

MAC2311 Section U08  
Suggested problems for Test 2  
(Test 2 is Friday March 3rd, in class)

Idris Mercer

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1. Write down the definition of the derivative.

$$f'(x) = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$$

2. Use the definition of the derivative to find the derivative of  $f(x) = x^2$ .

$$\begin{aligned} f'(x) &= \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h} = \lim_{h \rightarrow 0} \frac{(x+h)^2 - x^2}{h} \\ &= \lim_{h \rightarrow 0} \frac{x^2 + 2xh + h^2 - x^2}{h} = \lim_{h \rightarrow 0} \frac{2xh + h^2}{h} = \lim_{h \rightarrow 0} \frac{(2x+h)h}{h} = \lim_{h \rightarrow 0} (2x+h) \\ &= 2x + 0 = 2x \end{aligned}$$

3. Use the definition of the derivative to find the derivative of  $f(x) = \frac{1}{x}$ .

$$\begin{aligned} f'(x) &= \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h} = \lim_{h \rightarrow 0} \frac{\frac{1}{x+h} - \frac{1}{x}}{h} \cdot \frac{x(x+h)}{x(x+h)} \\ &= \lim_{h \rightarrow 0} \frac{x - (x+h)}{hx(x+h)} = \lim_{h \rightarrow 0} \frac{x - x - h}{hx(x+h)} = \lim_{h \rightarrow 0} \frac{-h}{hx(x+h)} \\ &= \lim_{h \rightarrow 0} \frac{-1}{x(x+h)} = \frac{-1}{x(x+0)} = \frac{-1}{x^2} \end{aligned}$$

4. Find  $dy/dx$ .

$$y = 3x^8 + 2x + 1$$

$$\begin{aligned} y' &= 3 \cdot 8x^7 + 2 \cdot 1 + 0 \\ &= 24x^7 + 2 \end{aligned}$$

5. Find  $dy/dx$ .

$$y = \frac{1}{2}(x^4 + 7) = \frac{1}{2}x^4 + \frac{7}{2}$$

$$y' = \frac{1}{2} \cdot 4x^3 + 0 = 2x^3$$

6. Find  $dy/dx$ .

$$y = \sqrt{2}x + (1/\sqrt{2})$$

$\swarrow$   $\sqrt{2} \cdot x$ , not  $\sqrt{2x}$

$$y = \sqrt{2} \cdot x + \frac{1}{\sqrt{2}}$$

$$y' = \sqrt{2} \cdot 1 + 0 = \sqrt{2}$$

7. Find  $dy/dx$ .

$$y = \frac{x^2 + 1}{5} = \frac{1}{5}(x^2 + 1) = \frac{1}{5}x^2 + \frac{1}{5}$$

$$y' = \frac{1}{5} \cdot 2x + 0 = \frac{2}{5}x \quad \text{or} \quad \frac{2x}{5}$$

8. Find  $f'(x)$ .

$$f(x) = x^{-3} + \frac{1}{x^7} = x^{-3} + x^{-7}$$

$$f'(x) = -3x^{-4} - 7x^{-8} \text{ . Can stop there.}$$

Other correct answers:  $-\frac{3}{x^4} - \frac{7}{x^8}$  or  $\frac{-3x^4 - 7}{x^8}$

9. Find  $f'(x)$ .

$$f(x) = \sqrt{x} + \frac{1}{x} = x^{1/2} + x^{-1}$$

$$f'(x) = \frac{1}{2}x^{-1/2} - 1x^{-2} \text{ Can stop there.}$$

Can also write as  $\frac{1}{2\sqrt{x}} - \frac{1}{x^2}$

10. Find  $f'(x)$ .

$$f(x) = x^e + \frac{1}{x^{\sqrt{10}}} = x^e + x^{-\sqrt{10}}$$

Remember,  $e$  and  $-\sqrt{10}$  are just numbers  
(constants)

$$f'(x) = ex^{e-1} - \sqrt{10}x^{-\sqrt{10}-1}$$

11. Find  $f'(x)$ .

$$f(x) = (3x^2 + 1)^2 \quad \text{Deriv. of } u^2 \text{ will be } 2u \cdot u'$$

$$\begin{aligned} f'(x) &= 2(3x^2 + 1) \cdot (3x^2 + 1)' \\ &= 2(3x^2 + 1) \cdot 6x \quad \text{Can stop there} \end{aligned}$$

