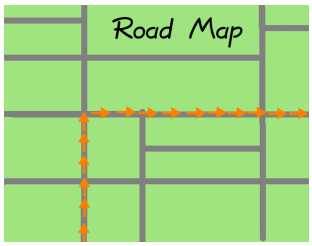
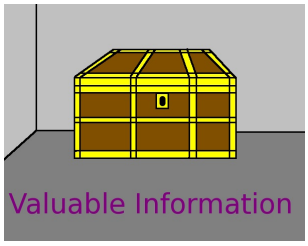
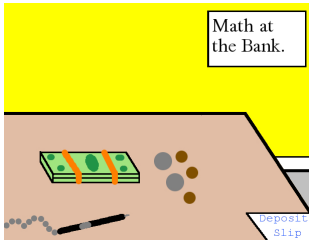
Module 2.1: Simple Interest



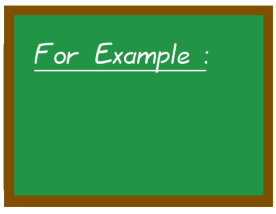
In this section, we will discuss *simple interest*. While this type of interest is not used very often, it is the building block of all of the loan and investment models that follow. Six places where it does come up are (1) very short-term loans, including both overnight interbank loans and something called commercial paper, (2) many settlements in law suits, (3) most promissory notes, (4) siphoning, (5) the "inner core" of compound interest, and (6) US Treasury bonds (not to be confused with US Savings bonds). In fact, the last three are where we will be using simple interest most frequently in this book.



The fundamental formula for finding the value added from simple interest is $A = P(1+rt)$. The P stands for the *principal*, which is how much money you have at the start of the loan or the investment. Then t stands for time, and the r is the interest rate. Usually both r and t are given in years. Finally, A is the total amount at the end—principal plus interest.



Banks often make very short-term loans to each other, even overnight loans, to ensure that they have sufficient capital on hand. The system *FedWire*, run by the Federal Reserve, brokers such transactions using simple interest. The Federal Reserve sets the common interest rate for such transactions, which is called the *Federal Funds Rate* (or *Fed Funds Rate* for short). That rate fluctuates depending on the status of the economy, and is set to try to control growth and inflation. For the next few boxes, we will assume it has been set to 4.5%.



2-1-1

Perhaps Bank Alpha says to Bank Beta, "I need $ 2,000,000 but only for one day, what can you do for me?" Then perhaps the response is "I can only offer you 1 million dollars." How much would Bank Alpha have to pay Bank Beta tomorrow, if the offer is accepted? (Use a 360-day year.)

We start with the formula, $A = P(1 + rt)$. The time would be $t = 1/360$, because it is only one day, and t is measured in years. The rate would be $r = 0.045$ and of course $P = 1,000,000$. Then we have

$$A = (1,000,000)(1 + 0.045 \times 1/360) = (1,000,000)(1.00012\cdots) = 1,000,125.00$$

The financial terminology would be "Bank Alpha pays Bank Beta $ 125.00 for the use of a million dollars for one day." You have to know by context that the $ 125.00 is interest. Presumably, Bank Alpha will find the other million from another bank.

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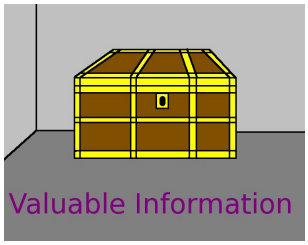
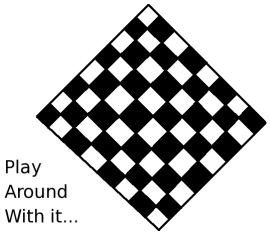


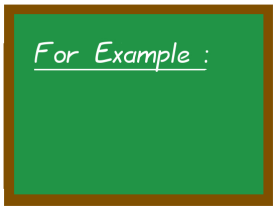
The 360-day year might surprise you. Of course, a year has 365 days, or 366 in a leap year. Also, some months have 30 days, others have 31, and February has 28 or 29. Despite all of that, the finance industry uses the *Banker's Rule* for time in any investment whose lifetime is less than or equal to one year. In the Banker's Rule, all months are accounted as 30 days, and 360 days is taken to be the year. This is at least consistent in that $30 \times 12 = 360$. Also, *a quarter* is an extremely common term, and means 90 days. The reason for the *Banker's Rule* is that it makes the calculations come out cleaner, and one need not remember which months are 30 and 31 days.

On the other hand, for investments that last longer than one year, a 365-day year is used, and a 91-day quarter. This tends to be confusing for students, so any time daily calculations are required, this book will simply specify whether you should be using a 360-day or 365-day year—so you have nothing to worry about.



2-1-2

- A more realistic scenario is a billion dollar loan. Suppose instead that the money were needed for 3 days, but still at 4.5%, how much would the amount repaid be? [Answer: \$ 1,000,375,000.00.]
- How about if the rate rose to 5% and the loan was for 2 days? (The principal is still for one billion dollars.) [Answer: \$ 1,000,277,777.77.]



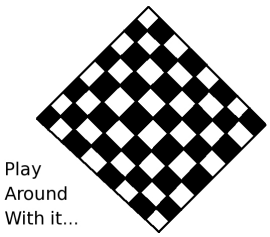
2-1-3

Perhaps Bank Alpha says "if you give me \$ 999,000 today then I will give you \$ 1,000,000 tomorrow." Sounds like a good deal, right? What is the interest rate?

We start with $A = P(1 + rt)$ and plug in $t = 1/360$ as well as $P = 999,000$ and $A = 1,000,000$. Then we have

$$\begin{aligned} 1,000,000 &= (999,000)(1 + r/360) \\ 1.00\overline{100} &= 1 + r/360 \\ 0.00\overline{100} &= r/360 \\ r &= 0.360\overline{360}\cdots \end{aligned}$$

but of course 36.03% is a horribly high rate of interest. It is a good deal for the lender, but a terrible deal for the borrower.



2-1-4

How about an agreement to pay 5 million dollars 180 days from now, in return for 4.5 million right now...

- What is the equivalent simple interest rate? [Answer: $22.2\overline{2}$%.]
- What is the equivalent simple interest rate:
  - ...if it were 120 days? [Answer: $33.3\overline{3}$%.]
  - ...if it were 150 days? [Answer: $26.6\overline{6}$%.]
  - ...if it were 210 days? [Answer: $19.04\cdots$%.]
  - ...if it were 270 days? [Answer: $14.\overline{814}$%.]

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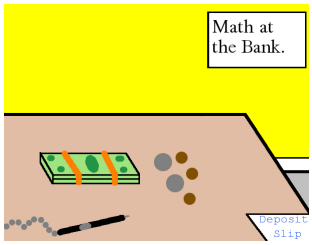
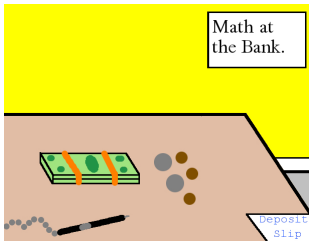
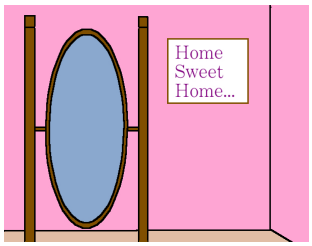


Notice that in the previous box, the interest rate wasn't explicitly stated, and it wasn't a clean fraction or round number. This can happen in practice. Interest rates are normally reported to the nearest 1% of 1%. This unit, 1/100th of a percent, is called a *basis point*. To be clear, a quarter of a percent would be 25 basis points, and half a percent would be 50 basis points.

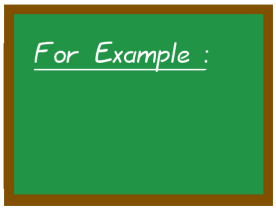


There are different ways that banks and businesses might invest in the debt of others, in order to be paid interest. One example is when a business pays some amount in return for a promise of a slightly larger amount in the near future on a fixed date. This is called *discount interest* and a very classic example of it is a *treasury bill*, sometimes called a *T-Bill*. The US Treasury sells T-Bills to acquire funds needed on a short-term basis.

