# A "cheat-proof" calculus exam

Lew Ludwig

Denison University

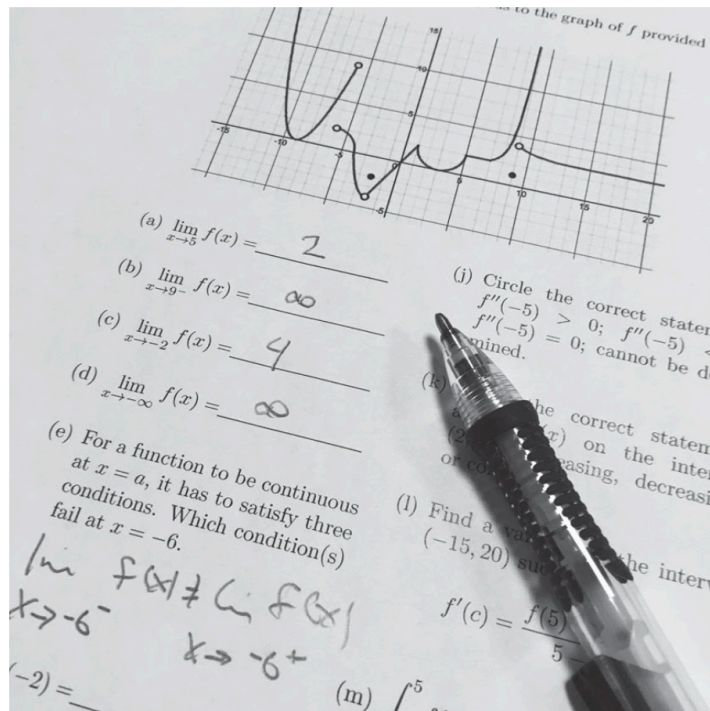Dept of Mathematics – Center for Learning and Teaching

CfLT

# Our game plan

- Pre-COVID – the one question calculus final

- What COVID did to our teaching – the surveillance state

- A lucky break

- The particulars

- Some bold claims and a chance to push back

- Does it transfer?

# The one question calculus final



The One Question Calculus Final

Lew Ludwig

# The one question calculus final

Use the following graph of the function $f$ to answer the questions below.
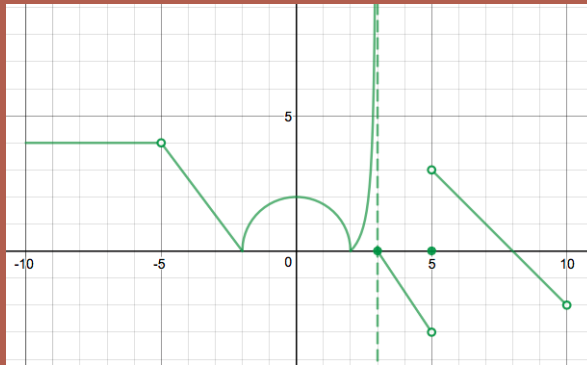


FIGURE 1. Graph of $f(x)$

(a) $\lim\limits_{x \to 5} |f(x)| = $ _____

(b) $\lim\limits_{x \to -5} f'(x) = $ _____

(c) $\lim\limits_{h \to 0} \dfrac{f(2+h) - f(2)}{h} = $ _____

(d) For a function to be continuous at $x = a$, it has to satisfy three conditions. Which condition fails for $f$ at $x = -5$? _____

(e) $f'(0) = 0$: must be true; must be false; cannot be determined (circle the correct response).

(f) If $g(x) = f(x^2)$, then $g'(-3) = $ _____

(g) Suppose $y^2 + [f(x)]^2 = 2$, then $\left.\dfrac{dy}{dx}\right|_{(7,1)} = $ _____

(h) Circle the correct statement $f''(\sqrt{3}) > 0$; $f''(\sqrt{3}) < 0$; $f''(\sqrt{3}) = 0$; cannot be determined.

(i) On the interval $[3, 10]$, $f$: does attain an absolute maximum; does not attain an absolute maximum; cannot be determined. (circle the correct repsonse).

(j) There exists a value $c$ on the interval $[-2, 0]$ such that $f(c) = \sqrt{2}$: must be true; must be false; cannot be determined (circle the correct response).

(k) There exists a value $c$ on the interval $[0, 2]$ such that $f'(c) = \dfrac{f(2) - f(0)}{2 - 0}$: must be true; must be false; cannot be determined (circle the correct response).

(l) For what value $c$ on the interval $[-10, 10]$ can the second derivative test be used? _____

(m) For $x_0 = -8$, $x_1 = -7$, $x_2 = -6$, $x_3 = -5$, $x_4 = -4$, $\sum\limits_{i=1}^{4} f(x_i)\Delta x_i = $ _____

(n) If $g(x) = \int_0^x f(t)\, dt$, then $g(2) = $ _____

(o) On the interval $[6, 9]$, $\int f(x)\, dx = $ _____

(p) $\int_3^8 f(x)\, dx = $ _____

1

https://drive.google.com/file/d/1BqSFwRqK6M3dSUqhXQjkpQBffarMAekM/view?usp=sharing

Notice & Wonder

(a) $\lim\limits_{x \to 5} |f(x)| = $ _____

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(c) $\lim\limits_{h \to 0} \dfrac{f(2+h) - f(2)}{h} = $_____

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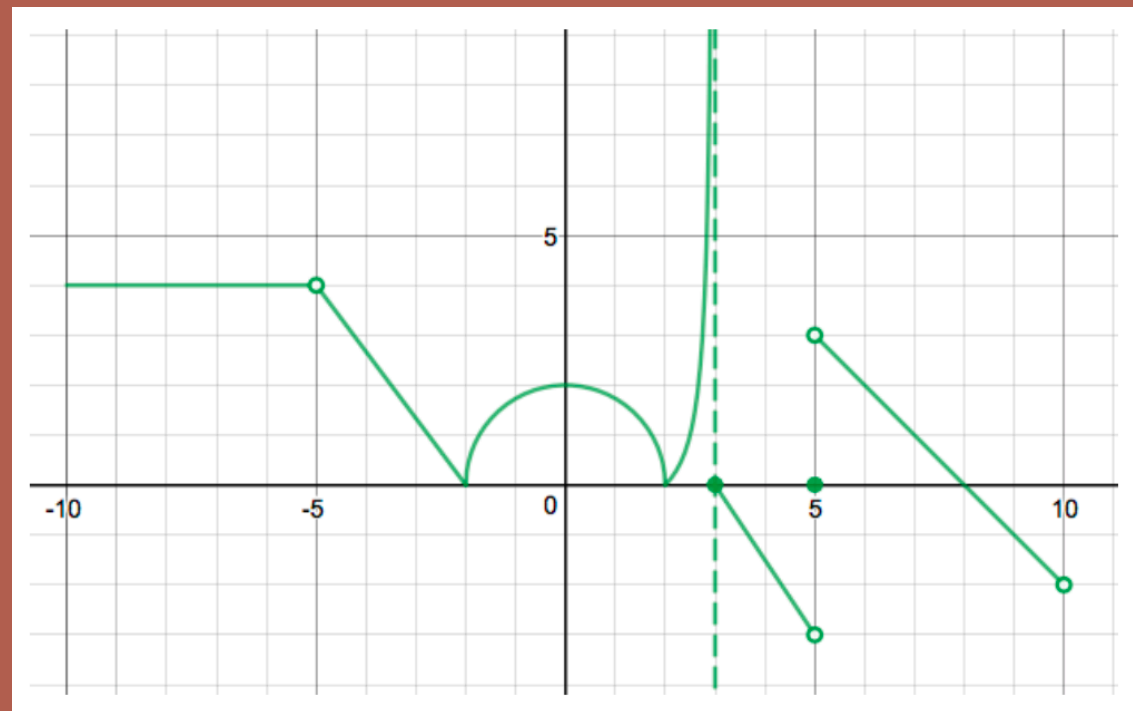(e) $f'(0) = 0$: must be true; must be false; cannot be determined (circle the correct response).

