROI – they both changed. But also notice the measure that was not affected by the change – the net benefit.

The important takeaway from this should be:

- Costs or disbursements are the outlays needed to build and sustain the project. Negative benefits are the drawbacks of the proposal, and should be deducted from the proposal's positive benefits, resulting in a proposal's overall benefits.
- An incorrect classification of negative benefits will not affect the net benefit (and later the net present value). Because of this, net present value is the preferred measure to use.
- On the other hand, the benefit-cost ratio and ROI are impacted, and incorrect classifications can skew these measures. This is why we should avoid selecting proposals based on these two measures.

However, one should not totally ignore the benefit-cost ratio and the ROI. Consider these two proposals with equal net benefits, and note how the benefit-cost ratio and the ROI can be useful as "tie-breakers":

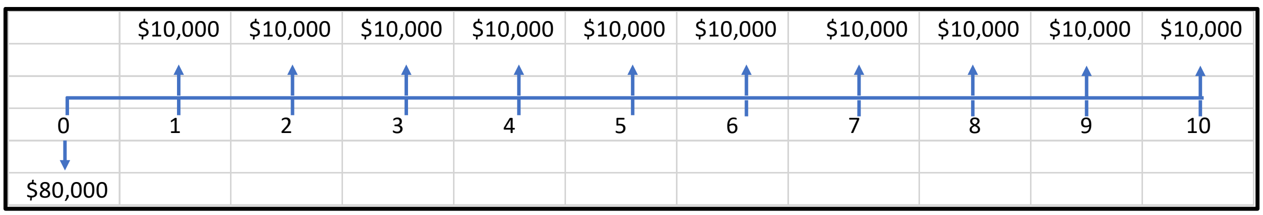
	Proposal 1	Proposal 2
Benefits	$10,000	$50,000
Costs	$8,000	$48,000
Net Benefit	$2,000	$2,000
Benefit-cost ratio	1.25	1.04
ROI	25%	4%

Obviously, the net benefit could not point us to the better proposal. But the benefit-cost ratio and the ROI do (Proposal 1).

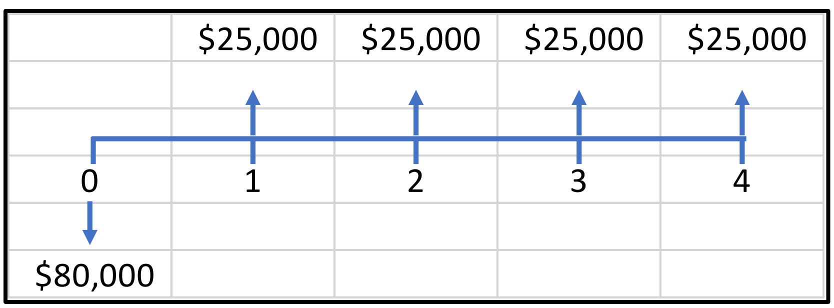
The Timing of the Costs and the Benefits

At this point in the course, we have looked at three different measures to evaluate proposals. The problem with all three measures is that they fail to account for the timing of the costs and the benefits. To illustrate, here are two investment choices for you. They both look like good ones, because in each case, you invest $80,000, and get back $100,000.

Here is one way to receive your $100,000 payout:



And here is another way to receive the $100,000:



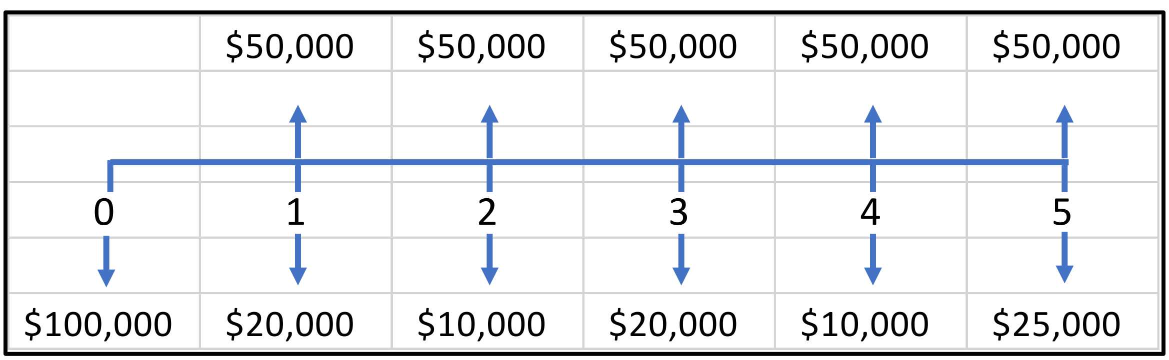
Both choices yield the same net benefit ($20,000), the same benefit-cost ratio (1.25), and the same ROI (25%). But note that the time variable is not entering into the calculations, and that the second investment choice is clearly preferable because you get the $100,000 return in 4 years rather than in 10 years.

The Payback Period (aka Payout Period)

In an effort to account for the timing of costs and benefits in a proposal, some like to say “When will we breakeven?” When I worked in manufacturing, I was told that my company would not consider any proposal with greater than “a two-year payback”.

Some years ago, when I was considering replacing my heat pump, the installer presented me with a choice between two different heat pump systems. The less expensive system had a Seasonal Energy Efficiency Ratio (SEER) of 13.0 and a Heating Seasonal Performance Factor (HSPF) of 7.7. The more expensive system had a higher SEER and HSPF. (The higher the numbers, the more energy efficient the device.) I asked what’s the difference, and the installer smiled and said $250. When he saw that I was not smiling, he asked how long I planned to stay in my house, and I said, “A long time, I hope.” He said that he would recommend the heat pump with the higher SEER and HSPF, because their studies showed there would be a “five-year payback” on that unit. I reasoned, therefore, that the heat pump with the higher efficiency would save me $50 a year in heating costs.

The expressions above are commonly used. You can think of the **payback period** as the length of time it would take to repay the initial costs of an investment. It can also be defined as the point in time when the cumulative cash flow of an investment becomes $0. Look at this calculation for the cash flow diagram we studied earlier:



Year	Benefits	Costs	Cash flow	Cumulative cash flow
0		$100,000	($100,000)	($100,000)
1	$50,000	$20,000	$30,000	($70,000)
2	$50,000	$10,000	$40,000	($30,000)
3	$50,000	$20,000	$30,000	$0
4	$50,000	$10,000	$40,000	$40,000
5	$50,000	$25,000	$25,000	$65,000

This proposal takes three years for the cumulative cash flow to become $0. Therefore, it has a 3-year payback period.

To illustrate the weakness of the payback period measure, compare the cash flows of the above proposal (called Proposal A) with two other proposals:

Year	Proposal A	Proposal B	Proposal C
0	($100,000)	($100,000)	($70,000)
1	$30,000	$20,000	($30,000)
2	$40,000	$30,000	$50,000
3	$30,000	$50,000	$50,000
4	$40,000	$100,000	$0
5	$25,000	$150,000	$0

Each proposal's cumulative cash flow would be $0 at the end of year 3. Hence, each proposal has a three-year payback period. But clearly Proposal B is the preferred choice, and the payback period measure fails to detect this. The deficiencies of the payback period are two-fold:

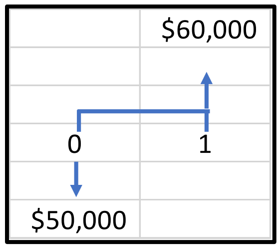
1. It fails to account for the time value of money (explained in the next section).
2. It ignores the cash flow once the payback period is met.

For these reasons, we conclude the payback period is actually the least reliable measure of a proposal's value, and we must look at other ways to account for the timing and amounts of future benefits and costs in a proposal.

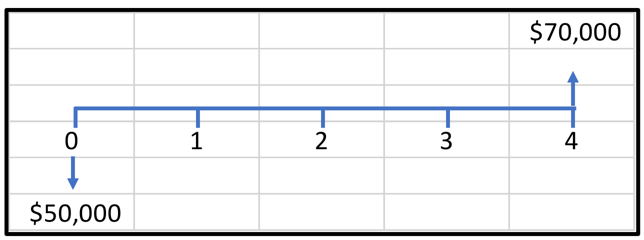
The Time Value of Money

Let's now look at three ways to get returns from a $50,000 investment.

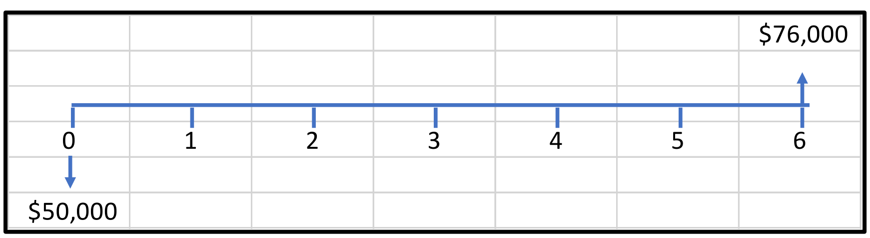
Here is Option 1:



And Option 2:



And Option 3:



I find that the typical person confronted with these three options will choose Option 1. Most people want their money ASAP (Option 1), even if it is $10,000 or $16,000 less than Option 2 and Option 3, respectively. We are what I call a "microwave society" that does not like to wait. I now chafe at waiting six minutes for a pot pie from the microwave, forgetting that back in my day we had to use an oven and wait an hour. Today, we get information nearly instantaneously rather than slug off to the library. Microwaves and the Internet and iPhones are great, don't get me wrong, but we need to take a thoughtful approach when we consider investments.

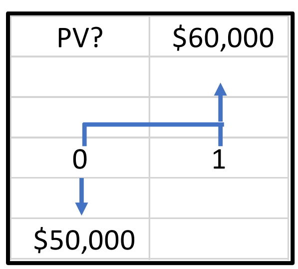
Along these same lines, nearly every winner of a lottery accepts a lump sum payout "now" worth only a little over ½ their total winnings, rather than wait 20 or 30 years and accept an annuity arrangement for their total winnings. (And at my advanced age, I would probably do the same thing.) But is this a "mistake" for someone under the age of 40? We will look at this later in the course.

In all of our illustrations, we realize that the timing of when we receive our benefits, along with the benefit amount, affects our decision. But the most sensitive variable we must consider is our own minimum attractive rate of return, a term we learned in our engineering economy class.

As engineers, when we evaluate proposals, we are going to be dealing with benefits and costs of differing amounts occurring at different times, and we need a way to properly evaluate them. The technique we use is called **present value analysis**. In this analysis, we remove the variable of the timing of the cash flows by creating an artificial cash flow in the present, or year 0. Put another way, we ask how much money today (shown as "PV" in the following cash flow diagrams) would be the same as money "n" years into the future, assuming a certain minimum attractive rate of return, which will be shown as "interest" in the following discussion.

Here is a demonstration of this as it relates to the three investment options. Assume that most people would be lucky to get 3% interest on their money today, given that recent interest rates on savings bonds, money market funds, CD's and passbook savings have been next to nothing.

For Option 1:

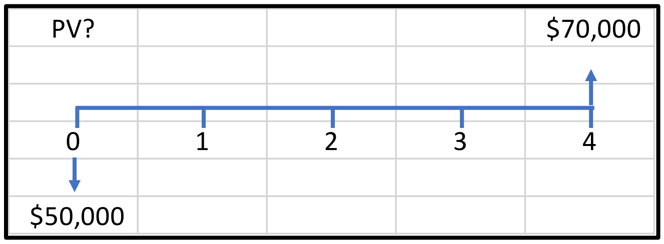


In Option 1, we have a future benefit of $60,000 in year 1 and an initial investment of $50,000. The question is: What amount of money today, would be the same as having $60,000 one year from now, assuming I usually make 3% on my investments? The algebra behind this is:

PV x 1.03 = $60,000; therefore PV = $60,000/1.03; therefore PV = $58,252.

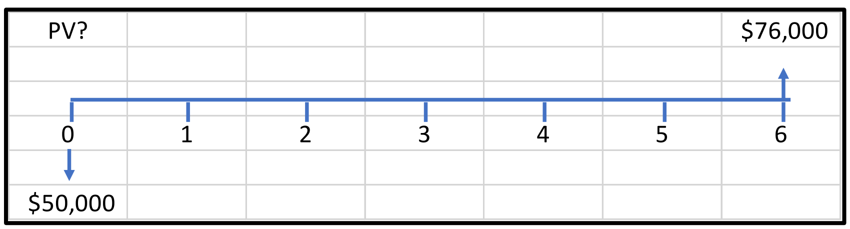
The $58,252 in year 0 (today) is the same as $60,000 in year 1. Since the benefit of $58,252 is greater than the Year 0 investment of $50,000, the investment option is monetarily attractive. But is it the best of the three options?