When a company has some significant sum of money that it will not use for some months, it could lend it out in the commercial paper market, but that entails some risk. A zero-risk investment is buying a treasury bill. Treasury bills are sold by the US Treasury to raise funds for day-to-day operation of the government, and they come in four sizes: 4 weeks, 13 weeks, 26 weeks, and 52 weeks, or one month, one quarter, half-a-year, and one year. They are sold at electronic auctions held by the Treasury Department.



A Pause for Reflection...
The exchange of short-term loans between very large companies is generally referred to as the *commercial paper market*. What do you think about the commercial paper industry? Do you think most people who have a money market account know how their money is being invested? Do you think this is a low-risk or a high-risk activity? There is an excellent article entitled "The Week the Economy Almost Died" about these inter-corporation short-term loans (the "commercial paper" industry) which can be found at
`http://www.npr.org/templates/story/story.php?storyId=95099470`



2-1-5

If the face value of a 13-week treasury bill is one million dollars, then it will probably sell for around $ 990,000. If it does, what is the equivalent simple-interest rate?

This can be calculated directly from the formula:

$$\begin{aligned} A &= P(1+rt) \\ 1,000,000 &= 990,000\left(1+r\frac{13}{52}\right) \\ 1.01\overline{01} &= 1+0.25r \\ 0.01\overline{01} &= 0.25r \\ 0.04\overline{04} &= r \end{aligned}$$

and so the rate is 4.04%.

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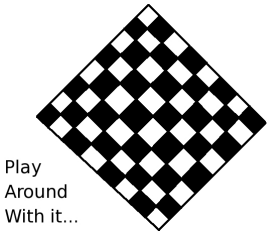
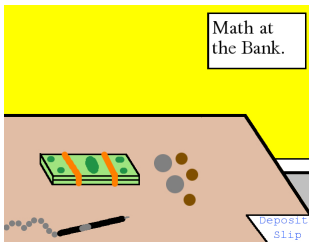


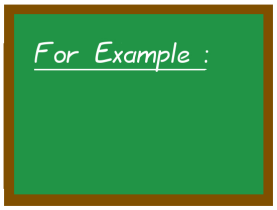
2-1-6

- How about if the treasury bill sells for $ 992,000? [Answer: 3.22%.]
- How about if the treasury bill sells for $ 988,000? [Answer: 4.85%.]



A *promissory note* is a written promise to repay a debt. Usually this is used for small private loans between people. With close friends, of course, one does not want to create paperwork. On the other hand, if you are sharing an apartment with someone else, and they cannot pay their half of the rent, then you are faced with a choice: pay your roommate's part or risk having both of you evicted. The promissory note gives you a document to prove that the loan exists, and what its amount was, as well as the date. Furthermore, if the debt becomes uncollectible, you can get a tax deduction for your losses!

A sample promissory note can be found at the following website:
`http://www.expertlaw.com/library/business/promissory_note_form.html`

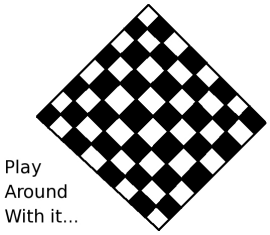


Bert and Ernie are sharing an apartment, but Ernie cannot pay his rent this month. Ernie's share is $ 750 (apartments in New York are expensive!) and he signs a promissory note written by Bert that says he'll pay it back in two weeks. They agree on 8% interest. How much will Ernie have to pay? Note, there are 52 weeks in the year.

The formula is $A = P(1 + rt)$, and so we have

$$A = P(1 + rt) = 750\left(1 + 0.08\frac{2}{52}\right) = 750(1.00307\cdots) = 752.30$$

2-1-7



2-1-8

- Perhaps Ernie is delinquent, and doesn't repay the loan for seven weeks. How much does he owe on the promissory note? [Answer: $ 758.07.]
- Repeat the above box with an interest rate of 10%. [Answer: $ 760.09.]

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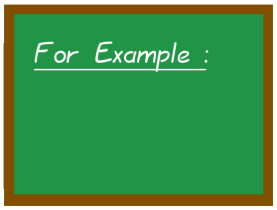


2-1-9

A small-business owner is completing a large contract, and expects a large payment in three weeks—but he needs to pay his employees today. He wants to borrow as much as he can from his neighbor. He will receive $ 50,000 in three weeks, but cannot repay anything more. They agree on an interest rate of 10%. What is the highest principal he can ask for?

We start with the formula and just proceed

$$\begin{aligned} A &= P(1+rt) \\ 50,000 &= P(1+0.10\frac{3}{52}) \\ 50,000 &= P(1.00576\cdots) \\ \frac{50,000}{1.00576\cdots} &= P \\ 49,713.19 &= P \end{aligned}$$



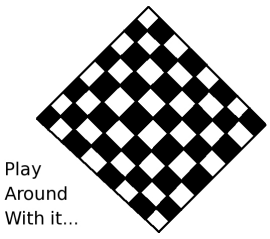
Now let's check out work. (This step is optional, but highly recommended.) If it is truly the case that our answer in the previous box is right, then using that principal, we should be able to invest it at simple interest at 10% for three weeks and get $ 50,000. We start with

$$A = (49,713.19)\left(1+0.10\frac{3}{52}\right) = (49,713.19)(1.00576\cdots) = 49,999.99$$

and end with a total that is off by only a penny. However, that error is due to the fact that we are using truncation. If you were to round, it would be exact to the penny.



It is noteworthy to observe that "3 weeks" means 3/52 years, and "2 weeks" means 2/52 years. While it is true that 3 weeks contain 21 days and 2 weeks contain 14 days, you cannot write 21/360 or 14/360. This is because the "fib" that the year has 360 days is inconsistent with 52 weeks of 7 days, in that $52 \times 7 = 364 \neq 360$.



2-1-10

- Repeat the previous example box with 9%, and $ 40,000.
  [Answer: $ 39,793.38.]
- Repeat the above problem with 11%, and 5 weeks, but still $ 40,000.
  [Answer: $ 39,581.35.]

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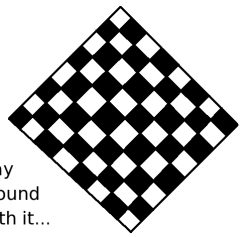
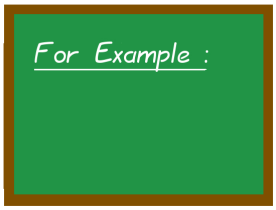


2-1-11

There has been a computer network security breach at East Bank. They have lost the records of the past few days, and trying to reconstruct their interbank loans. East Bank has been lending its excess reserves at 2.25% interest, consistently, over the last two weeks. Today, a payment has arrived from North Bank and another has arrived from South Bank.

- The North Bank payment is to repay a loan of 11 days and is in the amount of \$ 12,353,487.18. What was the principal? [Answer: \$ 12,345,000.]
- The South Bank payment is to repay a loan of 8 days and is in the amount of \$ 9,881,438.25. What was the principal? [Answer: \$ 9,876,500.]



2-1-12

Returning to Bert and Ernie, Ernie pays Bert back, and he pays him late. For another year or two, all is well between them. Then Ernie needs another loan from Bert, because he cannot pay the rent again. Bert remembers that Ernie was late last time, and digs through his records. He discovers that Ernie paid him \$ 756.50 for the \$ 750 promissory note, but he forgot how long it took Ernie to pay him. Can we figure out how many days Ernie took to pay? Remember, the interest rate is set at 8%.

