CS 241: Spring 2022 **HW 4** **Due 23 Feb by 11:59pm**

Name: ______________________________ Student ID: _________________

Instructions. Print out this assignment, fill in your answers in the space provided and upload your work to Gradescope. **Important**. You must write your answers on a printout of this pdf! Please do not upload additional pages or scratch work.

(4pts) 1. Given two statements A and B, we say that A is *stronger* than B if A → B, while A is *weaker* than B if B → A. We say A and B are *equivalent* if each implies the other; that is, A → B ∧ B → A. (We sometimes denote the latter by A ↔ B.)

Consider the following induction principle.

(A) Principle of Mathematical Induction. Let $S(n)$ be a predicate whose domain is the set of natural numbers. Suppose there exists m such that $S(m)$ holds and $\forall n \geq m$ if $S(n)$ holds then so does $S(n+1)$. Then $S(n)$ holds for every natural number $n \geq m$.

We state this principle formally as follows:

$$\exists m(S(m) \wedge \forall n(n \geq m \rightarrow (S(n) \rightarrow S(n+1)))) \rightarrow \forall n(n \geq m \rightarrow S(n)). \tag{1}$$

Consider the following induction principle which is closer to the one appearing on page 90 of our textbook.[1]

(B) Principle of Mathematical Induction. Let $S(n)$ be a predicate whose domain is the set of natural numbers. Suppose $S(0)$ holds and suppose that whenever $S(n)$ holds then so does $S(n+1)$. Then $S(n)$ holds for every natural number n.

(a) Express induction principle (B) as a logical formula (just like we did in (1) for (A)).

(b) Is induction principle (A) stronger, weaker, or equivalent to induction principle (B)?

- ◯ (A) is stronger than (B).
- ◯ (B) is stronger than (A).
- ◯ (A) and (B) are equivalent.

[1] We modified it slightly to allow for the case $n = 0$.

(c) (Extra Credit.) For up to 3 bonus points, prove your answer to part (b) is correct.

(6pts) 2. Using induction, verify that each equation is true for every natural number $n \geq 0$.

(a) $0 \cdot 1 + 1 \cdot 2 + 2 \cdot 3 + 3 \cdot 4 + \cdots + n(n+1) = n(n+1)(n+2)/3$

(b) $1^3 + 2^3 + 3^3 + \cdots + n^3 = \left[\frac{n(n+1)}{2}\right]^2$

(6pts) 3. Use induction to verify the inequality.

(a) $2n + 1 \leq 2^n, \quad n = 3, 4, \ldots$

(b) $(1 + x)^n \geq 1 + nx$, for $x \geq -1$ and $n = 1, 2, \ldots$

(6pts) 4. Show that any amount of postage greater than or equal to 12 cents can be achieved by using only 3-cent and 7-cent stamps.