http://vlsicad.ucsd.edu/courses/cse21-s14/
http://webwork.cse.ucsd.edu/webwork2/CSE21_Spring2014/
Homework 2 due Sunday 11:59pm
https://piazza.com/ucsd/spring2014/cse21/home
Outline

- Office Hours today: Friday Noon-1 (4122), Friday 2-3 (Porters Pub)
- Counting Review
- Poker Hands
- Dice rolls, other Random Events
  - (If there is time after the quiz)
- The Enigma Plugboard (6 letter example)
  - Two methods of counting
- Friday’s Quiz
If you get one tattoo to remember this course, this might be it *(partial credit for Wu-Tang Wednesday Tattoo)*:

For a sample of $r$ objects from $n$ objects:

<table>
<thead>
<tr>
<th></th>
<th>No repeats <em>(sampling without replacement)</em></th>
<th>Repeats allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>ordered</td>
<td>$P(n, r) = \frac{n!}{(n-r)!}$</td>
<td>$n^r$</td>
</tr>
<tr>
<td>unordered</td>
<td>$C(n, r) = \binom{n}{r} = \frac{n!}{r!(n-r)!}$</td>
<td>$\binom{n-1+r}{r}$</td>
</tr>
</tbody>
</table>

Rubalcaba (rrrubalcaba@eng.ucsd.edu)
One more Stars and Bars Example

Let’s say you have four integer variables summing to exactly 10. Each of the $x_i$’s are non-negative integers (can be zero). How many solutions are there to this equation?

$$x_1 + x_2 + x_3 + x_4 = 10$$
One more Stars and Bars Example

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<table>
<thead>
<tr>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$x_3$</th>
<th>$x_4$</th>
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<tbody>
<tr>
<td>4</td>
<td>6</td>
<td>0</td>
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<tr>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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</tbody>
</table>
One more Stars and Bars Example

Let’s say you have four integer variables summing to exactly 10. Each of the \( x_i \)'s are non-negative integers (can be zero). How many solutions are there to this equation?

\[
x_1 + x_2 + x_3 + x_4 = 10
\]

\[
\begin{array}{cccc}
  x_1 & x_2 & x_3 & x_4 \\
  4 & 6 & 0 & 0 \\
  0 & 10 & 0 & 0 \\
  1 & 2 & 3 & 4 \\
\end{array}
\]

\[
\begin{array}{cccc}
  \ast & \ast & \ast & \ast \\
  \ast & \ast & \ast & \ast \\
  \ast & \ast & \ast & \ast \\
  \ast & \ast & \ast & \ast \\
\end{array}
\]

Rubalcaba (rrrubalcaba@eng.ucsd.edu)
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<th>$x_3$</th>
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\[
\binom{10 + 4 - 1}{4 - 1} = \binom{10 + 4 - 1}{10} = \binom{\text{stars + bars}}{\text{bars}} = \binom{\text{stars + bars}}{\text{stars}}
\]
# Standard Deck of Cards

## The Deck

- **13 Ranks** \{2, 3, 4, 5, \ldots, K, A\}
- **4 Suits** \{ hearts, diamonds, clubs, spades \}

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Rubalcaba (rrrubalcaba@eng.ucsd.edu)