Yes! We just need to solve for t.

$$\begin{aligned} A &= P(1+rt) \\ 756.50 &= 750(1+0.08t) \\ \frac{765.50}{750} &= 1+0.08t \\ 1.0086\overline{6} &= 1+0.08t \\ 0.0086\overline{6} &= 0.08t \\ \frac{0.0086\overline{6}}{0.08} &= t \\ 0.108333\overline{3} &= t \end{aligned}$$

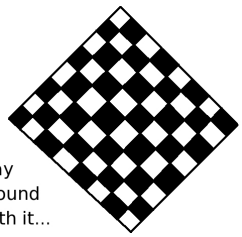
Finally, we learn that $t = 0.108333\overline{3}$—but this is in years. So we multiply by 360 to get 39.0, which means 39 days, or 5 weeks and 4 days.



After a problem like the one above, it is very useful to check one's work. While it does take a bit of time, it can save you a lot of lost points on an exam. Let us forget the \$ 756.50 for a moment, and see what amount we get with 39 days, 8% interest and a \$ 750 principal. We have

$$A = P(1+rt) = (750)(1+0.08\times\frac{39}{360}) = (750)(1.0084\overline{4}) = 756.50$$

which is clearly exact to the penny.



2-1-13

A short-term loan between two banks is for one billion dollars, and the repayment is a billion plus \$ 208,333.33. The Fed Funds rate is currently 2.5%. How many days was the loan for? [Answer: 3 days.]

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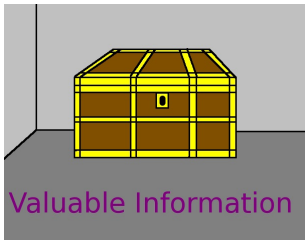
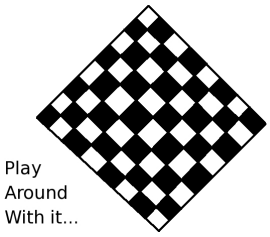
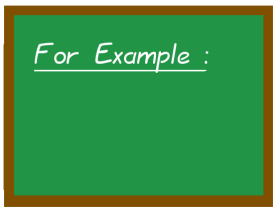


Hint: for big dollar value problems like the above, you can make your unit "a grand." In other words, the principal is a million grand (instead of a billion), and the interest is $205.479\cdots$ grand. This may make it easier on the calculator, because when you enter many zeros, it is easy to enter too many or too few. Just remember to write the final answer in the form that the grader (or your instructor) expects.



2-1-14

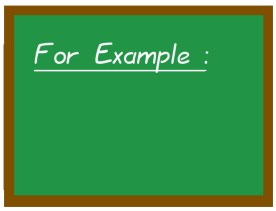
Fred's grandfather has died and Fred expects a large inheritance. He is going to buy an expensive sports car with it, but it takes time for the estate to get settled in probate court, and Fred has terrible credit and cannot get a car loan. The estate lawyer gives him a loan in return for a promissory note, which he can repay when he gets his inheritance. The promissory note for 90 days was repaid for $ 36,093.75, and the loan was originally for $ 35,000. What was the interest rate? [Answer: 12.50%, which is worse than any car loan. That's why the lawyer was excited to give the promissory note!]



2-1-15

The *total interest paid* in any loan or investment is simply the final amount (A) minus the principal (P). I'm now going to calculate the total interest paid in each of the example boxes of this module so far. In the first three example boxes we have

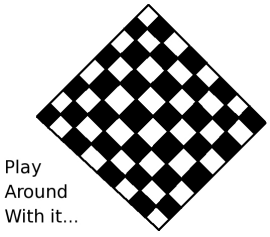
- Bank Alpha paid $ 1,000,125.00 for $ 1,000,000; therefore $ 125.00 was the total interest paid.
- Bank Alpha paid $ 1,000,000 for $ 999,000; therefore $ 1000.00 was the total interest paid.
- Ernie paid $ 752.30 for $ 750; therefore $ 2.30 was the total interest paid.



2-1-16

Similarly, we can calculate the total interest paid for the next three example boxes that we saw earlier in this module:

- The small business owner paid $ 50,000 for $ 49,713.19; therefore $ 286.81 was the total interest paid.
- Ernie paid $ 756.25 for $ 750; therefore $ 6.25 was the total interest paid.
- In general, the total interest paid is just $A - P$.



2-1-17

Go back to all the previous chessboards and find the total interest paid.
[Answer: $ 375,000.00; $ 277,777.77; $ 500,000 for all the bullets in the box; $ 8,000; and $ 12,000 for the treasury bills; $ 8.07; $ 10.09; $ 206.62; $ 418.65; $ 208,333.33; $ 1,093.75.]

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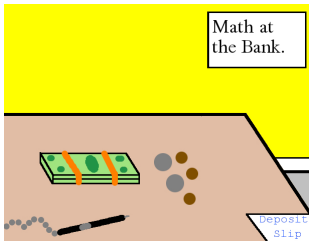
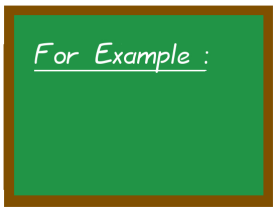


It is universally true in finance, economics, *et cetera...* that if one says "3% interest" without saying "per month," "per day," "per year" or giving some other unit of time (like "quarterly" or "weekly") then this means annually (per year). In fact, we've been assuming this throughout this module. However, what you might not know is that unless a contract or other legal document, like a promissory note, specifies "compounded weekly," "compounded monthly" or some other form of compounding, then it is simple interest. This includes, for example, the penalty charges if you are late on paying taxes, utilities bills, or other contractual debts, unless otherwise stated.



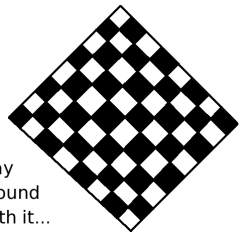
2-1-18

Fine print on a "buy now, pay later" advertisement says that you must pay within 90 days, otherwise you will be charged 19.95% interest counting from the date of purchase. You want to purchase a big-screen TV for $ 2495 plus 5% tax. You have loaned $ 3000 to a friend, but expect it back 60 days after the date of purchase. Sadly, your friend is late! You only scrape up the money to pay for the TV after about 5 months. You sit down with a calendar and discover that 158 days have gone by from the date of purchase. How much do you have to pay? How much of that is interest? (Use a 360-day year.)

The principal is $(2495)(1.05) = 2619.75$, and the rate is $r = 0.1995$, and of course the time is $158/360$. Then we have

$$A = (2619.75)\left(1 + 0.1995\frac{158}{360}\right) = (2619.75)(1.08636\cdots) = 2849.13$$

which means $2849.13 - 2619.75 = 229.38$ is interest.

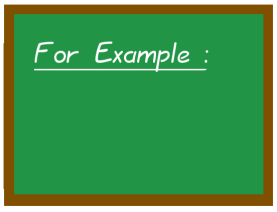


2-1-19

In fact, usually the interest is counted from the first day that the debt is overdue, and not from the date of purchase. Using the rate of 19.95% per year, how much would you have to pay? [Answer: $ 2718.47.]

Note $t = 68/360$ because the problem explicitly says you have 90 days to pay, and

$$158 - 90 = 68 \text{ days.}$$



2-1-20

The most common penalty rate, by far, among store charge-cards and other agreements is "2% simple interest per month." Then what would you have to pay, if payment was exactly 5 months late?

While interest rates without a time attached always indicate "per year," it is possible for them to be stated "per month" or otherwise. Here, it is indicated that it is 2% per month, which is 24% per year. Then we have

$$A = P(1 + rt) = (2619.75)(1 + 0.24\frac{5}{12}) = (2619.75)(1.10) = 2881.72$$

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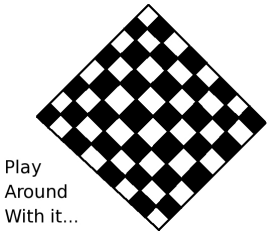
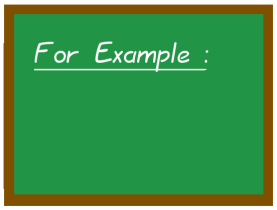


2-1-21

The electric bill for an apartment that I once had in New Orleans had a penalty of 2% per month, if I were late. Suppose that I forgot to pay the final bill, which was $ 120, and finally paid it 3 months late. How much is the total interest that I must pay? [Answer: $ 7.20.]

