

Boolos and Jeffrey - HW1

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1 A question about \cap

Proposition:

The intersection of a finite set \mathbf{S} and an enumerable set \mathbf{T} is enumerable.

Lemma 1.1. *Any finite set is enumerable.*

Proof. Let \mathbf{S} be a finite set with n elements. Let $\mathbf{K} = \{1, 2, \dots, n\}$. Choose an element $\mathbf{s} \in \mathbf{S}$ and assign $f(n) = \mathbf{s}$. Set \mathbf{S}' to $\mathbf{S} - \{\mathbf{s}\}$. Choose an element $\mathbf{s}' \in \mathbf{S}'$ and assign $f(n-1) = \mathbf{s}'$. Repeat this procedure until \mathbf{S} is exhausted. The resulting function $f : \mathbf{K} \rightarrow \mathbf{S}$ is an enumeration of \mathbf{S} . \square

Theorem 1.1. *The intersection of two enumerable sets is enumerable.*

Proof. Let $f : \mathbb{N} \rightarrow \mathbf{A}$ represent a function that enumerates the first set. Let $g : \mathbb{N} \rightarrow \mathbf{B}$ represent a function that enumerates the second set. Let $h : \mathbb{N} \rightarrow \mathbf{A} \cap \mathbf{B}$ be a new function defined as follows:

$$h(x) = \begin{cases} f(x) & \text{if } f(x) \in \mathbf{B} \\ \text{undefined} & \text{if } f(x) \notin \mathbf{B}. \end{cases}$$

\square

Conclusion:

Proof. By **Lemma 1.1** the set \mathbf{S} is enumerable. By **Theorem 1.1** the intersection of \mathbf{S} and \mathbf{T} is enumerable. \square

2 A slightly harder question about \cap

Proposition:

The intersection of an enumerable set of enumerable sets is itself enumerable.

Conclusion:

Proof. Let \mathbf{S} be an enumerable set of enumerable sets. Pick a set $\mathbf{A} \in \mathbf{S}$. Let \mathbf{B} be $\bigcap(\mathbf{S} - \mathbf{A})$. By **Theorem 1.1** we can define a function $h : \mathbb{N} \rightarrow \mathbf{A} \cap \mathbf{B}$ that enumerates $\bigcap \mathbf{S}$. \square

3 It takes two...

Proposition:

Let \mathbf{F} be the set of all *one to one* functions that both i) have a domain that's a subset of the positive integers, and ii) are *onto* a two element set $\{a, b\}$. \mathbf{F} is enumerable.

Lemma 3.1. *The Cartesian product of two finite sets is enumerable.*

Proof. Let \mathbf{A} and \mathbf{B} be two sets with a finite number n many members. The Cartesian product $\mathbf{A} \times \mathbf{B}$ has $n \cdot n$ members which is also a finite number. By **Lemma 1.1** this finite set is enumerable. \square

Theorem 3.1. *Any set of enumerable sets is enumerable*

I'm probably going the wrong direction with this proof as I can't figure out how to prove this. Or even if this is correct (I have a gut feeling it's not).

Conclusion: IN PROGRESS - NOT YET PROVED

Proof. each $\mathbf{f} \in \mathbf{F}$ can be represented as a Cartesian product of finite sets: $(\{k_1, k_2\} \subset \mathbb{N}) \times \{a, b\}$. By **Lemma 3.1** each $\mathbf{f} \in \mathbf{F}$ is enumerable. By **Theorem 3.1** the set \mathbf{F} is enumerable. \square

4 Enumerate all the things!

Proposition:

The set of all finite sequences of positive integers is enumerable.

Theorem 4.1. *The union of an enumerable set of enumerable sets is itself enumerable.*

Proof. Let \mathbf{A} be an enumerable set of enumerable sets. The members of \mathbf{A} can be enumerated as (a_1, a_2, a_3, \dots) . The members of each a_i can be enumerated as $(a_{i1}, a_{i2}, a_{i3}, \dots)$. We can arrange them on a two-dimensional grid as follows:

$$\begin{array}{cccc} a_1 & a_{11} & a_{21} & \dots \\ a_2 & a_{12} & a_{22} & \dots \\ a_3 & a_{13} & a_{23} & \dots \\ \vdots & \vdots & \vdots & \ddots \end{array}$$

$\bigcup \mathbf{A}$ can now be enumerated by sweeping through the grid in a triangular fashion: $(a_1, a_{11}, a_2, a_{21}, a_{12}, a_3, \dots)$. \square

Conclusion:

Proof. Let \mathbf{S} be the set of all finite sequences of positive integers. \mathbf{S} is the union of all one member sequences, all two member sequences, all three member sequences, etc. Each n -member sequence is a Cartesian product of two finite sets which by **Lemma 3.1** is enumerable. Therefore by **Theorem 4.1** the $\bigcup \mathbf{S}$ is enumerable. \square