For Option 2:



PV x $(1.03)^4$ = $70,000; therefore PV = $70,000/$(1.03)^4$; therefore PV = $62,194

For Option 3:



PV x $(1.03)^6$ = $76,000; therefore PV = $76,000/$(1.03)^6$; therefore PV = $63,649

Given that all three options had the same initial investment of $50,000, a 3% investor should choose Option 3, since the present value of the benefits is the highest. The table below shows how the choice may differ if our investor was able to get higher interest rates:

	Present Values of Benefits		
Interest	Option 1	Option 2	Option 3
3%	$58,252	$62,194	$63,649
4%	$57,692	$59,836	$60,064
5%	$57,143	$57,589	$56,712
6%	$56,604	$55,447	$53,577
7%	$56,075	$53,403	$50,642
8%	$55,556	$51,452	$47,893
9%	$55,046	$49,590	$45,316
10%	$54,545	$47,811	$42,900

Option 3 is more attractive at the 3% and 4% rates; Option 2 at 5%; and Option 1 at 6% and higher. (By the way, making this table in *Excel* is easy with the *Data Table* tool that we will cover later.)

Another interesting finding from the table is that given the $50,000 initial investment, Option 2 is monetarily unattractive at 9% and 10%, and likewise Option 3 at 8%, 9%, and 10% (since the present values of each option's benefit at these interest rates are lower than the $50,000 investment).

As we will see later, *Excel* will be able to calculate the present value using the function *=PV.*

Excel's Financial Functions to Calculate the Time Value of Money

Excel offers a number of financial functions that we can use to calculate present value, as well as future value. We can also calculate annuities, length of time to achieve certain goals, and interest rates needed to attain goals. The variables used in the *Excel* functions are:

<u>PV</u>: This is the present value, PV, or in investing it is the principal. In our engineering economy classes, it was the "P" in the equations we learned. It would be a single (lump-sum) amount that occurs in Year 0.

<u>FV</u>: This is the future value, also called "F" or FV. We use this variable for single, one time amounts that occur in the future, such as the liquidation of a CD.

<u>PMT</u>: Think of this as an annuity. It refers to an equal on-going amount (which was called "A" in those equations). A future benefit that re-occurs year after year would be a PMT. It could also be an equal yearly contribution made into a retirement fund, or even a repetitive loan payment.

<u>NPER</u>: Think of this as "number of periods", which we called "n". It could be the year that a future cost or benefit occurs, or the number of years that an annual payment is made.

<u>RATE</u>: This is the interest rate, which was denoted as "i". It can be an interest rate that you seek on an investment, or it could be a minimum attractive rate of return desired by a company.

The respective *Excel* functions are:

=PV: This will calculate the present value of future amounts. In engineering economy, we used this equation to calculate the present value, “P”, given a single future amount, “F”, occurring in year “n” at an interest rate of “i”:

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

=FV: This will calculate the future value of present amounts and annuities. We used this equation to calculate a future value “F” of a beginning principal, “P”, given a certain interest rate and number of years.

$$F = P(1+i)^n$$

=PMT: This will calculate an annual amount equivalent to either present or future amounts. One of the equations we used (in our engineering economy class) to calculate the required repetitive year-end investments, “A”, to achieve a future goal, “F”, was:

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

The equations presented above were actually the simpler ones, and with more complex equations, the math became pretty tedious. Fortunately, we had interest tables ranging from 1% to 30% where we could look up factors, such as the “*To find A Given F*” for various “n’s” ranging from 1 to 35 years, for example. We will not need the tables anymore, thanks to *Excel*.

=NPER: This will calculate the length of time to either achieve certain future goals given certain investments, or it could be used to calculate how long it would take to spend down a lump sum. This required interpolation from those interest tables prior to *Excel*.

=RATE: This will calculate a minimum interest rate needed to achieve certain goals, or to calculate the equivalent interest rate we would get from a proposal. This also required interpolation.

Using *Excel*'s Financial Functions

We will now use *Excel* to solve some engineering and personal financial problems.

=PV

Go to the *Excel* worksheet named "PV". So that you can check your work, the answers are shown on the spreadsheet.

PV Problem 1:

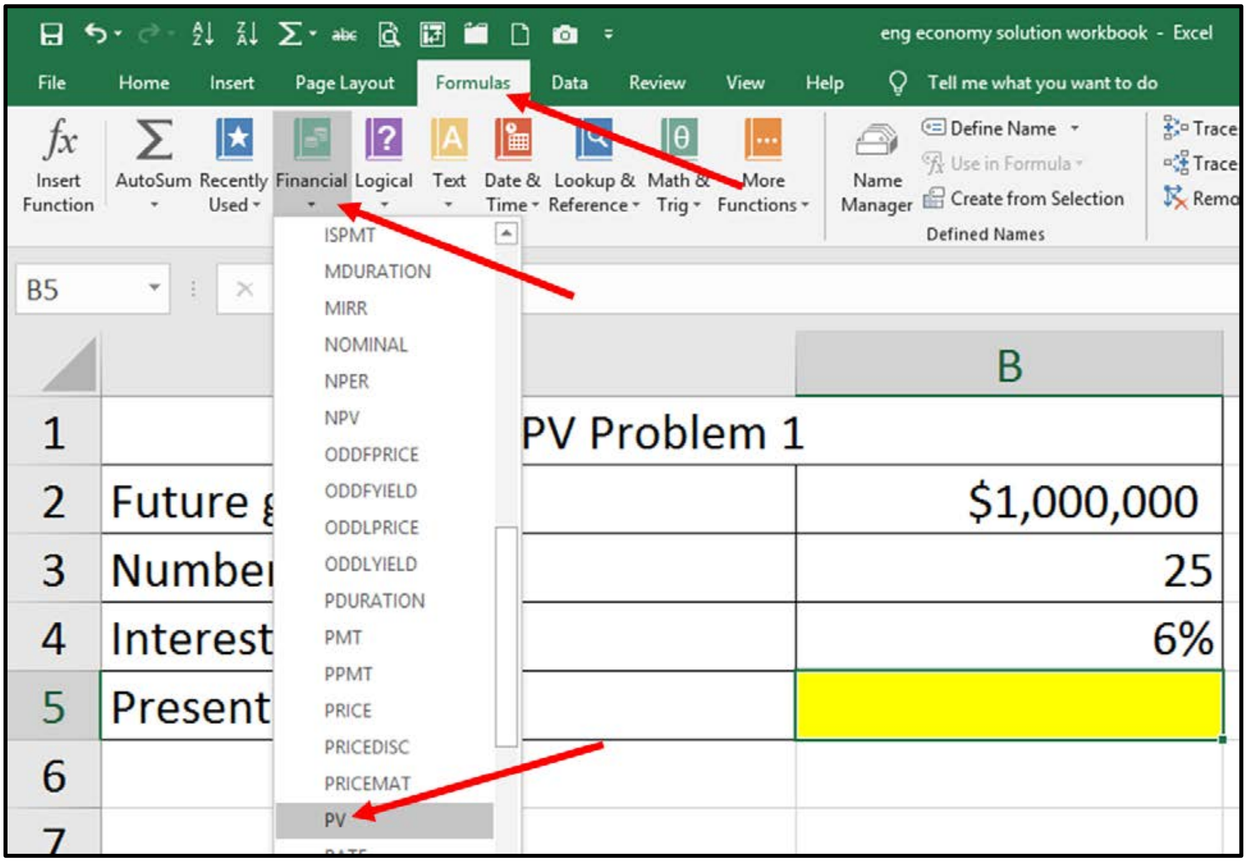
You desire to have a $1,000,000 nest egg built up when you retire in 25 years. You typically get a 6% annual rate of return on your investments. How much must you invest now (PV) to achieve that goal?

Given information:

FV = $1,000,000
NPER = 25
RATE = 6%
PV = ?

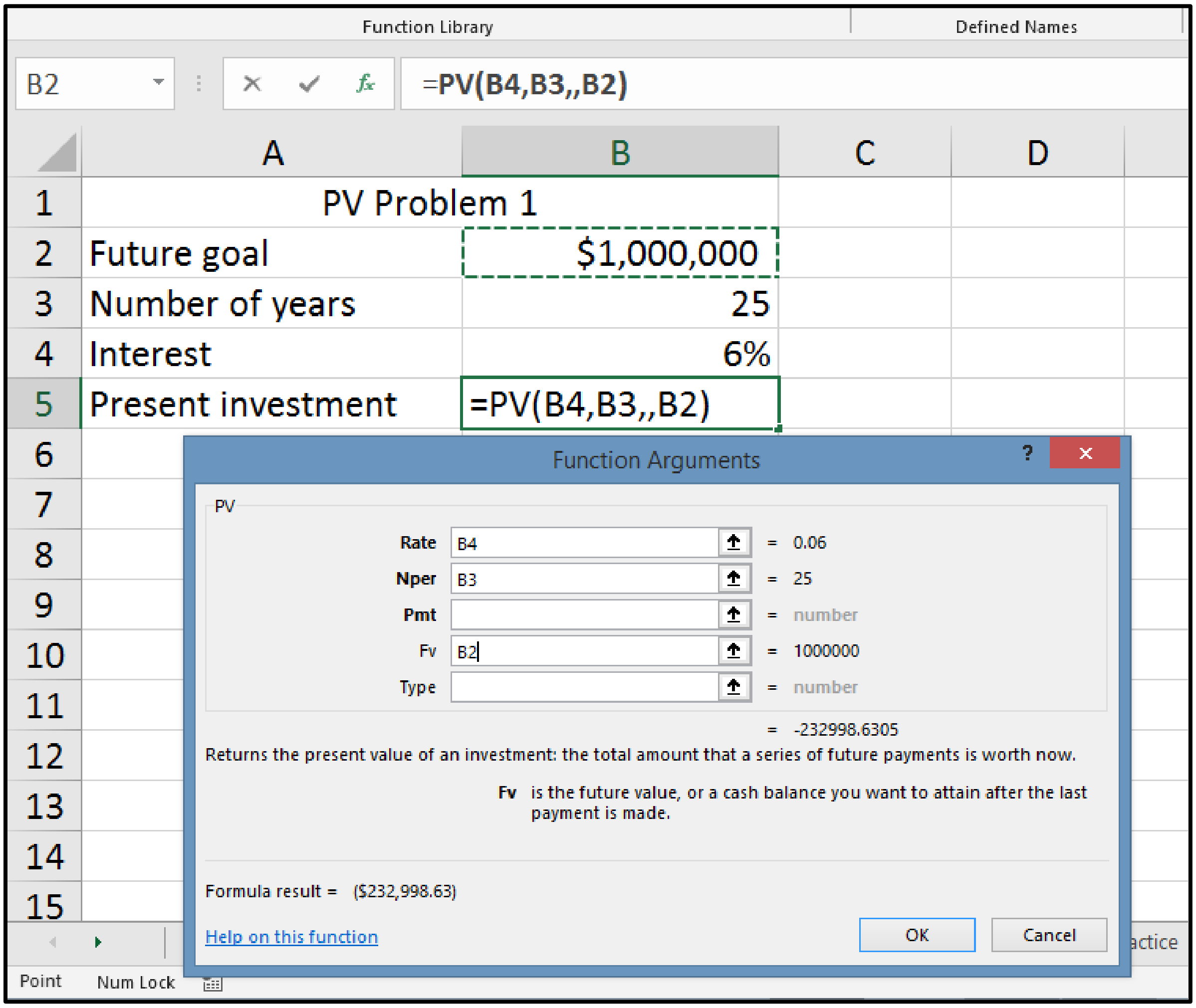
Study the screenshots below.

Make cell *B5* your active cell by selecting it.



As depicted in the screenshot, click/select the *Formulas* tab, then click/select *Financial*, then click/select *PV*. (For future problems, you will repeat similar steps in selecting *FV*, *PMT*, *NPER* and *RATE*.)

Now, by selecting the appropriate cells, fill in the fields needed for =*PV* using the interface box shown in the screenshot below.



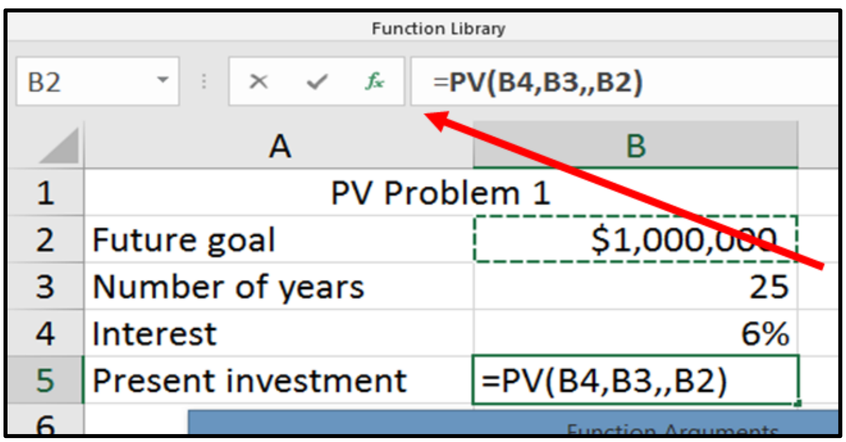
In this case, there was no *Pmt*. We will always leave the *Type* field empty. Leaving it empty, or entering “0”, will make the calculation assume an end-of-year cash flow. This will be consistent with the cash flow diagram assumptions. (Entering a “1” into the field would have the calculation assume a beginning-of-year cash flow.)

