Math 104 section 108 Quiz #5 Column B Date: Grade:

First Name: ______________________ Last Name: ______________________

Student-No: ______________________ Section: ______________________

You must show your work

1. $\boxed{\text{3 marks}}$ A wholesale flour producer wants to sell flour in cubic containers. The cost of making a cubic container with edge x meters is $3x^3 + 85x^{\frac{3}{2}}$ dollars. A market research shows that people are willing to be y cubic meters of flour for $90\sqrt{y}$ dollars. Find the size of the edge of the box which will produce the maximal profit per box.

Answer: $x = \left(\frac{5}{6}\right)^{\frac{2}{3}}$

Solution: The volume of the box is $V(x) = x^3$ and the revenue per box is

$$R(x) = 90\sqrt{V(x)} = 90x^{\frac{3}{2}}.$$

The profit function is

$$P(x) = R(x) - C(x) = 5x^{\frac{3}{2}} - 3x^3.$$

We are interested in values of x in the open interval $(0, \infty)$. We look for critical points

$$P'(x) = \frac{15}{2}\sqrt{x} - 9x^2$$

Solving $P'(x) = 0$ for x we get $x^{\frac{3}{2}} = \frac{5}{6}$ so the only critical point of $P(x)$ is at $\left(\frac{5}{6}\right)^{\frac{2}{3}}$.

The second derivative of P is

$$P''(x) = \frac{15}{4\sqrt{x}} - 18x.$$

Which is positive for $0 < x < \left(\frac{5}{24}\right)^{\frac{2}{3}}$ and negative for $x > \left(\frac{5}{24}\right)^{\frac{2}{3}}$. In particular, it follows that P is increasing for $0 < x < \left(\frac{1}{2}\right)^{\frac{2}{3}}$ and decreasing for $x > \left(\frac{5}{6}\right)^{\frac{2}{3}}$ so $x = \left(\frac{5}{6}\right)^{\frac{2}{3}}$ is the absolute maximum of $P(x)$ at $(0, \infty)$. The profit is going to be $\$\frac{25}{12}$.

2. $\boxed{\text{3 marks}}$ Approximate $\sqrt[3]{15}$ as rational number, using a 2-nd Taylor Polynomial of $f(x) = \sqrt[3]{x}$.

Answer: $2+\frac{7}{12}-\frac{7^2}{288}$ or $3-\frac{12}{27}-\frac{12^2}{2187}$

Solution:

- The closest cubes to 15 are 8 and 27. I solve for both choices but you needed choose only one. Write

$$A(x) = a_0 + a_1(x-8) + a_2(x-8)^2$$
$$B(x) = b_0 + b_1(x-27) + b_2(x-27)^2$$

- 0-term:
$$a_0 = f(8) = 2, \quad b_0 = f(27) = 3.$$
In particular $2 < \sqrt[3]{15} < 3$ (since f is increasing).

- 1-term: $f'(x) = \frac{1}{3x^{\frac{2}{3}}}$
$$a_1 = f'(8) = \frac{1}{3 \cdot 2} = \frac{1}{12}, \quad b_1 = f'(27) = \frac{1}{3 \cdot 9} = \frac{1}{27}$$

- 2-term: $f''(x) = \frac{-2}{9x^{\frac{5}{3}}}$
$$a_2 = \frac{f''(8)}{2} = \frac{-2}{2 \cdot 9 \cdot 2^5} = \frac{-1}{288}, \quad b_2 = \frac{f''(27)}{2!} = \frac{-2}{2 \cdot 9 \cdot 243} = \frac{-1}{2187}$$

- The 2-nd taylor polynomial centered at $x = 8$ is
$$A(x) = 2 + \frac{1}{12}(x-8) - \frac{1}{288}(x-8)^2$$
$$B(x) = 3 + \frac{1}{27}(x-27) - \frac{1}{2187}(x-27)^2$$

- The approximations of $\sqrt[3]{15}$ are given by
$$A(15) = 2 + \frac{7}{12} - \frac{7^2}{288}, \quad B(15) = 3 - \frac{12}{27} - \frac{12^2}{2187}.$$

3. $\boxed{\text{4 marks}}$ Sketch the graph of the function $f(x) = \frac{4(x-9)^2}{x^2-9}$. You may use the fact that $f''(x) = 0$ only at $x_0 = 5 + 4\sqrt[3]{2} + 2\sqrt[3]{2^2} \approx 13.2$.

Solution:

- The domain of $f(x)$ is $x \neq \pm 2$, i.e. $(-\infty, -3)$, $(-3, 3)$ and $(3, \infty)$.
- Vertical asymptotes:
$$\lim_{x \to 3^+} f(x) = \infty$$
$$\lim_{x \to 3^-} f(x) = -\infty$$
$$\lim_{x \to -3^+} f(x) = -\infty$$
$$\lim_{x \to -3^-} f(x) = \infty$$

Horizontal asymptotes:

$$\lim_{x\to\infty} f(x) = 4$$
$$\lim_{x\to-\infty} f(x) = \lim_{x\to\infty} f(-x) = 4$$

- The first derivative of $f(x)$ is

$$f'(x) = 72\frac{(x-9)(x-1)}{(x^2-9)^2}$$

The derivative is defined for any x in the domain (i.e. $x \neq \pm 3$) and so the only critical points are the points c where $f'(c) = 0$, i.e. $c = 1$ and $c = 9$. Also, since the denominator is always positive, the sign of the first derivative is the same as the sign of its numerator. So, $f'(x)$ is positive (and $f(x)$ is increasing) for $x < -3$ and $x > 3$ and it is negative (and $f(x)$ is decreasing) for $-3 < x < 3$. It follows that $c = 1$ is a local maximum and $c = 9$ is a local minimum.

- $f(1) = -32$, $f(9) = 0$
- The second derivative of $f(x)$ is

$$f''(x) = 144\frac{-x^3 + 15x^2 - 27x + 45}{(x^2-9)^3}$$

The denominator is positive for $x > 3$ and $x < -3$ and negative for $-3 < x < 3$. The numerator is negative for $x > x_0$ and positive for $x < x_0$. It follows that $f''(x)$ is positive (and $f(x)$ is concave up) for $x < -3$ and $3 < x < x_0$ and negative (and $f(x)$ is concave down) for $-3 < x < 3$ and $x > x_0$. So x_0 is an inflection point.