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1

| Topic | | |
|---|---|---|
| Limit | Critical point | Riemann Sum |
| Continuity | Inflection point | Indefinite Integral |
| Discontinuity | Second derivative test | Fund Thm Calculus |
| Definition of Derivative | Intermediate Value Thm | Definite Integral |
| Chain rule | Extreme Value Thm | |
| Implicit Differentiation | Mean Value Thm | |



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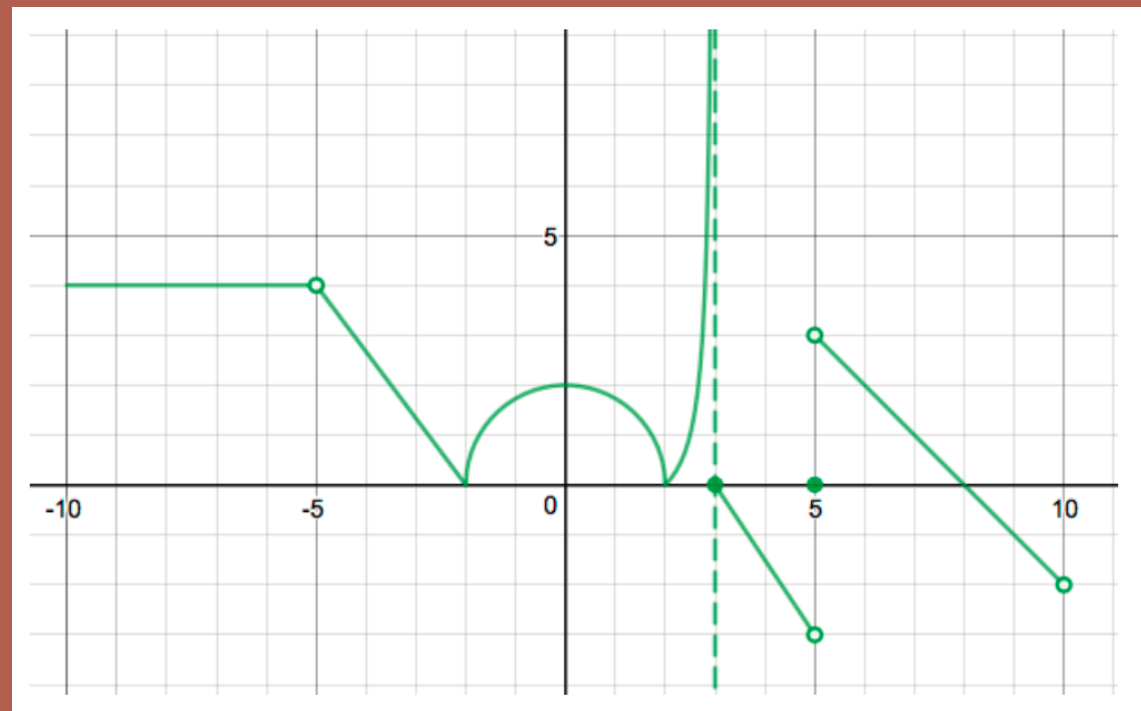(e) $f'(0) = 0$: must be true; must be false; cannot be determined (circle the correct response).

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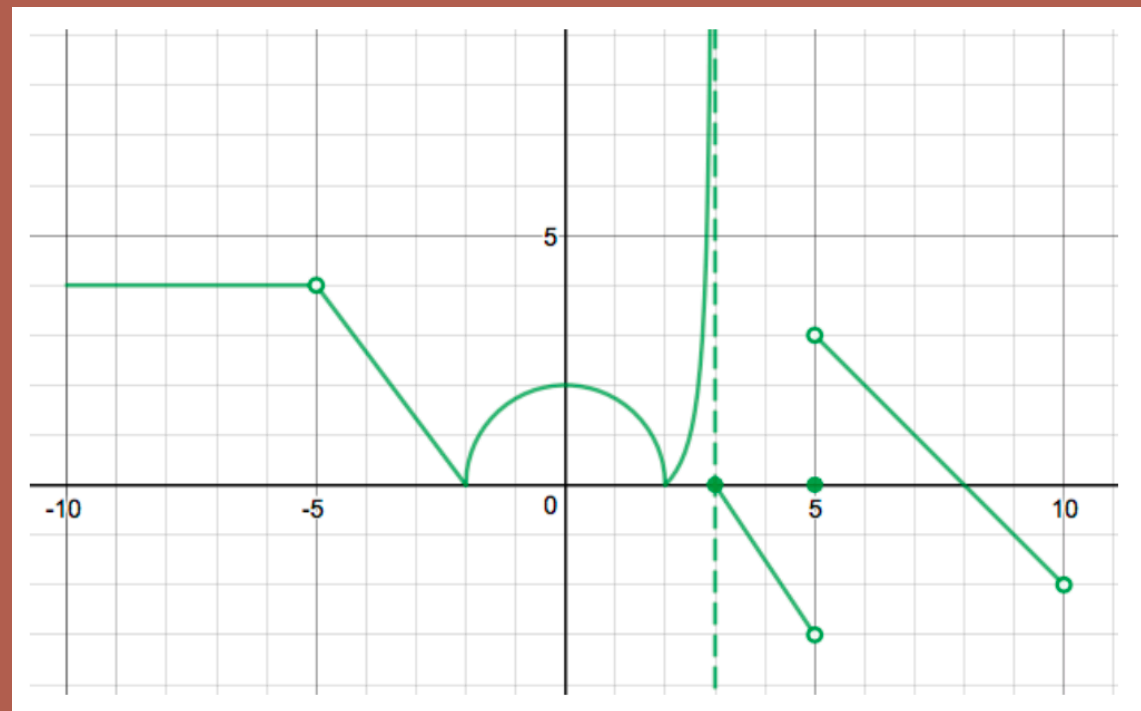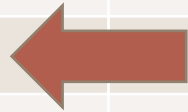(e) $f'(0) = 0$: must be true; must be false; cannot be determined (circle the correct response).

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(j) There exists a value $c$ on the interval $[-2, 0]$ such that $f(c) = \sqrt{2}$: must be true; must be false; cannot be determined (circle the correct response).

(k) There exists a value $c$ on the interval $[0, 2]$ such that $f'(c) = \dfrac{f(2) - f(0)}{2 - 0}$: must be true; must be false; cannot be determined (circle the correct response).