Can also write  $f'(x) = 12x(3x^2 + 1)$  or  $36x^3 + 12x$

ALSO can write  $f(x) = 9x^4 + 6x^2 + 1$  so  $f'(x) = 36x^3 + 12x$

12. Find  $f'(x)$ .

$$f(x) = (3x^2 + 6)(2x - \frac{1}{4})$$

More than one correct method. Can expand first.

$$f(x) = 6x^3 - \frac{3}{4}x^2 + 12x - \frac{6}{4}$$

$$f'(x) = 18x^2 - \frac{6}{4}x + 12 \quad \text{or} \quad 18x^2 - \frac{3}{2}x + 12$$

Can also use product rule.

13. Find  $f'(x)$ .

$$f(x) = (2 - x - 3x^3)(7 + x^5)$$

More than one correct method. I will use product rule.

$$\begin{aligned} f'(x) &= (2 - x - 3x^3)'(7 + x^5) + (2 - x - 3x^3)(7 + x^5)' \\ &= (-1 - 9x^2)(7 + x^5) + (2 - x - 3x^3) \cdot 5x^4 \end{aligned}$$

Since the question just said find  $f'(x)$ , you can stop there.

However, it can be good practice to simplify.

$$\begin{aligned} f'(x) &= -7 - x^5 - 63x^2 - 9x^7 + 10x^4 - 5x^5 - 15x^7 \\ &= -24x^7 - 6x^5 + 10x^4 - 63x^2 - 7 \end{aligned}$$

14. Find  $f'(x)$ .

$$f(x) = \frac{x-2}{x^4+x+1}$$

$$f'(x) = \frac{(x-2)'(x^4+x+1) - (x-2)(x^4+x+1)'}{(x^4+x+1)^2}$$

$$= \frac{x^4+x+1 - (x-2)(4x^3+1)}{(x^4+x+1)^2}$$

Can stop there, but can also simplify.  
Numerator is  $x^4+x+1 - (4x^4-8x^3+x-2)$   
etc.

15. Find  $f'(x)$ .

$$f(x) = (x^3+2x)^{37}$$

Deriv. of  $u^{37}$  is  $37u^{36} \cdot u'$  CHAIN RULE  $f = u^{37}$  and  $u = x^3+2x$

$$f'(x) = 37(x^3+2x)^{36} \cdot (x^3+2x)'$$
$$= 37(x^3+2x)^{36} \cdot (3x^2+2)$$

16. Find  $f'(x)$ .

$$f(x) = \sin\left(\frac{1}{x^2}\right) = \sin(x^{-2})$$

Deriv. of  $\sin u$  is  $\cos u \cdot u'$  CHAIN RULE

$$f'(x) = \cos(x^{-2}) \cdot (x^{-2})'$$
$$= \cos(x^{-2}) \cdot (-2x^{-3})$$

Can stop here

Which can also be written in other ways

$$\cos\left(\frac{1}{x^2}\right) \cdot \frac{-2}{x^3} \quad \text{or} \quad \frac{-2\cos(1/x^2)}{x^3}$$

17. Find  $f'(x)$  using any correct method.

$$f(x) = \left(\frac{1+x^2}{1-x^2}\right)^{17}$$

Chain rule,  
then later, quotient rule

$$f'(x) = 17 \left(\frac{1+x^2}{1-x^2}\right)^{16} \cdot \left(\frac{1+x^2}{1-x^2}\right)'$$

$$= 17 \left(\frac{1+x^2}{1-x^2}\right)^{16} \cdot \frac{(1+x^2)'(1-x^2) - (1+x^2)(1-x^2)'}{(1-x^2)^2}$$

$$= 17 \left(\frac{1+x^2}{1-x^2}\right)^{16} \cdot \frac{2x(1-x^2) - (1+x^2)(-2x)}{(1-x^2)^2}$$

(Can stop there, but it might be good practice to simplify the numerator.)

