



Exponential Growth, Decay, and the Math of Money

Four focused lessons, worked examples, a mistake clinic, and 60 practice problems with full explanations.

In this booster

16.1 Exponential Functions and Their Graphs

16.2 Growth and Decay Models

16.3 Compound Interest and Savings

16.4 Loans, Annuities, and Financial Decisions

Every section teaches the idea, walks through the most common problem types, flags the traps students fall into, and ends with fifteen practice problems. Full answers and explanations are at the back.

16.1 Exponential Functions and Their Graphs

Learn what makes a function exponential, how the growth factor works, and how to tell linear from exponential in tables and graphs. You will build equations from tables and points.

Why This Matters

Some things grow by adding the same amount each time, like a savings jar that gets 5 dollars a week. Those are linear. Other things grow by multiplying by the same amount each time, like a video that doubles its views every day, or a bacteria colony that doubles every hour. Those are **exponential**. Exponential change starts slowly and then explodes, which surprises almost everyone the first time they see it.

This idea runs through science, money, and technology: population growth, radioactive decay, viral spread, compound interest, and computer storage. Students typically get stuck on three points. They confuse $2x$ with 2^x , they think the base of an exponential function is a rate you add instead of a factor you multiply, and they have trouble deciding from a table whether a pattern is linear or exponential. We will solve all three in this section.

Core Ideas

Exponential Function

An **exponential function** has the form

$$y = a \cdot b^x, \quad a \neq 0, b > 0, b \neq 1.$$

a is the **initial value** (the y -value at $x = 0$). b is the **growth factor**: each time x goes up by 1, y is multiplied by b .

If $b > 1$ the function shows **growth**. If $0 < b < 1$ it shows **decay**.

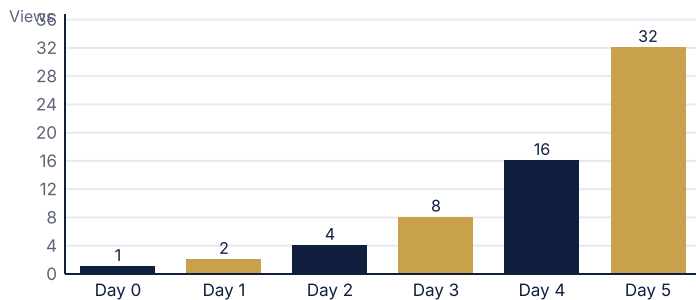
Compare this with a linear function $y = mx + c$, where each step of 1 in x **adds** m to y . In an exponential function, each step **multiplies** y by b . That is the key test when you look at a table: if equal steps in x give a constant difference in y , the function is linear. If they give a constant ratio, it is exponential.

x	0	1	2	3	4
Linear $y = 5 + 3x$	5	8	11	14	17
Exponential $y = 5 \cdot 2^x$	5	10	20	40	80
Change	+3 each step		times 2 each step		

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A video with 1 view that doubles each day: $y = 2^x$. Each bar is twice the one before it.

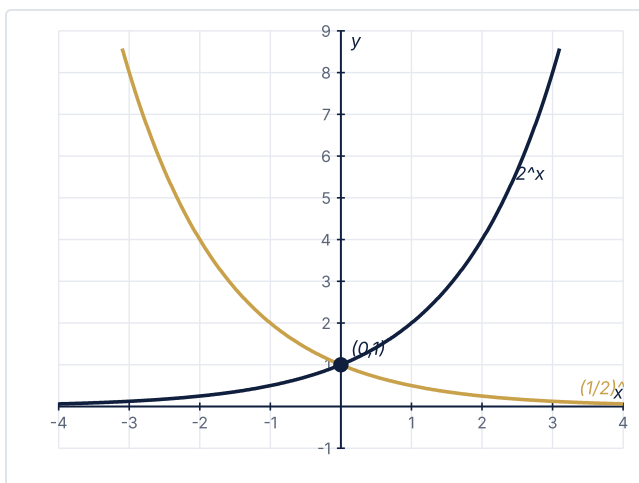
Finding the Equation

If you know two points, divide to find b and then find a . For points (x_1, y_1) and (x_2, y_2) :

$$b^{x_2 - x_1} = \frac{y_2}{y_1}.$$

If one point is the y -intercept $(0, a)$, you can read a directly.

The graph of $y = a \cdot b^x$ has a distinctive shape. For $b > 1$ the graph rises faster and faster to the right and flattens toward the x -axis on the left. For $0 < b < 1$ the graph is a mirror image: it falls toward the x -axis on the right. The x -axis ($y = 0$) is a **horizontal asymptote**: the graph gets as close as you like but never touches it, because b^x is never zero. Adding a constant, as in $y = 3 \cdot 2^x - 4$, shifts the whole curve and moves the asymptote to $y = -4$.



Growth $y = 2^x$ (rising) and decay $y = (1/2)^x$ (falling). Both pass through $(0, 1)$ and approach the x -axis.

Worked Examples

EXAMPLE 1

Let $f(x) = 3 \cdot 2^x$. Find $f(0)$, $f(1)$, $f(4)$, and $f(-1)$.

SOLUTION

$f(0) = 3 \cdot 1 = 3$ (any nonzero base to the power 0 is 1).

$f(1) = 3 \cdot 2 = 6$.

$f(4) = 3 \cdot 16 = 48$.

$f(-1) = 3 \cdot 2^{-1} = 3 \cdot \frac{1}{2} = \frac{3}{2}$. A negative exponent means a reciprocal.

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EXAMPLE 2

The table shows $x = 0, 1, 2, 3$ and $y = 5, 10, 20, 40$. Is it linear or exponential? Write the equation.

SOLUTION

Differences are 5, 10, 20, which are not constant, so it is not linear.

Ratios are $\frac{10}{5} = 2$, $\frac{20}{10} = 2$, $\frac{40}{20} = 2$: constant, so it is exponential with $b = 2$.

The first value is $a = 5$. The equation is $y = 5 \cdot 2^x$.

EXAMPLE 3

An exponential function passes through $(0, 4)$ and $(3, 108)$. Find its equation.

SOLUTION

From $(0, 4)$ we get $a = 4$.

Use the second point: $108 = 4 \cdot b^3$, so $b^3 = 27$ and $b = 3$.

The equation is $y = 4 \cdot 3^x$. Check $x = 3$: $4 \cdot 27 = 108$.

EXAMPLE 4

Plan A starts with 100 points and adds 20 points each week. Plan B starts with 5 points and doubles each week. After how many weeks does Plan B first have more points?

SOLUTION

Plan A: $A(n) = 100 + 20n$. Plan B: $B(n) = 5 \cdot 2^n$.

Check weeks: week 4: $A = 180$, $B = 80$. Week 5: $A = 200$, $B = 160$. Week 6: $A = 220$, $B = 320$.

Plan B first passes Plan A in **week 6**. Exponential growth always wins in the long run.

EXAMPLE 5

For $y = 3 \cdot 2^x - 4$, state the y -intercept and the horizontal asymptote.

SOLUTION

y -intercept: set $x = 0$: $3 \cdot 1 - 4 = -1$, so the point is $(0, -1)$.

Asymptote: $3 \cdot 2^x$ approaches 0 as x decreases, so y approaches -4 . The line $y = -4$ is the asymptote.