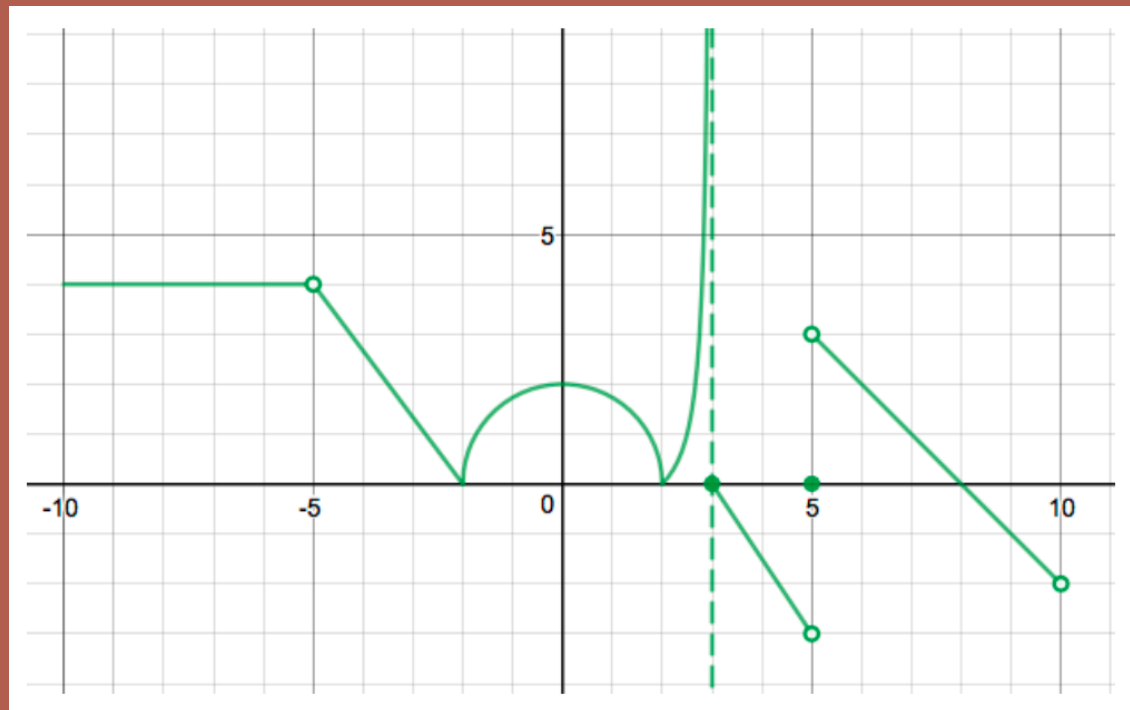(l) For what value $c$ on the interval $[-10, 10]$ can the second derivative test be used? _____

(m) For $x_0 = -8$, $x_1 = -7$, $x_2 = -6$, $x_3 = -5$, $x_4 = -4$, $\displaystyle\sum_{i=1}^{4} f(x_i)\Delta x_i = $ _____

(n) If $g(x) = \int_0^x f(t)\, dt$, then $g(2) = $ _____

(o) On the interval $[6, 9]$, $\displaystyle\int f(x)\, dx = $ _____

(p) $\displaystyle\int_3^8 f(x)\, dx = $ _____

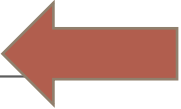| Topic | | |
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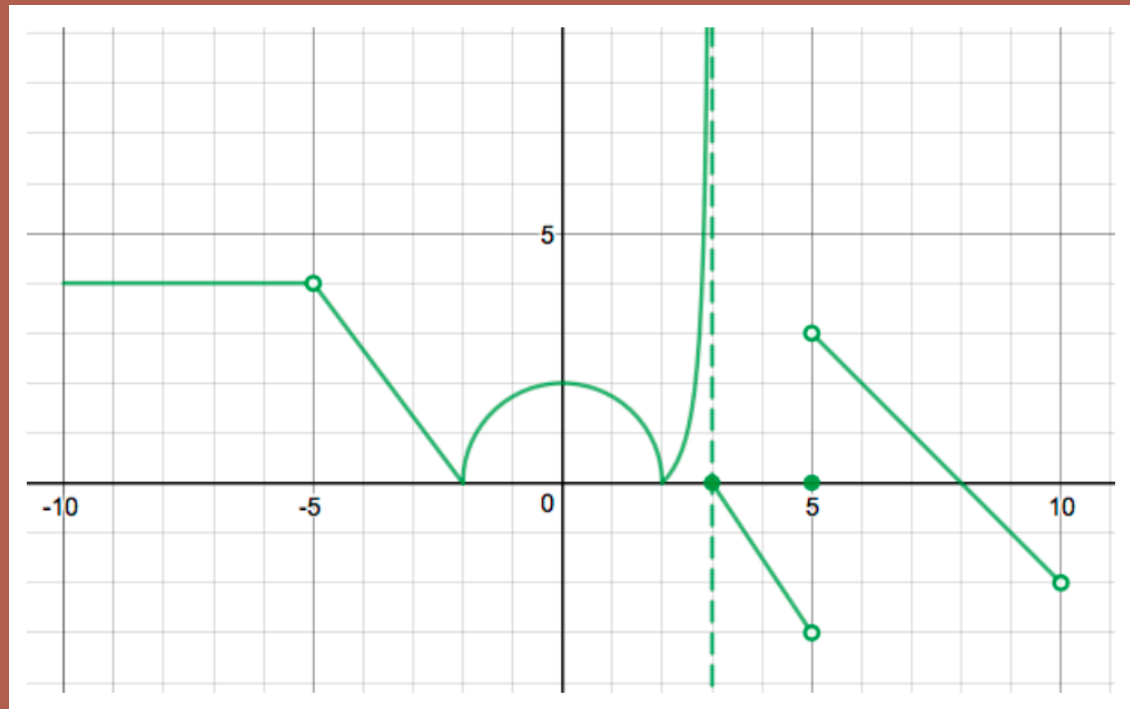(l) For what value $c$ on the interval $[-10, 10]$ can the second derivative test be used? _____

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Some words of warning

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- *Scaffold*

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- *[Scaffold](#)*

# Some words of warning

- *Scaffold*
- *Scaffold*
- ***Scaffold***

(a) $f(5) =$ _____

(b) $\lim\limits_{x \to -2} f(x) =$ _____

(c) $\lim\limits_{x \to -4} (f(x) + 3x^2) =$ _____

(d) $\lim\limits_{x \to 3^-} f(x) =$ _____

(e) $\lim\limits_{x \to -6} f(x) =$ _____

(f) $\lim\limits_{x \to -\infty} f(x) =$ _____

(g) $f'(-2) =$ _____

(h) $f'(3) =$ _____

(i) $\lim\limits_{x \to 8} \dfrac{f(x) - f(0)}{x - 8} =$ _____

(j) $\lim\limits_{h \to 0} \dfrac{f(h) - 2}{h} =$ _____

Test 1

(a) $f(5) =$ _____

(b) $\lim_{x \to -2} f(x) =$ ___

(c) $\lim_{x \to -4} (f(x) + 3x$

(d) $\lim_{x \to 3^-} f(x) =$ ___

(e) $\lim_{x \to -6} f(x) =$ ___

(f) $\lim_{x \to -\infty} f(x) =$ ___

(g) $f'(-2) =$ _____

(h) $f'(3) =$ _____

(i) $\lim_{x \to 8} \dfrac{f(x) - f(0)}{x - 8}$

(j) $\lim_{h \to 0} \dfrac{f(h) - 2}{h} =$ _

(a) $\lim_{x \to -\infty} f(x) =$ _____

(b) $\lim_{x \to \infty} f'(x) =$ _____

(c) $f'(6) =$ _____

(d) $\lim_{x \to -3} f(x) =$ _____

(e) $\lim_{x \to 5^-} f(x) =$ _____

(f) $\lim_{x \to 2} \dfrac{f(x) - 5}{x - 2} =$ _____

(g) If $h(x) = \dfrac{f(x)}{x}$, then

$h'(10) =$ _____

(h) If $g(x) = f(x^2)$,

then $g'(1) =$ _____

(i) $f(5) =$ _____

(j) For a function to be continuous at $x = a$, it has to satisfy three conditions. Check these three conditions for $f$ at $x = -3$

# Test 2

(a) $f(5) =$___

(b) $\lim_{x \to -2} f(x) =$ __

(c) $\lim_{x \to -4} (f(x) + 3x$

(d) $\lim_{x \to 3^-} f(x) =$__

(e) $\lim_{x \to -6} f(x) =$__

(f) $\lim_{x \to -\infty} f(x) =$__

(g) $f'(-2) =$___

(h) $f'(3) =$___

(i) $\lim_{x \to 8} \dfrac{f(x) - f(0)}{x - 8}$

(j) $\lim_{h \to 0} \dfrac{f(h) - 2}{h} =$

(a) $\lim_{x \to -\infty} f(x) =$ _____

(b) $\lim_{x \to \infty} f'(x) =$ _____

(c) $f'(6) =$ _____

(d) $\lim_{x \to -3} f(x) =$ _____

(e) $\lim_{x \to 5^-} f(x) =$ _____

(f) $\lim_{x \to 2} \dfrac{f(x) - 5}{x - 2} =$_____
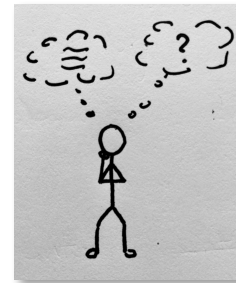
(g) If $h(x) = \dfrac{f(x)}{x}$, then

$h'(10)=$ _____

(h) If $g(x) = f(x^2)$,

then $g'(1) =$ _____

(i) $f(5) =$_____

(j) For a function to be continuous at $x = a$, it has to satisfy three conditions. Check these three conditions for $f$ at $x = -3$

# Test 2

New topics?