18. Find  $dy/dx$  using any correct method.

Implicit differentiation.  $x^3 + y^3 = 3xy^2$   
 $y$  is "secretly" a function of  $x$ .  
 We must treat  $y^3$  and  $y^2$  like  $(g(x))^3$  and  $(g(x))^2$ .

$$\frac{d}{dx} [x^3 + y^3] = \frac{d}{dx} [3xy^2]$$

$$3x^2 + 3y^2 \cdot y' = (3x)'y^2 + 3x(y^2)'$$

$$3x^2 + 3y^2 \cdot y' = 3y^2 + 3x \cdot 2y \cdot y'$$

$$3y^2 \cdot y' - 6xy \cdot y' = 3y^2 - 3x^2$$

$$(3y^2 - 6xy)y' = 3y^2 - 3x^2$$

$$y' = \frac{3y^2 - 3x^2}{3y^2 - 6xy} \text{ or } \frac{y^2 - x^2}{y^2 - 2xy} \text{ or } \frac{(y+x)(y-x)}{y(y-2x)}$$

where  
prime  
means  
 $\frac{d}{dx}$

NOTE: Asking for the SECOND derivative

19. Find  $\frac{d^2y}{dx^2}$  using any correct method.

$x^3 + y^3 = 1$  Can use implicit differentiation

$$\frac{d}{dx} [x^3 + y^3] = \frac{d}{dx} [1] \Rightarrow 3x^2 + 3y^2 y' = 0 \Rightarrow 3y^2 y' = -3x^2$$

$$\Rightarrow y' = \frac{-3x^2}{3y^2} = -\frac{x^2}{y^2}. \text{ Then } y'' = -\left(\frac{x^2}{y^2}\right)' = -\frac{(x^2)'y^2 - x^2(y^2)'}{(y^2)^2}$$

$$= -\frac{2xy^2 - x^2 \cdot 2yy'}{y^4} = -\frac{2xy^2 - 2x^2y\left(-\frac{x^2}{y^2}\right)}{y^4} \text{ Can stop there, or can simplify.}$$

Maybe easier: Start with  $y^3 = 1 - x^3 \Rightarrow y = (1 - x^3)^{1/3}$

$$\Rightarrow y' = \frac{1}{3}(1 - x^3)^{-2/3} \cdot (-3x^2) = -x^2(1 - x^3)^{-2/3}$$

20. Find  $dy/dx$ .

$y = \ln 5x$

Then take derivative AGAIN.  
Still time-consuming.

METHOD 1.  $y = \ln(5x)$

$$y' = \frac{1}{5x} \cdot (5x)' = \frac{1}{5x} \cdot 5 = \frac{1}{x}$$

METHOD 2. First rewrite using rules of logs

$$y = \ln(5x) = \underbrace{\ln 5}_{\text{constant}} + \ln x$$

$$y' = 0 + \frac{1}{x} = \frac{1}{x}$$

21. Find  $dy/dx$ .

$$y = \ln|x^2 - 1|$$

FACT: Derivative of  $\ln|x|$  is  $\frac{1}{x}$ . Don't need to "do" anything with the absolute value.

$$y = \ln|u| \text{ and } u = x^2 - 1$$

$$\frac{dy}{du} = \frac{1}{u} \text{ and } \frac{du}{dx} = 2x \Rightarrow \frac{dy}{dx} = \frac{1}{u} \cdot 2x = \frac{2x}{x^2 - 1}$$

22. Find  $dy/dx$ .

$$y = \ln(x^2)$$

METHOD 1.  $y' = \frac{1}{x^2} \cdot (x^2)' = \frac{1}{x^2} \cdot 2x = \frac{2}{x}$

METHOD 2. By rules of logs,  $y = \ln(x^2) = 2 \ln x$   
 $y' = 2 \cdot \frac{1}{x} = \frac{2}{x}$

23. Find  $dy/dx$ .

$$y = (\ln x)^3$$

$$\begin{aligned} y' &= 3(\ln x)^2 \cdot (\ln x)' \\ &= 3(\ln x)^2 \cdot \frac{1}{x} \quad \text{or} \quad \frac{3(\ln x)^2}{x} \end{aligned}$$



24. Find  $dy/dx$ .

$$y = \ln\left(\frac{x}{x^2+1}\right)$$

More than one correct method, but easiest to use log rules first.

$$y = \ln x - \ln(x^2+1)$$

$$y' = \frac{1}{x} - \frac{1}{x^2+1} \cdot (x^2+1)'$$

$$= \frac{1}{x} - \frac{2x}{x^2+1}$$

25. Find  $dy/dx$ .

$$y = \ln(\ln x)$$

$$y' = \frac{1}{\ln x} \cdot (\ln x)'$$

$$= \frac{1}{\ln x} \cdot \frac{1}{x}$$