Welcome Back!
Differential Calculus

Instructor:

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South Hall 6701

Office Hours:

T R 11-11:50, T 3:45-4:35 Details on Gauchospace.

Warm-up

- $\log(x) = 5$

Warm-up

- $\log(x) = 5$ $\qquad x = \boxed{10^5}$

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- $\log(\log(x)) = 2$

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  $8700 = 8.7 \cdot 10^3$ $\quad \log(8700) = \log(8.7) + 3$
- $10^{4x-5} = 7$ $\quad x = \boxed{(\log(7) + 5)/4} \approx \boxed{?}$ just leave it that way

Logarithm Strategy

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- $4^{2x+1} = 3$ $\qquad x = \boxed{(\log_4(3) - 1)/2} = (\frac{\log(3)}{\log(4)} - 1)/2$

In general,

$$\boxed{\log_b(x) = \frac{\log(x)}{\log(b)}}$$

Midterm 2: One week from today

Bring:

- A pen or sharp pencil.
- A 3" $\times$ 5" card with your notes.
- Student ID.

Don't bring:

- A calculator

No bluebook or scratch paper necessary, just the above materials and hopefully a fresh, well-practiced you! Scratch paper will be provided.

Midterm 2 Topics

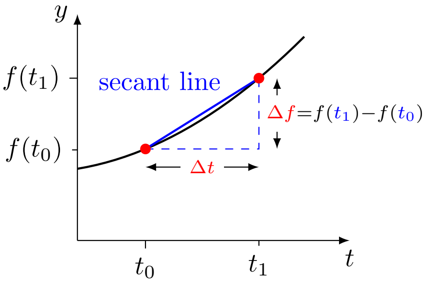
- All topics from Midterm 1
- Sums (like the example below, more examples on Gauchospace)

$$\sum_{n=1}^{4} 2^n - 1$$

- Advanced Logarithm Methods (the full chapter on logarithms in the book)
- Change and Average Rate of Change for a function or graph.
- Limits with h (used to find exact speed, examples on the old midterm and extra problems)

If you struggled on Midterm 1 with algebra or word problems, you need to improve these skills immediately. **They are essential for success in this course**.

Graphical Approach



Δf = change in f
Δt = change in t

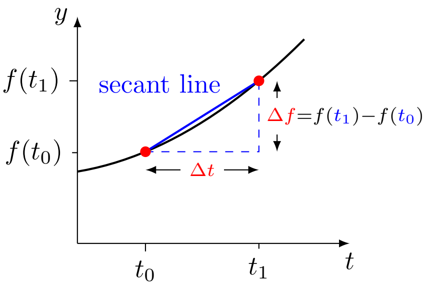
Many ways to say same thing:

$$\left(\begin{array}{c}\text{average rate of}\\ \text{change of } f\end{array}\right) = \frac{\text{change in } f}{\text{change in } t}$$

$$= \frac{\Delta f}{\Delta t}$$

$$= \text{slope of secant line} = \frac{f(t_1) - f(t_0)}{t_1 - t_0}$$

Graphical Approach



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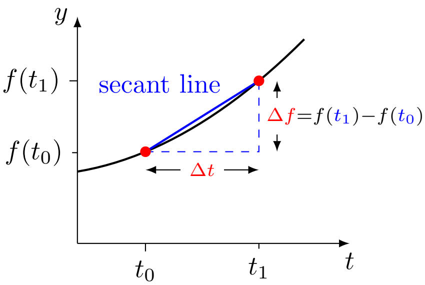

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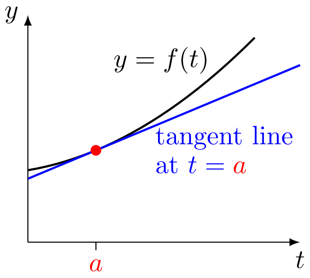
Idea: As t_1 moves closer to t_0 the secant line approaches the tangent line at t_0. This is the line with the same slope as the graph at t_0.