Check a second point: $x = 2$ gives $y = 12 - 4 = 8$.

EXAMPLE 6

Solve $4^x = 32$.

SOLUTION

Write both sides with base 2: $4 = 2^2$ and $32 = 2^5$.

Then $(2^2)^x = 2^5$, so $2^{2x} = 2^5$.

Equal bases mean equal exponents: $2x = 5$, so $x = \frac{5}{2}$.

Check: $4^{2.5} = 2^5 = 32$.

Coch's Playbook

- 1 **Test the table.** Compute differences and ratios. A constant difference means linear. A constant ratio means exponential.
- 2 **Find a first.** It is the value at $x = 0$. If the table starts at another x , work backward by dividing by b .
- 3 **Find b by dividing.** $b = \frac{y_{\text{next}}}{y_{\text{current}}}$ for consecutive x -values.
- 4 **Sanity-check.** Plug in a second point. For decay, the values must shrink; for growth, they must rise.

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- ◆ Remember the order of operations: $5 \cdot 2^3$ means $5 \cdot 8$, not 10^3 . Evaluate the power first.
- ◆ $2x$ is linear, doubling x doubles the answer. 2^x is exponential, adding 1 to x doubles the answer.
- ◆ Make a quick table of values for $x = 0, 1, 2, 3$ to see the pattern.
- ◆ To check a solved exponent, rewrite both sides with the same base whenever you can.

Common traps

1. Computing $5 \cdot 2^3$ as $10^3 = 1000$. 2. Using the wrong ratio direction, so a decay problem returns $b > 1$. 3. Calling a table exponential after only checking that the numbers get bigger. 4. Reading a as the first number in the table even when the table does not start at $x = 0$.

Mistake Clinic

Spot the error

A student evaluates $f(x) = 5 \cdot 2^x$ at $x = 3$ and writes $f(3) = 10^3 = 1000$. **Where it goes wrong:** The student multiplied 5 and 2 before applying the exponent. The exponent applies only to the base 2. **Correct solution:** $f(3) = 5 \cdot 2^3 = 5 \cdot 8 = 40$.

Spot the error

A student sees $x : 0, 1, 2, 3$ and $y : 2, 5, 10, 17$ and says it is exponential because the numbers grow quickly. **Where it goes wrong:** Fast growth is not the test. The ratios are 2.5, 2, 1.7, not constant, and the differences 3, 5, 7 are not constant either. **Correct solution:** The table is neither linear nor exponential. It is $y = x^2 + 2$, a quadratic.

Spot the error

A student finds the equation through $(1, 6)$ and $(3, 54)$ and writes $b = \frac{54}{6} = 9$, so $y = 6 \cdot 9^x$. **Where it goes wrong:** The ratio 9 is b^2 because the x -values are 2 apart. Also, $y = 6$ at $x = 1$ is not a . **Correct solution:** $b^2 = 9$ so $b = 3$. Then $6 = a \cdot 3$, so $a = 2$ and $y = 2 \cdot 3^x$. Check $x = 3$: $2 \cdot 27 = 54$.

Real-World Connection

A rumor is told to 2 people in the first minute, and each person who hears it tells 2 new people each minute, so the number of new listeners follows 2^n . After 10 minutes that is $2^{10} = 1024$ new listeners in one minute alone. This is why viral posts spread so fast.

Challenge Corner

A sheet of paper is 0.1 millimeter thick. Each fold doubles the thickness, so after n folds it is $0.1 \cdot 2^n$ millimeters. What is the least number of folds needed for a stack taller than 1 meter (1000 millimeters)? **Solution.** We need $0.1 \cdot 2^n > 1000$, so $2^n > 10000$. Since $2^{13} = 8192$ is too small and $2^{14} = 16384$ is large enough, the answer is **14 folds**. (In practice paper cannot be folded that many times, but the math shows how quickly doubling grows.)

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Practice

PRACTICE Exponential Functions and Their Graphs

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- If $f(x) = 5 \cdot 2^x$, what is $f(3)$?
(A) 40 (B) 30 (C) 125 (D) 1000
- Which function represents exponential decay?
(A) $y = 0.4(6)^x$ (B) $y = 6 - 0.4x$ (C) $y = 6(0.4)^x$
(D) $y = 0.4x^2 + 6$
- A table has $x = 0, 1, 2, 3$ and $y = 2, 6, 18, 54$. Which equation fits?
(A) $y = 3 \cdot 2^x$ (B) $y = 2 \cdot 3^x$ (C) $y = 4x + 2$ (D) $y = 2x^3$
- What is the y -intercept of $y = 7 \cdot \left(\frac{1}{2}\right)^x$?
(A) $\frac{1}{2}$ (B) 0 (C) 3.5 (D) 7
- What is the growth factor of $y = 120(1.06)^x$?
(A) 1.06 (B) 6 (C) 0.06 (D) 120
- What is the horizontal asymptote of $y = 2^x + 5$?
(A) $y = 0$ (B) $y = 5$ (C) $x = 5$ (D) $y = -5$
- Savings Plan A starts with 20 dollars and adds 50 dollars each week. Plan B starts with 1 dollar and doubles each week. After how many weeks does Plan B first have more money than Plan A?
(A) 9 weeks (B) 8 weeks (C) 10 weeks (D) 12 weeks
- Solve $9^x = 27$.
(A) $x = 3$ (B) $x = \frac{2}{3}$ (C) $x = \frac{3}{2}$ (D) $x = 18$
- An exponential function passes through $(0, 5)$ and $(2, 45)$. Which is its equation?
(A) $y = 5 \cdot 3^x$ (B) $y = 5 \cdot 9^x$ (C) $y = 5 \cdot 20^x$ (D) $y = 45 \cdot 5^x$
- Let $f(x) = 2 \cdot 3^x$. Find $f(-2)$.
- Find y when $x = 3$ for $y = 250 \cdot (0.8)^x$.
- A table gives $y = 6, 12, 24, 48$ for $x = 0, 1, 2, 3$. Find y when $x = 6$.
- Write the exponential function $y = a \cdot b^x$ that passes through $(1, 6)$ and $(3, 54)$ with $b > 0$.
- Solve $4^x = 32$.
- A club has 30 members and adds 12 members each week (Plan A). Another club starts with 3 members and doubles each week (Plan B). In which week does Plan B first have more members?

16.2 Growth and Decay Models

Turn percent rates into growth and decay factors and model populations, depreciation, and half-life. You will solve for time by building tables and testing values.

Why This Matters

Exponential models are everywhere: a town growing a few percent a year, a car losing value every year, a medicine leaving your body, a social media account gaining followers. In every case the quantity changes by a **percent** of its current size, so the amount of change gets bigger when the quantity is big and smaller when it is small. That is why the graphs curve instead of forming straight lines.

Students most often get stuck turning a percent into a multiplier (what do I multiply by for a 15% drop?), mixing up growth and decay, and finding the time needed to reach a goal. Since these equations need logarithms that you will meet later, we solve for time here using tables and trial. That is how many people solve these problems in real life, and it builds strong number sense.

Core Ideas

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The Growth and Decay Model

If a quantity starts at a and changes by a fixed percent rate r (written as a decimal) each period, then after t periods

$y = a(1 + r)^t$ (growth) $y = a(1 - r)^t$ (decay).