A preview of the answer, -232998.6305, appears, as well as a formula result ($232,998.63). Click/select *OK*, and the answer will appear in cell *B5*. Unfortunately, nearly $233,000 is a lot of money to come up with, but check beneath the sofa cushions.

The answer is negative because we made the *FV* positive. *Excel's* functions treat the cash flows from the individual's perspective. In this case, when you write a check and invest $233,000 at a financial institution, your checkbook entry is a debit, or a minus. (You will have $233,000 less in your checkbook.) But in 25 years, when you cash out, you will receive $1,000,000 which you can then add to your checkbook. When we work with some other functions such as *=NPER* and *=RATE*, this cash flow distinction will be very important.

However, the cash flow signage will be confusing when we calculate the present value of benefits. The present value of benefits should be a positive number, but *Excel* is going to show the answer as negative, and for now, we will have to "fool" *Excel* by switching the signage. Later, when we use a function called *=NPV*, we will not have to do this.

Before proceeding with more *Excel* work, here is a tip. Let's say that something went wrong in cell *B5* where you wrote the *Excel* function *=PV*, and that you would like to correct it. In order to get back into the interface box for *=PV*, click on cell *B5* and then select the f_x (named *Insert Function*) located directly next to the *Formula Bar*, and this will bring back the interface box for the function.



Continue using the "PV" worksheet to answer PV Problem 2 and 3. So that you can check your work, the answers are shown on the spreadsheet.

PV Problem 2:

You plan to retire at age 67. After retirement, you plan to conservatively invest your money and hope to earn 4% annual interest. Your genetics are good and you hope to live a very long time. How much money will you need to have at retirement age to be able to pay yourself $40,000 per year, and have nothing left in the retirement fund at age 97?

Given information:

PMT = $40,000/year
NPER = 30
RATE = 4%
PV = ?

PV Problem 3:

You want to calculate the present value of the Option 3 benefit of $76,000, occurring in Year 6, for three different interest rates: 3%, 7%, and 10%. Remember to switch the signage as needed to make the PV's come out positive.

Given information:

FV = $76,000
NPER = 6
RATE = 3%, and then 7%, and then 10%.
PV = ?

=FV

Now we will use *Excel*'s *=FV* function in various scenarios. Go to the worksheet "FV".

(Go through similar steps shown in the *=PV* section to retrieve the *=FV* function.)

So that you can check your work, the answers are shown on the spreadsheet.

FV Problem 1:

Your rich Aunt Emma has bequeathed to her favorite relative (you) $100,000, under the condition that you maintain your PE license. You plan to invest this into a stock mutual fund which has historically earned about 9% annually. You are now 25, and want to know how much this investment will grow to when you reach age 65, assuming you keep your license current by taking courses like this.

Given information:

PV = $100,000
NPER = 40
RATE = 9%
FV = ?

Remember to show the $100,000 as a negative amount. (When you calculate the answer, you will see you were wise to be nice to Aunt Emma, and to choose an engineering profession.)

FV Problem 2:

You are a Federal Government employee and plan to invest into your Thrift Savings Plan (TSP). You are allowed to contribute a maximum of $19,000 annually. Because you are in the FERS retirement program, if your annual contribution is at least 5% of your salary, the government will match up to that amount. Since your annual salary is $80,000, and 5% of that is $4,000, you easily qualify for the $4,000 match. You plan to diversify your investments and hope to earn a 7% average rate of return. You plan to work 30 years. How much will your TSP be worth when you retire if you invest as much as you are allowed, and don't withdraw any monies for a new truck?

PMT = $19,000 (your annual contribution) + $4,000 (the annual match) = $23,000
NPER = 30
RATE = 7%
FV = ?

FV Problem 3:

You decide to leave your current employer and have $40,000 in a 401k. You decide to roll this over into your new employer's 401k program. You plan to contribute $15,000 annually into the 401k program, and are expecting no match from your new employer. Assuming an 8% annual return on investment, how much will you have in 15 years? (See if you can determine the given information and enter it correctly into *Excel*. You will have both a PV and a PMT.)

=PMT

Now we will use *Excel*'s *=PMT* function in various scenarios. Go to the worksheet "PMT".

(Perform similar steps shown in the prior sections to retrieve the *=PMT* function.)

So that you can check your work, the answers are shown on the spreadsheet.

PMT Problem 1:

You wish to have $100,000 saved when your newborn is of college age, 18 years from now. You plan to invest in bonds and stocks yielding about a 5.5% annual rate of return. How much money would you have to invest each year to achieve that goal?

FV = $100,000
NPER = 18
RATE = 5.5%
PMT = ?

PMT Problem 2:

You plan to retire with $2,000,000, and want to know how much you could withdraw annually for each of 20 years after you retire to pay for possible home health. You desire that after the 20 years there remains no money in the account, and you'll just let the government take care of you at that point. You hope to earn 4% on your investments.

PV = $2,000,000
NPER = 20
RATE = 4%
PMT = ?

PMT Problem 3:

You plan to buy a house, and will have to take out a $250,000 mortgage. The terms of the mortgage are a fixed rate at 4.25%, and it will be a 30-year loan. How much will your principal and interest (P&I) be each month?

HINT: In this case, the annual interest rate must be adjusted to a monthly rate by dividing by 12. Likewise, the number of periods must be adjusted to monthly by multiplying the number of years by 12.

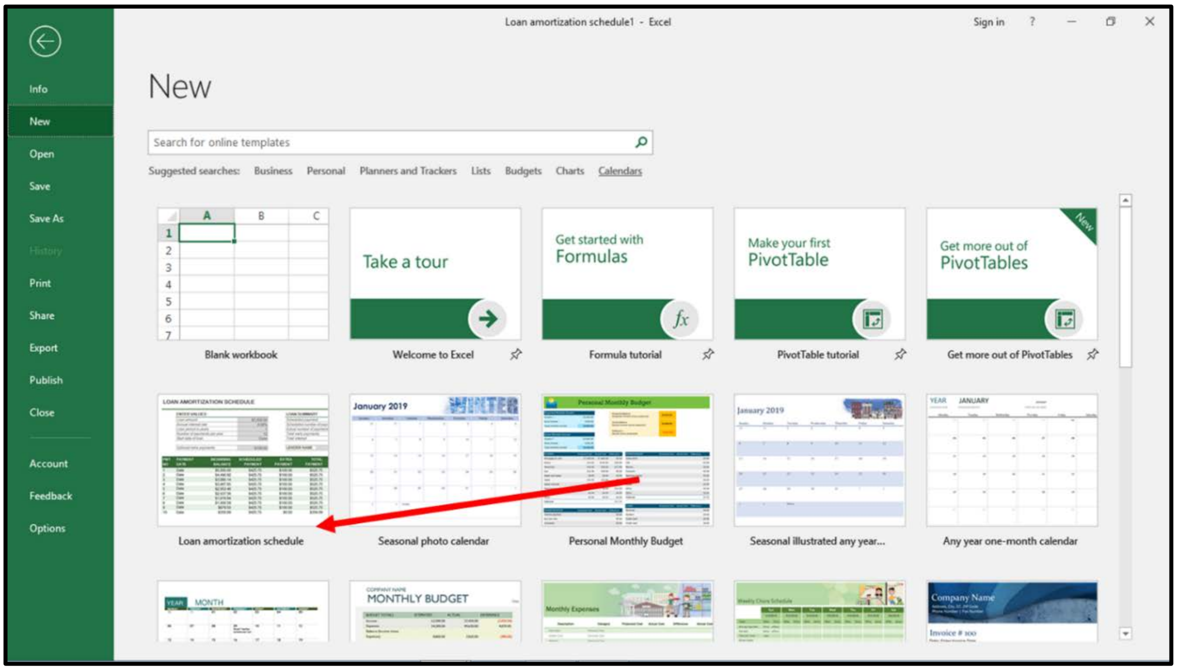
PV = $250,000 (this will be a positive value for a fleeting moment)

NPER = 30*12 (You can simply enter 30*12 into the NPER field and *Excel* will calculate the 360)

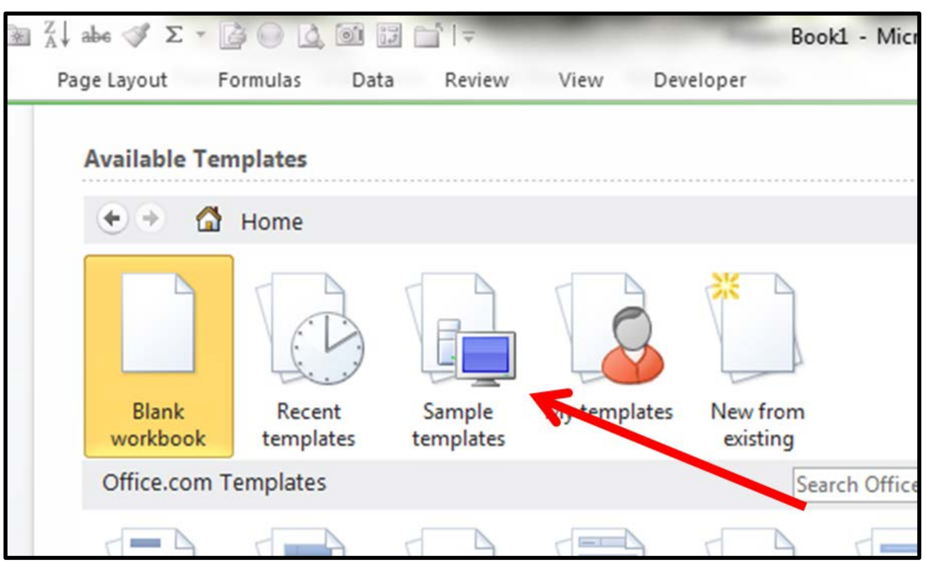
RATE = 4.25%/12 (Enter 4.25%/12 into the RATE field and *Excel* will divide the annual rate by 12. Make sure you use the % symbol. Otherwise, you must enter .0425/12)

PMT = ?

BONUS! *Excel* has a sample template you can use in lieu of the approach we used in PMT Problem 3. It is called *Loan Amortization Schedule*, and it gives you loads of information about your mortgage. To access this in *Excel 2016* (screenshot below) click/select the *File* tab, and then click/select *New*. You may have to scroll down a few rows to find it.



In earlier versions of *Excel* (see screenshot below), click/select the *File* tab, then click/select *New*, then click/select *Sample Templates*. In earlier versions it is called *Loan Amortization*.



Once you open the *Loan Amortization Schedule/Loan Amortization* template, enter the following:

ENTER VALUES	
Loan amount	$250,000.00
Annual interest rate	4.25%
Loan period in years	30
Number of payments per year	12
Start date of loan	3/1/2019
Optional extra payments	$0.00

Then look at the *Loan Summary*. Compare the scheduled payment with the answer to PMT Problem 3.

LOAN SUMMARY	
Scheduled payment	$1,229.85
Scheduled number of payments	360
Actual number of payments	360
Total early payments	$0.00
Total interest	$192,745.90

And then begin to look at the next 30 years of your life:

PMT NO	PAYMENT DATE	BEGINNING BALANCE	SCHEDULED PAYMENT	EXTRA PAYMENT	TOTAL PAYMENT	PRINCIPAL	INTEREST	ENDING BALANCE	CUMULATIVE INTEREST
1	3/1/2019	$250,000.00	$1,229.85	$0.00	$1,229.85	$344.43	$885.42	$249,655.57	$885.42
2	4/1/2019	$249,655.57	$1,229.85	$0.00	$1,229.85	$345.65	$884.20	$249,309.91	$1,769.61
3	5/1/2019	$249,309.91	$1,229.85	$0.00	$1,229.85	$346.88	$882.97	$248,963.04	$2,652.59

=NPER

Now we will use *Excel*'s *=NPER* function in various scenarios. Go to the worksheet "NPER".

(Perform similar steps shown in the prior sections to retrieve the *=NPER* function. When you use this function, you must have at least one positive and one negative cash flow.)

So that you can check your work, the answers are shown on the spreadsheet.

NPER Problem 1:

A building is priced at $300,000. A down payment of $50,000 is made, so the outstanding loan is $250,000. A $20,000 annual payment will be made on the loan. At a 5% interest rate, how many years will it take to pay off the loan?

PV = $250,000 (make this positive)
PMT = $20,000 (make this negative)
RATE = 5%
NPER = ?

NPER Problem 2:

A person has saved $325,000 in a retirement fund, and plans to withdraw $50,000/year from it. She hopes to get 6% interest. How long with her fund last? (See if you can determine the given information and enter it correctly into *Excel*.)

NPER Problem 3:

A traveler wishes to save $40,000 for a tour around the world, and can set aside $3,000 annually. At an interest rate of 4%, how many years from now can the traveler take the tour? (See if you can determine the given information and enter it correctly into *Excel*.)

