MATH 113: DISCRETE STRUCTURES
HOMEWORK DUE FRIDAY WEEK 3

Suppose we have an identity $E = F$ where E and F are two algebraic expressions that evaluate to the same integer (see the examples below). A *combinatorial* explanation for the identity $E = F$ requires identifying both E and F as solutions to counting problems and explaining why these counting problems should have the same solution. As an example, we give a proof of the identity

$$\binom{n}{k} = \binom{n-1}{k-1} + \binom{n-1}{k}$$

in the case where $n > k > 0$. (It is true for general n and k, but we will skip these trivial cases.)

Proof. Let $S = \{1, \ldots, n\}$. The left-hand side counts the k-subsets of S. Each k-subset of S is of exactly one of two types: (1) those that contain n, and (2) those that do not. To find the number of k-subsets of S, we can just count the numbers of each type and add. A subset of size k containing n, i.e, of type (1), is the same thing as a subset of $\{1, \ldots, n-1\}$ of size $k-1$ to which we then append n. Thus, there are $\binom{n-1}{k-1}$ subsets of type (1). A k-subset of S that does not contain n, i.e., of type (2), is the same as a subset of $\{1, \ldots, n-1\}$, and there are $\binom{n-1}{k}$ of these. □

Problem 1. Consider the identity

$$\binom{n}{k} - \binom{n-3}{k} = \binom{n-1}{k-1} + \binom{n-2}{k-1} + \binom{n-3}{k-1}$$

for $n \geq 3$ and $n \geq k$.

(a) Suppose there is a set S of n people, and in that set, there are three special people a, b, and c. What is the left-hand side of the identity counting in the context of S and its three distinguished members?
(b) Provide a combinatorial proof of the identity by showing the thing you counted in part (a) can be counted a different way.

Problem 2. Give a combinatorial explanation of the following identity:

$$\binom{17}{5} = \binom{10}{0}\binom{7}{5} + \binom{10}{1}\binom{7}{4} + \binom{10}{2}\binom{7}{3} + \binom{10}{3}\binom{7}{2} + \binom{10}{4}\binom{7}{1} + \binom{10}{5}\binom{7}{0}.$$

Hint: you might think about coloring the elements of a set.