The number $1 \pm r$ is the **factor**. A factor above 1 means growth and a factor below 1 means decay.

Situation	Rate r	Factor	Model
Grows 6% per year	0.06	1.06	$y = a(1.06)^t$
Falls 15% per year	0.15	0.85	$y = a(0.85)^t$
Grows 100% (doubles)	1	2	$y = a \cdot 2^t$
Falls 50% (halves)	0.5	0.5	$y = a(0.5)^t$

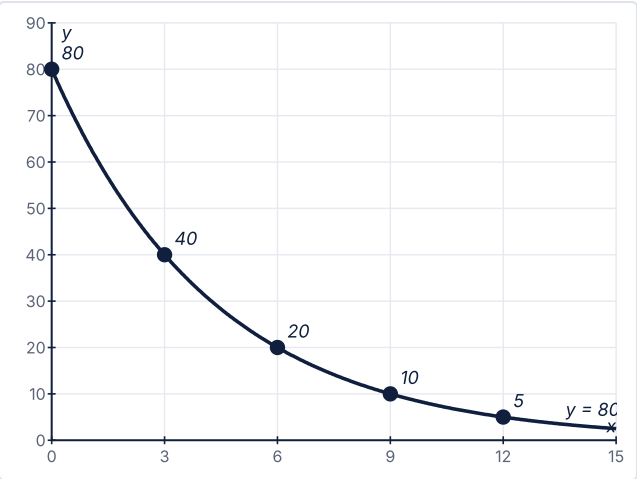
Why does the factor work? A 6% increase means you keep the original 100% and add 6% more, so you now have 106% = 1.06 times as much. A 15% decrease means you keep 85% of what you had, which is 0.85. Multiply once per period, and repeat. Do **not** multiply the rate by the number of periods, because each period's change is based on the new amount.

Half-Life

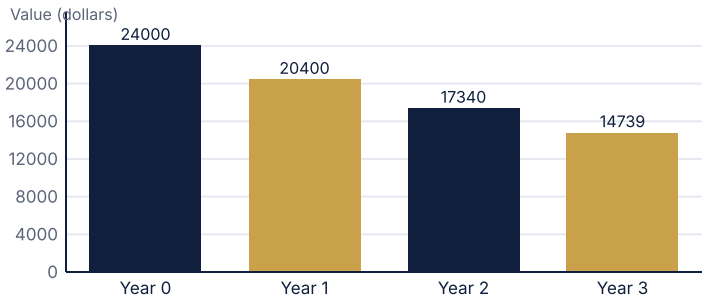
The **half-life** is the time it takes for a quantity to fall to half its amount. If the half-life is h then

$y = a \left(\frac{1}{2}\right)^{t/h}$.

Count how many half-lives have passed (t/h) and halve that many times.



A medicine of 80 mg with half-life 3 days. Each 3 days the amount is cut in half.



A 24000 dollar vehicle losing 15 percent of its value each year. Each bar is 85 percent of the one before.

Finding time. To find when a model reaches a target, build a table of values by trying whole numbers of periods. Find the two consecutive times that surround the target. Because the value moves in one direction, the first time it passes the target is your answer. A calculator makes the table fast. Later, logarithms will do the same job exactly.

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Choosing the Right Model

Linear change adds the same **amount** each period. Exponential change multiplies by the same **factor** each period. A percent rate always means an exponential model.

Worked Examples

EXAMPLE 1

Write the factor for (a) 7% growth and (b) 12% decay.

SOLUTION

(a) Growth: $1 + 0.07 = 1.07$.

(b) Decay: $1 - 0.12 = 0.88$.

Check: the growth factor is above 1 and the decay factor is below 1.

EXAMPLE 2

A town of 5000 people grows 4% per year. How many people will there be after 10 years? Use a calculator.

SOLUTION

Model: $y = 5000(1.04)^t$.

At $t = 10$: $1.04^{10} \approx 1.4802$.

$y \approx 5000(1.4802) = 7401.2$, so about **7401 people**.

EXAMPLE 3

A vehicle bought for 24000 dollars loses 15% of its value each year. Find its value after 3 years.

SOLUTION

Model: $V = 24000(0.85)^t$.

$0.85^3 = 0.614125$.

$V = 24000 \cdot 0.614125 = 14739$ dollars.

EXAMPLE 4

A medicine has a half-life of 3 days. If a patient takes 80 mg, how much remains after 9 days?

SOLUTION

Number of half-lives: $9 \div 3 = 3$.

Halve three times: $80 \rightarrow 40 \rightarrow 20 \rightarrow 10$.

10 mg remain. Formula check: $80 \left(\frac{1}{2}\right)^3 = 10$.

EXAMPLE 5

A population of 200 grows to 288 in 2 years at a constant percent rate. Find the yearly rate.

SOLUTION

Model: $288 = 200 \cdot b^2$, so $b^2 = 1.44$.

$b = \sqrt{1.44} = 1.2$.

$b = 1 + r$ gives $r = 0.2$: a growth rate of **20% per year**.

EXAMPLE 6

A town of 12000 grows 5% per year. In which year does the population first exceed 15000?

SOLUTION

Model: $P = 12000(1.05)^t$.

Table: $t = 3$: 13892. $t = 4$: 14586. $t = 5$: 15315.

$14586 < 15000 < 15315$. The population first exceeds 15000 in **year 5**.

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Coach's Playbook

- 1 Name the starting value and the period.** Is the change per year, per day, per hour? Make sure t uses the same unit.
 - 2 Convert the percent.** Divide by 100. Then use $1 + r$ for growth or $1 - r$ for decay.
 - 3 Write the model and substitute.** Do the power first, then multiply by a .
 - 4 Check direction.** For growth the answer must be above the start. For decay it must be below.
- ◆ Use the exact value for the factor all the way through, and round only at the end.
 - ◆ A quick estimate: 5% growth for 10 years is about 1.63 times, not 1.5 times. Percent growth is more than simple addition.
 - ◆ For doubling or half-life questions, count steps: 2, 4, 8, 16, ... or 80, 40, 20, 10, ...
 - ◆ To solve for time, make a table and look for the pair of values that surround the target.

Common traps

1. Using the rate itself as the factor, such as $a(0.06)^t$ for 6% growth. 2. Using $1 + r$ for a decay problem. 3. Multiplying rt (simple growth) instead of raising the factor to the power t . 4. Mixing the time unit, like using months in the formula for a yearly rate.

Mistake Clinic

Spot the error

A student models a 15% yearly decrease from 24000 dollars as $V = 24000(1.15)^t$. **Where it goes wrong:** The factor 1.15 means 15% growth. A decrease keeps 85% of the value. **Correct solution:** $V = 24000(0.85)^t$. After 1 year: $24000 \cdot 0.85 = 20400$, which is lower, as it should be.

Spot the error

A student says a 5% yearly increase over 10 years is a 50% increase, so 2000 dollars becomes 3000 dollars. **Where it goes wrong:** Each year the 5% applies to a larger amount. Adding 5% ten times undercounts. **Correct solution:** $2000(1.05)^{10} \approx 2000(1.6289) = 3257.79$ dollars.

Spot the error

A student finds the amount of a 100 gram sample after 2 half-lives and writes $100 \cdot \frac{1}{2} \cdot 2 = 100$. **Where it goes wrong:** Half-life means halve, then halve again. The student multiplied by 2 instead of halving twice. **Correct solution:** $100 \rightarrow 50 \rightarrow 25$, or $100 \left(\frac{1}{2}\right)^2 = 25$ grams.