=RATE

And finally, let's use the *Excel* function *=RATE.* Go to the worksheet "RATE".

(When you use this function, you must have at least one positive and one negative cash flow.)

So that you can check your work, the answers are shown on the spreadsheet.

RATE Problem 1:

A corporation is looking to invest $10,000,000 today in a new product line, and forecasts that in 10 years it will be able to sell the business for $50,000,000. It wants to know what annual interest rate would be returned by this product line.

PV = $10,000,000 (make this negative)
FV = $50,000,000 (make this positive)
NPER = 10
RATE = ?

RATE Problem 2:

You purchase a whole life insurance policy at age 30 and agree to pay premiums of $1,423 annually. At age 65, you are guaranteed a cash value of $100,000. What interest have you earned on this policy?

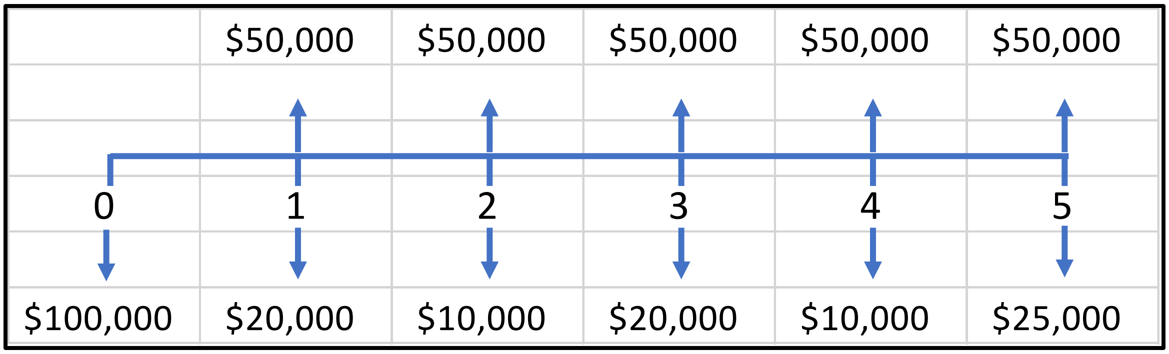
FV = $100,000 (make this positive)
PMT = $1,423 (make this negative)
NPER = 35
RATE = ?

RATE Problem 3:

For the next 20 years, you plan to invest $20,000 annually into stock mutual funds. Your goal is to have $4,000,000 in those funds when you cash out. You are also able to invest a $30,000 lump sum immediately into the funds. What is minimum interest rate needed to achieve these goals, and do you think that would be possible with the investment choice you made?

FV = $4,000,000 (make this positive)
PMT = $20,000 (make this negative)
PV = $30,000 (make this negative)
NPER = 20
RATE = ?

Performing Present Value Analysis Using *Excel*



Let's use *Excel* to calculate the present value of the benefits and costs shown above. We will use 7% as the minimum attractive rate of return. Refer to the worksheet "PV Analysis Long Way".

Benefits PV Calculation (Yrs. 1 - 5)	
Benefits (PMT)	$50,000
Number of years (NPER)	5
Rate of Return (RATE)	7%
Present Value of Benefits =	$205,010

The present value of the benefits calculation is easy. Since each year's benefit is identical, we can use the *PMT* field in the *=PV* function, rather than treat each future benefit as an *FV*. Remember, we can only use the *PMT* field if each future benefit is the same.

Unfortunately, we are not going to be as lucky with the costs, since each one has to be treated as an *FV*. That is going to require that five different =*PV* calculations be made, and the resultant present values, along with the Year 0 cost, be added together to get the present value of the costs.

Year 1 PV Cost Calculation	
Cost Year 1 (FV)	$20,000
Number of years (NPER)	1
Rate of Return (RATE)	7%
Present Value of Yr. 1 Cost =	$18,692

Year 2 Cost PV Calculation	
Cost Year 2 (FV)	$10,000
Number of years (NPER)	2
Rate of Return (RATE)	7%
Present Value of Yr. 2 Cost =	$8,734

Year 3 PV Cost Calculation	
Cost Year 3 (FV)	$20,000
Number of years (NPER)	3
Rate of Return (RATE)	7%
Present Value of Yr. 3 Cost =	$16,326

Year 4 PV Cost Calculation	
Cost Year 4 (FV)	$10,000
Number of years (NPER)	4
Rate of Return (RATE)	7%
Present Value of Yr. 4 Cost =	$7,629

Year 5 PV Cost Calculation	
Cost Year 5 (FV)	$25,000
Number of years (NPER)	5
Rate of Return (RATE)	7%
Present Value of Yr. 5 Cost =	$17,825

In summary,

Summary		
Present value benefits =		$205,010
Present value Year 0 costs =	$100,000	
Present value Year 1 costs =	$18,692	
Present value Year 2 costs =	$8,734	
Present value Year 3 costs =	$16,326	
Present value Year 4 costs =	$7,629	
Present value Year 5 costs =	$17,825	
Total present value costs =		$169,206
Net present value =		$35,804

Don't worry about the "long way" because *Excel* has a function named =*NPV* that will really speed up the net present value calculation. And some of you may notice that we are using the term <u>net present value</u> instead of net benefit. Let's go to the next section.

The Net Present Value

The **net present value** (**NPV**) is *the* preferred measure to use when evaluating a single proposal, or when deciding upon multiple alternatives to accomplish a certain goal. This applies to both private-sector and public-sector evaluations. The net present value is defined as:

NPV = Present Value of All Benefits – Present Value of All Costs

You will note that this is similar to the net benefit definition we developed earlier. The major difference is that the net benefit ignored the timing of the benefits and costs, whereas the NPV's present value calculations account for them.

As noted earlier, the present value calculations account for the time value of money by using an appropriate interest rate. It places the equivalent values of both benefits and costs into Year 0. And its calculation can be made regardless of the differing values of benefits and costs, and the differing timing of them. Thus, if all proposals or alternatives benefits and costs are placed into Year 0, we can make a proper comparison and evaluation.

Federal Government guidance (OMB Circular A-94) also cites that the net present value be used:

> *The standard criterion for deciding whether a government program can be justified on economic principles is net present value -- the discounted [2] monetized value of expected net benefits (i.e., benefits minus costs).*

So now we just need a way to calculate the net present value that is easier than what we just did in the previous section.

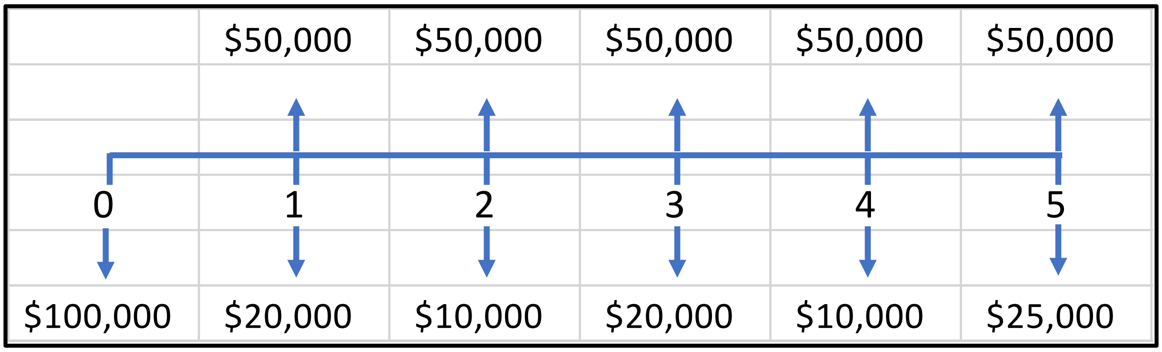
[2] Discounting is a synonym for present value

Excel's =NPV Function

Excel's *=NPV* function requires that the benefits and costs of the proposal be set up in a series of cash flows. After we work through the function steps, we will note some other requirements to properly use the function.

Go to the worksheet "NPV Demo".

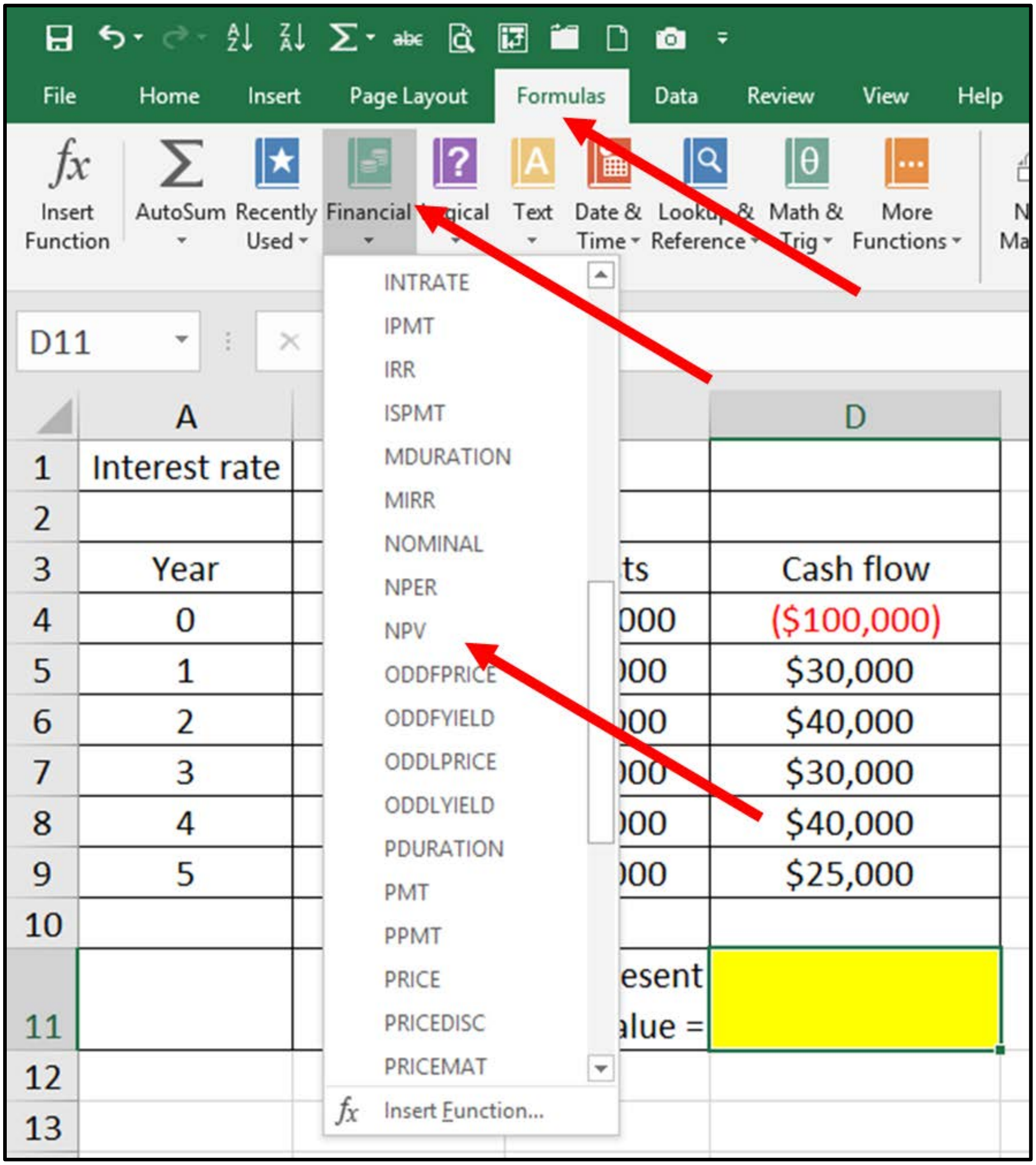
In this worksheet we will calculate the net present value for the cash flow diagram we just looked at.