4/11/2014
### Poker Hands

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Cards</th>
</tr>
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<tbody>
<tr>
<td>(i)</td>
<td><strong>nothing:</strong></td>
<td>3♠, 7♥, 8♦, 6♠, J♣</td>
</tr>
<tr>
<td>(ii)</td>
<td><strong>one pair:</strong></td>
<td>5♠, 5♦, K♥, Q♥, J♥</td>
</tr>
<tr>
<td>(iii)</td>
<td><strong>two pair:</strong></td>
<td>8♦, 8♠, 6♣, 6♥, Q♣</td>
</tr>
<tr>
<td>(iv)</td>
<td><strong>three of a kind:</strong></td>
<td>10♣, 10♦, 10♥, K♣, Q♦</td>
</tr>
<tr>
<td>(v)</td>
<td><strong>straight (not straight flush, not royal flush):</strong></td>
<td>7♠, 6♦, 5♥, 4♠, 3♥</td>
</tr>
<tr>
<td>(vi)</td>
<td><strong>flush (not straight flush, not royal flush):</strong></td>
<td>8♣, 7♣, 5♣, 4♦, 3♣</td>
</tr>
<tr>
<td>(vii)</td>
<td><strong>full house:</strong></td>
<td>9♠, 9♣, 9♥, 4♦, 4♥</td>
</tr>
<tr>
<td>(viii)</td>
<td><strong>four of a kind:</strong></td>
<td>2♠, 2♣, 2♥, 2♦, A♦</td>
</tr>
<tr>
<td>(ix)</td>
<td><strong>straight flush (not royal flush):</strong></td>
<td>5♠, 4♣, 3♠, 2♣, A♣</td>
</tr>
<tr>
<td>(x)</td>
<td><strong>royal flush:</strong></td>
<td>A♥, K♥, Q♥, J♥, 10♥</td>
</tr>
</tbody>
</table>
Counting Royal Flushes

Royal Flushes

- 4 Suits to choose \{ hearts, diamonds, clubs, spades \}

\[
\begin{array}{cccccccccc}
2\heartsuit & 3\heartsuit & 4\heartsuit & 5\heartsuit & 6\heartsuit & 7\heartsuit & 8\heartsuit & 9\heartsuit & 10\heartsuit & J\heartsuit & Q\heartsuit & K\heartsuit & A\heartsuit \\
2\diamondsuit & 3\diamondsuit & 4\diamondsuit & 5\diamondsuit & 6\diamondsuit & 7\diamondsuit & 8\diamondsuit & 9\diamondsuit & 10\diamondsuit & J\diamondsuit & Q\diamondsuit & K\diamondsuit & A\diamondsuit \\
2\clubsuit & 3\clubsuit & 4\clubsuit & 5\clubsuit & 6\clubsuit & 7\clubsuit & 8\clubsuit & 9\clubsuit & 10\clubsuit & J\clubsuit & Q\clubsuit & K\clubsuit & A\clubsuit \\
2\spadesuit & 3\spadesuit & 4\spadesuit & 5\spadesuit & 6\spadesuit & 7\spadesuit & 8\spadesuit & 9\spadesuit & 10\spadesuit & J\spadesuit & Q\spadesuit & K\spadesuit & A\spadesuit \\
\end{array}
\]
Counting Straight Flushes

Straight Flushes

- 4 Suits to choose from \{ hearts, diamonds, clubs, spades \}

![Diagram of straight flushes with hearts suit]
Counting Straight Flushes

Straight Flushes

- 4 Suits to choose from \{ hearts, diamonds, clubs, spades \}
Counting Straight Flushes

Straight Flushes

- 4 Suits to choose from \{ hearts, diamonds, clubs, spades \}
Counting StraightFlushes

- 4 Suits to choose from: {hearts, diamonds, clubs, spades}

A♠ 2♠ 3♠ 4♠ 5♠ 6♠ 7♠ 8♠ 9♠ 10♠ J♠ Q♠ K♠ A♠
Counting Two Pair Poker Hands

How many ways can we pick the rank for the pair?
Counting Two Pair Poker Hands

How many ways can we pick the rank for the pair? 13

How many ways can we pick the two suits for the pair?
Counting Two Pair Poker Hands

How many ways can we pick the rank for the pair? 13

How many ways can we pick the two suits for the pair? \( \binom{4}{2} \)

We have three cards left, don’t want any other hands (not three of a kind, four of a kind, or full house)
The hand: \(8\spadesuit\ 8\clubsuit\ 4\heartsuit\ J\clubsuit\ 2\clubsuit\)

- How many ways can we pick the rank for the pair? 13
- How many ways can we pick the two suits for the pair? \(\binom{4}{2}\)
- We have three cards left, don’t want any other hands (not three of a kind, four of a kind, or full house)
  - \(\binom{12}{3}\) ways to pick the three ranks (must be different from the pair and different from each other)
  - \(4^3\) ways to pick the suits
Counting Full House Hands