(a) $f(5) =$ _____

(c) (b) $\lim\limits_{x\to\infty} f'(x) =$ _____

(d) (c) $f'(6) =$ _____

(e) (d) $\lim\limits_{x\to-3} f(x) =$ _____

(f) (e) $\lim\limits_{x\to5^-} f(x) =$ _____

(g) $f'(-2)$

(h) $f'(2)$   (f) $\lim\limits_{x\to2} \dfrac{f(x)-5}{x-2} =$ _____

(i) $\lim\limits_{x\to8} \dfrac{f(x)-f(0)}{x-8} =$   (g) If $h(x) = \dfrac{f(x)}{x}$, then

(j) $\lim\limits_{h\to0} \dfrac{f(h)-2}{\;}$   $h'(10)=$ _____

---

Be careful whether you are considering: $f$, $f'$, or $f''$.

(a) $f'(-2)=$ _____

(b) $\lim\limits_{x\to3} \dfrac{f(x)-2}{x-3} =$ _____

(c) Suppose $y^2+(f(x))^2 = 5$. Compute $y'$ when $x = -2.5$ and $y = 2$.

_____

(d) $\lim\limits_{x\to-2} f(x) =$ _____

(e) Circle the correct response for the blank provided: $<\,,\,>\,,=$
$f''(-3)$ ___ $f'(-3)$

(f) If $g(x) = \dfrac{x}{f(x)}$, determine

$g'(-3.5) =$ _____

(g) If $g(x) = \displaystyle\int_0^x f(t)\ dt$, then

$g(2) =$ _____

(h) $\displaystyle\int_4^6 f(x)\ dx=$ _____

(i) $\displaystyle\int_{-4}^{t} f(x)\ dx$ is largest at what value of $t$? _____

(j) $\displaystyle\int_{-4}^{-2} f(x)\ dx=$ _____

Test 3

(a) $f(5) =$ ___

(b) $\lim\limits_{x\to-\infty} f(x) =$ ___

(c) $\lim\limits_{x\to\infty} f'(x) =$ ___

(d) $\lim f(x) =$ ___

(e) $\lim f(x) =$ ___

(f) $\lim f(x) =$ ___

(g) $f'(-2) =$ ___

(h) $f'(2) =$ ___

(i) $\lim\limits_{x\to 8} \dfrac{f(x)-f(0)}{x-8} =$ ___

(j) $\lim\limits_{h\to 0} \dfrac{f(h)-2}{h} =$ ___

(a) $\lim\limits_{x\to-\infty} f(x) =$ ___

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(f) $\lim\limits_{x\to 2} \dfrac{f(x)-5}{x-2} =$ ___

(g) If $h(x) = \dfrac{f(x)}{x}$, then $h'(10) =$ ___

Be careful whether you are considering: $f$, $f'$, or $f''$.

(a) $f'(-2) =$ ___

(b) $\lim\limits_{x\to 3} \dfrac{f(x)-2}{x-3} =$ ___

(c) Suppose $y^2 + (f(x))^2 = 5$. Compute $y'$ when $x = -2.5$ and $y = 2$.

___

(d) $\lim\limits_{x\to-2} f(x) =$ ___

(e) Circle the correct response for the blank provided: $<$ , $>$ , $=$
$f''(-3)$ ___ $f'(-3)$

(f) If $g(x) = \dfrac{x}{f(x)}$, determine $g'(-3.5) =$ ___

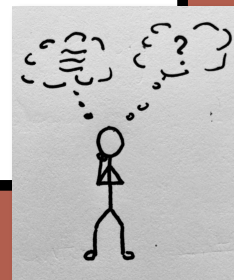(g) If $g(x) = \displaystyle\int_0^x f(t)\ dt$, then $g(2) =$ ___

(h) $\displaystyle\int_4^6 f(x)\ dx =$ ___

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(j) $\displaystyle\int_{-4}^{-2} f(x)\ dx =$ ___

New topics?

Test 3

(a) $f(-5) =$ _____

(b) $f'(5) =$ _____

(c) $f''(8) =$ _____

(d) $\lim_{x \to 0+} f'(x) =$ _____

(e) $\lim_{x \to 3^-} f(x) =$ _____

(f) $\lim_{x \to -3} \dfrac{f(x) - 0}{x + 3}$ _____

(g) If $g(x) = (x^2 \cdot f(x))$, then

$g'(-3) =$ _____

(h) Suppose $y^2 + [f(x)]^2 = 26$. Compute $y'$ when $x = 9$ and $y = 1$.

_____

(i) $\int_{-2}^{2} f(x)\, dx =$ _____

(j) $\int_{9}^{10} f'(x)\, dx =$ _____

(k) If $g(x) = \int_{0}^{x} f(t)\, dt$, then

$g(2) =$ _____

(l) Circle the correct response for the blank provided: $+,\ -,\ 0$:

$\int_{1}^{4} f''(x)\, dx =$ _____

(m) Circle the correct response for the blank provided: $+,\ -,\ 0$:

$\int_{4}^{6} f'''(x)\, dx =$ _____

(n) $f$ has a maximum value on the interval $(0, 7)$: true or false (circle correct response).

(o) Circle the correct response for the blank provided: $<\ ,\ >\ ,=$

$f''(-7) \rule{1cm}{0.4pt} f'(1)$

$f$, $f'$, or $f''$.

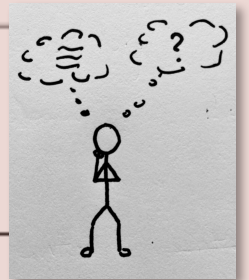(f) If $g(x) = \dfrac{x}{f(x)}$, determine