Interest rate	7%		
Year	Benefits	Costs	Cash flow
0	$0	$100,000	($100,000)
1	$50,000	$20,000	$30,000
2	$50,000	$10,000	$40,000
3	$50,000	$20,000	$30,000
4	$50,000	$10,000	$40,000
5	$50,000	$25,000	$25,000
		Net present value =	

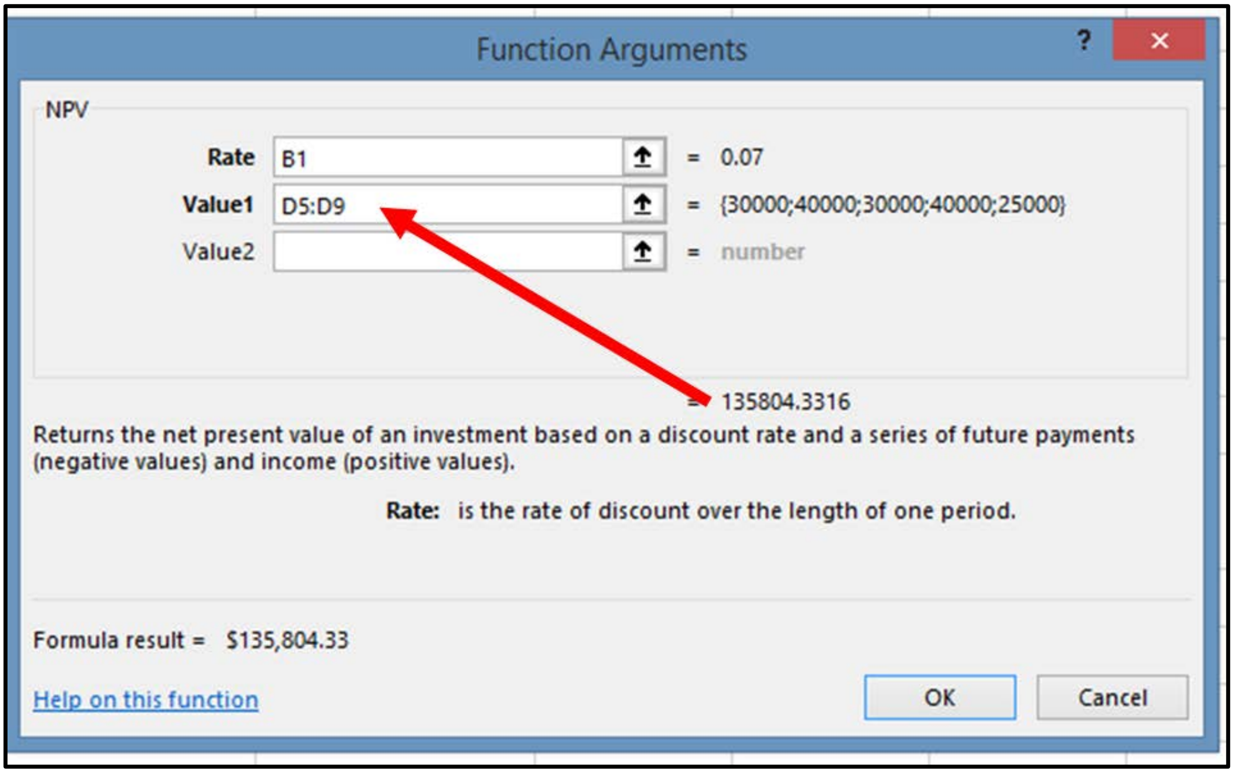
First note that a series of cash flows are set up in cells *D4:D9*. In *D4*, the formula *=B4-C4* was entered and then copied into cells *D5:D9*. Also note we entered an interest rate of 7% into cell *B1*.

Click into cell *D11*.



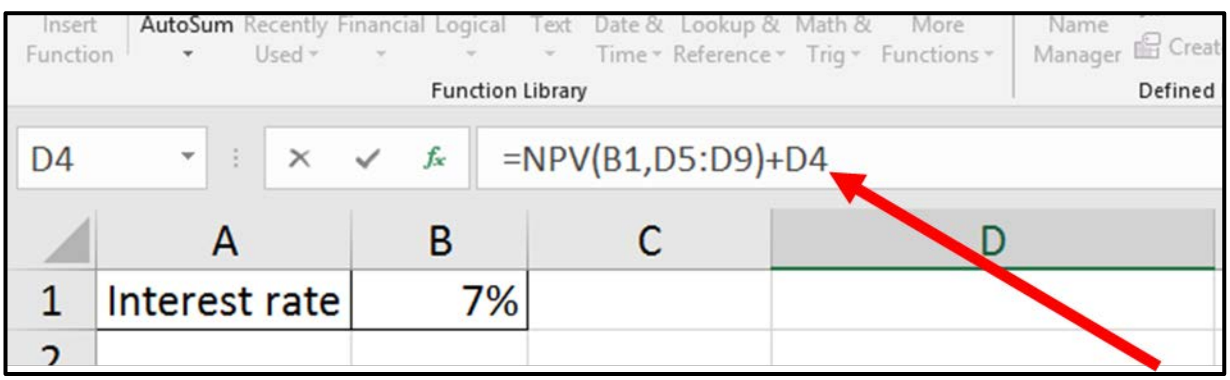
As depicted in the screenshot, click/select the *Formulas* tab, then click/select *Financial*, then click/select *NPV*.

Now, by selecting the appropriate cells, fill in the fields needed for =*NPV* using the interface box shown in the screenshot below.

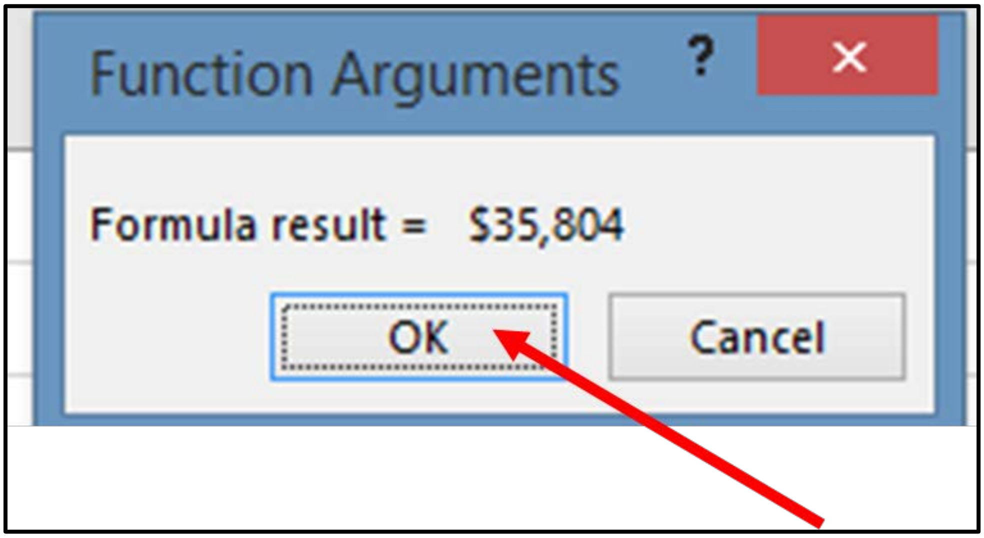


Especially note that the *Value1* field, *D5:D9*, excludes cell *D4*. Do <u>not</u> click *OK* yet!!

Now, click into the *Formula Bar*, directly to the right of *=NPV(B1,D5:D9)* and type "*+D4*"



Now select/click *OK*.



And observe the answer in cell *D11*.

Interest rate	7%		
Year	Benefits	Costs	Cash flow
0	$0	$100,000	($100,000)
1	$50,000	$20,000	$30,000
2	$50,000	$10,000	$40,000
3	$50,000	$20,000	$30,000
4	$50,000	$10,000	$40,000
5	$50,000	$25,000	$25,000
		Net present value =	$35,804

Compare this to the answer we have using the "long way".

Now let's look at the rules we need to follow when using this tool, especially why we ignore the Year 0 amount when we are working within the =*NPV* interface box, but then we later add it to the =*NPV* function result.

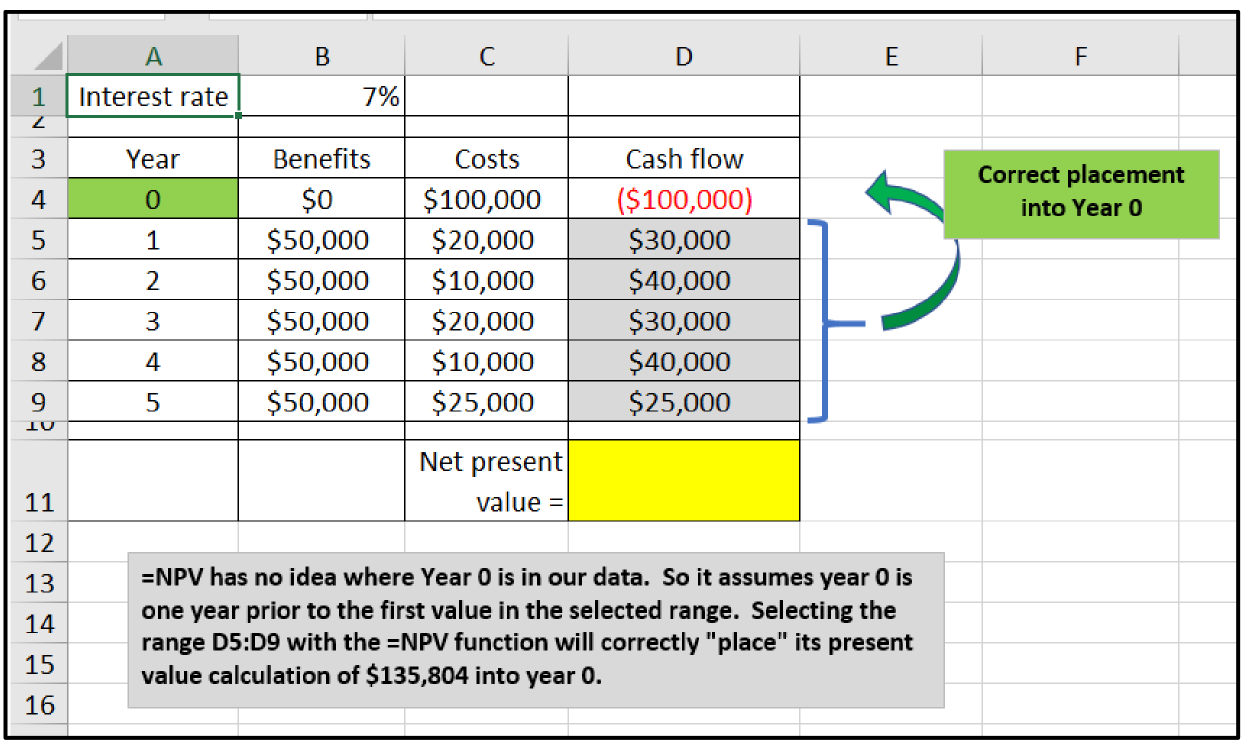
1. The =*NPV* function requires that receipts and disbursements be shown as cash flows in a single column (or row).

2. The cash flows need to be equally spaced apart in time. For example: 2015, 2016, 2017, 2018… is acceptable. Unacceptable would be skipping years, such as 2015, 2017, 2018.

3. Blank cells in the *Value1* field are not acceptable. If there are no cash flows, you must use $0.

4. =*NPV* will take the range of cash flows that you input into *Value1*, and calculate the present value one time period prior to the first cash flow in the range. These screenshots may help you understand this:

First,



	A	B	C	D	E	F
1	Interest rate	7%				
2						
3	Year	Benefits	Costs	Cash flow		
4	0	$0	$100,000	($100,000)		
5	1	$50,000	$20,000	$30,000		
6	2	$50,000	$10,000	$40,000		
7	3	$50,000	$20,000	$30,000		
8	4	$50,000	$10,000	$40,000		
9	5	$50,000	$25,000	$25,000		
10						
11			Net present value =			

Then,

	A	B	C	D	E	F	G
1	Interest rate	7%					
2							
3	Year	Benefits	Costs	Cash flow			
4	0	$0	$100,000	($100,000)			
5	1	$50,000	$20,000	$30,000			
6	2	$50,000	$10,000	$40,000			
7	3	$50,000	$20,000	$30,000			
8	4	$50,000	$10,000	$40,000			
9	5	$50,000	$25,000	$25,000			
10							
11			Net present value =	$35,804			
12							

The PV of D5:D9 is $135,804, and it is added to Year 0's ($100,000) to equal $35,804 as shown in cell D11.

However, the below calculation is not correct.

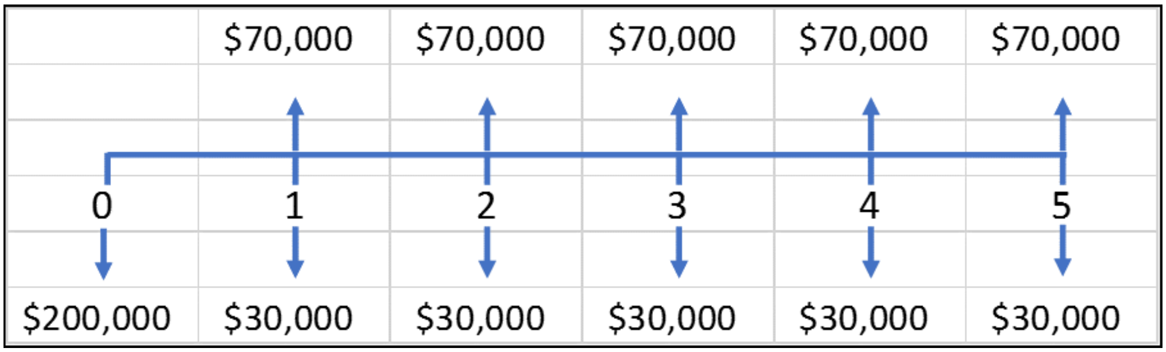
	A	B	C	D	E
1	Interest rate	7%			
2	Year			Cash flow	
3	-1	Benefits	Costs	xxxxxxx	
4	0	$0	$100,000	($100,000)	
5	1	$50,000	$20,000	$30,000	
6	2	$50,000	$10,000	$40,000	
7	3	$50,000	$20,000	$30,000	
8	4	$50,000	$10,000	$40,000	
9	5	$50,000	$25,000	$25,000	
10					
11			Net present value =	$33,462	
12					
13					
14					
15					

Wrong placement into Year -1

On the other hand, if we had selected the range D4:D9, it would incorrectly place the present value calculation into what would be Year -1, one year prior to our Year 0, giving us an incorrect answer of $33,462.