Real-World Connection

Caffeine in your body has a half-life of about 5 hours. If you drink a coffee with 100 mg of caffeine, about 50 mg remain after 5 hours and 25 mg remain after 10 hours. That is why a late afternoon drink can still be in your system at bedtime.

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Challenge Corner

A savings balance grows 8% per year. After how many whole years will the balance first be at least double? **Solution.** Test 1.08^t : at $t = 9$ the factor is about 1.999, which is just under 2. At $t = 10$ it is about 2.159. So the balance first doubles in **10 years**. Notice that $72 \div 8 = 9$, a close estimate (the rule of 72 is a shortcut you will meet in a later section).

Practice**PRACTICE Growth and Decay Models**

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- What is the growth factor for 7% growth per year?
(A) 1.07 (B) 0.07 (C) 7 (D) 1.7
- What is the factor for a 15% decrease?
(A) 1.15 (B) 0.15 (C) 0.85 (D) 15
- A savings account of 2000 dollars earns 3% each year. Which model gives the balance after t years?
(A) $y = 2000(0.03)^t$ (B) $y = 2000(1.03)^t$ (C) $y = 2000 + 0.03t$
(D) $y = 2000(3)^t$
- A tool worth 500 dollars loses 10% of its value each year. What is its value after 2 years?
(A) 405 dollars (B) 400 dollars (C) 450 dollars
(D) 550 dollars
- A sample has a half-life of 4 hours. If it starts at 64 mg, how much remains after 12 hours?
(A) 16 mg (B) 32 mg (C) 8 mg (D) 4 mg
- A quantity doubles every 5 years and starts at 3. What is it after 20 years?
(A) 48 (B) 12 (C) 24 (D) 96
- A population of 800 grows 25% per year. What is it after 2 years?
(A) 1200 (B) 1250 (C) 1000 (D) 1600
- A device worth 400 dollars loses 20% of its value each year. After how many whole years is it first worth less than 200 dollars?
(A) 4 years (B) 3 years (C) 5 years (D) 2 years
- An investment of 6000 dollars grows 5% per year. What is its value after 3 years?
(A) 6900.00 dollars (B) 6300.00 dollars (C) 7200.00 dollars
(D) 6945.75 dollars
- Write the decay factor for a 9% yearly decrease.
- A vehicle bought for 18000 dollars loses 12% of its value each year. Find its value after 2 years in dollars.
- A sample of 96 grams has a half-life of 6 days. How many grams remain after 18 days?
- A population of 500 grows to 720 in 2 years at a constant yearly percent rate. Find the rate as a percent.
- A balance of 2000 dollars grows 6% per year. In which whole year does it first exceed 2800 dollars?
- A deer herd of 400 shrinks 5% per year. Find the herd size after 10 years, rounded to the nearest whole animal.

16.3 Compound Interest and Savings

Compare simple and compound interest, use the formula $A = P(1 + r/n)^{nt}$, and meet continuous growth with e . You will see why starting early matters.

Why This Matters

When you put money in a savings account, the bank pays you for using your money. When you borrow, you pay the bank. That payment is called **interest**. The big question is how the interest is calculated. With simple interest, you earn on your original amount only. With **compound interest**, you earn interest on your interest too, and over many years that makes a dramatic difference.

Understanding compounding helps you choose savings plans, understand loans, and compare offers. Students typically get stuck on what the letters in the formula mean, on how the number of compounding periods changes the exponent, and on rounding. We will build the formula from simple examples so that you can rebuild it from memory instead of just memorizing it.

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Core Ideas

Simple Interest

If a principal P earns interest at annual rate r (as a decimal) for t years, then

$$I = Prt \quad \text{and} \quad A = P + I = P(1 + rt).$$

The balance grows by the same amount each year, so simple interest is a **linear** model.

Now consider compounding. Suppose you invest 1000 dollars at 5% interest, compounded once a year. After year 1 you have $1000(1.05) = 1050$. In year 2, the 5% applies to 1050, not 1000, so you have $1050(1.05) = 1102.50$. Each year multiplies by 1.05, so after t years the balance is $1000(1.05)^t$. This is the exponential growth model from the last section, with the interest rate as the percent rate.

Compound Interest Formula

$$A = P \left(1 + \frac{r}{n} \right)^{nt}$$

A = final amount, P = principal (starting amount), r = annual rate as a decimal, n = number of compounding periods per year, t = time in years.

Each period earns $\frac{r}{n}$ interest, and there are nt periods in total.

Compounding	Periods per year n	Rate per period
Annually	1	r
Semiannually	2	$\frac{r}{2}$
Quarterly	4	$\frac{r}{4}$
Monthly	12	$\frac{r}{12}$
Daily	365	$\frac{r}{365}$

Compounding more often gives slightly more money, because interest starts earning interest sooner. The effect is real but small. For 1000 dollars at 8% for one year, annual compounding gives 1080 dollars, monthly gives about 1083.00 dollars, and daily gives about 1083.28 dollars. Even compounding every second cannot go beyond a limit, which leads to the special number e .

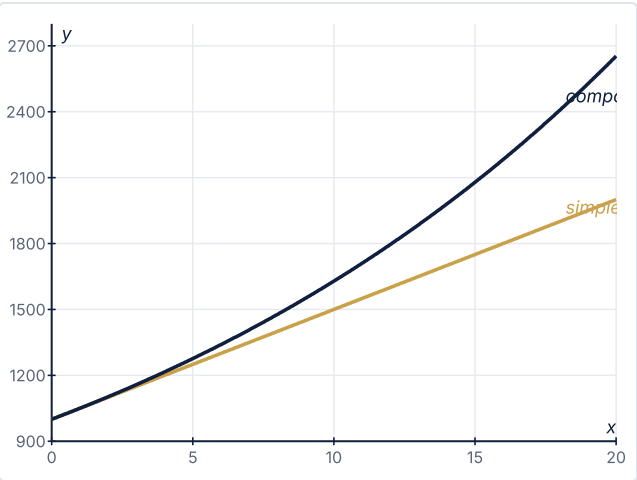
Continuous Compounding

When the compounding happens continuously, the formula becomes

$$A = Pe^{rt},$$

where $e \approx 2.71828$ is a special constant. Use the e^x key on a calculator.

Continuous compounding is the upper limit of what compounding more often can reach.

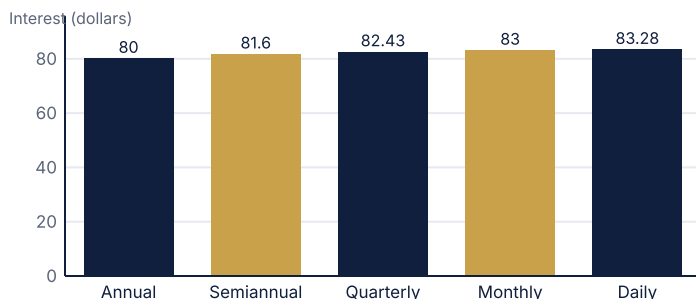


1000 dollars at 5 percent. The simple interest line adds 50 dollars a year. The compound curve bends upward and reaches about 2653 dollars after 20 years, compared with 2000 dollars for simple interest.