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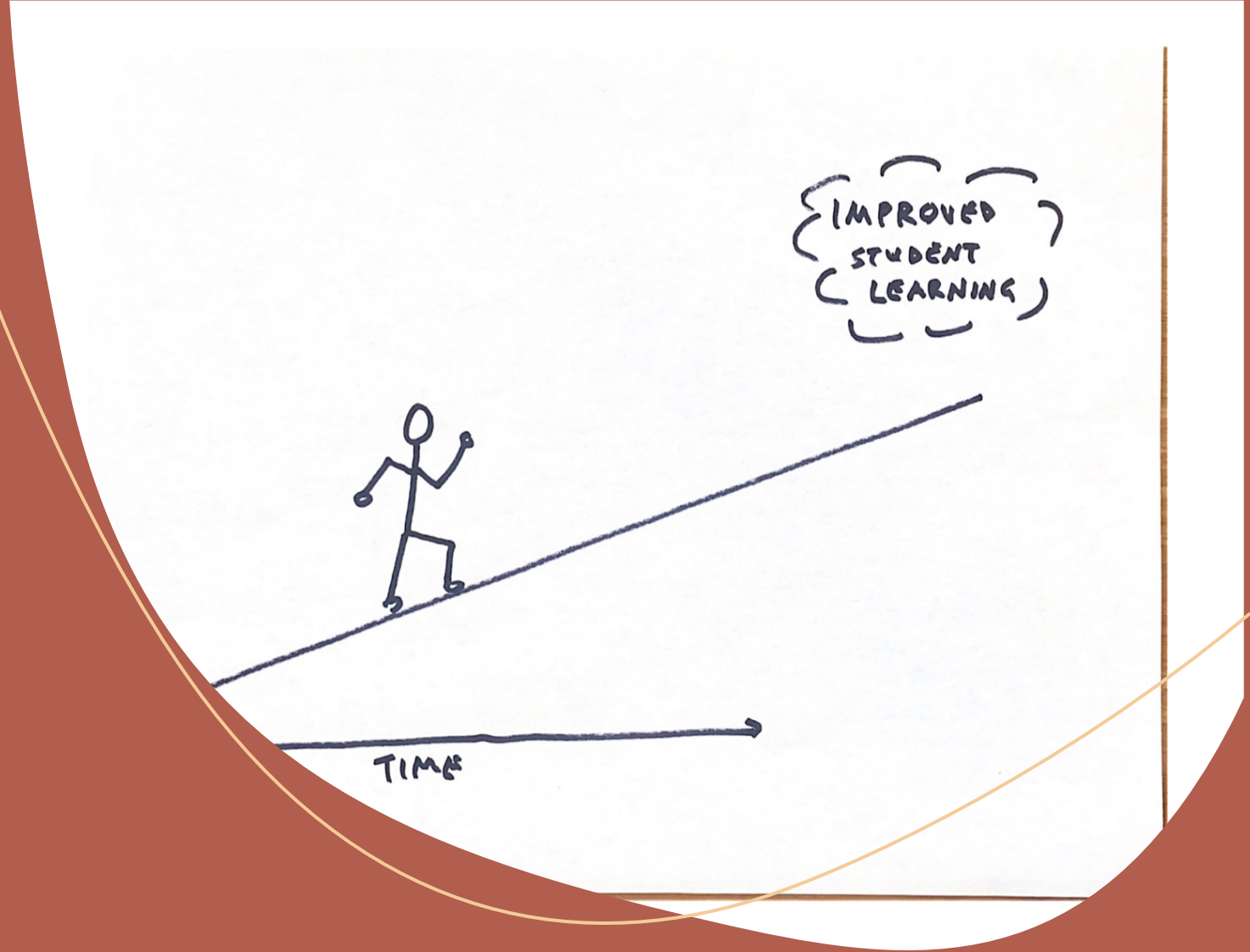
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(h) $\int_{4}^{6} f(x)\, dx =$ _____

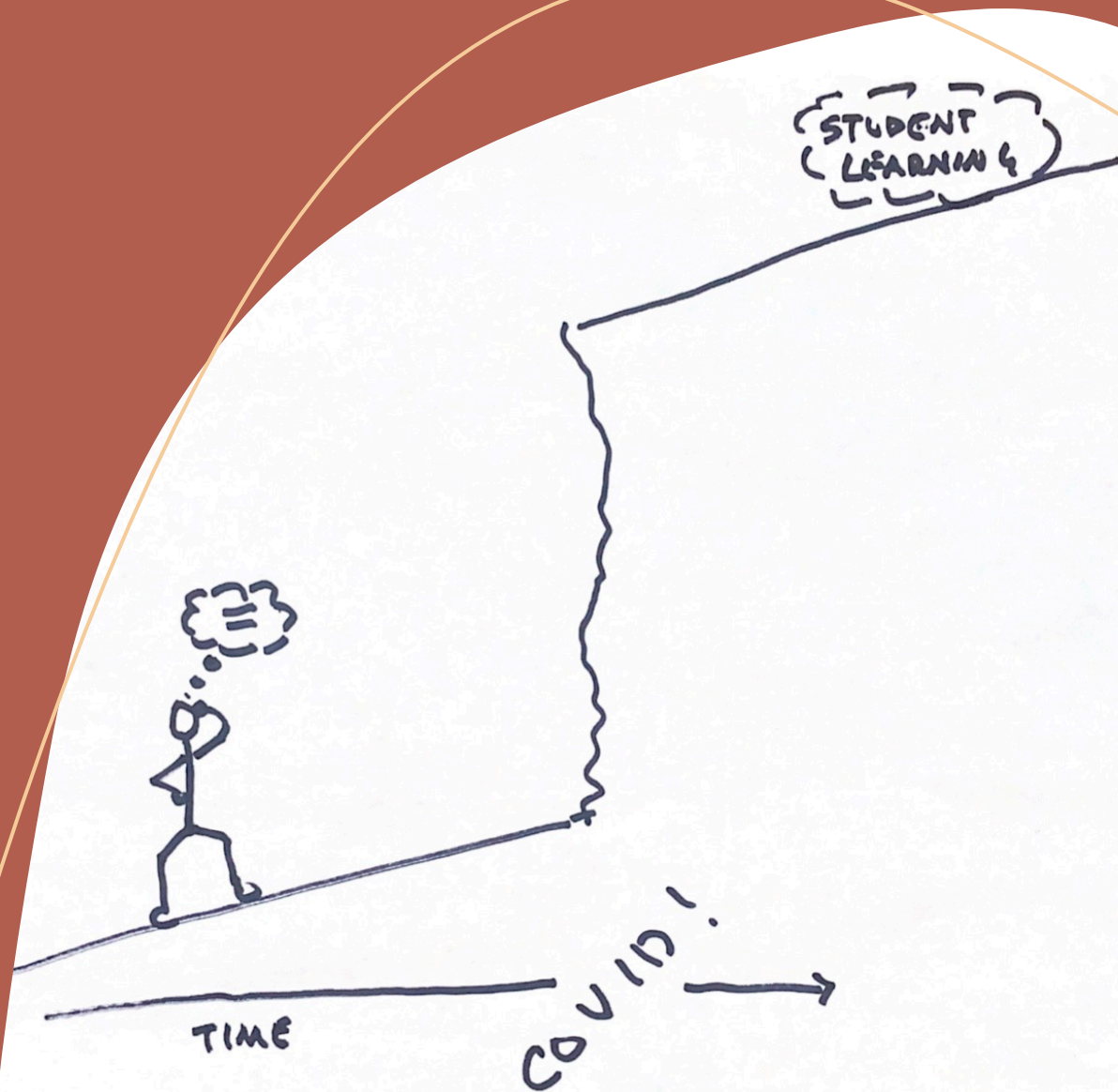(i) $\int_{-4}^{t} f(x)\, dx$ is largest at what value of $t$? _____

(j) $\int_{-4}^{-2} f(x)\, dx =$ _____

New topics?