Understanding Derivatives

There are many ways to think about derivatives. We need to understand how derivatives apply to problems.



slope of graph at a
= slope of tangent line
= instantaneous rate of change of f at a

$$= \left(\begin{array}{c} \text{limit of average rate of change} \\ \text{of } f \text{ over shorter and shorter} \\ \text{time intervals starting at } a \end{array} \right)$$

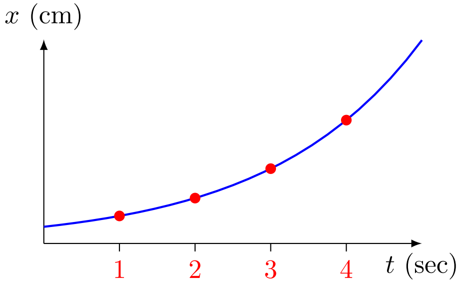
= limit of slopes of secant lines

$$= f'(a) = \left.\frac{df}{dt}\right|_{t=a}$$

Summary

- How fast something changes = rate of change
- Instantaneous rate of change is the limit of the average rate of change over shorter and shorter time spans. This gets around the changing speed problem, and works a whole lot better that getting frustrated and trying $0/0$.
- speed = rate of change of distance traveled.

Speed=Slope=Derivative



The graph shows the distance from the origin in cm after t seconds of a hamster. Which of the numbers below is the largest?

Hint: Speed is a slope!

A = speed of the hamster at $t = 1$

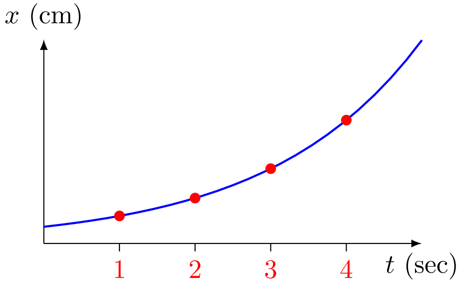
B = speed of the hamster at $t = 2$

C = speed of the hamster at $t = 3$

D = average speed of the hamster between $t = 2$ and $t = 3$

E = average speed of the hamster between $t = 3$ and $t = 4$

Speed=Slope=Derivative



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Answer: $\boxed{\text{E}}$

Practical Meaning

Our goal is that you understand the practical meaning of the derivative in various situations.

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$$
\begin{aligned}
f(t) &= \text{temperature in }^\circ\text{ F at } t \text{ hours after midnight} \\
f(7) &= 48 \text{ means the temperature at 7am was } 48^\circ \text{ F} \\
f'(7) &= 3 \text{ means at 7am the temperature was rising at a rate of } 3^\circ \text{ F/hr} \\
f'(9) &= -5 \text{ means at 9am the temperature was falling at a rate of } 5^\circ \text{ F/hr} \\
&\qquad \text{or rising at a rate of } -5^\circ \text{ F/hr}
\end{aligned}
$$

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$$f'(9) = -5 \text{ means at } 9\text{am the temperature was falling at a rate of } 5^\circ \text{ F/hr}$$
$$\text{or rising at a rate of } -5^\circ \text{ F/hr}$$

$$g(t) = \text{distance from origin in cm of hamster on } x\text{-axis after } t \text{ seconds}$$
$$g(7) = 3 \text{ means after } 7 \text{ seconds hamster was } 3 \text{ cm from origin}$$
$$g'(9) = -5 \text{ means after } 9 \text{ seconds our furry friend was running towards}$$
$$\text{the origin at a speed of } 5 \text{ cm/sec}$$

Another Context

Suppose $f(t) =$ temperature of oven in °C after t minutes.

What do $f(3) = 20$ and $f'(3) = 15$ mean?

- A After 20 minutes the oven was at 3° C and heating up at a rate of 15° C/min
- B After 3 minutes oven temperature was 15° C and cooling down at a rate to 20° C/min
- C The oven was heating up at rate of 3° C/min after 15 minutes and also after 20 minutes
- D After 3 minutes the oven was at 20° C and heating up at a rate of 15° C/min
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Answer: $\boxed{\text{D}}$

Context: Population

Suppose $f(t)$ = the population of the ancient city of Lyrad in year t. We are told that $f(1550) = 1820$ and $f'(1650) = 1100$. Which of the following is true?