Note: The next problem has been quoted from *College Mathematics* by Raymond Barnett, Michael Ziegler, and Karl Byleen, 11th edition, Chapter 3, Section 1, Problem 44.



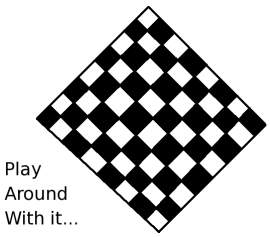
2-1-22

A radio commercial once said that you can pay only 59 cents per day for each $ 1000 borrowed. Suppose you borrow $ 3,000 for 120 days. What is the amount due? What is the equivalent simple interest rate? (Sounds like a great deal, doesn't it?) Use a 360-day year.

Well, we would pay $0.59 \times 3 = 1.77$ per day, and after 120 days that is $120 \times 1.77 = 212.40$. Then you are paying back $3000 + 212.40 = 3212.40 = A$. The principal is 3000 and $t = 120/360 = 0.3\overline{3}\cdots$. Thus we have

$$\begin{aligned} A &= P(1+rt) \\ 3212.40 &= (3000)(1+r(0.3\overline{3}\cdots)) \\ 1.0708 &= 1+r(0.3\overline{3}\cdots) \\ 0.0708 &= r(0.3\overline{3}\cdots) \\ 0.2124 &= r \end{aligned}$$

So we learn that the equivalent simple interest is 21.24%, which is rather high but not unheard of.



2-1-23

- Repeat the above problem with 4 cents a day for each $ 50 borrowed. [Answer: $ 3288.00 is due, and the rate would be 28.80%.]
- Repeat the above problem with 30 cents a day for each $ 1000 borrowed. [Answer: $ 3108.00 is due, and the rate would be 10.80%.]



Let's check the last three "equivalent rates of simple interest" as follows:

- $A = P(1+rt) = (3000)(1+0.2124\frac{120}{360}) = (3000)(1.0708) = 3212.40$
- $A = P(1+rt) = (3000)(1+0.2880\frac{120}{360}) = (3000)(1.096) = 3288.00$
- $A = P(1+rt) = (3000)(1+0.1080\frac{120}{360}) = (3000)(1.036) = 3108.00$
- All of these are exact to the penny!

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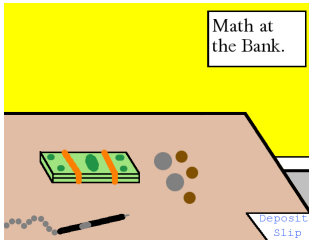
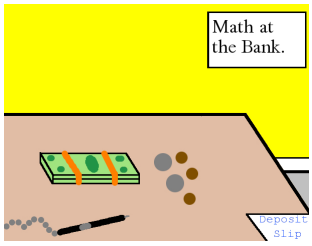


A *Refund Anticipation Loan*, or *RAL*, is a somewhat common arrangement when people file their taxes. As you know, many individuals, families and small businesses file their taxes through a tax-accounting firm. Others do their taxes themselves. When you file yourself, you mail in the return, and some number of weeks go by, and the IRS mails you your tax refund check.

When you file with a firm and are not using a RAL, you give them your financial information, and at some point, when they are finished with it (often it is the same day) they mail it to the IRS for you. Of course, you pay some small charge for the accountant's time. As before, the check arrives in the mail in a few weeks.

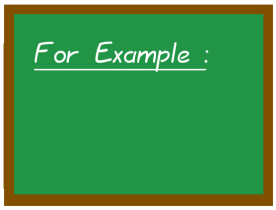
In contrast, the idea of a RAL will be explained in the next box.



Continuing with the previous box, let's explore what happens if you use a RAL. The firm would give you the tax refund immediately as cash, perhaps one hour after you hand in your financial data. However, you have to pay a fee much larger than the charge for the firm's time.

In this case, the IRS sends the refund to the firm instead of to you. Since you leave with the money in your hands on the day that you hand in your financial information, but the firm does not get the money for a few weeks, this arrangement is (technically speaking) a loan.

What makes it a bit complicated compared to the typical loan is that the duration isn't known. The IRS might take a month or a week to send back the check.

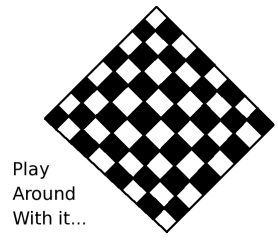


2-1-24

Suppose that Alice is due a $ 2200 tax refund, and she is told that she will have to pay a fee of $ 119 for an RAL. If she accepts, and if the check would have arrived in three weeks, what would the equivalent simple interest rate be? Note that this means she would receive $ 2081 today from the firm, and the firm will get $ 2200 from the IRS, directly.
We just calculate r from the simple-interest formula:

$$\begin{aligned} A &= P(1+rt) \\ 2200 &= 2081\left(1+r\frac{3}{52}\right) \\ 1.05718\cdots &= 1+r(0.0576923\cdots) \\ 0.0571840\cdots &= r(0.0576923\cdots) \\ 0.991190\cdots &= r \end{aligned}$$

and therefore the answer is 99.11% interest, an extremely bad deal.



2-1-25

One argument in defense of these high interest rates is that the firm is at risk if the tax return is wrong, because then the IRS would quite possibly return a much smaller check, and the firm would have less money. This is foolish, because the tax firm is staffed by trained tax accountants, who should correctly be able to calculate everything without errors. Another argument is that the firm does not know when the IRS will pay. Let's see why that makes no sense:

- What if it takes two weeks? [Answer: 148.67%.]
- What if it takes four weeks? [Answer: 74.33%.]
- What if it takes five weeks? [Answer: 59.47%.]
- As you can see, none of these are reasonable rates of interest.

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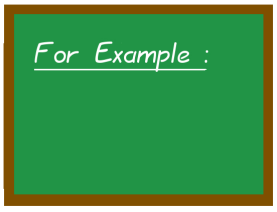
One of the reasons it is crucial that every adult be numerically literate (*numerate*, in the words of John Allen Paulos) is that there are products which are offered by financial companies that are disastrously bad for the consumer. These companies are taking advantage of the financial illiteracy and innumeracy of the common worker. Since no one is really forced to use these products, their immorality is open to debate; but mathematically, they are extremely stupid.

One example is the above mentioned refund-anticipation loan. Another example are payday loans, and the most extraordinary example is the Adjustable Rate Mortgage or ARM. A major goal of this entire book is to raise the financial literacy of every student (and, I dare say, some instructors) so that they will not suffer from these pitfalls.



2-1-26

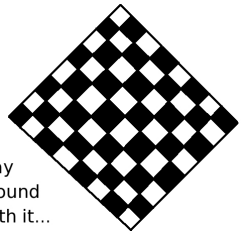
The way a payday loan usually works is as follows. Suppose you will be paid by your job on December 2nd, December 16th, and December 30th. On December 5th, you discover yourself very short of money. Your paycheck will be for $ 800. On December 5th, you go to the payday loan place, and they tell you that you can receive 85% of your check, right now, as cash. You simply write a check for $ 800, and date it as December 17th. They will not (and cannot) cash the check until December 17th. In return for this, you leave with

$$0.85 \times 800 = 680$$

Is this a good deal? Let's find out, remembering that the loan is for 12 days. We'll use a 360-day year.

$$\begin{aligned} A &= P(1+rt) \\ 800 &= 680(1+r\frac{12}{360}) \\ 1.17647\cdots &= 1+r(0.03\overline{3}) \\ 0.176470\cdots &= r(0.03\overline{3}) \\ \frac{0.176470\cdots}{0.03\overline{3}} &= r \\ 5.29411\cdots &= r \end{aligned}$$

and so the equivalent simple-interest rate is 529.41%, an unbelievable rip-off.



2-1-27

Not all places use 85%, some even use 80%. Let us suppose that one establishment uses 90%, but you are going to be paid 5 days from now. Again, your paycheck is $ 800.