# Final exam

My teaching pre-COVID

COVID

# A new norm

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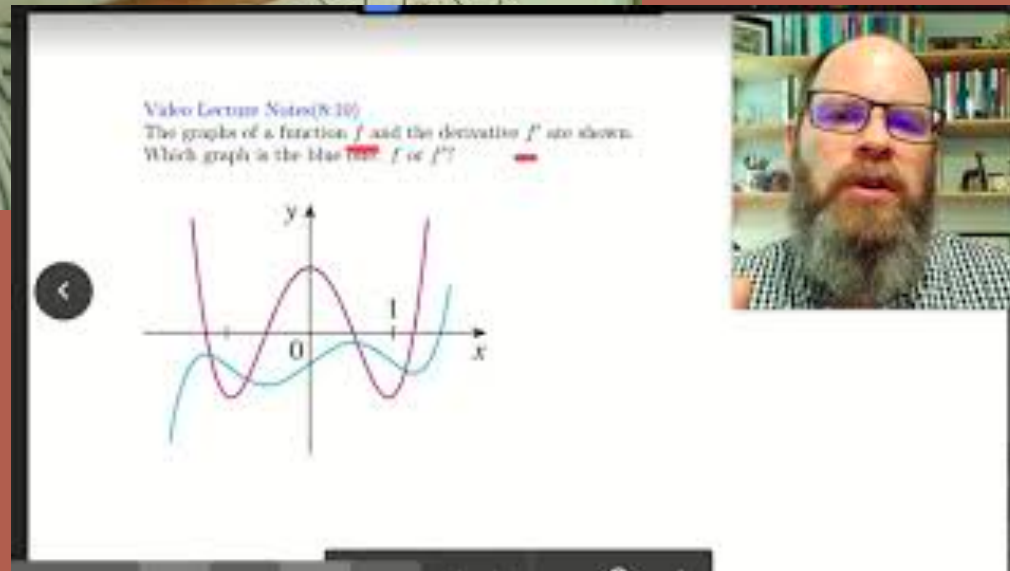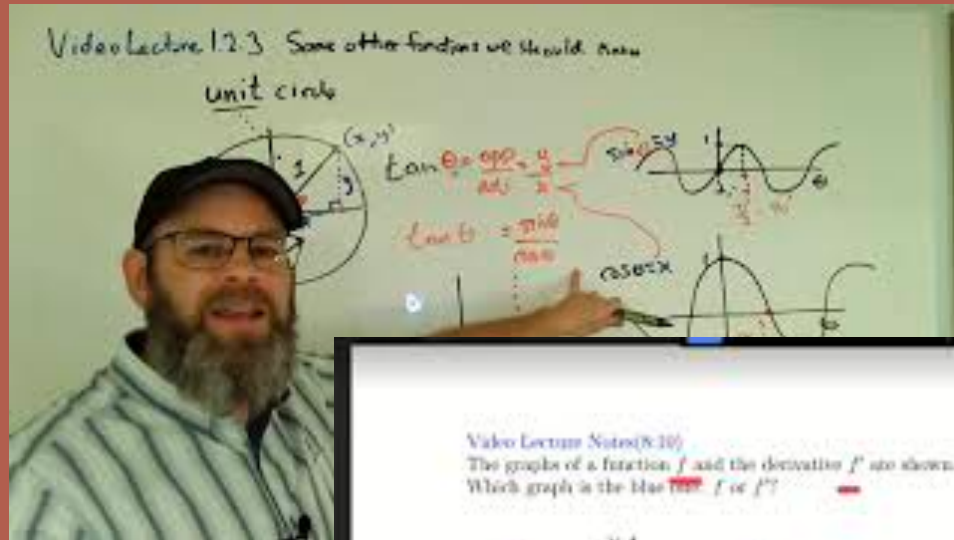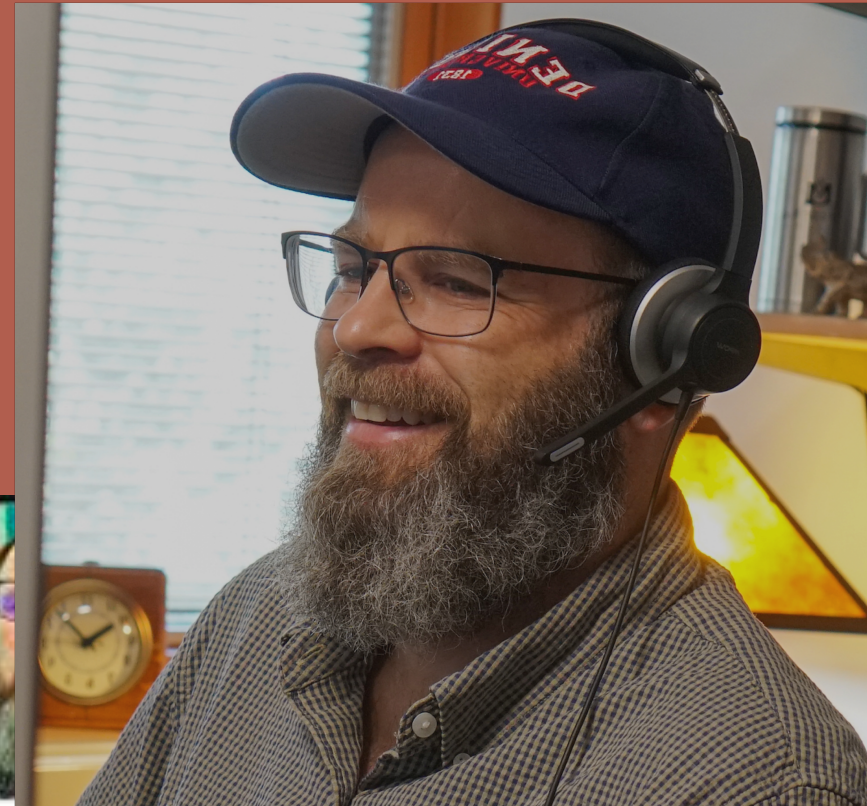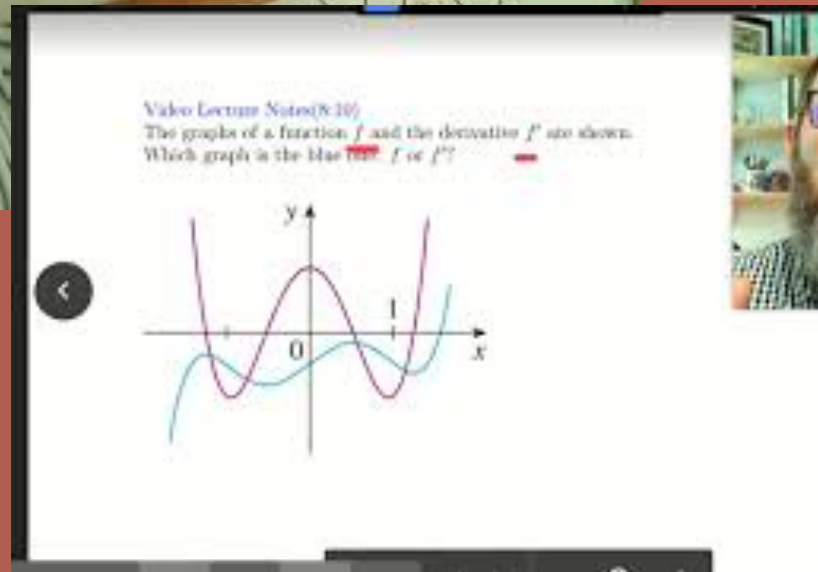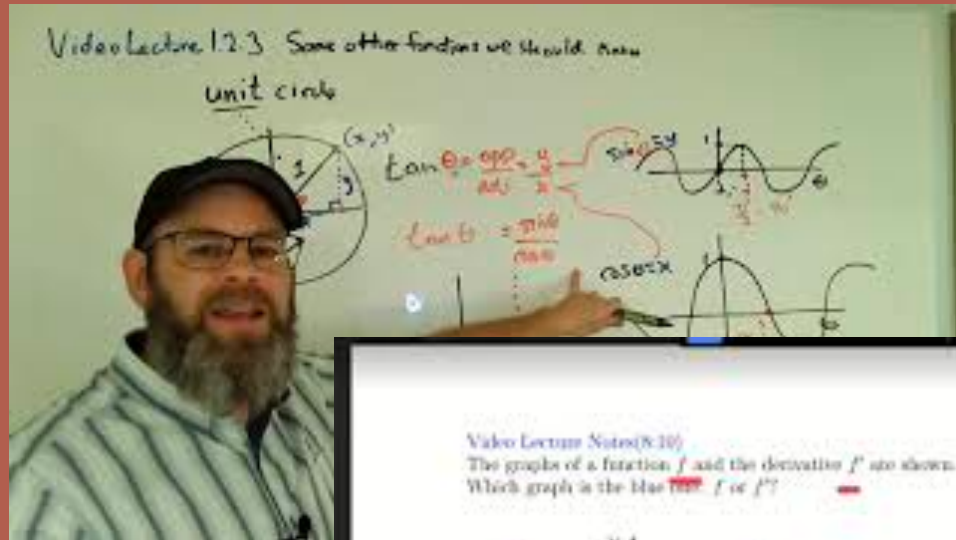
# A new norm