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Interest earned on 1000 dollars at 8 percent for one year. More frequent compounding adds a little each time, so the bars grow slowly.

Worked Examples

EXAMPLE 1

Find the simple interest and the total on 1500 dollars at 4% for 3 years.

SOLUTION

$$I = Prt = 1500 \cdot 0.04 \cdot 3 = 180 \text{ dollars.}$$

$$\text{Total: } 1500 + 180 = 1680 \text{ dollars.}$$

EXAMPLE 2

Find the balance when 1500 dollars is invested at 4% compounded annually for 3 years.

SOLUTION

$$A = 1500(1 + 0.04)^3 = 1500(1.04)^3.$$

$$1.04^3 = 1.124864, \text{ so } A = 1500 \cdot 1.124864 = 1687.296.$$

The balance is about **1687.30 dollars**, which is 7.30 dollars more than simple interest.

EXAMPLE 3

Find the balance when 2000 dollars earns 6% compounded quarterly for 5 years.

SOLUTION

$$\text{Here } P = 2000, r = 0.06, n = 4, t = 5.$$

$$\text{Rate per period: } \frac{0.06}{4} = 0.015. \text{ Number of periods: } nt = 20.$$

$$A = 2000(1.015)^{20} \approx 2000(1.34686) = 2693.71 \text{ dollars.}$$

EXAMPLE 4

Compare 1000 dollars at 8% for one year compounded annually and compounded monthly.

SOLUTION

$$\text{Annually: } A = 1000(1.08) = 1080 \text{ dollars.}$$

$$\text{Monthly: } A = 1000 \left(1 + \frac{0.08}{12}\right)^{12} \approx 1000(1.0830) = 1083.00 \text{ dollars.}$$

Monthly compounding earns about **3.00 dollars more**.

EXAMPLE 5

Find the balance when 3000 dollars grows at 5% compounded continuously for 4 years.

SOLUTION

$$\text{Use } A = Pe^{rt} \text{ with } rt = 0.05 \cdot 4 = 0.2.$$

$$A = 3000e^{0.2} = 3000(1.221403) = 3664.21 \text{ dollars.}$$

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EXAMPLE 6

How much must be invested now at 5% compounded annually to have 5000 dollars in 10 years?

SOLUTION

Set $5000 = P(1.05)^{10}$.

$1.05^{10} \approx 1.628895$, so $P = \frac{5000}{1.628895} \approx 3069.57$.

About **3069.57 dollars** must be invested now.

Coach's Playbook

- 1 List the five quantities.** Write P , r , n , t , and what is asked. Convert the rate to a decimal.
 - 2 Compute the rate per period and the number of periods.** $\frac{r}{n}$ and nt . Write them down before touching the calculator.
 - 3 Enter the power in one go.** Compute $(1 + r/n)$ with its full decimal, then use the power key. Do not round in the middle.
 - 4 Round at the end to the nearest cent.** Then check that the answer is larger than P and not by a silly amount.
- ◆ A quick check: simple interest gives a lower bound. Your compound answer must be a little larger.
 - ◆ If the problem gives months, convert to years by dividing by 12, as in 18 months = 1.5 years.
 - ◆ To find the starting amount, divide the final amount by the growth factor.
 - ◆ Use parentheses on the calculator for $(1 + 0.06/4)^{20}$.

Common traps

1. Forgetting to divide r by n , such as using $(1.06)^{20}$ for quarterly 6%. 2. Using $r = 6$ instead of 0.06. 3. Rounding $(1 + r/n)$ too early, which changes the cents. 4. Using t instead of nt as the exponent.

Mistake Clinic**Spot the error**

A student computes 2000 dollars at 6% compounded quarterly for 5 years as $2000(1.06)^{20}$. **Where it goes wrong:** The rate per quarter is $\frac{0.06}{4} = 0.015$, not 0.06. Using the full rate every quarter more than doubles the effect. **Correct solution:** $2000(1.015)^{20} \approx 2693.71$ dollars, compared with the incorrect 6414.27 dollars.

Spot the error

A student invests 500 dollars at 4% compounded semiannually for 1 year and writes $A = 500(1 + 0.04/2)^1$. **Where it goes wrong:** The exponent should be $nt = 2 \cdot 1 = 2$, not $t = 1$. Two periods of interest are earned. **Correct solution:** $A = 500(1.02)^2 = 520.20$ dollars.

Spot the error

A student finds the simple interest on 800 dollars at 5% for 2 years and writes $800 \cdot 5 \cdot 2 = 8000$. **Where it goes wrong:** The rate must be written as a decimal: 5% is 0.05, not 5. **Correct solution:** $I = 800 \cdot 0.05 \cdot 2 = 80$ dollars.

Real-World Connection

A family puts 1000 dollars in a college fund at 5% compounded annually. After 20 years it holds about 2653.30 dollars. With simple interest it would hold only 2000 dollars. The extra 653.30 dollars is interest earned on earlier interest, and it grows faster the longer you wait. Starting early is the strongest tool in saving.

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Challenge Corner

How many whole years does it take for money to double at 6% interest compounded annually? **Solution.** We need $1.06^t \geq 2$. Test: $1.06^{11} \approx 1.898$ is too small and $1.06^{12} \approx 2.012$ is enough. So it takes **12 years**. For comparison, simple interest at 6% would need $\frac{1}{0.06} \approx 16.7$ years, so compounding is much faster.

Practice**PRACTICE Compound Interest and Savings**

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- What is the simple interest on 800 dollars at 5% for 2 years?
 (A) 80 dollars (B) 40 dollars (C) 84 dollars (D) 880 dollars
- In $A = P \left(1 + \frac{r}{n}\right)^{nt}$, what does n represent?
 (A) The number of years
 (B) The number of times interest is compounded each year
 (C) The annual interest rate
 (D) The starting amount
- What is the balance after 2 years if 1000 dollars earns 6% compounded annually?
 (A) 1120.00 dollars (B) 1060.00 dollars (C) 1360.00 dollars (D) 1123.60 dollars
- Which account earns the most in one year at the same 6% rate?
 (A) Compounded annually (B) Compounded quarterly (C) Compounded daily (D) Compounded monthly
- A deposit earns interest compounded quarterly for 3 years. What exponent goes on $\left(1 + \frac{r}{n}\right)^{nt}$?
 (A) 3 (B) 4 (C) 12 (D) 7
- An account pays 8% compounded monthly. What is the interest rate per month, as a decimal?
 (A) 0.08 (B) 0.96 (C) 0.667 (D) about 0.0067
- What is the balance after 1 year if 500 dollars earns 4% compounded semiannually?
 (A) 520.00 dollars (B) 520.20 dollars (C) 510.00 dollars (D) 540.80 dollars
- What is the balance after 5 years if 2000 dollars earns 3% compounded continuously?
 (A) 2300.00 dollars (B) 2318.55 dollars (C) 2323.67 dollars (D) 2350.00 dollars
- A 1200 dollar deposit grows 5% each year, compounded annually. In which whole year does the balance first exceed 1500 dollars?
 (A) Year 4 (B) Year 5 (C) Year 6 (D) Year 3
- Find the simple interest on 2400 dollars at 3.5% for 4 years.
- Find the balance, to the nearest cent, of 1500 dollars invested at 4% compounded annually for 3 years.
- Find the balance, to the nearest cent, of 2000 dollars at 6% compounded quarterly for 5 years.
- Find the balance, to the nearest cent, of 3000 dollars at 5% compounded continuously for 4 years.
- How much must be invested now at 5% compounded annually to have 5000 dollars in 10 years? Round to the nearest cent.
- Starting with 1000 dollars at 8% for one year, how many dollars more does monthly compounding earn than annual compounding? Round to the nearest dollar.