- A In 1550, the population was 1820 and rising at a rate of 1100 people per year
- B In 1650, the population was 1100 more than in 1550
- C In 1650, Lyrad contained 1100 people
- D In 1550, there were 1820 people in Lyrad, and by 1650 this had increased to 2920
- E None of above

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Answer: $\boxed{\text{E}}$

Context: Mathematics

Suppose $f(0) = 50$ and $f(10) = 70$. Which of the following is true?

A For all t between 0 and 10, the derivative is $f'(t) = 2$

B $f'(0) = 2$

C It is possible that $f'(0) = -8$

D It is impossible that $f'(0) = -8$

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Answer: $\boxed{\text{C}}$

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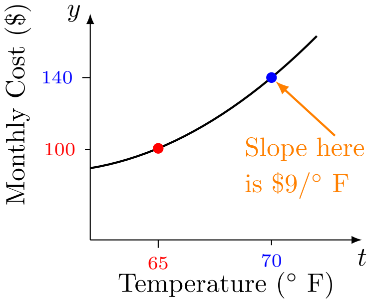
E None of above

Answer: $\boxed{\text{C}}$

We'll see later that, for example, that $f(x) = x^2 - 8x + 50$ has $f(0) = 50$, $f(10) = 70$, and $f'(0) = -8$.

It doesn't have to be about time!



$f(x)$ = monthly cost of heating house to $x°$ F

$f(70) = 140$ means it costs \$140 to heat the house for one month to a temperature of 70°F.

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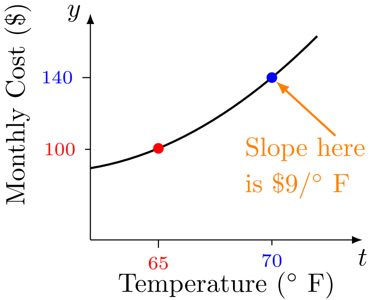

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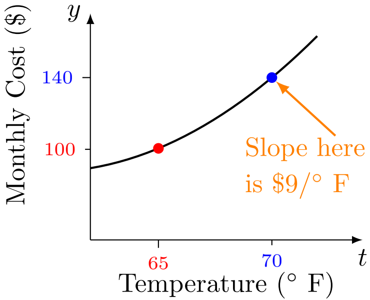

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In practical terms this means you pay an extra $9 during each month for each extra $1^o F$. If you turn it up two degrees you pay an extra $18 each month. Each extra degree of warmth costs an extra $9 each month. In economics this is called a marginal cost or marginal rate

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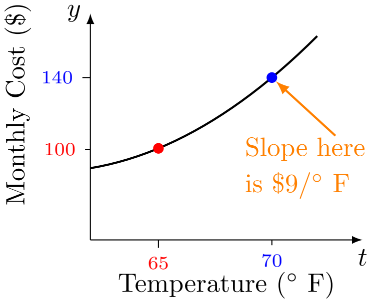

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This is not exactly true:

average rate of change versus instantaneous rate of change.

In the following examples we will ignore this subtlety.

Get Pumped!

Adrenaline cause the heart to speed up.
x = number of mg (milligrams) of adrenaline in the blood.
$f(x)$ = number of beats per minute (bpm) of the heart with x mg of adrenaline in the blood.

What does $f'(5) = 2$ mean?

- A When there are 5 mg of adrenaline the heart beats at 2 pbm
- B When the amount of adrenaline is increased by 2 mg the heart speeds up by 5 bpm
- C When the heart beats at 5 bpm the adrenaline is increased by 2 mg
- D When there are 5 mg of adrenaline the heart speeds up by 2bpm
- E When there are 5 mg of adrenaline in the blood the heart speeds up by 2 bpm for each extra mg of adrenaline.

Hint: The units of $f'(5)$ are bpm per milligram of adrenaline

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One quantity, y, depends on another quantity x.
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In our example, the derivative is 7. This tells you:

the output $= y$ of the function changes
7 times as fast
as the input $= x$ to the function.

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7 times as fast
as the input $= x$ to the function.

If x is changed by 0.1 how much does y change by?