A new norm
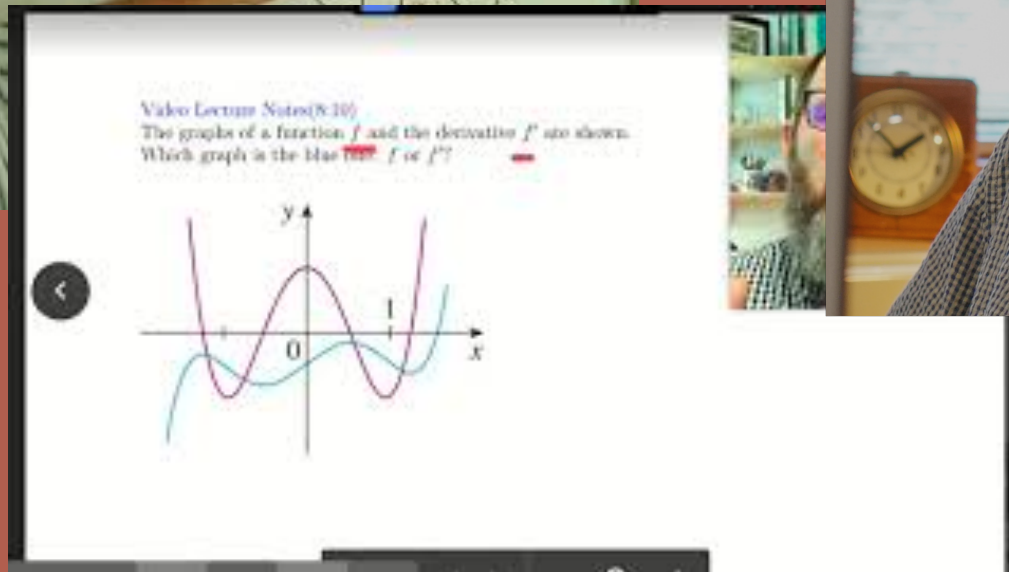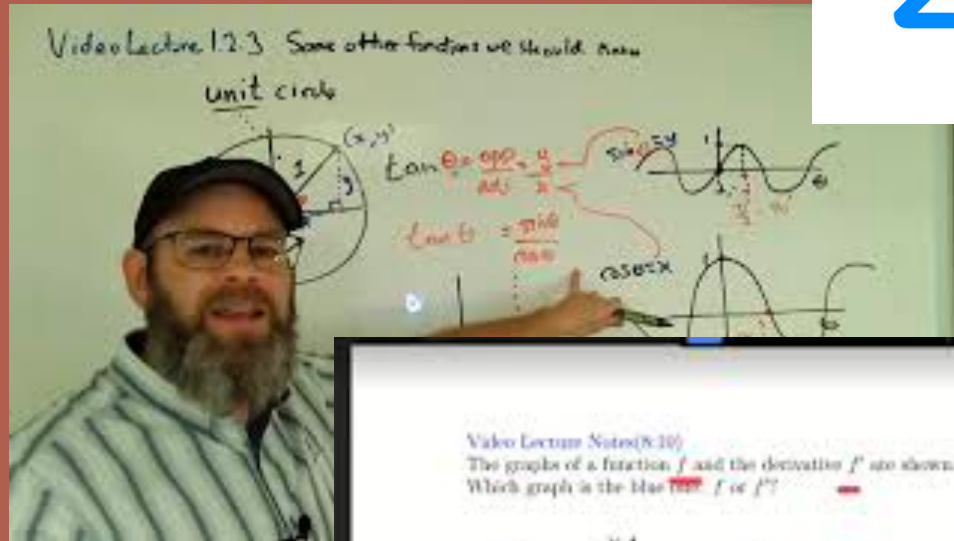
# Online
# Testing
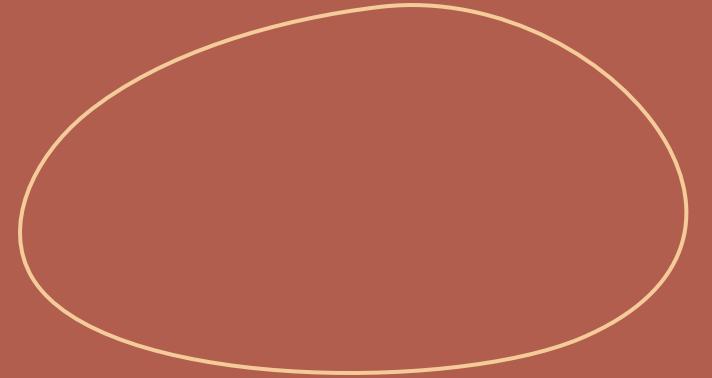
# Online Testing

Online
Testing

# A lucky break…

My students were scaffolded in the graph question, could they create their own?

# Intermission

Take 20 seconds and stare at something 20 feet away

# Intermission

Take 20 seconds and stare at something 20 feet away

What questions do you have?

A "cheat-proof" take-home calculus test

Quiz 04
Math 130, Spring Remote, 2021
Due Friday, 05/14/2021 to NB 23:59

Video – Directions Please watch before starting.
**(50-level)** Create your own graph using demos and 20 questions following below guidelines.
**(43-level)** Use the graph provided on NB to create 19 questions following below guidelines.

(5 points) General guidelines for 50- and 44-level – Be sure to:

- use Word to create a type-written quiz and submit as PDF to NB by 05/14/2021 to NB 23:59.
- create Page 1: include the graph on your PDF and the questions on your PDF, numbered 1-20 (use same order as question guidelines below).
- create Page 2: include the answer followed by a complete solution to each of your questions with enough detail that a classmate would fully understand your reasoning.

(5 points) Specific guidelines for 50-level. Make sure your graph includes:

- a vertical asymptote at $x = 3$
- a horizontal asymptote
- a vertical tangent $x = -3$
- a jump discontinuity at $x = -6$
- a cusp at $x = 6$

(Two points each) Question guidelines for 50- and 43-level – create a question

(1) with a definite integral equal to 0
(2) with a definite integral less than 0
(3) with a definite integral greater than 0
(4) with a definite integral using $f'$
(5) with a definite integral using $f''$
(6) with a definite integral using $f'''$
(7) where a left-handed limit equals $-\infty$
(8) where the limit of $f'$ as $x \to a$ exists, but $f(a) = DNE$
(9) using a limit at infinity
(10) using an infinite limit
(11) using the product rule for $f(x) \cdot \sqrt{x}$
(12) using the quotient rule for $\dfrac{f(x)}{\cos x}$
(13) using the chain rule for $f(x^3)$
(14) using increasing or decreasing to determine $f'$
(15) using concave up or down to determine $f''$
(16) using definition 1 of the derivative
(17) using definition 2 of the derivative
(18) where $f(a) = 3$
(19) where $f(a) = DNE$
(20) where $f'(a) = DNE$

The particulars 3.0

CfLT

Quiz 04
Math 130, Spring Remote, 2021
Due Friday, 05/14/2021 to NB 23:59

Video – Directions Please watch before starting.
(50-level) Create your own graph using demos and 20 questions following below guidelines.
(43-level) Use the graph provided on NB to create 19 questions following below guidelines.

(5 points) General guidelines for 50 and 44 level. Be sure to:
- use Word to create a type-written quiz and submit as PDF to NB by 05/14/2021 to NB 23:59.
- create Page 1: include the graph on your PDF and the questions on your PDF, numbered 1-20 (use same order as question guidelines below).
- create Page 2: include the answer followed by a complete solution to each of your questions with enough detail that a classmate would fully understand your reasoning.

(5 points) Specific guidelines for 50-level. Make sure your graph includes:
- a vertical asymptote at $x = 3$

The particulars 3.0

Video – Directions Please watch before starting.
(50-level) Create your own graph using Desmos and 20 questions following below guidelines.
(43-level) Use the graph provided on NB to create 19 questions following below guidelines.