NPV Problem 1:

Go to the worksheet “NPV 1”. So that you can check your work, the answer is shown on the spreadsheet.

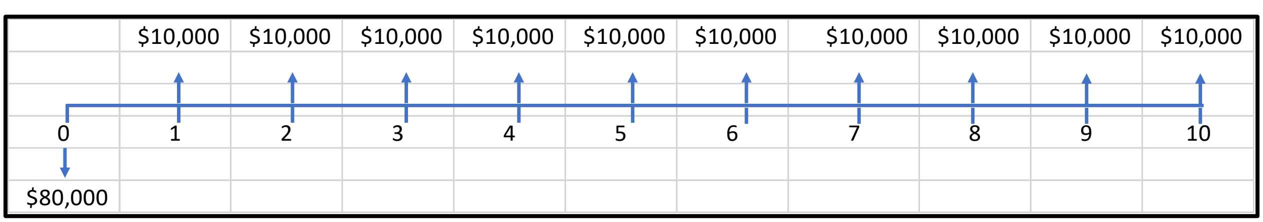


This is cash flow diagram we showed earlier in the course. Prior to learning about net present value, we said this was a “breakeven” proposal since its net benefit = $0. Using the =*NPV* function, calculate its net present value at a minimum attractive rate of return of 5%.

NPV Problem 2

Go to the worksheet “NPV 2”. So that you can check your work, the answer is shown on the spreadsheet.

This is a cash flow diagram we looked at earlier in the course. There is an $80,000 initial cost, but it yields benefits of $10,000/year over the next 10 years. Earlier we said that this looked monetarily attractive. Based on a 7% minimum attractive rate of return, evaluate its net present value using =*NPV*. Is the proposal monetarily attractive at 7%? At approximately what interest rate does it breakeven?



NPV Problem 3

Go to the worksheet "NPV 3". So that you can check your work, the answer is shown on the spreadsheet.

An engineer bought a $2 lottery ticket and won $245,000,000 in the Mega Millions lottery, and is faced with two ways of receiving her winnings. In this problem, we will compare the two alternatives by using =*NPV* to calculate the present value of her "benefits".[3]

Alternative 1 (the graduated annuity): She can receive her winnings as a graduated annuity. The first check she will get (before tax) will come immediately, and we show that in Year 0. It is $3,687,602. Her last check (Year 29) is $15,178,668. See table below:

Year	Gross Payment	Year	Gross Payment
0	$3,687,602	15	$7,666,259
1	$3,871,982	16	$8,049,572
2	$4,065,581	17	$8,452,050
3	$4,268,860	18	$8,874,653
4	$4,482,303	19	$9,318,386
5	$4,706,418	20	$9,784,305
6	$4,941,739	21	$10,273,520
7	$5,188,826	22	$10,787,196
8	$5,448,267	23	$11,326,556
9	$5,720,680	24	$11,892,884
10	$6,006,714	25	$12,487,528
11	$6,307,050	26	$13,111,904
12	$6,622,403	27	$13,767,499
13	$6,953,523	28	$14,455,874
14	$7,301,199	29	$15,178,668

Alternative 2 (the immediate lump sum): Or, she can receive a check immediately for $148,300,000, before tax. (Thus, its present value is $148,300,000.)

Using =*NPV*, at a 4% minimum attractive rate return, calculate the present value of the annuity. Remember to include only years 1 through 29 within the =*NPV* function, and then add the year 0 benefit to the =*NPV* calculation. Compare the annuity's present value to the immediate lump sum.

1. Which of the two alternatives should be chosen?

2. At what interest rate does there appear to be a breakeven between the two alternatives?

[3] This is an illustration of the cost effectiveness technique. The cost of each alternative is the same (the $2 lottery ticket), so we only need to compare the present value benefits of the two alternatives.

Applying a Minimum Attractive Rate of Return (aka Discount Rate)

As demonstrated in the problems we have worked, the net present value is very sensitive to the choice of the interest rate. The interest rate used in present value analysis may be called: the desired rate of return, or the **minimum attractive rate of return**, or the **discount rate**.

With some interest rates the NPV of a proposal may be attractive, and with other interest rates it may be a breakeven or a loss. Is there a correct one to use? Well, it depends.

For individuals considering various ways of how they should invest their money, or deciding whether or not to take a company's buyout and retire early, or considering drawing Social Security benefits at age 62 versus waiting until full retirement age at 67, the rate of return depends on how they invest their money. For example, are they conservative or aggressive? Are they investing "everyday" money or is it "extra" money to risk? Is it money that is borrowed, or is it free and clear? Dependent on these answers, their rates of return may range from 1% - 2% up to 9% - 10%.

For businesses, the minimum attractive rate of return is at least as high as its cost of capital, i.e. financing a loan. For risky, long-term, investments, businesses may demand a higher rate of return than it normally would demand on less risky investments. For a publicly held company, it can be affected by the amount of the dividend paid to stockholders. It would not be unusual for businesses to demand a 15% to 25% minimum attractive rate of return.

In the evaluation of Federal Government proposals, if the beneficiaries of a proposed investment or regulation are "external" (meaning the public is directly impacted in some way), the OMB Circular A-94 guidance states that:

> *Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years.*

The OMB Circular A-94 guidance further states that for Federal Government proposals that involve lease-purchase agreements or that return only internal benefits to the Government and not to the public (such as a new heating system for a Federal building):

> *Analyses that involve constant-dollar costs should use the real Treasury borrowing rate on marketable securities of comparable maturity to the period of analysis. This rate is computed using the Administration's economic assumptions for the budget, which are published in January of each year. A table of discount rates based on the expected interest rates for the first year of the budget forecast is presented in Appendix C of this Circular. Appendix C is updated annually and is available upon request from OMB. Real Treasury rates are obtained by removing expected inflation over the period of analysis from nominal Treasury interest rates.*

Dependent on the length of the proposal, these discount rates currently (2019) range from 1.3% to 1.5%.

The Federal Government OMB Circular A-4 cites the use of both a 3% and a 7% discount rate:

> *For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent. An example of this approach is EPA's analysis of its 1998 rule setting both effluent limits for wastewater discharges and air toxic emission limits for pulp and paper mills. In this analysis, EPA developed its present-value estimates using real discount rates of 3 and 7 percent applied to benefit and cost streams that extended forward for 30 years. You should present a similar analysis in your own work.*

Remember that all of the rates of return discussed in this section are "real" interest rates. As noted earlier in our section called The Cash Flow Diagram, we use constant-dollar cash flows. Constant-dollar cash flows ignore inflation, and in turn our rates of return must also ignore inflation. To get what are termed "nominal" rates of return, add about 2.5% to the real rates.

Any time the discount rate is higher than 0%, the value of the future benefits and costs decreases. During a recent class that I taught at the Nuclear Regulatory Commission, one of their analysts told me that their practice was to only use discount rates of 0%, because otherwise their projected benefits would not be as high. However, I cannot confirm that this practice is true.

Labor unions in the past have effectively blocked OSHA (Occupational Safety and Health Administration) from numerically quantifying benefits, believing that if many safety program benefits had dollars attached to them, they may not be approved. OSHA has also been pressured in the past to use discount rates of 0%, so that future benefit amounts were not lowered. However, in a recent proposed rule change "Revising the Beryllium Standard for General Industry", dated May 7, 2018, OSHA cites annualized net cost savings using both a 3% and a 7% discount rate.

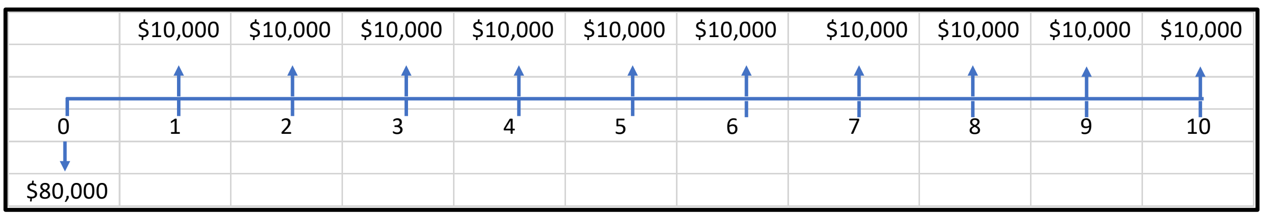
I once had a group of managers ask if I would not use present value analysis because it made their proposals look less attractive. In a benefit to cost comparison, the benefits are discounted proportionately more than the costs, because every benefit is in the future; but the majority of costs are initial costs, and Year 0 costs are not discounted at all.

In cases when the discount rate is uncertain, we can calculate an interest rate such that the proposal would break-even. This is called the internal rate of return, covered in the next section.

Internal Rate of Return (IRR)

The **internal rate of return** (**IRR**) is another measure of a proposal's monetary value. It is defined as the discount rate at which the present value of the benefits equals the present value of the costs. It is useful especially when the organization for whom we are working for has difficulty determining a minimum attractive rate of return. Although the IRR will indicate the monetary attractiveness of a proposal, it will not necessarily rank the monetary desirability of numerous proposals in the same order as the NPV. Therefore, the NPV is still the desired measure of a proposal's monetary worth.

When we looked at NPV Problem 2 earlier, we were given this cash flow diagram and asked at what minimum attractive rate of return would this be a break even, meaning when the benefits would equal the costs.

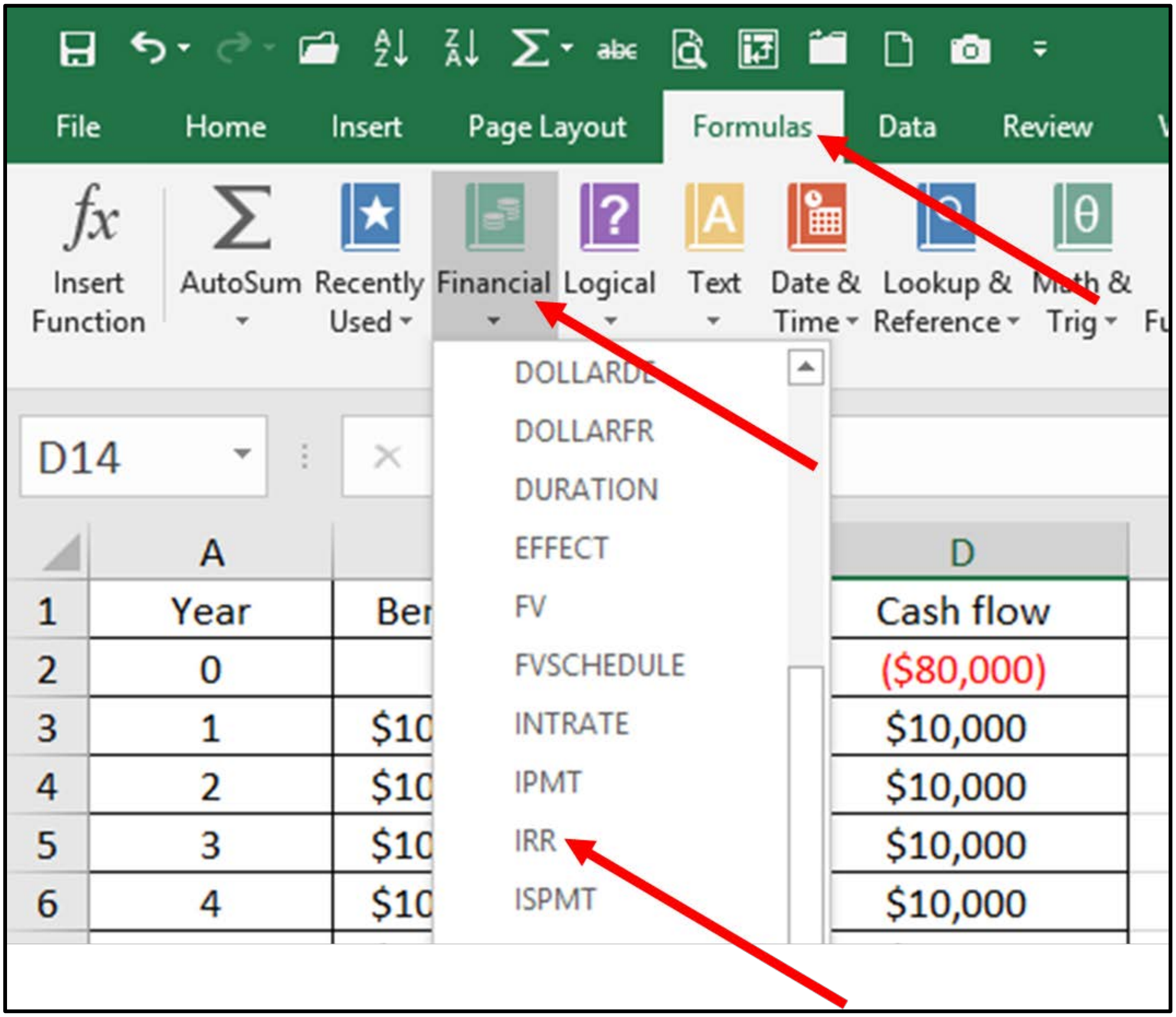


We estimated the answer to be between 4% and 5%.