- How many ways can we pick the rank for the three of a kind?
- How many ways can we pick the three suits?
- We have ? ways to pick the rank for the pair
- ? ways to pick the suits for the pair
Let’s look at a smaller example were our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect one plugboard wires?
Let’s look at a smaller example were our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect one plugboard wires?

\[ \binom{6}{2} = 15 \] ways to pick the pair of letters that are swapped

Let’s list them all in cycle notation lexicographically (dictionary order):

\[ \{(AB), (AC), (AD), (AE), (AF), (BC), (BD), (BE), (BF), (CD), (CE), (CF), (DE), (DF), (EF)\} \]
Enigma (mini edition)

Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect two plugboard wires?
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect two plugboard wires?

\[
\binom{6}{2} = 15 \text{ ways to pick the pair of letters for the first wire}
\]
Enigma (mini edition)

Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect two plugboard wires?

- \( \binom{6}{2} = 15 \) ways to pick the pair of letters for the first wire
- \( \binom{4}{2} = 6 \) way to pick the second wire. Third wire is forced.
- The answer is not \( 15 \cdot 6 \cdot 1 = 90 \).
Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect two plugboard wires?

- \( \binom{6}{2} = 15 \) ways to pick the pair of letters for the first wire
- \( \binom{4}{2} = 6 \) way to pick the second wire. Third wire is forced.
- The answer is not \( 15 \cdot 6 \cdot 1 = 90 \). It’s \( 90/2! = 45 \)

Let’s list them all in cycle notation:
\{(AB)(CD), (AB)(CE), (AB)(CF), (AB)(DE), (AB)(DF), (AB)(EF), \}

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\[
\{(AB)(CD), (AB)(CE), (AB)(CF), (AB)(DE), (AB)(DF), (AB)(EF), (AC)(BD), (AC)(BE), (AC)(BF), (AC)(DE), (AC)(DF), (AC)(EF), (AD)(BC), (AD)(BE), (AD)(BF), (AD)(CE), (AD)(CF), (AD)(EF), \}
\]
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(AD)(BC), (AD)(BE), (AD)(BF), (AD)(CE), (AD)(CF), (AD)(EF),
Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect two plugboard wires?

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Let’s list them all in cycle notation:
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect two plugboard wires?

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- \( \binom{4}{2} = 6 \) way to pick the second wire. Third wire is forced.

The answer is not \( 15 \cdot 6 \cdot 1 = 90 \). It’s \( 90 / 2! = 45 \)

Let’s list them all in cycle notation:

\[
\begin{align*}
(AB)(CD), & \quad (AB)(CE), \quad (AB)(CF), \quad (AB)(DE), \quad (AB)(DF), \quad (AB)(EF), \\
(AC)(BD), & \quad (AC)(BE), \quad (AC)(BF), \quad (AC)(DE), \quad (AC)(DF), \quad (AC)(EF), \\
(AD)(BC), & \quad (AD)(BE), \quad (AD)(BF), \quad (AD)(CE), \quad (AD)(CF), \quad (AD)(EF), \\
(AE)(BC), & \quad (AE)(BD), \quad (AE)(BF), \quad (AE)(CD), \quad (AE)(CF), \quad (AE)(DF), \\
(AF)(BC), & \quad (AF)(BD), \quad (AF)(BE), \quad (AF)(CD), \quad (AF)(CE), \quad (AF)(DE), \\
(BC)(DE), & \quad (BC)(DF), \quad (BC)(EF), \quad (BD)(CE), \quad (BD)(CF), \quad (BD)(EF),
\end{align*}
\]
Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect two plugboard wires?

\[
\binom{6}{2} = 15 \text{ ways to pick the pair of letters for the first wire}
\]

\[
\binom{4}{2} = 6 \text{ way to pick the second wire. Third wire is forced.}
\]

The answer is not \(15 \cdot 6 \cdot 1 = 90\). It’s \(90/2! = 45\)

Let’s list them all in cycle notation:

\{(AB)(CD), (AB)(CE), (AB)(CF), (AB)(DE), (AB)(DF), (AB)(EF),
(AC)(BD), (AC)(BE), (AC)(BF), (AC)(DE), (AC)(DF), (AC)(EF),
(AD)(BC), (AD)(BE), (AD)(BF), (AD)(CE), (AD)(CF), (AD)(EF),
(AF)(BC), (AF)(BD), (AF)(BE), (AF)(CD), (AF)(CE), (AF)(DE),
(BC)(DE), (BC)(DF), (BC)(EF), (BD)(CE), (BD)(CF), (BD)(EF),
(BE)(CD), (BE)(CF), (BE)(DF), (BF)(CD), (BF)(CE), (BF)(DE),\}
Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect two plugboard wires?