- What is the value of the principal? [Answer: $ 720.]
- What is the equivalent simple-interest rate? [Answer: 800%.]

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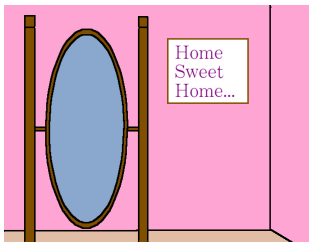
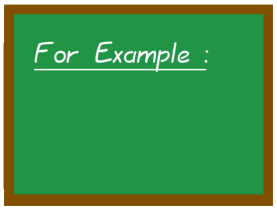


A Pause for Reflection...

Do you think financial instruments like Refund Anticipation Loans and Payday Loans should be illegal? Is it right for financial companies to take advantage of the innumeracy of the public? I used to think that the government should make such products illegal. But what if someone has no cash on hand of any kind, and really needs money, and they are going to be paid a few days from now?

It happened to a close friend of mine, whose roommate had a habit of recreational cocaine use. This is hardly uncommon. The roommate built up a small debt with his drug dealer, who visited the apartment one day, and said that the debt had to be paid tomorrow, or else he would kill everyone who lived there. Without the nearby payday loan service, my friend would have died for the sake of his roommate's drug habit. Of course, one could discuss ideal worlds that have no drug dealers in them, but we don't live in such a world, and so that discussion would be pointless.



2-1-28

Suppose one company accepts a promissory note from a client, to pay $ 80,000 plus interest in 270 days. The going rate at that moment happens to be 5%. Then, about 60 days afterward, the company decides they need the money now, and they wish to sell the note. Suppose the going rate at that time is 6%. What is the fair-market value of the note? (Use a 360-day year.)

First, we need to figure out what amount would be paid by the client 270 days from the start of the problem. This is $A = (80,000)(1 + 0.05 \times 270/360) = 83,000.00$.

Second, 60 days later, the payment is $270 - 60 = 210$ days away. With the rate of interest being 6%, and the amount being 83,000.00, the equivalent principal is given by

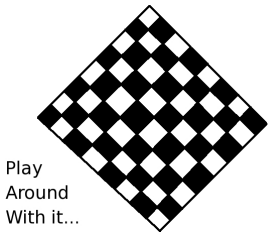
$$\begin{aligned} A &= P(1+rt) \\ 83,000.00 &= P(1+0.06\times 210/360) \\ 83,000.00 &= P(1.035) \\ \frac{83,000.00}{1.035} &= P \\ 80,193.23 &= P \end{aligned}$$



Let's check our work. If $P = 80,193.23$ and $t = 210$, as well as $r = 0.06$ then we have

$$A = P(1+rt) = (80,193.23)\left(1 + 0.06\frac{210}{360}\right) = 82,999.99$$

This is off by only a penny. In fact, that's because we use truncation. If you round to the nearest penny, it comes out perfectly.



2-1-29

Let's repeat the above example, but instead of the interest rate going from 5% to 6%...

- ...let the interest change from 5% to 4%. [Answer: $ 81,107.49.]
- ...let the interest change from 5% to 3%. [Answer: $ 81,572.48.]
- ...let the interest change from 5% to 7%. [Answer: $ 79,743.79.]
- What if the interest rate did not change, and stayed at 5%? [Answer: $ 80,647.77.]

This box and the next one are very important. Please read them entirely and carefully.

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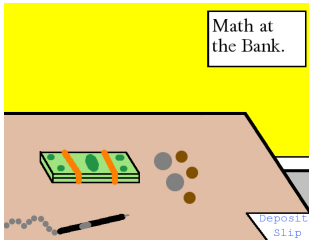
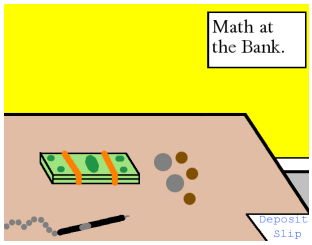


Let's look at what just happened in the previous set of boxes.

The interest rate...	The note's fair-market value.
Rose from 5% to 7%	$ 79,743.79
Rose from 5% to 6%	$ 80,193.23
Stayed at 5%	$ 80,647.77
Fell from 5% to 4%	$ 81,107.49
Fell from 5% to 3%	$ 81,572.48

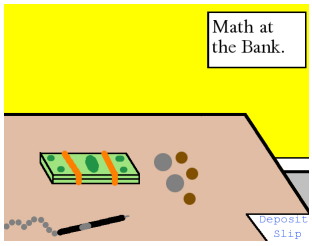
As you can see, as the going rate went up, the note was worth a bit less, and as the going rate went down the note was worth more. Why should this be the case? Think about it, and then read the next box.



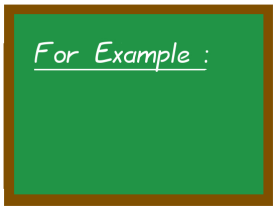
Now let's try to explain the situation in the previous box. Put yourself in the shoes of someone who has about $ 83,000 to lend out.

Now suppose the rates rise. Then a new promissory note would be worth a great deal more to you than this old note that someone is selling, because new rates are significantly higher than the old note's rate of 5%. Therefore, you wouldn't even consider this old note for sale at all... unless its owner gave you a very good deal, and sold it for a low price. A banker would say this instrument is *trading at a discount*.

Likewise, suppose the rates fell. Then this old note has a rate of 5%, but out on the market, new notes are going for 4% or 3%. Therefore, this old note is actually quite valuable. And since it is quite valuable, then the seller can ask a higher-than-normal price for it, naturally. A banker would say this instrument is *trading at a premium*. Any instrument not trading at a discount nor trading at a premium is *trading at par*.



This can happen with all sorts of instruments, from corporate bonds, to treasury bills, preferred stock to promissory notes. As we mentioned before, the trading of short-term obligations to pay fixed sums in this manner is called the *financial paper market*. When bankers speak of *interest rate risk* they are talking about the risk that rate will rise during an investment, thus forcing your own investment to "trade at a discount."



2-1-30

Suppose the interest rate is 5%, and General Motors lends one billion to Johnson & Johnson for 10 days. On the fifth day, the interest rates for new commercial paper are around 5.25%. What is the fair-market value of this note? Use a 360-day year.

First, we have to calculate the amount due at the end. Our unit shall be "a grand" as explained on Page 260. We would have

$$A = P(1+rt) = (1,000,000)\left(1+0.05\frac{10}{360}\right) = 1,001,388.88$$

Now, what principal would a note worth $ 1,001,388.88, for five days, at 5.25% have?

$$1,001,388.88 = P\left(1+0.0525\frac{5}{360}\right) = P(1+0.000729166\overline{6})$$

which gives

$$P/(1.00072\cdots) = 1,000,659.\cdots = P$$

Note, that is roughly $ 1,000,659,241.51 in dollars, since our unit was "a grand."

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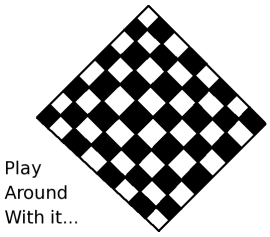
The type of computation in the previous box is highly subject to rounding error, so do not be alarmed if your answer differs after the sixth significant digit. Looking at

$$1,000,659,241.51$$

the rules of significant digits require that you must try to match the "1,000,65$\cdots$" part, and the last digit could also be a 4 or a 6. However, the "9241.51" part might be slightly off, and that's fine.

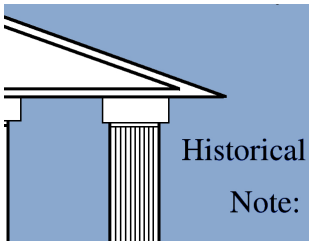


2-1-31

What if the rate had instead:

- Fallen to 4.75%? [Answer: $ 1,000,728,685.92.]
- Remained at 5.00%? [Answer: $ 1,000,693,962.51.]
- Rocketed to 5.50%? [Answer: $ 1,000,624,522.92.]