16.4 Loans, Annuities, and Financial Decisions

Use simple formulas and tables to find loan payments, track a credit card balance, plan regular savings, compare offers, and estimate doubling time with the rule of 72.

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Why This Matters

Sooner or later you will borrow money (a car loan, a phone plan, a credit card) and save money (for college, a trip, an emergency). The math you learned about exponential growth is what decides whether a loan costs a little or a lot, and whether a savings plan reaches its goal. Banks do these calculations every day, and understanding them helps you avoid expensive mistakes.

Students often get stuck in three places: they think a loan with a lower monthly payment is always cheaper, they do not realize that a credit card balance can grow even while they make payments, and they are unsure how to compare two different offers fairly. In this section we use simple tables and a few formulas, with a calculator doing the heavy arithmetic, to make good decisions.

Core Ideas

When you borrow money, you repay the **principal** (the amount borrowed) plus **interest** over a number of months. The lender usually quotes a yearly rate called the **APR** (annual percentage rate). For monthly payments, you use the **monthly rate** $i = \frac{\text{APR}}{12}$. For example, a 6% APR is $i = 0.005$ per month.

Loan Payment Formula

For a loan of P dollars at monthly rate i repaid in n equal monthly payments, the payment is

$$M = \frac{Pi}{1 - (1 + i)^{-n}}.$$

Total paid = $M \cdot n$. Total interest = $M \cdot n - P$.

You do not need to derive this. Use a calculator, keep the full decimals until the end, and round the payment to the cent.

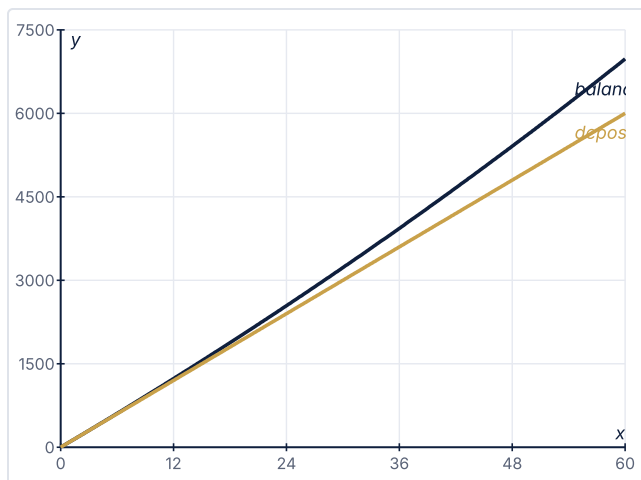
Notice what the formula tells you. A longer loan (larger n) has a smaller monthly payment, but you pay interest for more months, so the total cost goes up. A shorter loan has a bigger payment and costs less overall.

Savings Plan (Regular Deposits)

If you deposit d dollars at the end of each month into an account with monthly rate i , then after n months the balance is

$$F = d \cdot \frac{(1 + i)^n - 1}{i}.$$

Your own deposits total $d \cdot n$. The rest of the balance is interest earned.



Saving 100 dollars a month for 60 months. The gap between the curve and the line is interest earned: 6977.00 minus 6000 equals 977.00 dollars.

Credit cards work differently. Each month the card company charges interest on your balance: $\text{interest} = \text{balance} \times \frac{\text{APR}}{12}$. Then your payment is subtracted. Only the part of your payment that is bigger than the interest reduces what you owe. If your payment is less than the interest, your balance actually grows.

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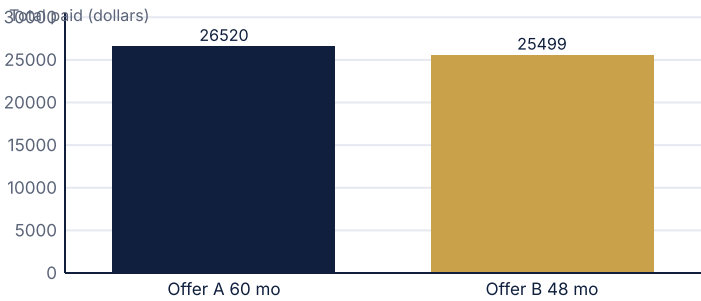
Month	Start balance	Interest (1.5%)	Payment	End balance
1	2000.00	30.00	50.00	1980.00
2	1980.00	29.70	50.00	1959.70
3	1959.70	29.40	50.00	1939.10

Rule of 72

A quick estimate for the doubling time of money growing at r percent per year is

years to double $\approx \frac{72}{r}$.

It works best for rates from about 4% to 12%. It also estimates the rate needed to double in a given time: $r \approx \frac{72}{\text{years}}$.



The same 24000 dollar loan. Offer A has a lower payment but costs about 1021 dollars more in total.

Worked Examples

EXAMPLE 1

A 12000 dollar loan has a 6% APR and is repaid over 36 months. Find the monthly payment and the total interest.

SOLUTION

Monthly rate: $i = \frac{0.06}{12} = 0.005$. Number of payments: $n = 36$.

$M = \frac{12000(0.005)}{1 - (1.005)^{-36}} \approx \frac{60}{0.16437} \approx 365.06$ dollars.

Total paid: $365.06 \times 36 \approx 13142$ dollars.

Total interest: $13142 - 12000 \approx 1142$ dollars.

EXAMPLE 2

A phone costs 480 dollars and is paid with no interest over 12 months. What is the payment? If a store instead charges 20 dollars in fees, what is the cost?

SOLUTION

With no interest: $\frac{480}{12} = 40$ dollars per month.

With fees: total cost $480 + 20 = 500$ dollars, so each payment is $\frac{500}{12} \approx 41.67$ dollars.

Lesson: always compare the **total paid**, not just the monthly payment.

EXAMPLE 3

You deposit 100 dollars at the end of each month into an account paying 6% APR. How much do you have after 5 years?

SOLUTION

Monthly rate: $i = 0.005$. Months: $n = 60$.

$F = 100 \cdot \frac{(1.005)^{60} - 1}{0.005} = 100 \cdot \frac{0.34885}{0.005} \approx 6977.00$ dollars.

Deposits total $100 \cdot 60 = 6000$ dollars, so interest earned is **977.00 dollars**.

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EXAMPLE 4

A credit card has a 2000 dollar balance and an 18% APR. You pay 50 dollars per month. Find the balance after one month.

SOLUTION

Monthly rate: $\frac{0.18}{12} = 0.015$.

Interest: $2000(0.015) = 30$ dollars.

New balance: $2000 + 30 - 50 = 1980$ dollars.

Only 20 of your 50 dollar payment reduced the debt. The other 30 went to interest.

EXAMPLE 5

Offer A: borrow 24000 dollars at 4% APR for 60 months. Offer B: 24000 dollars at 3% APR for 48 months. Which is cheaper overall?