- \( \binom{6}{2} = 15 \) ways to pick the pair of letters for the first wire
- \( \binom{4}{2} = 6 \) way to pick the second wire. Third wire is forced.

The answer is not \( 15 \cdot 6 \cdot 1 = 90 \). It’s \( 90/2! = 45 \)

Let’s list them all in cycle notation:

\{(AB)(CD), (AB)(CE), (AB)(CF), (AB)(DE), (AB)(DF), (AB)(EF),
  (AC)(BD), (AC)(BE), (AC)(BF), (AC)(DE), (AC)(DF), (AC)(EF),
  (AD)(BC), (AD)(BE), (AD)(BF), (AD)(CE), (AD)(CF), (AD)(EF),
  (AF)(BC), (AF)(BD), (AF)(BE), (AF)(CD), (AF)(CE), (AF)(DE),
  (BC)(DE), (BC)(DF), (BC)(EF), (BD)(CE), (BD)(CF), (BD)(EF),
  (BE)(CD), (BE)(CF), (BE)(DF), (BF)(CD), (BF)(CE), (BF)(DE),
  (CD)(EF), (CE)(DF), (CF)(DE)\}
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect \textit{two} plugboard wires?
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect two plugboard wires?

- We have decided to use two cables, therefore 4 sockets (letters) will be used.
- We have \( \binom{6}{4} = 15 \) ways of selecting the 4 sockets.
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect two plugboard wires?

- We have decided to use two cables, therefore 4 sockets (letters) will be used.
- We have \( \binom{6}{4} = 15 \) ways of selecting the 4 sockets.
- Plug the end of the first cable in to one of the four sockets, order does not matter since all of the four sockets will be used.
- 3 choices for the end of the first cable.
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect two plugboard wires?

- We have decided to use two cables, therefore 4 sockets (letters) will be used.
- We have \( \binom{6}{4} = 15 \) ways of selecting the 4 sockets.
- Plug the end of the first cable in to one of the four sockets, order does not matter since all of the four sockets will be used.
- 3 choices for the end of the first cable.
- There is only one choice for both ends of the second cable (only two free sockets left).
- There are \( 15 \cdot 3 \cdot 1 = 45 \) possibilities.
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect three plugboard wires?
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect three plugboard wires?

- \( \binom{6}{2} = 15 \) ways to pick the pair of letters for the first wire.
Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect three plugboard wires?

- \( \binom{6}{2} = 15 \) ways to pick the pair of letters for the first wire
- \( \binom{4}{2} = 6 \) way to pick the second wire. Third wire is forced.
- The answer is not \( 15 \cdot 6 \cdot 1 = 90 \).
Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect three plugboard wires?

- \( \binom{6}{2} = 15 \) ways to pick the pair of letters for the first wire
- \( \binom{4}{2} = 6 \) way to pick the second wire. Third wire is forced.
- The answer is not \( 15 \cdot 6 \cdot 1 = 90 \). It's \( 90/3! = 15 \)

Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect three plugboard wires?
Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect three plugboard wires?

- We have \( \binom{6}{6} = 1 \) ways of selecting the 6 sockets (choose them all).
- Plug the end of the first cable in A.
- 5 choices to send where A goes (5 free sockets for the end of the first cable).
The Enigma (mini edition) alternate solution

Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect three plugboard wires?

- We have \( \binom{6}{6} = 1 \) ways of selecting the 6 sockets (choose them all).
- Plug the end of the first cable in A.
- 5 choices to send where A goes (5 free sockets for the end of the first cable).
- Plug the end of the second cable in letter ”X”
  - X is any of the four letters not used by the first cable.
The Enigma (mini edition) alternate solution

Our alphabet is only 6 letters \{A, B, C, D, E, F\}. How many ways are there to connect **three** plugboard wires?