As before, this type of calculation is highly subject to rounding error, so do not be alarmed if your answer differs after the sixth significant digit.

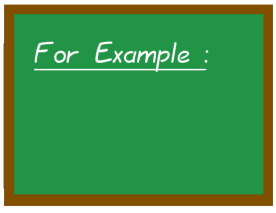


Marcus Goldman (1821–1904) was one of the pioneers of the commercial paper market in the USA. He was born in what is now Germany, and fled the turmoil of 1848 to Philadelphia.

Incidentally, the year 1848 is sometimes called "the year everything happened," because of the numerous revolutions and anarchist movements that swept the planet. Many governments in Europe fell, but the chaos was not isolated to Europe, with major turning points in the history of Brazil, and of Mexico, as well as the California Gold Rush, and the influx of the Irish into New York City because of the Irish potato famine.

Now back to Marcus Goldman: he started out as the proprietor of a push-cart. In 1869 he opened a small shop in Manhattan, buying and selling IOUs, under the name "Marcus Goldman & Co." In 1882 he invited his son-in-law, Samuel Sachs to join him, and that his how the firm Goldman-Sachs came to exist.

Goldman died one of the richest men in the country, and today his firm employs more than thirty thousand people, and is worth just under a trillion dollars.



2-1-32

An interesting thing will occur when you graph simple interest versus time. In particular, if you know P and r, but are curious how A will change as t changes (in other words, how the amount changes over time) you could graph. For example, if $P = 5000$ and $r = 0.08$ we would have

$$A = 5000(1 + 0.08t)$$

or equivalently

$$A = 5000(0.08)t + 5000 = 400t + 5000$$

and that results in the following graph:

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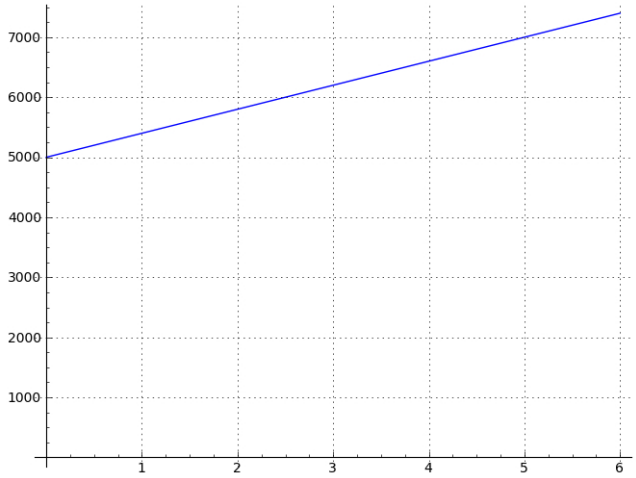
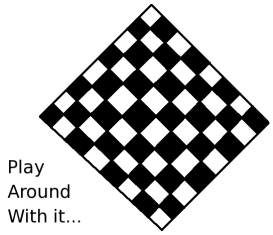


As you can see, it is a line. (Just to be clear, here A is acting as y and t is acting as x.) You can tell from both the equation in the previous box, and from the graph, that the y-intercept is just the principal. That makes sense, as the y-intercept is for $t = 0$, and $t = 0$ is the start of the loan, but of course the amount of money at the start of the loan is called the principal. You cannot tell so easily from the graph, but you can tell from the equation, that the slope is 400, which is the annual income Pr. In this situation, \$ 400 is received each year.

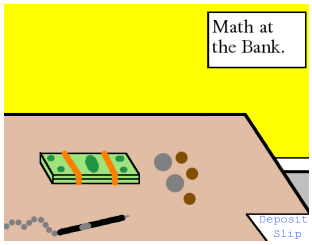
We'll see in the next module, on Page 284, that compound interest does not form a line.



2-1-33

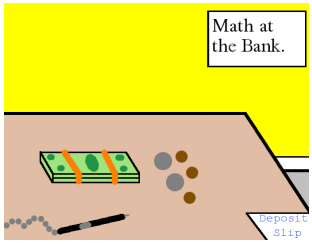
If it were instead,

- A principal of \$ 6000 and 4% simple interest, what would you graph? [Answer: $A = 6000(1 + 0.04t) = 6000 + 240t$.]
- A principal of \$ 8000 and 7% simple interest, what would you graph? [Answer: $A = 8000(1 + 0.07t) = 8000 + 560t$.]



The United States Treasury sells *US Treasury Bonds*, and these bonds are important ways for saving throughout many people's lives. When you buy a bond, you are giving the government a loan. Suppose you buy a bond with "face value" \$ 1000, and a rate of 4%. As it turns out, the US Treasury organizes its bonds to pay interest payments semi-annually, or every six months. Thus, after six months one has $A = (1000)(1 + 0.04 \times (1/2)) = 1020$. However, this \$ 20 is sent out as a payment, and the \$ 1000 is not sent out. Then, six months later another \$ 20 is sent out. This process continues year after year until a fixed date, such as 5 years in the future, called the *maturity date*. On that day, the last \$ 20 payment is sent out, as well as the original principal of \$ 1000. Very shortly we are going to learn about a shortcut formula for these sorts of calculations.

Just in case you are curious, there are three different names for US Treasury bonds. The names depend on the *term* of the bond, which is the length of time from when the bond is first created to the *maturity date*.



- They are called *treasury bills* if the length of term is up to 1 year.
- If longer than a year, but not more than 10 years, they are called *treasury notes*.
- If longer than 10 years, then they are called *treasury bonds*. The common sizes are 20 years and 30 years.
- A treasury bill doesn't make interest payments, but treasury notes and treasury bonds make interest payments semiannually.
- Savings bonds are something else entirely. We will examine that distinction in the next box.

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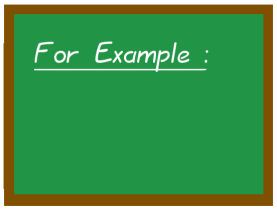
It is important to note that "treasury bonds" and "savings bonds," while both pieces of the US public debt, are very different instruments. Treasury bonds are meant to be held by institutions such as banks and investment funds, as well as private investors; they pay simple interest, and are widely traded. Savings bonds are meant to be held by private investors; they pay compound interest, and cannot be traded away, though they can be cashed-in early.

The treasury bonds are a major portion of the US government's financial infrastructure, held by banks and investment firms. Meanwhile, savings bonds are instead intended to stimulate saving and investing among the nation's populace. Never confuse these two instruments, as that would reveal you as being among the financially uninitiated.

We will discuss savings bonds more on Page 288.



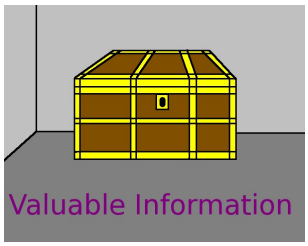
2-1-34

Janice's grandparents buy a 30-year $ 10,000 treasury bond when she is born. The rate happens to be 5.5%. How much is each payment, and how many payments will there be? What is the total interest paid? How much does Janice have at the end?

Remember that US Treasury bonds pay semi-annually, or twice per year. First, we use the simple interest formula

$$A = (10,000)(1 + 0.055/2) = (10,000)(1.0275) = 10,275.00$$

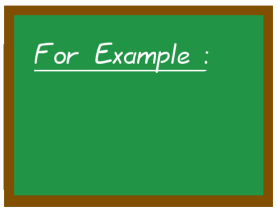
Thus we learn that each payment is $ 275. There will be $30 \times 2 = 60$ payments on this 30-year bond. Therefore, the total interest paid is $275 \times 60 = 16,500$. At the end, Janice will have $16,500 + 10,000 = 26,500$.



There is a shortcut formula for calculating the interest in a simple-interest problem, useful whenever the total interest is all you need to know. The formula is $I = Prt$. Where does this come from? Well start with two ingredients $A = P(1 + rt)$ and $I = A - P$.

$$\begin{aligned} A &= P(1+rt) \\ A &= P + Prt \\ A - P &= Prt \\ I &= Prt \end{aligned}$$

Let's see how that would have helped us in the last two problems.