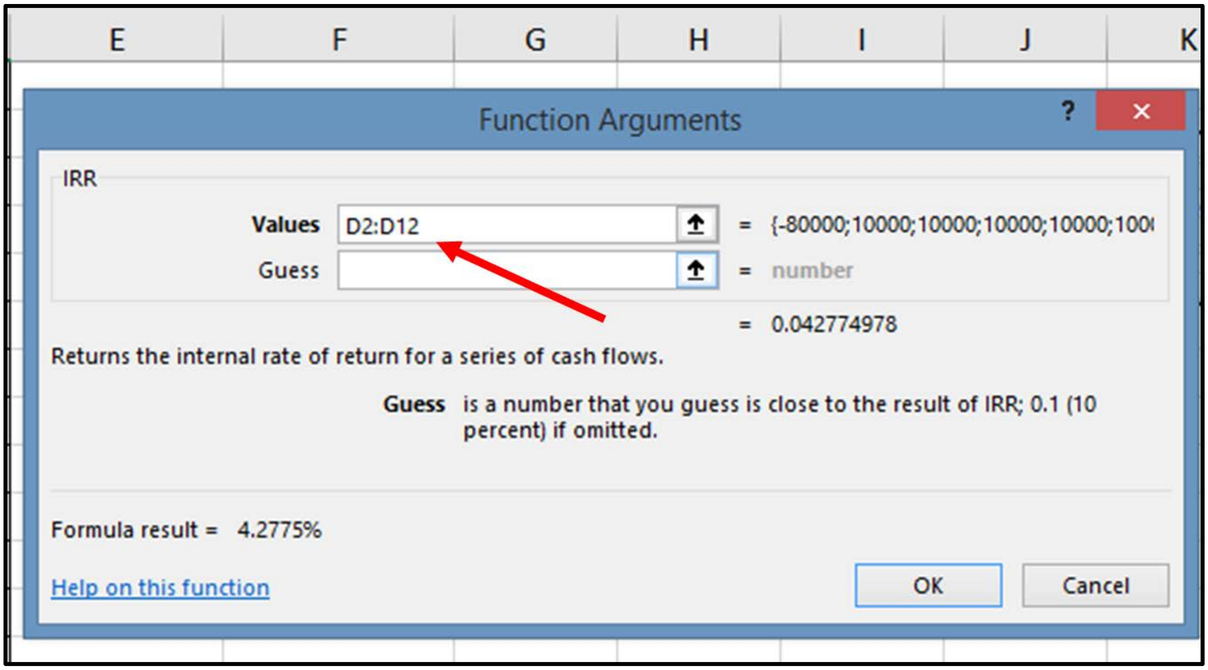
But rather than estimate the answer, we can use the *Excel* function =*IRR*.

Go to the worksheet "IRR Demo" and follow the screenshots.

Begin with your active cell as *D14*, and select *Formulas*, *Financial*, and *IRR*.



This time, select the entire range of cash flows. (Unlike when we used =*NPV*, we do not have to avoid selecting the Year 0 amount.)



Click *OK*, and the answer 4.2775% appears. (We formatted the cell to show 4 decimal places.) This answer is between the 4% and 5% we estimated earlier.

Therefore, if there was uncertainty over the minimum attractive rate of return, the engineer could demonstrate that if the proposal were implemented, the organization would essentially be getting back a 4.2775% return.

The =*IRR* function requires a similar spreadsheet setup that we used for =*NPV*:

1. The =*IRR* function requires that receipts and disbursements be shown in cash flows.

2. The cash flows need to be equally spaced apart in time. For example: 2015, 2016, 2017, 2018… is acceptable. Unacceptable would be skipping years, such as 2015, 2017, 2018.

3. Blank cells in the *Values* field are not acceptable. If there are no cash flows, you must use $0.

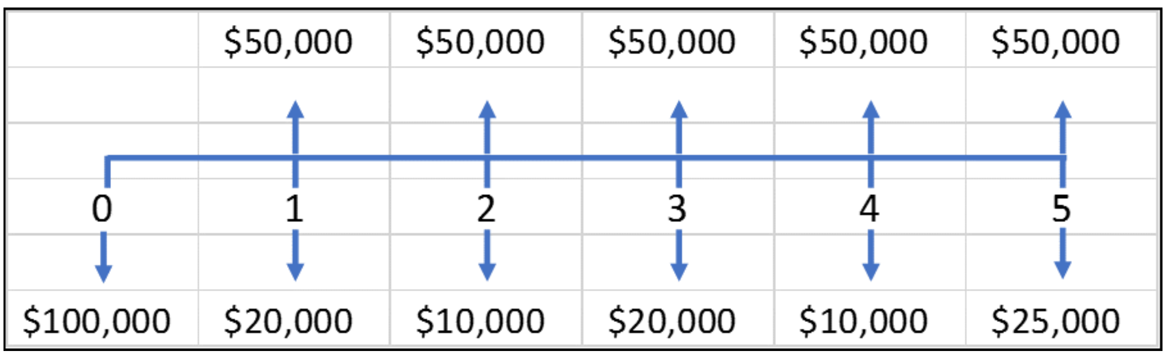
4. The *Guess* field is rarely needed. (I have never had to use it.) To explain this in simple terms, =*IRR* is designed to go through a certain number of iterations as it works its way around the final answer. For example, in developing a solution for this problem, let's say *Excel* started with a 10% interest rate (the default), but the net present value was below $0. So, then suppose *Excel* went to 0%, but the net present value was above $0. So, then back to 9%, then back to 1%, each time narrowing in on the answer. It is possible that after many tries, *Excel* cannot produce a solution. To narrow the search, we can type in an interest rate that we think is close – called a guess – in order to reduce the number of searches. (Under *File*, *Options*, *Formulas*, there is a setting for *maximum iterations* and *maximum change*, which regulates the number of calculations *Excel* will make.)

Now let's practice what we learned.

IRR Problem 1

Go to the worksheet "IRR 1". So that you can check your work, the answer is shown on the spreadsheet.

In the "NPV demo" worksheet we looked at earlier, we found that a company's proposal shown below was attractive at a 7% minimum attractive rate of return. This would mean that this proposal's benefits versus the costs that are invested into it exceed the 7% desired by the company. But, would it exceed an 8% minimum attractive rate of return? 9%? At what minimum attractive rate of return does this proposal start to become monetarily unattractive.



Use the =*IRR* function to determine this proposal's breakeven rate of return, called the internal rate of return.

IRR Problem 2

Go to the worksheet “IRR 2”. So that you can check your work, the answer is shown on the spreadsheet.

An investor began contributing to a stock mutual fund back in 1993, and over the years invested $58,000 at various times and in different amounts. In 2017, the investor cashed out with $206,466. Using =*IRR*, what annual rate of return did the investor receive? Place your calculation into cell *B28*.

IRR Problem 3

Go to the worksheet “IRR 3”. So that you can check your work, the answer is shown on the spreadsheet.

In 2009, an individual had $40,000 and decided to diversify her investments. She took $10,000 and locked it away in a safe. She took $10,000 and played the lottery. She took $10,000 and bought government savings bonds. She took her final $10,000 and invested into an aggressive stock mutual fund. Ten years later, she assessed her situation and decided to “cash out”.

In her safe was $10,000, but the lottery investment took its toll and she had $0. The government savings bonds were only worth $11,376, but her mutual fund grew to $31,058. Therefore, her $40,000 grew to a total of $52,434.

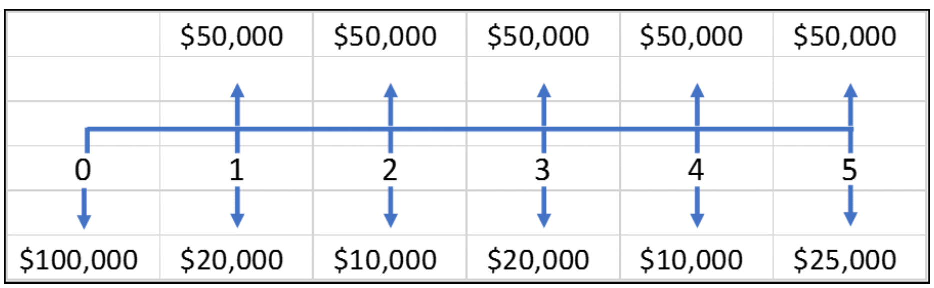
Using =*IRR*, what was her internal rate of return?

Using *Excel's Data Table* Tool

To summarize from the two prior sections, it would be wise as engineers to perform our present value analysis of proposals covering a wide range of possible rates of return. *Excel* gives us a tool called *Data Table* with which we could show the net present value calculation for varying rates of return. This would be called a "one-variable" *Data Table*, and it is what we will use for solving the *Data Table* Demo, and Problem DT 1. In Problem DT 2 and Problem DT 3, we will construct "two-variable" *Data Tables*. *Excel's Data Table* is limited to displaying two changing variables.

Go to the worksheet "Data Table Demo".

Let's say you calculated the net present value for this proposal, but were also asked to cover a range of rate of returns from 0% to 25%, in increments of 1%. You need a speedy way to create such a table of values and have elected to use the *Data Table* tool.



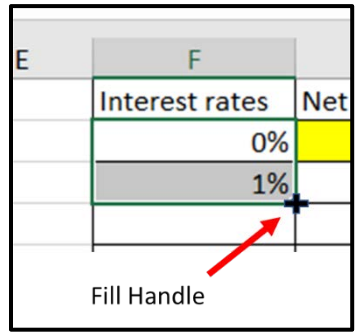
Begin by setting up an *Excel* spreadsheet (as shown) to calculate the net present value. (If necessary, refer back to the "NPV Demo" worksheet.) Set up the initial calculation based on the 0% interest rate (done for you).

Interest rate	0%		
Year	Benefits	Costs	Cash flow
0	$0	$100,000	($100,000)
1	$50,000	$20,000	$30,000
2	$50,000	$10,000	$40,000
3	$50,000	$20,000	$30,000
4	$50,000	$10,000	$40,000
5	$50,000	$25,000	$25,000
		Net present value =	$65,000

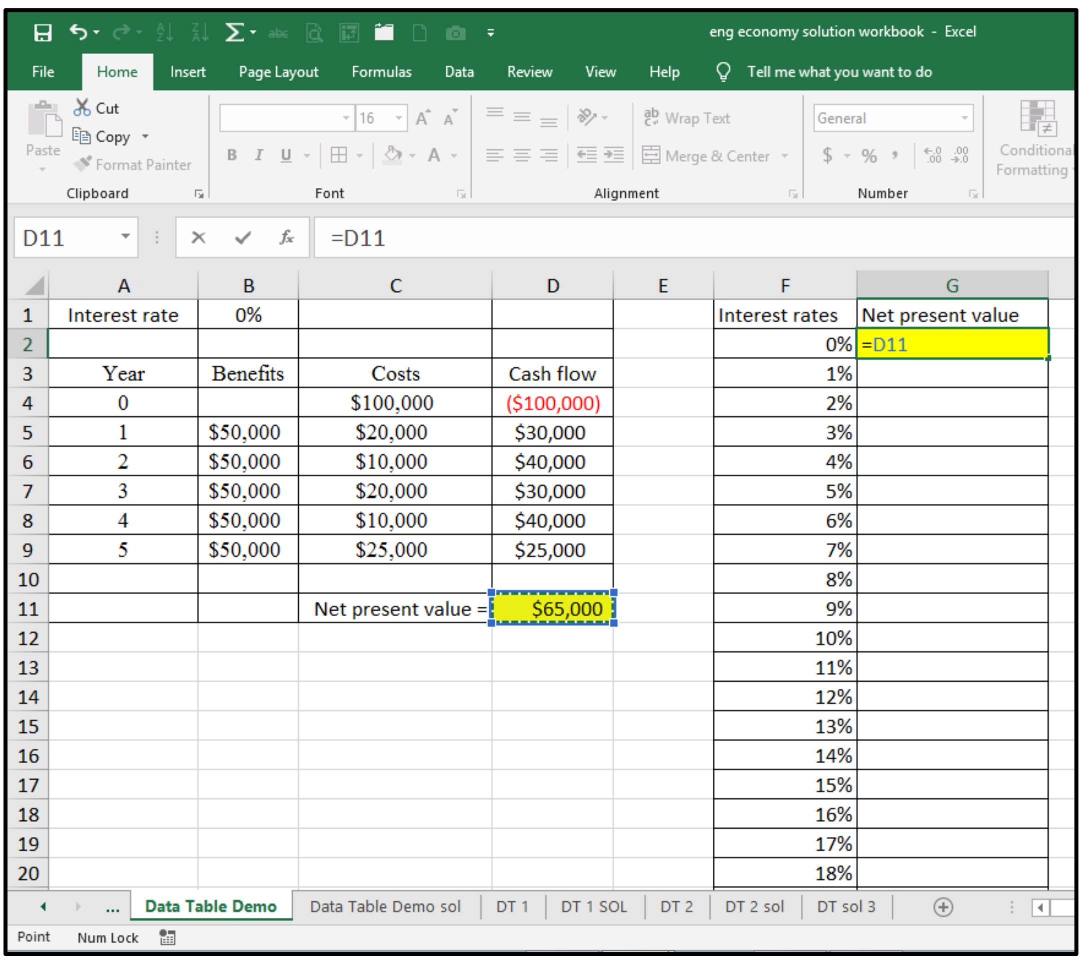
Beginning in cell *F1*, create the following table (see the trick on the next page):

Interest rates	Net present value
0%	
1%	
2%	
3%	
4%	
5%	
6%	
7%	
8%	
9%	
10%	
11%	
12%	
13%	
14%	
15%	
16%	
17%	
18%	
19%	
20%	
21%	
22%	
23%	
24%	
25%	

To easily enter the interest rates, type 0% into cell *F2*, and 1% into cell *F3*. Then highlight both cells, and place the cursor on the lower right corner of the highlighted selection where there is a small black square. Then depress and hold down the left mouse button to get the *Fill Handle.* Then drag the selection down into cell *F27*, and then release the mouse. Now you will have interest rates ranging from 0% to 25% in increments of 1%.



