

## Calculus Optimization Problems/Related Rates Problems Solutions

- 1) A farmer has 400 yards of fencing and wishes to fence three sides of a rectangular field (the fourth side is along an existing stone wall, and needs no additional fencing). Find the dimensions of the rectangular field of largest area that can be fenced.

$$2x + y = 400 \Rightarrow y = 400 - 2x$$

$$A(x) = x(400 - 2x) = 400x - 2x^2$$

$$A'(x) = 400 - 4x \quad 400 - 4x = 0 \Rightarrow x = 100$$

$$A''(x) = -4$$

By the 2<sup>nd</sup> derivative test, the dimensions would be 100 yd by 200 yd.

- 2) A metal box (without a top) is to be constructed from a square sheet of metal that is 20 cm on a side by cutting square pieces of the same size from the corners of the sheet and then folding up the sides. Find the dimensions of the box with the largest volume that can be constructed in this manner.

$$V(x) = x(20 - 2x)(20 - 2x) = 400x - 80x^2 + 4x^3$$

$$V'(x) = 400 - 160x + 12x^2$$

$$400 - 160x + 12x^2 = 0 \Rightarrow 4(100 - 40x + 3x^2) = 0 \Rightarrow 4(3x - 10)(x - 10) \Rightarrow x = \frac{10}{3}, 10$$

$$V''(x) = -160 + 24x \quad V''\left(\frac{10}{3}\right) = -160 + 80 < 0 \quad V''(10) = -160 + 240 > 0$$

By the 2<sup>nd</sup> derivative test, the dimensions would be  $\frac{10}{3}$  cm by  $\frac{40}{3}$  cm by  $\frac{40}{3}$  cm

- 3) A rectangular field adjacent to a river is to be enclosed. Fencing along the river costs \$5 per meter, and the fencing for the other sides costs \$3 per meter. The area of the field is to be 1200 square meters. Find the dimensions of the field that is the least expensive to enclose.

Call the length of fence along the river  $x$ , and the length perpendicular to the river  $y$ .

$$C(x) = 5x + 3(2y + x) \quad xy = 1200 \Rightarrow y = \frac{1200}{x} \Rightarrow C(x) = 8x + \frac{7200}{x}$$

$$C'(x) = 8 - \frac{7200}{x^2} \quad 8 - \frac{7200}{x^2} = 0 \Rightarrow 8x^2 = 7200 \Rightarrow x^2 = 900 \Rightarrow x = 30$$

$$C''(x) = \frac{14400}{x^3} \quad C''(30) = \frac{14400}{30^3} > 0$$

By the 2<sup>nd</sup> derivative test, a field that is 30 m along the river by 40 m perpendicular to the river would be least expensive.

- 4) A 4-meter length of stiff wire is cut in two pieces. One piece is bent into the shape of a square and the other into a rectangle whose length is 3 times its width. Let  $x$  be the length of the side of the square.

a) Find a formula  $A(x)$ , the sum of the areas of the square and rectangle, in terms of the variable  $x$ .

The length of wire left for the rectangle is  $4 - 4x$ . In the rectangle,  $l = 3w$ .  $4 - 4x = 2(3w) + 2w$ ,

$$\text{so } w = \frac{4 - 4x}{8} = \frac{1 - x}{2} \Rightarrow l = \frac{3 - 3x}{2} \quad A(x) = x^2 + \left(\frac{3 - 3x}{2}\right)\left(\frac{1 - x}{2}\right)$$

# Calculus Optimization Problems Solutions

**SB Merriam**

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