Math 140 Section 4.9

Notes:

(a) For graphing problems, find all relative extreme values, concavity, inflection points and asymptotes of the function.

(b) Recall that the graph of a function is symmetric with respect to the y axis if $f(x) = f(-x)$ for all x in the domain of f. Also, the graph of f is symmetric with respect to the origin if $f(-x) = -f(x)$ for all x in the domain of f. For graphs, include symmetry with respect to the y axis or the origin, if it exists.

(c) Under what conditions on a function can there be symmetry with respect to the x axis?

Example 1: Let $f(x) = x^4 - 2x^2 + 2$. Sketch the graph of f, and indicate any relative extreme values, concavity, inflection points, asymptotes, and symmetry.

Solution: Let us first mention that the graph of f is symmetric with respect to the y axis, since there are only even powers of x in its formula. Next, note that $f'(x) = 4x^3 - 4x$ and $f''(x) = 12x^2 - 4$. Then $f'(x) = 4x(x^2 - 1) = 0$ if $x = -1, 0$, or 1. Since $f''(-1) > 0$ and $f''(1) > 0$, it follows that $f(-1) = 1$ and $f(1) = 1$ are relative minimum values. Analogously, $f''(0) < 0$ implies that $f(0) = 2$ is a relative maximum value. Next, we see that $f''(x) = 4(3x^2 - 1) = 0$ if $x = \pm 1/\sqrt{3}$. Then we find that the graph of f is concave upward on $(-\infty, -1/\sqrt{3})$ and on $(1/\sqrt{3}, \infty)$, and is concave downward on $(-1/\sqrt{3}, 1/\sqrt{3})$. Therefore the inflection points for f are $(\pm 1/\sqrt{3}, 13/9)$. Finally, there are no vertical or horizontal asymptotes for f. Now to the graph of f.

Example 2: Let $g(x) = x^3 - 3x$. Sketch the graph of g, and indicate any relative extreme values, concavity, inflection points, asymptotes, and symmetry.

Solution: First we note that the graph is symmetric with respect to the origin since $g(-x) = -g(x)$. Next, $g'(x) = 3x^2 - 3 = 3(x^2 - 1)$, and $g''(x) = 6x$. Therefore $g'(x) = 0$ if $x = \pm 1$. Since $g''(1) > 0$, it follows that $g(1) = -2$ is a relative minimum value of g. By the symmetry with respect to the origin, $g(-1) = 2$ is a relative maximum value of g. Since $g''(x) = 6x$, the graph is concave downward on $(-\infty, 0)$ and is concave upward on $(0, \infty)$. It follows that $(0,0)$ is an inflection point. There are no asymptotes, and it is time to sketch the graph.

Example 3: Let $h(x) = \dfrac{x}{(x+3)^2}$. Sketch the graph of h, and indicate any relative extreme values, concavity, inflection points, asymptotes, and symmetry.

Solution: For this example, there is no symmetric with respect to the y axis or the origin. Next,

$$h'(x) = \frac{(x+3)^2(1) - 2x(x+3)}{(x+3)^4} = \frac{3-x}{(x+3)^3} \text{ and } h''(x) = \frac{(x+3)^3(-1) - (3-x)3(x+3)^2}{(x+3)^6} = \frac{2(x-6)}{(x+3)^4}.$$

Now $h'(x) = 0$ if $x = 3$, and since $h''(3) < 0$, it follows that $h(3) = 1/12$ is a relative maximum value. Next, the graph of h is concave upward on $(6, \infty)$, and is concave downward on $(-\infty, -3)$ and $(-3, 6)$. Thus $(6, 2/27)$ is an inflection point. As for asymptotes, the line $x = -3$ is a vertical asymptote, and since $\lim_{x \to \pm\infty} h(x) = \lim_{x \to \pm\infty} \dfrac{x}{(x+3)^2} = 0$, the line $y = 0$ is a horizontal asymptote. Now to the graph.

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