Lesson #7: Combining Differentiation Rules
(Section 4.9)

Learning Targets:

i) Calculating derivatives by combining multiple differentiation rules.

ii) Putting derivative answers into factored form.

Example #1:

Find the derivative of the following:

$$F(x) = (x^2+1)^3(2-3x)^4$$

$$F(x) = f(x) \cdot g(x)$$

$$F'(x) = fg' + gf'$$

Product Rule

Both f(x) and g(x) are composite functions (powers of polynomials).

To find f' and g' will require the Chain Rule

$f \cdot g' + g \cdot f'$

$F'(x) = (x^2 + 1)^3$

$$F(x) = (x^2 + 1)^3 (2 - 3x)^4$$

f · g' + g · f'

$$F'(x) = (x^2 + 1)^3 \cdot 4(2 - 3x)^3(-3)$$

$$F(x) = (x^2 + 1)^3(2 - 3x)^4$$

$f \cdot g' + g \cdot f'$

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4$$

$$F(x) = (x^2+1)^3(2-3x)^4$$

$$f \cdot g' + g \cdot f'$$

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

$$F(x) = (x^2+1)^3(2-3x)^4$$

f · g' + g · f'

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

$$F'(x) = -12(x^2+1)^3(2-3x)^3$$

f · g' + g · f'

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + \underline{(2-3x)^4 \cdot 3(x^2+1)^2(2x)}$$

$$F'(x) = -12(x^2+1)^3(2-3x)^3 + \underline{6x(2-3x)^4(x^2+1)^2}$$

f · g' + g · f'

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

$$F'(x) = -12(x^2+1)^3(2-3x)^3 + 6x(2-3x)^4(x^2+1)^2$$

Look for common factors

$$GCF = -6(x^2+1)^2(2-3x)^3$$

$f \cdot g' + g \cdot f'$

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

$$F'(x) = -12(x^2+1)^3(2-3x)^3 + 6x(2-3x)^4(x^2+1)^2$$

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f · g' + g · f'

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

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$$F'(x) = -6(x^2+1)^2(2-3x)^3[2(x^2+1)$$

f · g' + g · f'

$$F'(x) = (x^2 + 1)^3 \cdot 4(2 - 3x)^3(-3) + (2 - 3x)^4 \cdot 3(x^2 + 1)^2(2x)$$

$$F'(x) = -12(x^2 + 1)^3(2 - 3x)^3 + 6x(2 - 3x)^4(x^2 + 1)^2$$

$$GCF = -6(x^2 + 1)^2(2 - 3x)^3$$

$$F'(x) = -6(x^2 + 1)^2(2 - 3x)^3[2(x^2 + 1) - x$$

$$f \cdot g' + g \cdot f'$$

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

$$F'(x) = -12(x^2+1)^3(2-3x)^3 + 6x(2-3x)^4(x^2+1)^2$$

$$GCF = -6(x^2+1)^2(2-3x)^3$$

$$F'(x) = -6(x^2+1)^2(2-3x)^3[2(x^2+1) - x(2-3x)]$$

f · g' + g · f'

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

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$$F'(x) = -6(x^2+1)^2(2-3x)^3[2x^2+2-2x+3x^2)]$$

$$f \cdot g' + g \cdot f'$$

$$F'(x) = (x^2+1)^3 \cdot 4(2-3x)^3(-3) + (2-3x)^4 \cdot 3(x^2+1)^2(2x)$$

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$$F'(x) = -6(x^2+1)^2(2-3x)^3[2x^2+2-2x+3x^2)]$$

$$F'(x) = -6(x^2+1)^2(2-3x)^3(5x^2-2x+2)$$

You Try:

Differentiate $y = (2x - 1)^3(x^2 + 4)^4$

You Try:

Differentiate $y = (2x-1)^3(x^2+4)^4$

$$y' = (2x-1)^3 \cdot 4(x^2+4)^3(2x) + (x^2+4)^4 \cdot 3(2x-1)^2(2)$$

$$y' = 8x(2x-1)^3(x^2+4)^3 + 6(x^2+4)^4(2x-1)^2$$

$$y' = 2(2x-1)^2(x^2+4)^3[4x(2x-1) + 3(x^2+4)]$$

$$y' = 2(2x-1)^2(x^2+4)^3[8x^2 - 4x + 3x^2 + 12]$$

$$y' = 2(2x-1)^2(x^2+4)^3[11x^2 - 4x + 12]$$

Example #2:

Find the derivative of the following:

$$s = \left(\frac{2t-1}{t+2}\right)^6$$

Power of a quotient
- use the Chain Rule to differentiate the power first, then use the Quotient Rule

$$s' = 6\left(\frac{2t-1}{t+2}\right)^5$$

Example #2:

Find the derivative of the following:

$$s = \left(\frac{2t-1}{t+2}\right)^6$$

Power of a quotient
- use the Chain Rule to differentiate the power first, then use the Quotient Rule

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$$s' = 6\left(\frac{2t-1}{t+2}\right)^5 \cdot \frac{(t+2)(2)-(2t-1)(1)}{(t+2)^2}$$

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$$s' = 6\left(\frac{2t-1}{t+2}\right)^5 \cdot \frac{(t+2)(2)-(2t-1)(1)}{(t+2)^2}$$

$$s' = 6\,\frac{(2t-1)^5}{(t+2)^5} \cdot \frac{2t+4-2t+1}{(t+2)^2}$$

$$s' = 6\,\frac{(2t-1)^5}{(t+2)^5} \cdot \frac{5}{(t+2)^2}$$

$$s' = \frac{30(2t-1)^5}{(t+2)^7}$$

Example #3:

Find the derivative of the following:

$$y = \frac{2x^4}{\sqrt{3x-1}}$$

Quotient Rule, but we will need the Chain Rule to find the derivative of the bottom function

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

$$y' = \frac{gf' - fg'}{g^2}$$

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

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

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3}{}$$

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

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4}{}$$

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

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{}$$

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

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{3x-1}$$

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

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{3x-1}$$

$$y' = \frac{8x^3(3x-1)^{\frac{1}{2}} - 3x^4(3x-1)^{-\frac{1}{2}}}{3x-1}$$

Look for common factors

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

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{3x-1}$$

$$y' = \frac{8x^3(3x-1)^{\frac{1}{2}} - 3x^4(3x-1)^{-\frac{1}{2}}}{3x-1}$$

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$$y' = \frac{8x^3(3x-1)^{\frac{1}{2}} - 3x^4(3x-1)^{-\frac{1}{2}}}{3x-1}$$

$$y' = \frac{x^3(3x-1)^{-\frac{1}{2}}[8}{3x-1}$$

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{3x-1}$$

$$y' = \frac{8x^3(3x-1)^{\frac{1}{2}} - 3x^4(3x-1)^{-\frac{1}{2}}}{3x-1}$$

$$y' = \frac{x^3(3x-1)^{-\frac{1}{2}}[8(3x-1)}{3x-1}$$

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{3x-1}$$

$$y' = \frac{8x^3(3x-1)^{\frac{1}{2}} - 3x^4(3x-1)^{-\frac{1}{2}}}{3x-1}$$

$$y' = \frac{x^3(3x-1)^{-\frac{1}{2}}[8(3x-1) - 3x}{3x-1}$$

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{3x-1}$$

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$$y' = \frac{x^3(3x-1)^{-\frac{1}{2}}[8(3x-1) - 3x]}{3x-1}$$

$$y' = \frac{x^3[24x - 8 - 3x]}{(3x-1)^{\frac{1}{2}}(3x-1)}$$

$$y' = \frac{(3x-1)^{\frac{1}{2}} \cdot 8x^3 - 2x^4 \cdot \left(\frac{1}{2}\right)(3x-1)^{-\frac{1}{2}}(3)}{3x-1}$$

$$y' = \frac{8x^3(3x-1)^{\frac{1}{2}} - 3x^4(3x-1)^{-\frac{1}{2}}}{3x-1}$$

$$y' = \frac{x^3(3x-1)^{-\frac{1}{2}}[8(3x-1) - 3x]}{3x-1}$$

$$y' = \frac{x^3[24x - 8 - 3x]}{(3x-1)^{\frac{1}{2}}(3x-1)} = \boxed{\frac{x^3(21x-8)}{(3x-1)^{\frac{3}{2}}}}$$

Example #4:

Find the derivative of the following:

$$y = \frac{\sqrt{x^2+3x}}{(x^2+2)^2}$$

Quotient Rule, but we will need the Chain Rule to find the derivative of both the top and bottom functions

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

$$y' = \frac{gf' - fg'}{g^2}$$

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

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

$$y' = (x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3)$$

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

$$y' = (x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}}$$

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

$$y' = (x^2 + 2)^2 \cdot \left(\frac{1}{2}\right)(x^2 + 3x)^{-\frac{1}{2}}(2x + 3) - (x^2 + 3x)^{\frac{1}{2}} \cdot 2(x^2 + 2)(2x)$$

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

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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Look for common factors

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

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

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

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

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

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

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

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[(x^2+2)(2x+3) - 8x}{(x^2+2)^4}$$

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[(x^2+2)(2x+3) - 8x(x^2+3x)]}{(x^2+2)^4}$$

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[(x^2+2)(2x+3) - 8x(x^2+3x)]}{(x^2+2)^4}$$

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[2x^3+3x^2+4x+6-8x^3-24x^2]}{(x^2+2)^4}$$

$$y' = \frac{(x^2+2)^2 \cdot \left(\frac{1}{2}\right)(x^2+3x)^{-\frac{1}{2}}(2x+3) - (x^2+3x)^{\frac{1}{2}} \cdot 2(x^2+2)(2x)}{(x^2+2)^4}$$

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

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[(x^2+2)(2x+3) - 8x(x^2+3x)]}{(x^2+2)^4}$$

$-6x^3$ $-21x^2$

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[2x^3+3x^2+4x+6-8x^3-24x^2]}{(x^2+2)^4}$$

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[-6x^3-21x^2+4x+6]}{(x^2+2)^4}$$

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$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[-6x^3-21x^2+4x+6]}{(x^2+2)^4}$$

$$y' = \frac{(x^2+2)[-6x^3-21x^2+4x+6]}{2(x^2+3x)^{\frac{1}{2}}(x^2+2)^4}$$

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[-6x^3-21x^2+4x+6]}{(x^2+2)^4}$$

$$y' = \frac{(x^2+2)[-6x^3-21x^2+4x+6]}{2(x^2+3x)^{\frac{1}{2}}(x^2+2)^4}$$

reduce

$$y' = \frac{\frac{1}{2}(x^2+2)(x^2+3x)^{-\frac{1}{2}}[-6x^3-21x^2+4x+6]}{(x^2+2)^4}$$

$$y' = \frac{(x^2+2)[-6x^3-21x^2+4x+6]}{2(x^2+3x)^{\frac{1}{2}}(x^2+2)^4}$$

reduce

$$y' = \frac{-6x^3-21x^2+4x+6}{2(x^2+3x)^{\frac{1}{2}}(x^2+2)^3}$$

Assignment

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Written Exercises: #2, 4, 5, 6, 9, 10, 12, 13, 14, 15, 18