SOLUTION

Offer A: payment ≈ 442.00 dollars. Total $\approx 442 \cdot 60 = 26520$ dollars.

Offer B: payment ≈ 531.22 dollars. Total $\approx 531.22 \cdot 48 = 25499$ dollars.

Offer B costs about **1021 dollars less**, even though its payment is higher by about 89 dollars per month.

EXAMPLE 6

Use the rule of 72 to estimate how long it takes money to double at 9%. Then check with a calculator.

SOLUTION

Estimate: $\frac{72}{9} = 8$ years.

Check: $1.09^8 \approx 1.9926$, just under 2, and $1.09^9 \approx 2.172$.

The estimate of 8 years is very close. Money is nearly doubled at 8 years and fully doubled in the 9th year.

Coach's Playbook

- 1 Convert to monthly numbers.** Divide the APR by 12 and count payments in months.
- 2 Choose the right tool.** Borrowing a lump sum: loan formula. Regular deposits: savings formula. Credit card: month by month table.
- 3 Compare totals.** Multiply payment by number of payments. Subtract the amount borrowed to see interest.
- 4 Judge the decision.** A low payment is not a bargain if it stretches over many years. Compare the total cost and your budget.

- ◆ Interest on a credit card is charged on the balance. Pay more than the interest or the debt never goes down.
- ◆ Paying extra early saves the most, because every extra dollar stops earning interest for every later month.
- ◆ Use the rule of 72 for quick mental estimates, and a calculator for exact values.
- ◆ Keep full decimals during calculations and round money to the cent only at the end.

Common traps

1. Using the APR instead of the monthly rate $\frac{\text{APR}}{12}$. 2. Comparing only the monthly payments of two loans. 3. Forgetting that a payment first covers interest, so it reduces the balance by less than you think. 4. Using the rule of 72 with the rate as a decimal (72 divided by 0.06) instead of a percent (72 divided by 6).

Mistake Clinic

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Spot the error

A student computes the first month of interest on a 2000 dollar card at 18% APR as $2000 \times 0.18 = 360$ dollars. **Where it goes wrong:** The 18% is a yearly rate. One month of interest uses one twelfth of it. **Correct solution:** $2000 \times \frac{0.18}{12} = 2000(0.015) = 30$ dollars.

Spot the error

A student chooses a 72-month car loan over a 48-month loan because the payment is lower, without comparing the totals. **Where it goes wrong:** A lower payment over a longer time means more months of interest. With the same rate and amount, the longer loan always costs more in total. **Correct solution:** Compute $M \cdot n$ for both loans. In Example 5 the longer loan costs about 1021 dollars more.

Spot the error

A student says the rule of 72 predicts that money at 6% doubles in $72 \div 0.06 = 1200$ years. **Where it goes wrong:** The rule needs the rate as a percent number, not a decimal. **Correct solution:** $72 \div 6 = 12$ years. Check: $1.06^{12} \approx 2.012$.

Real-World Connection

A teen who invests 100 dollars a month for 5 years at 6% has about 6977.00 dollars, which includes 977.00 dollars of interest. If the same teen waits and puts in 100 dollars for only 12 months, there is much less time for growth. Starting early gives the interest more time to compound, which is why advisors say to save as soon as you can.

Challenge Corner

A credit card balance is 3000 dollars at 18% APR. You pay 100 dollars per month and make no new purchases. (a) What is the smallest payment that makes the balance go down in the first month? (b) How many months to pay off the balance? **Solution.** (a) The first month's interest is $3000(0.015) = 45$ dollars, so any payment above 45 dollars reduces the balance. (b) Tracking month by month on a calculator, the balance reaches zero during month 41, with total payments of about 4015.49 dollars, so the interest paid is about 1015.49 dollars.

Practice**PRACTICE Loans, Annuities, and Financial Decisions**

Show your work on paper. Use a calculator only when a problem says so, or if it is allowed at your level.

- A person borrows 5000 dollars and repays 150 dollars a month for 36 months. How much interest was paid?
(A) 400 dollars (B) 5400 dollars (C) 150 dollars
(D) 4600 dollars
- A credit card has an APR of 12%. What monthly rate is used for interest?
(A) 0.12 (B) 0.01 (C) 12 (D) 0.1
- A credit card has a balance of 1500 dollars at 18% APR. What interest is charged for the first month?
(A) 270.00 dollars (B) 27.00 dollars (C) 225.00 dollars
(D) 22.50 dollars
- You deposit 100 dollars a month for 5 years. The balance is 6977.00 dollars at 6% APR. How much of the balance is interest?
(A) 6977.00 dollars (B) 6000.00 dollars (C) 977.00 dollars
(D) 377.00 dollars
- Using the rule of 72, about how long does money take to double at 6% interest per year?
(A) 6 years (B) 72 years (C) 18 years (D) 12 years

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6. A 24000 dollar loan is offered two ways: 442 dollars a month for 60 months, or 531 dollars a month for 48 months. Which statement is true?
 - (A) The 60 month loan is cheaper because the payment is lower
 - (B) The two loans cost the same
 - (C) The 48 month loan has the higher payment but the lower total cost
 - (D) The 48 month loan has the lower payment
7. A credit card balance is 2000 dollars at 18% APR. You pay 50 dollars. What is the balance after one month?
 - (A) 1950 dollars
 - (B) 1980 dollars
 - (C) 2030 dollars
 - (D) 1920 dollars
8. Using the rule of 72, about what yearly rate doubles money in 6 years?
 - (A) 6%
 - (B) 12%
 - (C) 8%
 - (D) 72%
9. The same loan at the same rate is offered for 36 months or for 60 months. Which statement is true?
 - (A) The 60 month loan has the larger payment
 - (B) The 36 month loan has more total interest
 - (C) Both loans have the same total interest
 - (D) The 60 month loan has the smaller payment but more total interest
10. A 5000 dollar loan has a 12% APR and 24 monthly payments. Find the monthly payment to the nearest cent.
11. You deposit 50 dollars at the end of each month into an account with 4.8% APR for 24 months. How much do you have, to the nearest cent?
12. An 8000 dollar loan has a 6% APR and 48 monthly payments. Find the monthly payment to the nearest cent.
13. A credit card balance is 3500 dollars at 24% APR. How much interest is charged for the first month?
14. A credit card balance is 1200 dollars at 18% APR. You pay 100 dollars each month. Find the balance after two months.
15. Use the rule of 72 to estimate how many years it takes for money to double at 8% per year.

Answers**Answers and Explanations**

Complete solutions for every practice problem, numbered to match. Read the explanation even when your answer is right.

