**Below are notes from my instructor telling how he wants us to approach the problems. Please show step by step & in the way that we are expected to in class. There are 5 problems in this problem set. Thanks very much. I really appreciate all your help thus far.**

**16 Local Extrema and Inflection Points**



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| http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dis a critical number, yet no minimum nor maximum there.  |      | **Critical numbers are necessary but not enough for local extrema** http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dis a critical number, yet no minimum nor maximum there. As illustrated in the figure below not all critical numbers give rise to local minima or local maxima. The function http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%2520%253D%2520%28x-1%29%255E3%252B2%257D%255Cend%257Bdisplaymath%257Dhas a critical number http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253D1%257D%255Cend%257Bdisplaymath%257D(http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%281%29%2520%253D%25200%257D%255Cend%257Bdisplaymath%257D) and yet it does not have a local extremum. This is because to the left of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dhttp://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257Dincreases and it continues increasing to the right of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D. In order for a critical number http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dto be a local extremum, in addition to http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28c%29%253D0%257D%255Cend%257Bdisplaymath%257D, http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257Dmust change its monotonicity at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D(decreasing to the left of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dand increasing to the right of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D, or the other way around). graph7.bmpNote that http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%257D%255Cend%257Bdisplaymath%257Dbeing the slope of the tangent line is negative for http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526lt%253B%2520c%257D%255Cend%257Bdisplaymath%257Dand http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%2520%2526lt%253B%2520c%257D%255Cend%257Bdisplaymath%257D.  |
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|  |      | **Example -- Second derivative test** graph8.bmpSometimes at a cricital number http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D, it is not difficult to find the sign of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28c%29%257D%255Cend%257Bdisplaymath%257D. For example, let http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257Df%28x%29%2520%253D%2520-%2520%28x%2520-%255Cfrac%257B3%257D%257B2%257D%29%255E2%2520%252B%2520%255Cfrac%257B3%257D%257B2%257D.%255Cend%257Bdisplaymath%257DThen http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%2520%253D%2520-2%2520%28x%2520-%255Cfrac%257B3%257D%257B2%257D%29%257D%255Cend%257Bdisplaymath%257D, and thus the critical number http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bc%253D%255Cfrac%257B3%257D%257B2%257D%257D%255Cend%257Bdisplaymath%257D. http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%253D%2520-2%257D%255Cend%257Bdisplaymath%257D, so also http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28-%255Cfrac%257B3%257D%257B2%257D%29%2520%253D-2%2520%2526lt%253B%25200%257D%255Cend%257Bdisplaymath%257D. Thus since http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28c%29%2520%2526lt%253B0%257D%255Cend%257Bdisplaymath%257Dhttp://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%257D%255Cend%257Bdisplaymath%257Dhas a local maximum at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bc%253D%255Cfrac%257B3%257D%257B2%257D%257D%255Cend%257Bdisplaymath%257D.  |
|  |      | **Example -- First derivative test** untitled.bmpIf it is difficult to compute http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28c%29%257D%255Cend%257Bdisplaymath%257Dor if http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28c%29%2520%253D%25200%257D%255Cend%257Bdisplaymath%257D, then we investigate if the sign of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%257D%255Cend%257Bdisplaymath%257Dchanges at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D. For example, let http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257Df%28x%29%2520%253D%255Cfrac%257B2%2520x%255E2%252B2%257D%257Bx%255E2%252B2%257D.%255Cend%257Bdisplaymath%257DSince http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257Dis a fraction, its first derivative is already more complicated. The second is even more complex. Check that http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257Df%27%28x%29%2520%253D%2520%255Cfrac%257B4%2520x%257D%257B%28x%255E2%252B1%29%255E2%257D.%255Cend%257Bdisplaymath%257DTo get a critical number we solve http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%2520%253D%25200%257D%255Cend%257Bdisplaymath%257Dand obtain http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bc%253D0%257D%255Cend%257Bdisplaymath%257Dto be the only critical number. Note that since the denominator of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%257D%255Cend%257Bdisplaymath%257Dis always positive, if http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526lt%253B0%257D%255Cend%257Bdisplaymath%257D, http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%2520%2526lt%253B%25200%257D%255Cend%257Bdisplaymath%257Dand if http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526gt%253B0%257D%255Cend%257Bdisplaymath%257D, http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%28x%29%2520%2526gt%253B%25200%257D%255Cend%257Bdisplaymath%257D. Thus the critical number http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253D0%257D%255Cend%257Bdisplaymath%257Dgives rise to a local maximum.  |

