Math 1231: Single-Variable Calculus 1
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Recitation 2

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Problem 1. Let $f(x) = 5x + 2$. We want to use an $\varepsilon - \delta$ argument to compute $\lim_{x \to 2} f(x)$.

(a) If x is about 2, what should $f(x)$ be?

(b) Write down expressions using absolute value for the input and output errors.

(c) If we want $\varepsilon = 1$, what does δ need to be?

(d) Find a formula for δ in terms of ε (same form as $\delta = \varepsilon/3$ or $\delta = \varepsilon$).

(e) Try to write a full proof.

Solution:

(a) $f(x) \approx 12$.

(b) Output error is $|f(x) - 12|$ or $|5x + 2 - 12|$, which we can simplify to $|5x - 10|$. Input error is $|x - 2|$.

(c) We want $|5x - 10| < 1$, and dividing by 5 gives $|x - 2| < 1/5$. So we'd need $\delta = 1/5$.

(d) We want $|5x - 10| < \varepsilon$, and dividing by 5 gives $|x - 2| < \varepsilon/5$. So we'd need $\delta = \varepsilon/5$.

(e) Let $\varepsilon > 0$ and set $\delta = \varepsilon/5$. Then if $0 < |x - 2| < \delta = \varepsilon/5$ we compute that

$$|f(x) - 12| = |5x - 10| = 5|x - 2| < 5 \cdot \varepsilon/5 = \varepsilon.$$

But we mostly want to practice the way we actually compute limits. Remember we have two key principles:

(a) Functions built out of algebra and trigonometry are *continuous* wherever they're defined. When a function is continuous, we can compute the limit by just plugging in.

(b) We say two functions are *almost identical* if they're the same except at a small collection of points. If two functions are almost identical, then their limits will always be the same. This allows us to replace complicated functions with simpler ones.

Problem 2 (Warmup)**.** Let $f(x) = \frac{x^2+\sin(x)+3}{x^2-x-2}$.

(a) Where is f continuous? Where is it discontinuous?

(b) What is $\lim_{x\to 0} f(x)$?

Solution:

(a) This function is made of algebra and trigonometry, so it's continuous where it's defined. The denominator is $x^2 - x - 2 = (x-2)(x+1)$ so the function is undefined at 2 and -1.

(b) Because this function is continuous at 0, we can just plug in:

$$\lim_{x\to 0} f(x) = f(0) = \frac{0^2 + \sin(0) + 3}{0^2 - 0 - 2} = -3/2.$$

Problem 3. Let $f(x) = \frac{x-1}{x^2-1}$.

(a) What is $f(2)$? Is f continuous at 2?

(b) What is $\lim_{x\to 2} f(x)$?

(c) What is $f(1)$? Is f continuous at 1?

(d) What function can we find that's almost the same as f, but defined and continuous at 1? (Is this function the same as f?)

(e) What is $\lim_{x\to 1} f(x)$?

Solution:

(a) $f(2) = 1/3$, and f is continuous here since it's a reasonable functions.

(b) $\lim_{x\to 2} f(x) = 1/3$.

(c) $f(1)$ isn't defined, and thus f is not continuous at 1.

(d) $\frac{x-1}{x^2-1} = \frac{x-1}{(x-1)(x+1)}$ is almost the same as $\frac{1}{x+1}$.

(e) $\lim_{x\to 1} f(x) = \lim_{x\to 1} \frac{1}{x+1} = \frac{1}{2}$.

Note we're using the Almost Identical Functions principle here. The function f was *not* continuous at 1, because it's not defined there. But we can replace it by an almost identical function that is continuous, and then that limit is simple to compute.

Problem 4. Let $g(x) = \frac{(x+1)^2-1}{x+2}$.

(a) Is g continuous where it's defined? Where is it undefined?

(b) Can you find a function that's almost identical to g but continuous everywhere?

(c) What is $\lim_{x\to -2} g(x)$?

Solution:

(a) g is a reasonable function so it's continuous where it's defined, but it isn't defined at $x = -2$.

(b) $\frac{x^2+2x+1-1}{x+1} = \frac{x(x+2)}{x+2}$ is almost the same as x. So $g(x)$ is almost the same as x.

(c) $\lim_{x\to -2} g(x) = \lim_{x\to -2} x = -2$.

Note that $\frac{x(x+2)}{x+2} \neq x$, but their limits at 0 are the same because the functions are the same near 0 (and in fact everywhere except at 0).