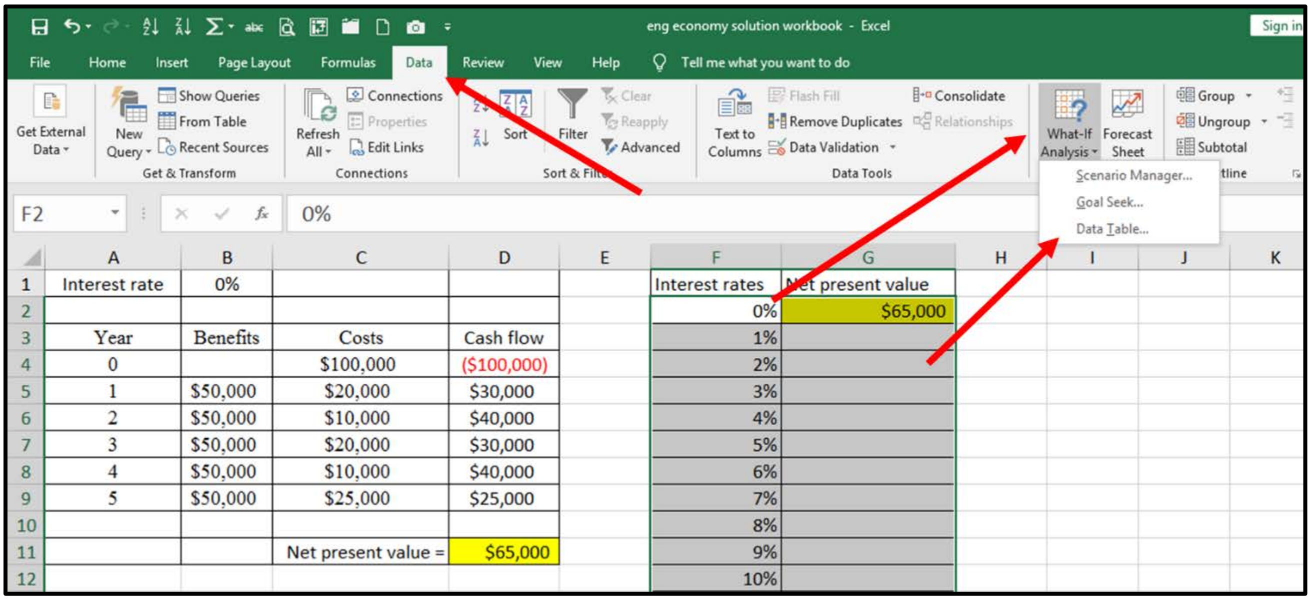
Set a link between cell *G2* and cell *D11* by typing "*=D11*" into cell *G2*. (The link is being set to the cell where you created the *=NPV* function to get the net present value for the 0% interest rate.) Press *Enter* to complete the link. (The cells are colored for emphasis.)



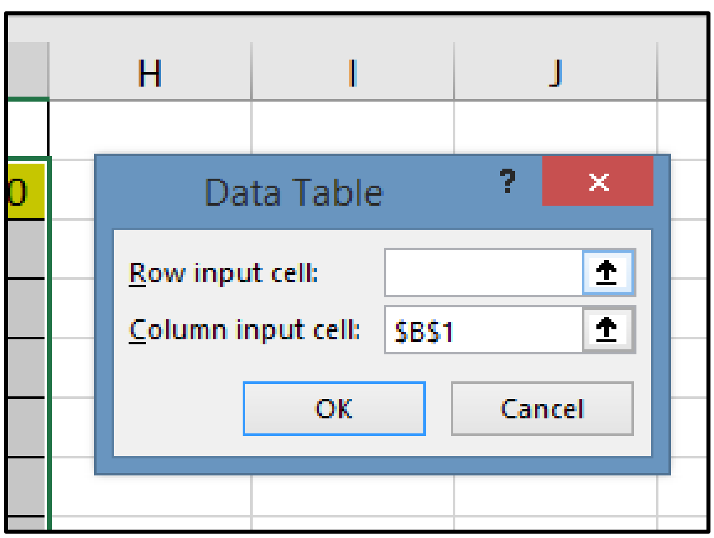
	A	B	C	D	E	F	G
1	Interest rate	0%				Interest rates	Net present value
2						0%	=D11
3	Year	Benefits	Costs	Cash flow		1%	
4	0		$100,000	($100,000)		2%	
5	1	$50,000	$20,000	$30,000		3%	
6	2	$50,000	$10,000	$40,000		4%	
7	3	$50,000	$20,000	$30,000		5%	
8	4	$50,000	$10,000	$40,000		6%	
9	5	$50,000	$25,000	$25,000		7%	
10						8%	
11			Net present value =	$65,000		9%	
12						10%	
13						11%	
14						12%	
15						13%	
16						14%	
17						15%	
18						16%	
19						17%	
20						18%	

Next, pre-select (highlight) the cell range *F2:G27*, making sure to not include cells *F1* and *G1* (otherwise this will not work correctly).

After making this pre-selection, select the *Data* tab, then *What-if Analysis*, then *Data Table.*



In the *Data Table* interface box, click in the field *Column input cell* and then click/select cell *B1*. Do this because the table shows the interest rates in a columnar form (rather than in a row), and because the interest rate was originally entered into cell *B1*.



Click *OK*.

Interest rates	Net present value
0%	$65,000
1%	60258.37268
2%	55725.27328
3%	51389.00126
4%	47238.63844
5%	43263.98882
6%	39455.52374
7%	35804.33158
8%	32302.07186
9%	28940.93301
10%	25713.59383
11%	22613.18796
12%	19633.27135
13%	16767.79228
14%	14011.0638
15%	11357.73839
16%	8802.784525
17%	6341.465113
18%	3969.317596
19%	1682.135543
20%	-524.0483539
21%	-2652.97801
22%	-4708.18851
23%	-6693.019602
24%	-8610.628202
25%	-10464

Clean up the results by applying a currency format to the data in cells *G2:G27*. Remember the *Shift+Ctrl+4* trick shown earlier in the course. Remove two decimal points.

Interest rates	Net present value
0%	$65,000
1%	$60,258
2%	$55,725
3%	$51,389
4%	$47,239
5%	$43,264
6%	$39,456
7%	$35,804
8%	$32,302
9%	$28,941
10%	$25,714
11%	$22,613
12%	$19,633
13%	$16,768
14%	$14,011
15%	$11,358
16%	$8,803
17%	$6,341
18%	$3,969
19%	$1,682
20%	($524)
21%	($2,653)
22%	($4,708)
23%	($6,693)
24%	($8,611)
25%	($10,464)

Now you may include the table in the analysis of the proposal, and state that for any minimum attractive rate of return of 19% or less, the proposal is monetarily attractive.

Let's practice making some *Excel Data Tables*:

DT Problem 1:

Go to the worksheet "DT 1".

So that you can check your work, the answer is shown on the spreadsheet.

Back in FV Problem 1, Aunt Emma left you $100,000, and you would like to see various future value scenarios based on different interest rates. You still plan to invest for 40 years. Use the *Data Table* tool to construct scenarios for interest rates ranging from 2% to 15%, in increments of 0.5%.

The future value calculation has already been done for you.

Out of the 27 scenarios, how many of them result in a future value greater than $2,000,000?

DT Problem 2:

Go to the worksheet "DT 2". So that you can check your work, the answer is shown on the spreadsheet.

Back in FV Problem 2, the Federal employee calculated the future value of her TSP to be $2,172,598, based on a rate of return of 7%, and retiring in 30 years. Assuming she still plans to invest the $23,000/yr. (which includes the government match of $4,000), she is interested in other scenarios.

One of her colleagues told her that if she worked an additional 5 years, and earned 8%, she could nearly double her retirement nest egg. All of this is becoming very confusing, so she wants to construct a table showing her different future values for a range of years and interest rates.

		Number of years					
		15	20	25	30	35	40
Interest rates	4%						
	5%						
	6%						
	7%						
	8%						
	9%						

When using the *Data Table* tool this time, we must set things up differently. Follow the instructions in the worksheet.

Is her colleague correct?

DT Problem 3:

Go to the worksheet "DT 3". So that you can check your work, the answers are shown on the spreadsheet.

An engineer has just completed the analysis of a proposal. At a minimum attractive rate of return of 7%, the proposal is monetarily attractive.

Discount rate	7%		
Year	Benefits	Costs	Cash flows
0	$0	$400,000	($400,000)
1	$100,000	$22,000	$78,000
2	$100,000	$32,000	$68,000
3	$100,000	$32,000	$68,000
4	$100,000	$26,000	$74,000
5	$100,000	$14,000	$86,000
6	$120,000	$74,000	$46,000
7	$120,000	$44,000	$76,000
8	$120,000	$44,000	$76,000
	Net present value =		$27,784

However, the engineer is concerned about the initial cost estimate of $400,000 that was provided by some estimators, and wants to conduct a sensitivity analysis (a best case and worst-case scenario) of the initial costs. In addition, there is some uncertainty about the discount rate to use.

The engineer wants to create a table of the net present values, a) showing a range of initial costs from $300,000 up to $650,000, in increments of $50,000; and b) showing a range of discount rates from 0% to 10%, in increments of 1%.

Create a *Data Table* and answer the following:

1. Based on the original $400,000 initial cost estimate, what is the highest discount rate that can be used so that the proposal is monetarily attractive?

2. At a 3% discount rate, what is the highest initial cost estimate that can be used so that the proposal is monetarily attractive?

3. If the initial cost were $350,000 or less, would the proposal be monetarily attractive at a 10% discount rate?

Some Closing Thoughts

I hope this course has shown what a valuable tool *Excel* can be in simplifying the calculations we typically use in an engineering analysis of the feasibility of proposals. Concurrent with this, I hope you are more aware of some of the nuances that enter into the engineering economics of evaluating proposals.

Our intent is to provide our clients with a mechanism they can use to approve or disapprove capital investments. Keep in mind that there are considerations other than money that often enter into a "go" versus "no-go" decision, such as the intangible benefits, or the "politics" of a proposal.

Also, the "bottom line answer" could vary based on which engineer does the analysis. Some engineers may take a rather narrow viewpoint when looking at the economic impacts of a proposal, where others may consider a broader perspective. I also alluded to some of the pressure that may be applied to monetize intangible benefits.

In closing, allow me to pass along some pointers:

- Get a thorough understanding of the scope of the proposal and the impact it will have on all operations. Consult with those most familiar with the inner workings of the operations being impacted by the proposal.
- Tend to be a little conservative with the savings estimates, and realistic with the cost estimates. Have at least two sources for most of your estimates.
- Carefully document all assumptions and estimates.
- Ensure your work is logical and defendable. If you cannot explain how you arrived at your results, you will not be taken seriously.
- Evaluate all cost and savings estimates with a sensitivity analysis using tools such as the *Data Table* covered in this course.
- Do not be pressured to produce a specific result. Be aware of the pressure and be responsive to it, but don't let it override what the data and your knowledge and experience tell you. Remember, it is your professional engineering seal that goes on the analysis.