(13) using the chain rule for $f(x^3)$
(14) using increasing or decreasing to determine $f'$
(15) using concave up or down to determine $f''$
(16) using definition 1 of the derivative
(17) using definition 2 of the derivative
(18) where $f(a) = 3$
(19) where $f(a) = DNE$
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CfLT

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Math 130, Spring Remote, 2021
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- create Page 2: include the answer followed by a complete solution to each your questions with enough detail that a classmate would fully understand your reasoning.

(5 points) Specific guidelines for 50-level. Make sure your graph includes:
- a vertical asymptote at $x = 3$
- a horizontal asymptote
- a vertical tangent $x = -3$

# The particulars 3.0

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(5 points) Specific guidelines for 50-level. Make sure your graph includes:
- a vertical asymptote at $x = 3$
- a horizontal asymptote

- **Access**
- **Equation editor video**
  - **(favorite free editor in chat)**

The particulars 3.0

(5 points) General guidelines for 50- and 44-level – Be sure to:

- use Word to create a type-written quiz and submit as PDF to NB by 05/14/2021 to NB 23:59.
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1

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**Specify audience**

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1

# The particulars 3.0

Video – Directions Please watch before starting.

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(5 points) Specific guidelines for 50-level. Make sure your graph includes:

- a vertical asymptote at $x = 3$
- a horizontal asymptote
- a vertical tangent $x = -3$
- a jump discontinuity at $x = -6$
- a cusp at $x = 6$

(Two points each) Question guidelines for 50- and 43-level – create a question

(1) with a definite integral equal to 0
(2) with a definite integral less than 0
(3) with a definite integral greater than 0

---

(5 points) Specific guidelines for 50-level. Make sure your graph includes:

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CfLT

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# The particulars 3.0

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- a cusp at $x = 6$

(20) where $f'(a) = DNE$

Specifics help with grading

CfLT

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(Two points each) Question guidelines for 50- and 43-level – create a question

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1

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(Two points each) Question guidelines for 50- and 43-level – create a question

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(20) where $f'(a) = DNE$

# Intermission

Take 20 seconds and stare at something 20 feet away

What questions do you have?

# Some **bold** claims

It's "cheat proof"

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can be graded in same or less time as traditional written test

# Some **bold** claims

It's "cheat proof"

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allows student choice and flexibility

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It's "cheat proof"

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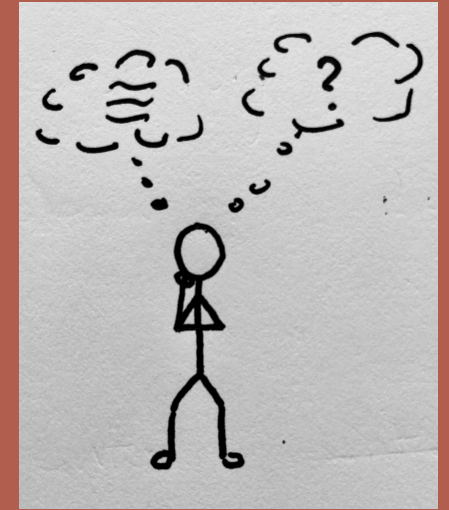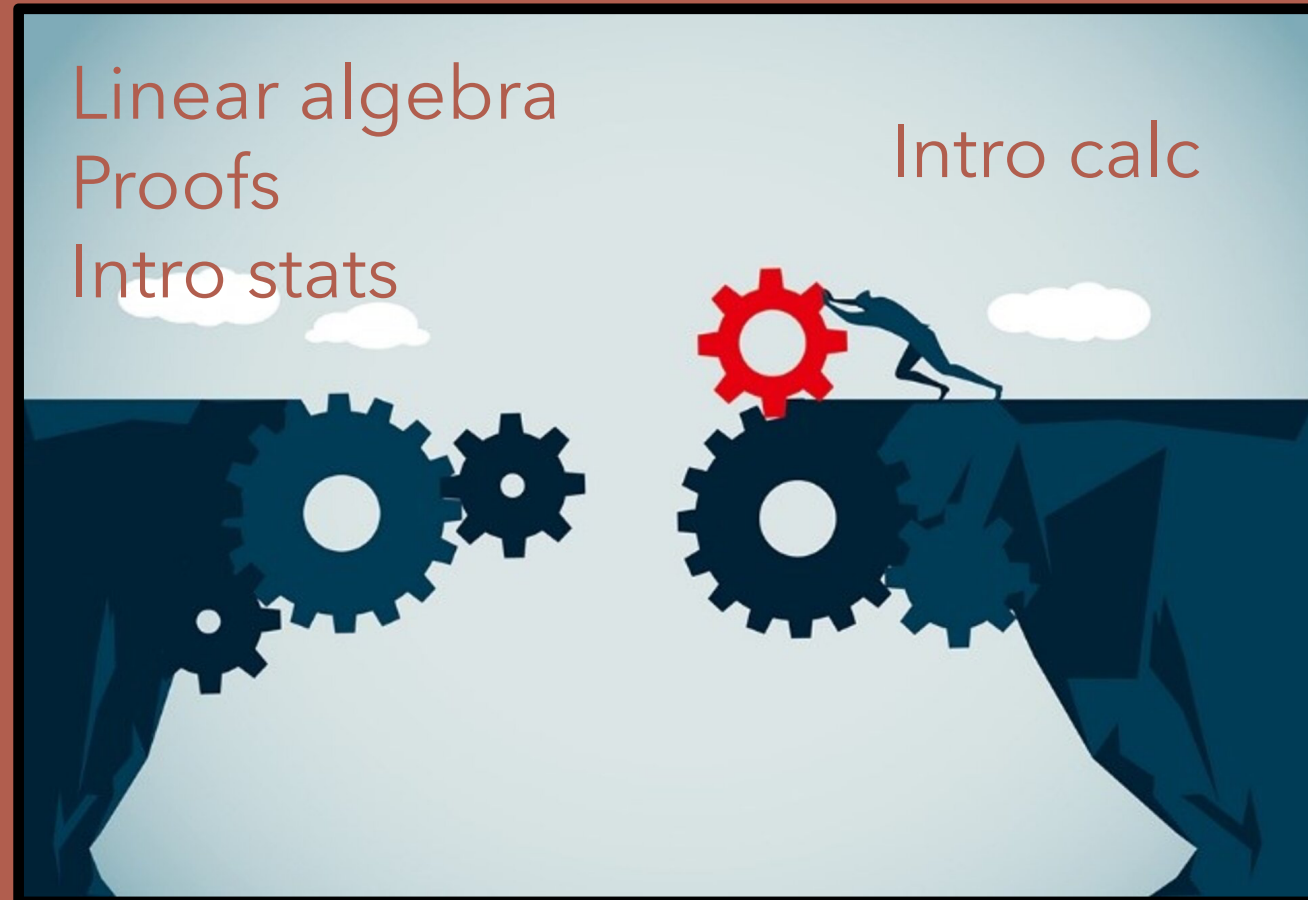
moves students beyond rote computation

allows student choice and flexibility

allows for student creativity

Time to push
back

# Does it transfer?



Linear algebra
Proofs
Intro stats

Intro calc

# Resources



- [https://drive.google.com/drive/folders/17QQ0pEH0Z3Aa1MTi-Ao9GaLXbyyiFiSf?usp=sharing](https://drive.google.com/drive/folders/17QQ0pEH0Z3Aa1MTi-Ao9GaLXbyyiFiSf?usp=sharing)

# Thanks

- Thanks to Tara and Haynes

# Thanks

- Thanks to Tara and Haynes

- Thanks to you for listening

# Thanks

- Thanks to Tara and Haynes

- Thanks to you for listening

- Thanks to my students