1 Propositional Logic Review

Note 0
Note 1

(a) For the following parts, suppose P is true, and Q is false. Evaluate the following propositions as either true or false.

P=T Q=F

(i) $P \wedge Q$ F
(ii) $P \implies Q$ F
(iii) $\neg P \implies Q$ T
(iv) $\neg Q \implies \neg P$ F

(b) Convert the following English sentence into propositional logic:

Every integer has at least one divisor. $(\forall x \in \mathbb{Z})(\exists y \in \mathbb{Z})(y | x)$

(c) Convert the following propositional logic statement into English:

$$\neg(\exists x \in \mathbb{Z})(\forall y \in \mathbb{Z})(x > y).$$

This is not the case that. there exist a integer which is bigger than any other integer.

Proofs Intro

Note 2

In this course, we'll be working a lot with proofs: a *proof* is a sequence of logical deductions which establishes that a particular statement is true. Here are four proof strategies that we typically use to prove that a statement is true.

1. **Direct Proof**: To prove $P \implies Q$, assume P, $[\cdots]$, therefore Q.
2. **Proof by Contraposition**: To prove $P \implies Q$, it is equivalent to prove $\neg Q \implies \neg P$. As such, assume $\neg Q$, $[\cdots]$, therefore $\neg P$.

   A proof by contraposition relies on the fact that the contrapositive is equivalent to the original implication: $P \implies Q \equiv \neg Q \implies \neg P$.
3. **Proof by Contradiction**: To prove P, assume $\neg P$, $[\cdots]$, therefore R, $[\cdots]$, therefore $\neg R$. This is a contradiction, since R and $\neg R$ cannot both be true, so P must be true.

   In a proof by contradiction, the propositions R and $\neg R$ often arise naturally as you construct the proof; in the majority of cases, you do not decide on R beforehand, and it can often be hard to determine what R should be.
4. **Proof by Cases**: Divide the problem into parts, and tackle each separately. Oftentimes, each case will involve one of the other proof types.

As you get familiar with these proof techniques, it can often be unclear which strategy to take: this is expected! It's natural to start out through trial and error: attempt a proof strategy, and if it doesn't work out, try another. There is no magical rule to tell you how to prove a statement: as you write more and more proofs, you'll likely find some patterns that indicate that a particular proof strategy may be most suitable for the claim. The best way to get better at writing proofs is to practice!

2 Perfect Square

Note 2

(a) Prove that if n^2 is odd, then n must also be odd.

prove by contraposition.

if n is even $\Rightarrow n=2k \Rightarrow n^2=4k^2=2\cdot 2k^2$

$\Rightarrow n^2$ is even

(b) Prove that if n^2 is odd, then n^2 can be written in the form $8k+1$ for some integer k.

by (a), n^2 is odd

$\Rightarrow n$ is odd

let $n=2k+1$, $k \in \mathbb{Z}$

$\Rightarrow n^2 = 4k^2+4k+1$

$= 4k(k+1)+1$

① if k is even

$\Rightarrow k=2a$

$\Rightarrow n^2 = 8a\cdot(k+1)+1$

② if k is odd

$\Rightarrow k+1$ is even, $k+1=2a$

$n^2 = 8ak+1$. ✓

∴ ✓

3 Numbers of Friends

Note 2

Prove that if there are $n \geq 2$ people at a party, then at least 2 of them have the same number of friends at the party. Assume that friendships are always reciprocated: that is, if Alice is friends with Bob, then Bob is also friends with Alice.

(Hint: The Pigeonhole Principle states that if n items are placed in m containers, where $n > m$, at least one container must contain more than one item. You may use this without proof.)

0 and n-1 can't both be box (if so, contradiction)

① if the person who has least friends has 0 friends then pigeonhole could be 0, 1, 2 … n-2, → n boxes and there are n people, so at lease 1 box has two person.

② if … has 1, then … could be 1 … n-1 → n boxes

4 Pebbles

Note 2

Suppose you have a rectangular array of pebbles, where each pebble is either red or blue. Suppose that for every way of choosing one pebble from each column, there exists a red pebble among the chosen ones. p

Prove that there must exist an all-red column. q

prove by contraposition

Assume there doesn't exist all red column

$\Rightarrow$ there's atleast one blue pebbles in each column

$\Rightarrow$ choose those blue ones from those columns, no red one among them

$\Rightarrow$ exise a chousen way where there's no red pebbles among them.

So, $p \Rightarrow q$