2-1-35

- In the bank-box on Page 268, with the $ 1000 treasury bond, we would have

$$I = Prt = (1000)(0.04)(1/2) = 20$$

- In the bond that Janice's grandparents bought her in the previous example box, we can use the shortcut formula. We start with $I = Prt$ and get $I = (10,000)(0.055)(1/2) = 275$ for the payment, and build up from there.

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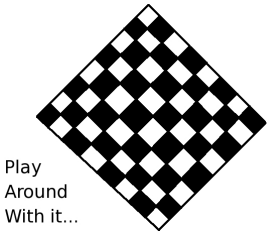
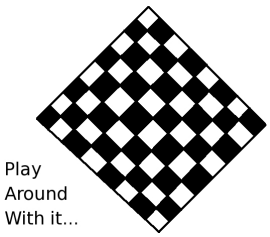


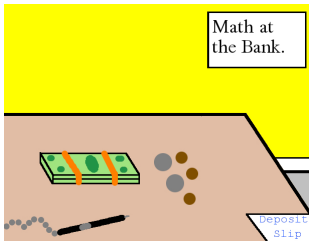
2-1-36

Repeat the above example of Janice and her bond, but with the interest rate being 4%. How much is each payment, and how many payments will there be? What is the total interest paid? How much does Janice have at the end? This time, use the shortcut formula. [Answer: Each payment is $ 200, and there are still 60 payments. The total interest paid is $ 12,000. At the end, Janice will have $ 22,000.]

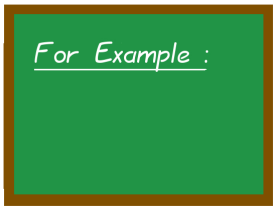


2-1-37

It was common, around the era of *The Great Gatsby*, for wealthy people to purchase large quantities of bonds, for the support of their children and widows. This was very difficult to actually accomplish. First, there is the problem of inflation, which you'll learn about on Page 455, but secondly there is the question of having a large enough principal to make this possible. Suppose that you wish to endow your heir with around $ 4500 per year, for 30 years. (Note, $ 4500 in 1913 is around $ 100,000 in today's money.) Suppose further that the interest rate is 5%, what principal must you invest in order to ensure this size of payment? [Answer: The principal must be $ 90,000. If you are curious, in today's money that would be worth around two million dollars.]



Perhaps a wealthy man dies and leaves his widow a large sum. The widow has no source of income, but a large quantity of money. Usually what one does in this situation is invest the inheritance, and live off of the interest. In a typical investment, a lump sum of money is invested and interest payments are made, and the amount of wealth grows. Interest is paid upon the interest, and this keeps compounding, resulting in the concept called *compound interest*, covered in the next module. However, if because of a lack of income, the interest is withdrawn and spent every time it arrives, then the principal never grows. This situation is called *siphoning*, a slang term in the vocabulary of private wealth management. When you learn about inflation in a later module, you will learn why this is unwise.



2-1-38

The widow in question has $ 535,500, and finds a nice fund that pays out annually, and has consistently performed around the 8% level. How much can she expect to get per year?

In this case $P = 535,500$ and $0.08 = r$, but $t = 1$. We then see can calculate:

$$\begin{aligned} A &= (535,500)(1 + 0.08 \times 1) \\ &= (535,500)(1.08) \\ &= 578,340 \end{aligned}$$

Thus, she will have

$$578,340 - 535,500 = 42,840$$

for the year. This sounds fairly good for someone who is unemployed, but remember that taxes have to be paid upon this. Let us hope that the mortgage on their family house was paid off before she became widowed.

Alternatively, we could use the shortcut formula, and get

$$I = Prt = (535,500)(0.08)(1) = 42,840$$

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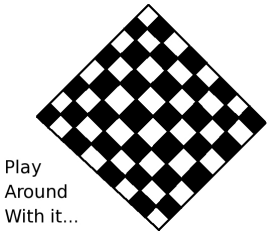
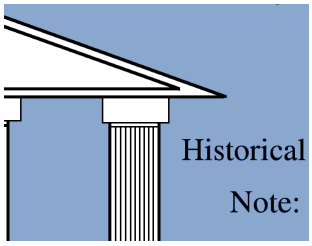


2-1-39

- Repeat the above problem with interest rate 9%. [Answer: $ 48,195.]
- Repeat the above problem with interest rate 7%. [Answer: $ 37,485.]



At the start of the American Civil War (1861–1865) there was a movement to help fund the war by selling penny-a-day bonds. The bonds sold for $ 50 each, and the owner of the bond received one cent per day. One of the bonds is shown below. To save on delivery costs, the bond holder would tear off one of the coupons, still visible below, twice per year. The coupon would then be exchanged for half of one year's interest. If you are curious, $ 50 in 1861 is roughly equivalent to $ 1331.44 in 2015. You'll learn how to compute that yourself when we study the module on inflation, starting on Page 455.

Besides looking impressive, these bonds were called by the nick-name "seven thirties."



The above image is part of the WikiMedia Commons. The bond itself is from the *National Numismatic Collection* of the *National Museum of American History*, a Smithsonian Institution. Of course, it goes without saying that an item from 1861 is no longer in copyright, but I am nonetheless happy to offer this academic citation.

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For Example :

2-1-40

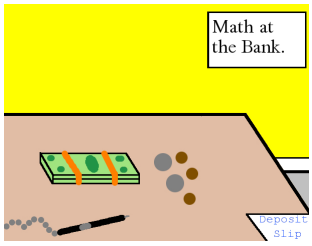
Considering the bond that we just described, we might be curious why they were called "seven thirties."

As noted, the bonds paid a penny per day. Using a 365-day year, that's $ 3.65 interest per year. We have $P = 50$, since it is a 50-dollar bond, and $t = 1$, representing one year.

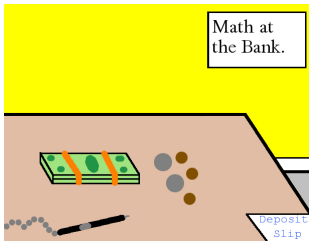
$$\begin{aligned} I &= Prt \\ 3.65 &= (50)(r)(1) \\ 3.65 &= (50)(r) \\ \frac{3.65}{50} &= r \\ 0.073 &= r \end{aligned}$$

As you can see, the interest rate was 7.30%, and that's why these bonds were called seven-thirties. It is also interesting that the bonds were only to be valid for three years, because everyone assumed that the civil war would be long over by then. Unfortunately, this was not true.

Since we've just finished a problem from 1861, I thought you might like to see something very modern next. I have some problems about what is commonly called "day trading."



Simple interest is frequently used by day traders to see how well a particular transaction went for them. When I was in college (1995–1999) it was very common for students to engage in day trading using the income that they had made at their summer jobs. It was the height of the "dot com boom" after all. When the "dot coms" turned into "dot bombs" during the market plunge of 1999, many of them lost the vast majority of their wealth. I'm glad that day trading is less common now.



The act of buying and selling stocks, having held them only for a few weeks, or two months at the most, destabilizes the market, and it is bad for the nation and the world. It also is extremely risky, and therefore bad for the investor as well.

Nonetheless, you cannot say that you understand financial mathematics unless you can perform simple calculations such as those that follow. For that reason, we will now explore how simple interest is used to rate the performance of a day-trading transaction.

For Example :

2-1-41

Let's imagine that Jordan buys nine shares of Green Herbal Products Limited (GHPL) on March 30th at 47 dollars per share. Then on June 6th, he sells them for 51 dollars per share. That's 68 days. Using a 365-day year, let's compute the equivalent simple interest rate of return of his investment.

First, we should compute the amount he paid for the stocks at the start. That's $(9)(47) = 423$ dollars. Then let's compute the amount he received back from the sale of the stocks at the end. That's $(9)(51) = 459$ dollars.

We will finish the problem in the next box.

