1. The-Real-and-Complex-Number-Systems
    1.1. Definition of Rational Numbers
    1.2. Rationals are Inadequate
    1.3. Order
    1.4. Ordered Set

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- **References:**
  - Analysis I
  - Rudin W., Principles of Mathematical Analysis

Main Content

Main Idea
Rational numbers are of the form $\frac{m}{n}$, where m and n are integers and $n \neq 0$.

Explanation

Review

1. Define the rational number system.

Links to Other Notes

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Main Content

Main Idea

The rational number system is inadequate for many purposes, both as a field and as an ordered set.

Explanation

For example, there is no rational p such that $p^2 = 2$.

Proof 0.1 *Suppose on the contrary there was a p that satisfied $p^2 = 2$. We could write $p = \frac{m}{n}$, where m and n are integers and coprime. The original expression implies*

$$\begin{aligned}(\frac{m}{n})^2 &= 2\\ \frac{m^2}{n^2} &= 2\\ m^2 &= 2n^2\end{aligned}$$

From this expression, we see that m^2 is even, and thus, m is even. Plugging $2k$ in for m, it is clear that m^2 is divisible by 4. It follows that $2n^2$ is divisible by 4 as well, which implies n^2 is even, and thus, n is even. Therefore, our assumption leads to a contradiction that both m and n are even, thus violating the coprime property of m and n. Hence, it is impossible for p to be rational.

Proof 0.2 (Alternative) *Let A be the set of all positive rationals p such that $p^2 < 2$ and let B consist of all positive rationals p such that $p^2 > 2$. By showing there is no largest element in A and no smallest element in B, we effectively partion the set of rational numbers, thus implying there is no rational p that falls outside these two sets, therefore satisfying $p^2 = 2$.*

To prove that for every p in A we can find a rational q in A such that $p < q$, we associate with each rational $p > 0$ the number

$$q = p - \frac{p^2 - 2}{p + 2} = \frac{2p + 2}{p + 2}. \tag{1}$$

Then

$$q^2 - 2 = \frac{2(p^2 - 2)}{(p + 2)^2}. \tag{2}$$

If p is in A then $p^2 - 2 < 0$, (1) shows that $q > p$, and (2) shows that $q^2 < 2$. Thus q is in A. If p is in B then $p^2 - 2 > 0$, (1) shows that $0 < q < p$, and (2) shows that $q^2 > 2$. Thus q is in B.

Review

1. Prove that there is no rational p such that $p^2 = 2$ in two different ways.

Links to Other Notes

- Definition of Rational Numbers

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Main Content

Main Idea

Let S be a set. An order on S is a relation, denoted by $<$, with the following two properties:

- If $x \in S$ and $y \in S$ then one and only one of the statements

  $$x < y, \qquad x = y, \qquad y < x$$

  is true.
- If $x, y, z \in S$, if $x < y$ and $y < z$, then $x < z$.

Explanation

Review

1. Define order.

Links to Other Notes

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Main Content

Main Idea
An ordered set is a set S in which an order is defined.

Explanation
For example, Q is an ordered set if $r < s$ is defined to mean that $s - r$ is a positive rational number.

Review

1. Define ordered set and give an example.

Links to Other Notes

- Order

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