

MATH 405, HW 3 SOLUTIONS

PROFESSOR SOOKE

The Way of Analysis

p. 49:

11.) To show that $x^2 \neq -1$ when x is a real number we have to consider three cases: $x = 0$, $x > 0$, and $x < 0$. Clearly $0^2 \neq -1$. If x is a positive real number then we proved in class that $x^2 > 0$, and so $x^2 \neq -1$ in this case. If $x < 0$ this also implies that we cannot have $x^2 = -1$, for $x^2 = x \cdot x = -1 \cdot -1 \cdot x \cdot x = (-x)^2 \neq -1$.

p. 54:

1.) Suppose that $\lim x_j = x$ and $\lim y_j = y$. Then given $n \in \mathbb{N}$ we can find an $m \in \mathbb{N}$ so that $|x_j - x|, |y_j - y| < 1/2n$ if $j \geq m$. But then we have $|(x_j + y_j) - (x + y)| \leq |x_j - x| + |y_j - y| < 1/n$ for $j \geq m$, and so $\lim(x_j + y_j) = x + y$.

2.) To see that there can only be one cube root of x it suffices to verify this for $x \neq 0$ since the case of $x = 0$ is obvious. Suppose then that y and z were cube roots of $x \neq 0$. Clearly neither y nor z could then be zero. On the other hand $0 = x - x = y^3 - z^3 = (y - z)(y^2 + yz + z^2)$. Since y and z are nonzero, it is not hard to check that $(y^2 + yz + z^2)$ is a positive number. Therefore after dividing the preceding equation by it we conclude that $y - z = 0$ and so the two cube roots must be the same.

Let us now show that every real number has a cube root. Clearly the cube root of 0 is 0. Also if $x > 0$ has a cube root z then $-z$ must be the cube root of $-x$ as $(-z)^3 = (-1)^3 z^3 = -x$. Because of this we only must show that every positive real number x has a cube root. We shall use the "divide and conquer" method. If $0 < x < 1$ let $y_1 = 0$ and $z_1 = 1$. If $x > 1$, let $y_1 = 1$ and $z_1 = x$. In either case we have $y_1^3 \leq x \leq z_1^3$. Let $m_1 = (y_1 + z_1)/2$ be the midpoint of the interval (y_1, z_1) . If $m_1^3 \geq x$ take $y_2 = y_1$ and $z_2 = m_1$, while if $m_1^3 < x$ take $y_2 = m_1$ and $z_2 = z_1$. In either case we still have $y_2^3 \leq x \leq z_2^3$. Moreover, the new interval (y_2, z_2) has half of the length of (y_1, z_1) . Continue the process. We obtain an increasing sequence of points y_j and a decreasing sequence of points z_j satisfying $y_j^3 \leq x \leq z_j^3$ for every j . Since $z_j - y_j = (z_1 - y_1)/2^{j-1}$ it is clear that the two sequences are equivalent, and since every z_k and y_k for $k \geq j$ is in the interval (y_j, z_j) whose length goes to zero with k , it is clear that the two sequences are Cauchy. Thus y_k and z_k must have a common limit y . Recalling that $y_k^3 \leq x \leq z_k^3$, we get by taking limits that $y^3 \leq x \leq y^3$, and so $y^3 = x$, which means that the limit of the sequences we have constructed must be the cube root of x .

3.) Suppose that $|x_n| \leq 1/2^n$ and set $y_n = x_1 + x_2 + \dots + x_n$. Suppose that $j < k$, then by the triangle inequality $|y_k - y_j| \leq \sum_{i=j+1}^k |x_i| \leq \sum_{i=j+1}^{\infty} 2^{-i} = 2^{-j}$. Since 2^{-j}

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