A= 7 B= 7.1 C= 0.7 D= 0.1/7 E= other

Summary of Derivatives

One quantity, y, depends on another quantity x.
In other words y is a function of x so $y = f(x)$. Example: $y = 7x$

If you change x, then y changes.
Question: How quickly does y change as x changes?

Answer: The derivative tells you.

In our example, the derivative is 7. This tells you:

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If x is changed by 0.1 how much does y change by?

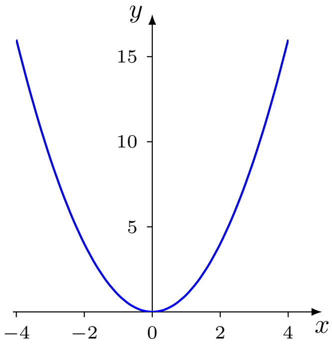
A$= 7$ B$= 7.1$ C$= 0.7$ D$= 0.1/7$ E$=$ other $\boxed{\text{C}}$

Graphical Meaning

$$\frac{d}{dx}\left(x^2\right) = 2x$$

What this means

The slope of the graph of $y = x^2$ at $x = a$ is $2a$



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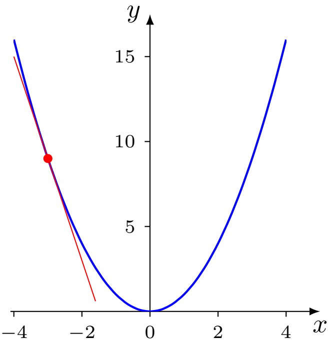

at $x = -3$, slope is $2(-3) = -6$

Graphical Meaning

$$\frac{d}{dx}\left(x^2\right) = 2x$$

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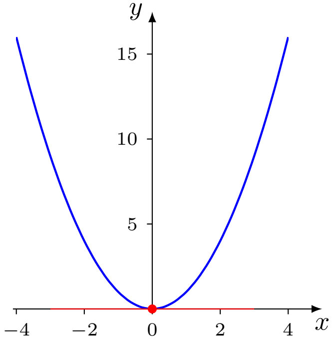
The slope of the graph of $y = x^2$ at $x = a$ is $2a$



