Applications of Logarithms: Compound interest
Compound interest

Suppose you put two dollar in the bank. The bank advertises an interest rate of \( 5\% = .05 \) compounded every month.

How much do you have after one year (12 months)
Compound interest

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How much do you have after one year (12 months)

After 0 months: 2$

After 1 month the bank multiplies adds 0.05 of your money back into the account.

You have 2 + 0.05 \times 2 = 2.1: You gained a dime!

Notice that adding 0.05 of your money back into the account is the same as multiplying by 1 + 0.05.

After 2 months the bank multiplies again by 1 + 0.05, giving you $2.1 \times 1.05 = 2.205 You gain another dime and a half penny!

In order to get to 12 months, you wind up multiplying by 1.05 12 times:

After 12 months you have $2 \times 1.05^{12} \approx 3.5917.$
Compound interest

Suppose you put two dollar in the bank. The bank advertises an interest rate of 5% = .05 compounded every month.

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After 2 months the bank multiplies again by 1.05, giving you

$2.1 \cdot 1.05 = 2.205$ You gain another dime and a half penny!
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After 12 months you have $2 \cdot 1.05^{12} \sim 3.5917$. 
Comparing various rates

After 12 months in a savings account with interest rate .05 compounded monthly you have $2 \cdot 1.05^{12} \sim \$3.5917$.

Another bank, hoping to compete offers a savings account which compounds its interest annually at a rate of $12 \cdot .05 = .6$. The bank advertises this as being equivalent since 5% per month should be the same as 60% per year.
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If you invest two dollars in this account how much do you have after a year?
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If you invest two dollars in this account how much do you have after a year?

$2 \cdot 1.6 = $3.2.$
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$2 \cdot 1.6 = $3.2$.

Which of these savings accounts is better?
The compound interest formula

Suppose that a bank offers a savings account with an annual interest rate of $r$ which it compounds $n$ times per year.
If you put $D$ dollars in this account and check mack in $t$ years then how much do you have?
You have

$$A(t) = D \cdot \left(1 + \frac{r}{n}\right)^{n \cdot t}$$

Compare an annual interest rate of 0.05 compounded 12 times per year with an annual interest rate of 0.10 compounded 4 times throughout the year.
Which produces better results after one year? Use a machine to help with the computations.
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Every time the bank updates it multiplies by $1 + (r/n)$. It does so $n$ times every year.
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Compare an annual interest rate of .5 compounded 12 times per year with an annual interest rate of .1 compounded 4 times throughout the year. Which produces better results after one year? Use a machine to help with the computations
Continuously compounded interest. Euler’s number

Suppose that a bank offers a savings account with an annual interest rate of $r$ which it compounds $n$ times per year. If you invest 1 dollar, then after $t$ years you have

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$$A(t) = (1 + r/n)^n$$

Compute this for $n = 1, 2, 10, 100, 1,000, 100,000, 1,000,000, 1,000,000,000$
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Is this getting close to something? It looks like it is getting close to a number around $2.7182$. Euler's number $e$ is defined to be the number that these numbers seem to be getting close to.

The limit of this collection of banks interest rates is the natural exponential $e^t$. If a bank offers continuously compounded interest with an annual interest rate of $r$ they mean $A(t) = D \cdot e^{rt}$.

If you leave $D = 1$ in a bank with continuous interest rate of $r$ for $t = 1$ years then how much do you have at the end of the year?
The natural exponential

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<td>2.7048</td>
<td>2.7181</td>
<td>2.7182</td>
</tr>
</tbody>
</table>

Is this getting close to something? It looks like it is getting close to a number around $2.7182$.

Euler’s number $e$ is defined to be the number that these numbers seem to be getting close to.

The limit of this collection of banks interest rates is the natural exponential $e^t$.

If a bank offers continuously compounded interest with an annual interest rate of $r$ they mean

$A(t) =$
The natural exponential

<table>
<thead>
<tr>
<th>$n$</th>
<th>1</th>
<th>2</th>
<th>10</th>
<th>100</th>
<th>1,000</th>
<th>$10^5$</th>
<th>$10^9$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A(t)$</td>
<td>$(1 + 1)^1 = 2$</td>
<td>2.25</td>
<td>2.5937</td>
<td>2.7169</td>
<td>2.7048</td>
<td>2.7181</td>
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The **limit** of this collection of banks interest rates is the **natural exponential** $e^t$.

If a bank offers **continuously compounded** interest with an annual interest rate of $r$ they mean

$$A(t) = D \cdot e^{rt}.$$
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The limit of this collection of banks interest rates is the natural exponential \( e^t \).
If a bank offers continuously compounded interest with an annual interest rate of \( r \) they mean
\[
A(t) = D \cdot e^{rt}.
\]
If you leave \( D = 1\) in a bank with continuous interest rate of \( r = 1 \) for \( t = 1 \) years then how much do you have at the end of the year?
Comparing some savings accounts

If you invest $D$ dollars in a bank account with an annual interest rate of $r$ compounded $n$ times per year then after $t$ time you have

$$A(t) = (1 + r/n)^{n\cdot t}$$

If you invest $D$ dollars in a bank account with an annual interest rate of $r$ compounded continuously then after $t$ time you have

$$A(t) = D \cdot e^{rt}.$$ 

Suppose you look at three different bank accounts. The first has an annual interest rate of $.06 = 6\%$ compounded annually. The second has an annual interest rate of $.05 = 5\%$ compounded three times per month. The final has an annual interest rate of $.04$ compounded continuously. How do they compare?

Compute (with the aid of a machine) how much each has at the end of the year.
Review for the midterm.