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|      | Example. To the left of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dthe function is convave down as http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526lt%253B%25200%257D%255Cend%257Bdisplaymath%257Dfor http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526lt%253B%2520c%257D%255Cend%257Bdisplaymath%257D. To the right of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D, the function http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%257D%255Cend%257Bdisplaymath%257Dis concave up since http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526gt%253B%25200%257D%255Cend%257Bdisplaymath%257Dfor http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526gt%253B%2520c%257D%255Cend%257Bdisplaymath%257D. Hence, at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dthe graph of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257Dhas an inflection.**Concavity and inflections**graph9.bmpExample. To the left of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dthe function is convave down as http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526lt%253B%25200%257D%255Cend%257Bdisplaymath%257Dfor http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526lt%253B%2520c%257D%255Cend%257Bdisplaymath%257D. To the right of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D, the function http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%257D%255Cend%257Bdisplaymath%257Dis concave up since http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526gt%253B%25200%257D%255Cend%257Bdisplaymath%257Dfor http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526gt%253B%2520c%257D%255Cend%257Bdisplaymath%257D. Hence, at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dthe graph of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257Dhas an inflection.Recall that the concavity of a function http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%257D%255Cend%257Bdisplaymath%257Dcan be determined by the sign of the second derivative http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%257D%255Cend%257Bdisplaymath%257D. The graph of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257By%253Df%28x%29%257D%255Cend%257Bdisplaymath%257Dis concave up when http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526gt%253B%25200%257D%255Cend%257Bdisplaymath%257Dand it is concave down when http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526lt%253B%25200%2520%257D%255Cend%257Bdisplaymath%257D. If at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dthe function http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257Dchanges its concavity, then we have call http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257B%28c%252Cf%28c%29%29%257D%255Cend%257Bdisplaymath%257Dis an ***inflection point*** for http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257D. Certainly, in this case http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28c%29%2520%253D%25200%257D%255Cend%257Bdisplaymath%257D. To ensure that the a number http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dfor which http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28c%29%2520%253D%25200%257D%255Cend%257Bdisplaymath%257Dgives rise to an inflection, we need to check that http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%257D%255Cend%257Bdisplaymath%257Dchanges its sign at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D | **Concavity and inflections**graph9.bmp http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%257D%255Cend%257Bdisplaymath%257Dchanges its sign at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D.Example. To the left of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dthe function is convave down as http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526lt%253B%25200%257D%255Cend%257Bdisplaymath%257Dfor http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526lt%253B%2520c%257D%255Cend%257Bdisplaymath%257D. To the right of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257D, the function http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%257D%255Cend%257Bdisplaymath%257Dis concave up since http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%27%27%28x%29%2520%2526gt%253B%25200%257D%255Cend%257Bdisplaymath%257Dfor http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%2520%2526gt%253B%2520c%257D%255Cend%257Bdisplaymath%257D. Hence, at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253Dc%257D%255Cend%257Bdisplaymath%257Dthe graph of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%257D%255Cend%257Bdisplaymath%257Dhas an inflection. |

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| **Homework** 2. (2--6) Determine the intervals on which the function is decreasing and increasing and then find local minima and maxima. http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%2520%253D%2520%28x-2%29%28x%252B3%29%257D%255Cend%257Bdisplaymath%257D3. http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%2520%253D%2520%28x-1%29%28x%252B2%29%28x-3%29%257D%255Cend%257Bdisplaymath%257D4. http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%2520%253D%2520x%2520e%255Ex%257D%255Cend%257Bdisplaymath%257D5. http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bf%28x%29%2520%253D%2520x%255Ex%257D%255Cend%257Bdisplaymath%257D6. The graph of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257By%253Df%27%28x%29%257D%255Cend%257Bdisplaymath%257Dis located below the X-axis but it touches the http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257BX%257D%255Cend%257Bdisplaymath%257D-axis at http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257Bx%253D7%257D%255Cend%257Bdisplaymath%257D. What can you say about the graph of http://calculus.sfsu.edu/latexrender/latex2image.php?data=%255Cbegin%257Bdisplaymath%257D%2520%255Ctextstyle%257By%253Df%28x%29%257D%255Cend%257Bdisplaymath%257D?  |

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