Problems in Math and Computer Science

Compiled and to be solved by Chad Estioco

Contents

Chapter 1

2015.1

1. Prove that
$$\exists x \forall y P(x,y) \leftrightarrow \forall y \exists x P(x,y)$$
(Curiously, the "reverse" of this implication is not true. That is,
$$\forall y \exists x P(x,y) \leftrightarrow \exists x \forall y P(x,y)$$
How do you reconcile this?)

2. Prove the following inference rules
$$\frac{P \to Q, Q \to R}{P \to R}$$
$$\frac{P \to Q, \neg Q}{\neg P}$$
$$\frac{\neg P \to \neg Q}{Q \to P}$$

3. Is the following also true? Prove or disprove.
$$\frac{\neg P \to \neg Q}{P \to Q}$$

4. Regarding the Horses proof in section 3.2.6 [MCS-LEHMAN], why is it wrong to claim that the mistake in the proof is with $P(n)$ being false for $n \geq 2$ and that it assumes something false, namely, $P(n)$ in order to prove $P(n+1)$?

Chapter 2

Programming Problems

A collection of programming problems I've thought up (ala Programming Praxis).

Away Goals

In some major football championships, each match-up sees teams play in home and in away conditions. Should there be a tie after two games, the winner is decided by the *away goals* rule: whoever scored the most goals while playing in away territory wins that leg of the championships.

Given the results of the first leg of a match-up, determine how many goals do each need to win the fixture.

Input

Each test case is made up of two lines indicating the score for each team. It will also indicate who took the home ground for the first leg. The format will be

```
(H) TeamName Score
```

The `(H)` will only be present for the home team. The team name will not contain spaces.

Chapter 3

Miscellaneous Problems

(I.e., problems that were compiled before and left unsolved)

1. Let $J(n)$ be the Josephus Numbers[CA-KNUTH], and 2^m be the largest power of 2 not exceeding n. Prove that $J(5 \cdot 2^m) = 2^{m+1} - 1$. What can you conjecture about $J(x2^m)$ if x is any arbitrary integer?

2. **Number Theory?** $2^m - 2$ is a multiple of 3 when m is an odd but no when m is even.

3. **Statistics** A soft drink machine is regulated so that it dispenses an average of 200ml per cup. If the amount of drink dispensed is normally distributed with a standard deviation equal to 15ml.

   (a) What fraction of the cups will contain more that 224ml?

   (b) What is the probability that a cup contains between 191ml and 209ml?

   (c) How many cups will likely overflow if 230ml cups are used for the next 1000 drinks?

   (d) Below what value do we get the smallest 2.5% of the drinks?

4. Prove: Let,

$$I = \sum \text{length of paths from root to internal node}$$

$$E = \sum \text{length of paths from root to external node}$$

$$n = \text{number of internal nodes}$$

   Then, $E = I + 2n$

5. What is the significance of the relationship between Pascal's triangle and combinations? That is, why does adding the two numbers above an entry in Pascal's triangle give the number of combinations?

6. Give a strong proof of the following statement: If n is composite, no item in the nth row of Pascal's triangle divides n.

7. **Statistics** Prove: The positive and negative distance from the mean cancel each other out.

Bibliography

[CA-KNUTH] Knuth, D. *Concrete Mathematics*

[MCS-LEHMAN] Lehman E. *Mathematics for Computer Science*