16.1 Exponential Functions and Their Graphs**PRACTICE · EXPONENTIAL FUNCTIONS AND THEIR GRAPHS**

1. A. $f(3) = 5 \cdot 8 = 40$. Choice B multiplies $5 \cdot 2 \cdot 3$, and choice D computes $(5 \cdot 2)^3$.
2. C. Decay needs a base between 0 and 1. Choice A has base 6 (growth), and choice B is a decreasing line, which is linear.
3. B. The ratio is 3 and the first value is 2. Choice A swaps a and b .
4. D. At $x = 0$, $(\frac{1}{2})^0 = 1$, so $y = 7$. Choice A confuses the base with the intercept.
5. A. The growth factor is the base. Choice B is the percent rate written as a whole number, and choice D is the starting value.
6. B. The shift of $+5$ raises the asymptote from $y = 0$ to $y = 5$. Choice A ignores the shift.
7. A. Week 8: A is 420, B is 256. Week 9: A is 470, B is 512. Choice B (8 weeks) is too early because Plan A still leads, and choice C is later than the first week.
8. C. Use base 3: $3^{2x} = 3^3$, so $2x = 3$. Choice B inverts the fraction.
9. A. $45 = 5b^2$ gives $b^2 = 9$, so $b = 3$. Choice B uses 9, which is b^2 , and choice C uses the slope between the points.
10. $\frac{2}{9}$. $f(-2) = 2 \cdot 3^{-2} = 2 \cdot \frac{1}{9}$.
11. 128. $0.8^3 = 0.512$, and $250 \cdot 0.512 = 128$.
12. 384. The ratio is 2, so $y = 6 \cdot 2^x$ and $y(6) = 6 \cdot 64 = 384$.
13. $y = 2 \cdot 3^x$. $b^2 = \frac{54}{6} = 9$, so $b = 3$. Then $6 = a \cdot 3$ gives $a = 2$.
14. $x = \frac{5}{2}$. $2^{2x} = 2^5$, so $2x = 5$.
15. Week 5. Week 4: A is 78, B is 48. Week 5: A is 90, B is 96.

16.2 Growth and Decay Models

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PRACTICE · GROWTH AND DECAY MODELS

1. A. Growth factor is $1 + 0.07 = 1.07$. Choice B is only the rate, and choice D misplaces the decimal.
2. C. Decay factor is $1 - 0.15 = 0.85$. Choice A is a 15% increase.
3. B. Percent growth multiplies by 1.03 each year. Choice A uses the rate as the factor, and choice C is a line.
4. A. $500(0.9)^2 = 405$. Choice B takes 20% off once, and choice C only does one year of loss.
5. C. There are $12 \div 4 = 3$ half-lives: $64 \rightarrow 32 \rightarrow 16 \rightarrow 8$. Choice A stops after 2 halvings, and choice D halves four times.
6. A. There are 4 doublings: $3 \cdot 2^4 = 48$. Choice B multiplies $3 \cdot 4$, and choice C uses 3 doublings.
7. B. $800(1.25)^2 = 800(1.5625) = 1250$. Choice A adds 25% of 800 twice, which treats it as linear.
8. A. Values: year 3 is 204.80, year 4 is 163.84. The first year below 200 is year 4. Choice B is when it is still above 200.
9. D. $6000(1.05)^3 = 6000(1.157625) = 6945.75$. Choice A uses simple growth of 15%, and choice B uses 5% once.
10. 0.91. $1 - 0.09 = 0.91$.
11. 13939.20 dollars. $18000(0.88)^2 = 18000 \cdot 0.7744 = 13939.2$.
12. 12 grams. $18 \div 6 = 3$ half-lives: $96 \rightarrow 48 \rightarrow 24 \rightarrow 12$.
13. 20%. $b^2 = \frac{720}{500} = 1.44$, so $b = 1.2$ and $r = 0.2$.
14. Year 6. $t = 5$: 2676.45. $t = 6$: 2837.04.
15. 239. $400(0.95)^{10} = 400(0.5987) \approx 239.5$, which rounds to 239 (keeping more digits, 239.49).

16.3 Compound Interest and Savings**PRACTICE · COMPOUND INTEREST AND SAVINGS**

1. A. $I = 800(0.05)(2) = 80$. Choice B uses one year, choice C is the compound interest, and choice D is the total.
2. B. n is the compounding frequency per year, such as 12 for monthly. Choice A is t , choice C is r , and choice D is P .
3. D. $1000(1.06)^2 = 1123.60$. Choice A is simple interest, and choice B is only one year.
4. C. More frequent compounding means interest starts earning interest sooner. Daily is the most frequent option.
5. C. The exponent is $nt = 4 \cdot 3 = 12$. Choice A uses only t , and choice D adds instead of multiplying.
6. D. Divide the annual rate by 12: $\frac{0.08}{12} \approx 0.0067$. Choice B does not divide, and choice C multiplies by 12.
7. B. $500(1.02)^2 = 520.20$. Choice A is annual compounding, and choice D uses the full 4% twice.
8. C. $2000e^{0.15} \approx 2323.67$. Choice A is simple interest, and choice B is annual compounding.
9. B. Year 4: 1458.61. Year 5: 1531.54. Choice A is not enough, since the balance is still below 1500 at year 4.
10. 336 dollars. $I = 2400(0.035)(4) = 336$.
11. 1687.30 dollars. $1500(1.04)^3 = 1500(1.124864) = 1687.296$.
12. 2693.71 dollars. $2000(1.015)^{20} \approx 2693.71$.
13. 3664.21 dollars. $3000e^{0.2} \approx 3000(1.2214) = 3664.21$.
14. 3069.57 dollars. $P = \frac{5000}{1.05^{10}} = \frac{5000}{1.628895}$.
15. 3 dollars. Monthly: $1000(1 + 0.08/12)^{12} \approx 1083.00$. Annual: 1080. Difference about 3.00.

16.4 Loans, Annuities, and Financial Decisions**PRACTICE · LOANS, ANNUITIES, AND FINANCIAL DECISIONS**

1. A. Total paid is $150 \cdot 36 = 5400$. Interest is $5400 - 5000 = 400$. Choice B is the total paid, not the interest.
2. B. Divide by 12: $\frac{0.12}{12} = 0.01$. Choice A uses the yearly rate for one month.
3. D. $1500 \cdot \frac{0.18}{12} = 22.50$. Choice A is a full year of interest.
4. C. Deposits are $100 \cdot 60 = 6000$. Interest is $6977 - 6000 = 977$. Choice B is the deposits alone.
5. D. $\frac{72}{6} = 12$. Choice A confuses the rate with the time, and choice B forgets to divide.
6. C. Totals are $442 \cdot 60 = 26520$ and $531 \cdot 48 = 25488$. The shorter loan costs less in total. Choice A compares payments only.
7. B. Interest is 30, so $2000 + 30 - 50 = 1980$. Choice A ignores the interest, and choice C ignores the payment.
8. B. $r \approx \frac{72}{6} = 12$. Choice A repeats the number of years.
9. D. A longer term spreads the principal into smaller payments but charges interest for more months. Choice B reverses this.
10. 235.37 dollars. $i = 0.01$, $n = 24$: $M = \frac{5000(0.01)}{1 - 1.01^{-24}} = 235.37$.
11. 1256.85 dollars. $i = 0.004$, so $F = 50 \cdot \frac{1.004^{24} - 1}{0.004} \approx 1256.85$.
12. 187.88 dollars. $i = 0.005$, $n = 48$: $M = \frac{8000(0.005)}{1 - 1.005^{-48}} \approx 187.88$.
13. 70 dollars. Monthly rate $\frac{0.24}{12} = 0.02$, and $3500(0.02) = 70$.
14. 1034.77 dollars. Month 1: interest 18, balance $1200 + 18 - 100 = 1118$. Month 2: interest 16.77, balance $1118 + 16.77 - 100 = 1034.77$.
15. 9 years. $\frac{72}{8} = 9$. (Check: $1.08^9 \approx 1.999$.)

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