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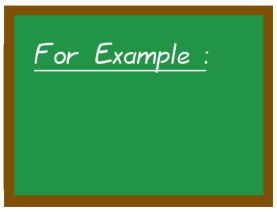
Continuing with the previous box,

$$\begin{aligned} A &= P(1+rt) \\ 459 &= 423(1+r(68/365)) \\ 459/423 &= 1+r(68/365) \\ 1.08510\cdots &= 1+r(68/365) \\ 0.0851063\cdots &= r(68/365) \\ 0.456821 &= r \end{aligned}$$

The shares of GHPL have produced an amazing return of 45.6821% over this 68 day period. Outstanding! Perhaps we should all be day traders? Actually, as it turns out, we have neglected something very important: commissions!

Here's an easy way to compute that it is 68 days from March 29th until June 5th.
June 6th is May 37th, which is April 67th, or March 98th. Then $98 - 30 = 68$ days.
(I will not ask you to perform calculations of this kind in this textbook.)



2-1-42

Now we're going to repeat the previous example, but taking into account the commissions. Let's suppose that for any stock trade, Jordan's broker charges 1% of the value of the trade, plus \$ 5. The commission at purchase comes to

$$5.00 + (0.01)(423) = 5.00 + 4.23 = 9.23$$

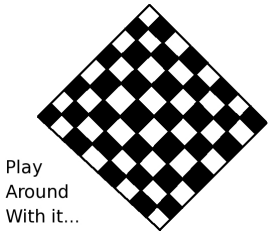
and therefore Jordan actually paid $423 + 9.23 = 432.23$ for his shares of GHPL.

Similarly, the commission at sale comes to

$$5.00 + (0.01)(459) = 5.00 + 4.59 = 9.59$$

thus Jordan actually received $459 - 9.59 = 449.41$ for his shares of GHPL.

We must now solve for r using $A = 449.41$ and $P = 432.23$. You will do this yourself in the next box.



2-1-43

Compute the value of r, knowing that Jordan held his shares for 68 days, using the P and A given in the previous box. As before, let's use a 365-day year.
[Answer: $r = 0.213349\cdots$, or $21.3349\cdots\%$.]

As you can see, the rate of return changed from over 45% to less than 22%. That's a huge change! The rate of return fell in half once we took into account the commissions.

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It is a good idea for us to check our work in problems like these.

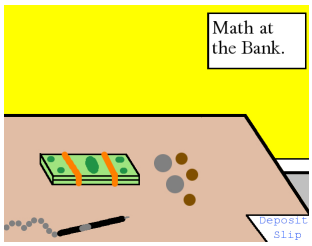
First, without commissions, we obtain

$$A = P(1+rt) = 423\left(1 + 0.456821(\frac{68}{365})\right) = 458.9999\cdots$$

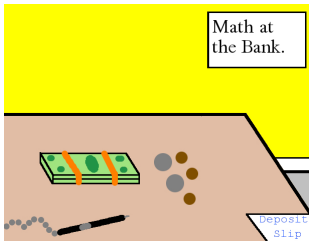
and with commissions, we obtain

$$A = P(1+rt) = 432.23\left(1 + 0.213349(\frac{68}{365})\right) = 449.4099\cdots$$

As you can see, these are within a hundredth of a penny, which is clearly just rounding error.

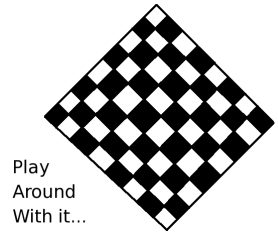


Usually around this point, I get three questions from my students. The first is if these rates of return are typical or not. Actually, for day trading, I'd say that usually the rate of return is about half of what I wrote above. It should be noted that there will be large gains (like what we just saw) but also large losses as well. Those will cancel out over a large number of trades. A highly skilled day trader can earn 15% when things go well. An eager amateur might make 10% to 13%. However, I have had good friends who have lost a great deal of money by investing in this high-risk manner. Financial advisers universally recommend that investors stay far away from day trading. For a comparison, the S&P500 has consistently returned around 11% over certain time periods, and has vastly lower risk. It is therefore silly for an individual to risk everything in return for a 1% or 2% increased rate of return.



The second question that I get is whether someone should choose to do the calculation with or without commissions. Well, the investor has to pay the commissions—therefore, we should include them. It is that simple.

The third question that I get is whether or not this calculation is performed in practice. A more correct tool, called the "Compounded Annual Growth Rate" or CAGR is actually more accurate, and we'll learn how to do that on Page 404. However, simple interest is much easier to calculate, it is the industry standard, and it gives answers extremely close to what CAGR provides. That's one reason day traders prefer the simple interest rate of return. Moreover, if you go back 30 or 40 years, most calculators simply didn't have the functions required to compute CAGR, but they could compute simple interest. That might be a factor in the choice to use simple interest. However, in the hay-day of day trading, the late 1990s, this simply was not true. If you're using your computer to day trade, you can simply use the on-board calculator app, and it did have the necessary functionality in that era. I remember it well.



2-1-44

Suppose Alice buys 81 shares of a particular corporation at $ 7.25 per share, and sells it for $ 8.00 per share. She held the stock for 177 days. Using a 365-day year, find the equivalent simple interest rate of return, ignoring commissions, of this trade.
[Answer: $21.3325\cdots\%$.]

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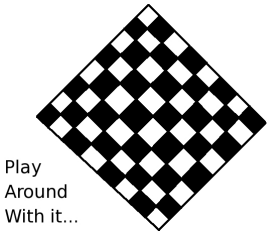
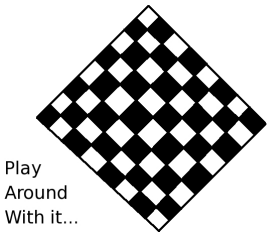


2-1-45

Returning to the previous box, suppose that Alice is using an online brokerage, which charges $ 9.95 per transaction. Let's now recompute the equivalent simple interest rate of return.

- How much did she pay for the stocks? [Answer: $ 597.20.]
- How much was she paid at sale? [Answer: $ 638.05.]
- What is the equivalent simple interest rate of return? [Answer: $14.1056\cdots\%$.]

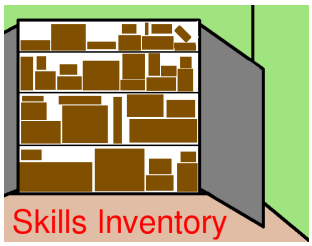
As you can see, it really is important to include the commissions.



2-1-46

Fred has bought 47 shares of a particular corporation at $ 88 per share, and sold it for $ 92 per share. He held these shares for 68 days. His brokerage house charges $ 7.95 plus $\frac{1}{2}\%$ commissions.

- How much did he pay for the stocks? [Answer: $ 4164.63.]
- How much was he paid at sale? [Answer: $ 4294.43.]
- With commissions, what is the equivalent simple interest rate of return? [Answer: $16.7294\cdots\%$.]
- Without commissions, what is the equivalent simple interest rate of return? [Answer: $24.3983\cdots\%$.]



We have learned the following skills in this module:

- To use the simple interest formula $A = P(1+rt)$, regardless if P, r, t, or A is unknown.
- To identify six situations in which simple interest is actually used.
- To calculate the total interest paid in a simple interest loan.
- To calculate the equivalent rates of simple interest of a repayment agreement not phrased in terms of interest.
- To calculate the size of the payment on a US Treasury Bond.
- To calculate the fair-market value of a note if the interest rate has changed since it was negotiated.
- To compute the equivalent simple-interest return when day-trading stocks, both without and with commissions.
- As well as the vocabulary terms: Banker's Rule, commercial paper market, compound interest, discount interest, FedWire, federal funds rate, financial paper market, interest rate risk, maturity date, principal, promissory note, quarter, RAL, refund anticipation loan, simple interest, siphoning, T-bill, term (of a bond), trading at a discount, trading at par, trading at a premium, treasury notes, total interest paid, US Treasury Bills, US Treasury Bonds, US Treasury Notes.

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