# CSC 226

## Algorithms and Data Structures: II
## Counting

Tianming Wei
twei@uvic.ca
ECS 466

# Fundamental Principles of Counting

**The Rule of Sum**

If a first task can be performed in $m$ ways, while a second task can be performed in $n$ ways, and the two tasks cannot be performed simultaneously, then performing either task can be accomplished in any one of $m + n$ ways.

# Fundamental Principles of Counting

**The Rule of Product**

If a first task can be performed in $m$ ways, while a second task can be performed in $n$ ways, and the two tasks can be performed simultaneously, then performing both tasks can be accomplished in any one of $m \cdot n$ ways.

# Example 1

I have 5 distinct red cards and 4 distinct black cards

a) How many ways can I choose 1 card?
b) How many ways can I choose 1 red card then 1 black card?
c) How many ways can I choose 2 cards?

# Fundamental Principles of Counting

**Permutation**

Application of the Rule of Products when counting linear arrangements of distinct objects.

# Example 2

I have 5 distinct red cards and 4 distinct black cards

a) How many arrangements of the red cards?
b) How many arrangements of the black cards?
c) How many ways of arranging all the red followed by all the black cards?
d) How many arrangements of all the cards?

# Example 3

Consider a full standard deck of 52 distinct cards

a) How many arrangements of a standard deck of cards are there? That is, what is the total number of possible shuffles?

b) How many ways can I arrange 5 cards from the deck? That is, how may permutations of 5 cards from 52?

# Fundamental Principles of Counting

**Permutations**

In general, the number of permutations of size $r$ from $n$ distinct objects, where $0 \leq r \leq n$, is given by

$$P(n, r) = \frac{n!}{(n-r)!}$$

- Note: $P(n, 0) = \frac{n!}{n!} = 1$ and $P(n, n) = \frac{n!}{0!} = n!$

# Example 3 Revisited

Consider a full standard deck of 52 distinct cards

c) How many distinct poker hands exist? That is, how many ways can you pull 5 cards from 52 where order doesn’t matter?

# Fundamental Principles of Counting

## Combinations

In general, the number of combinations of $r$ objects from $n$ distinct objects, where $0 \leq r \leq n$, is given by

$$\binom{n}{r} = C(n, r) = \frac{P(n, r)}{r!} = \frac{n!}{r!\,(n-r)!}$$

- Note: $C(n, 0) = \frac{n!}{0!n!} = 1$ and $C(n, n) = \frac{n!}{n!0!} = 1$

# Example 3 Revisited

Consider a full standard deck of 52 distinct cards

d) How many royal flushes exist?

e) How many straight flushes?

f) 4 of a kind?

g) Full house?

h) …

# Fundamental Principles of Counting

**The Binomial Theorem**

If $x$ and $y$ are variables and $n$ a positive integer, then

$$(x+y)^n = \sum_{k=0}^{n} \binom{n}{k} x^k y^{n-k}$$

- Proof: Consider $(x+y)^n = \underbrace{(x+y)\cdots(x+y)}_{n\ times}$.

  For any $0 \le k \le n$, the number of combinations of $k$ $x$'s is $\binom{n}{k}$.

# Example 4

What is the coefficient of $x^5y^2$ in the expansion of $(2x-3y)^7$?

Answer:

$$\binom{7}{5}(2)^5(-3)^2 = 21 \cdot 32 \cdot 9 = 6048$$

# Example 5

7 people go for lunch. Each person has an option of one of a cheeseburger (c), hot dog (h), taco (t), or fish sandwich (f). How many possible orders are there?

- Possibilities:
  1. ccccccc
  2. chhttff
  3. hhhffff
  4. …

# Fundamental Principles of Counting

**Combinations with Repetition**

In general, taking $n$ distinct objects, with repetition, taken $r$ at a time can be done in

$$\binom{n+r-1}{r} = \frac{(n+r-1)!}{r!\,(n-1)!}$$

ways.

# Example 6

A donut shop has 20 distinct types of donuts with at least 12 of each type in the store. How many ways can you select a dozen (12) donuts?

# Example 7

Determine all the integer solutions to the equation

$$x_1 + x_2 + x_3 + x_4 = 7$$

where $x_i \geq 0$ for all $i = 1,2,3,4$.