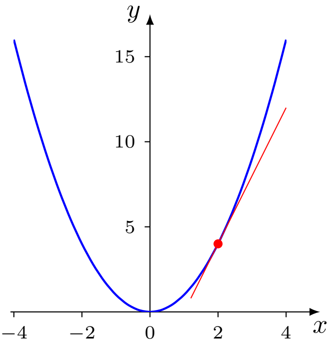
at $x = 0$, slope is $2(0) = 0$

Graphical Meaning

$$\boxed{\frac{d}{dx}\left(x^2\right) = 2x}$$

What this means

The slope of the graph of $y = x^2$ at $x = a$ is $2a$



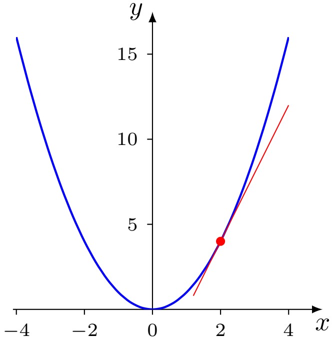
at $x = 2$, slope is $2(2) = 4$

Graphical Meaning

$$\frac{d}{dx}\left(x^2\right) = 2x$$

What this means

The slope of the graph of $y = x^2$ at $x = a$ is $2a$

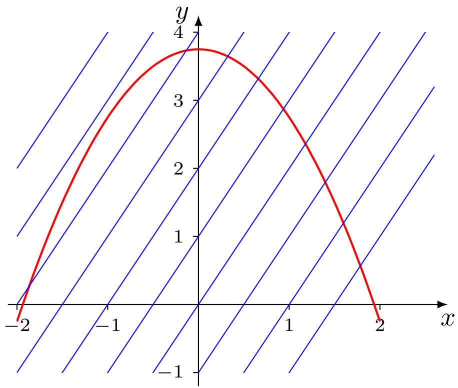


at $x = 2$, slope is $2(2) = 4$

derivative = rate of change = slope of graph = slope of tangent line

Slope Question

This graph shows $y = f(x)$ and lines parallel to $y = 2x$

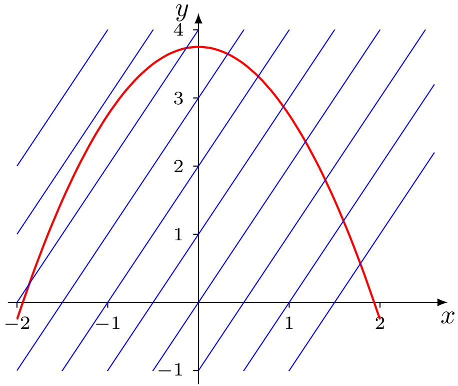


Question: For which values of x is $f'(x) > 2$?

A $x < 1.2$ B $x < 0$ C $x < -1.5$ D $x < -1$ E $x < -0.5$

Slope Question

This graph shows $y = f(x)$ and lines parallel to $y = 2x$



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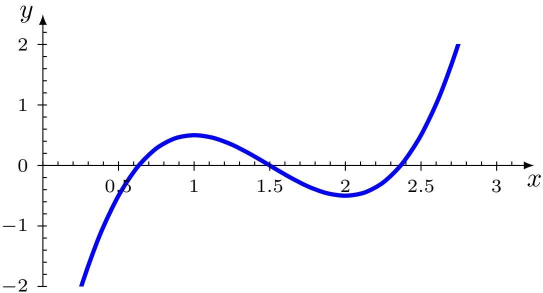
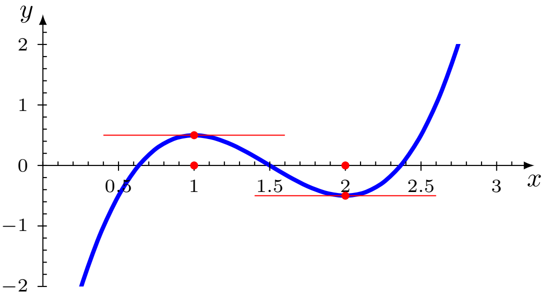
More Slope Questions



(1) For which values of x is $f'(x) = 0$?

A= none B= $\{0.63,\ 1.5, 2.38\}$ C= 1 D= $\{1, 2\}$ E= 2

More Slope Questions



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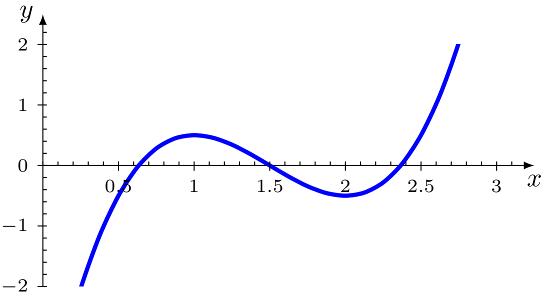


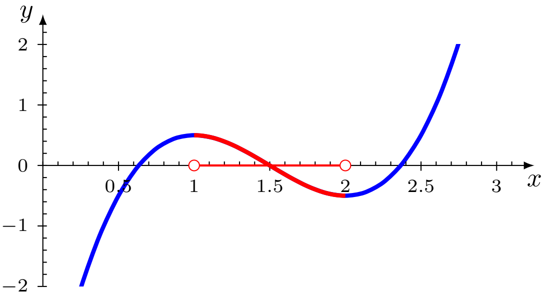
(1) For which values of x is $f'(x) = 0$?

A= none B= $\{0.63,\ 1.5, 2.38\}$ C= 1 D= $\{1, 2\}$ E= 2 $\boxed{\text{D}}$

(2) For which values of x is $f'(x) < 0$?

A $x < 0.63$ B $x < 1$ C $1 < x < 2$ D $1.5 < x < 2.38$ E none

More Slope Questions



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(2) For which values of x is $f'(x) < 0$?

A $x < 0.63$ B $x < 1$ C $1 < x < 2$ D $1.5 < x < 2.38$ E none $\boxed{\text{C}}$

That's it. Thanks for being here.