- We have \(\binom{6}{6} = 1\) ways of selecting the 6 sockets (choose them all).
- Plug the end of the first cable in A.
- 5 choices to send where A goes (5 free sockets for the end of the first cable).
- Plug the end of the second cable in letter ”X”
  - X is any of the four letters not used by the first cable.
- There are 3 choices to send X to.
The Enigma (mini edition) alternate solution

Our alphabet is only 6 letters \( \{A, B, C, D, E, F\} \). How many ways are there to connect three plugboard wires?

- We have \( \binom{6}{6} = 1 \) ways of selecting the 6 sockets (choose them all).
- Plug the end of the first cable in A.
- 5 choices to send where A goes (5 free sockets for the end of the first cable).
- Plug the end of the second cable in letter ”X”
  - X is any of the four letters not used by the first cable.
- There are 3 choices to send X to.
- There is only one choice for both ends of the third cable.
- There are \( \binom{6}{6} \cdot 5 \cdot 3 \cdot 1 = 15 \) possibilities.

\{ (AB)(CD)(EF), \ (AB)(CE)(DF), \ (AB)(CF)(DE) \\
(AC)(BD)(EF), \ (AC)(BE)(DF), \ (AC)(BF)(ED) \\
(AD)(BC)(EF), \ (AD)(BE)(CF), \ (AD)(BF)(CE) \\
(AE)(BC)(DF), \ (AE)(BD)(CF), \ (AE)(BF)(CD) \\
(AF)(BC)(DE), \ (AF)(BD)(CE), \ (AF)(BE)(CD) \}
1. How many **five** card Poker hands are there using a standard deck of 52 playing cards?

2. What is the value of $k$ after the following code has been executed?

   ```
   k := 1 
   for j = 1 to n 
   k := k \cdot j 
   ```

3. How many ways are there to order **five** pieces of sushi if there are **three** kinds of fish (Ahi, Albacore, Salmon)?

4. How many **four** character passwords are there that use only lowercase letters and digits 0-9? *(Hint there are 26 letters and 10 digits, 36 characters total.)* For example: abc1, 1234, or 9999 are acceptable passwords.

EC What is the probability that the winner in a best of five series was never behind at any point in the series (assuming both teams are evenly matched and play to the best of their ability)?
Question 1

How many **five** card Poker hands are there using a standard deck of 52 playing cards?

A. \( \binom{52}{5} \)

B. \( 52 \cdot 51 \cdot 50 \cdot 49 \cdot 48 \)

C. \( 52 \cdot 52 \cdot 52 \cdot 52 \cdot 52 \)

D. \( \binom{52 + 5 - 1}{5 - 1} \)

E. \( (13 \cdot 4)^5 \)
Question 2

What is the value of $k$ after the following code has been executed?

\[
k := 1 \\
\text{for } j = 1 \text{ to } n \\
\quad k := k \cdot j
\]

A. 1  
B. $n!$  
C. $\binom{n}{2}$  
D. $(k \cdot j)^n$  
E. $j^n$  
F. The code will segfault
Question 3

How many ways are there to order five pieces of sushi if there are three kinds of fish (Ahi, Albacore, Salmon)?

A. \( \binom{5}{3} \)

B. \( \binom{7}{2} \)

C. \( \binom{7}{3} \)

D. \( \binom{7}{4} \)

E. \( \binom{7}{5} \)

F. I don’t eat sushi (where is that F button?)
Question 4

How many four character passwords are there that use only lowercase letters and digits 0-9? (Hint there are 26 letters and 10 digits, 36 characters total.)
For example: abc1, 1234, or 9999 are acceptable passwords

A. \(\binom{36}{4}\)
B. \(36 \cdot 35 \cdot 34 \cdot 33\)
C. \(\binom{26}{10}\)

D. \(36 \cdot 36 \cdot 36 \cdot 36\)
E. \(\binom{36 + 4 - 1}{4 - 1}\)
F. I never use passwords, too hard to remember!
Question 5 (Extra Credit)

What is the probability that the winner in a best of five series was never behind at any point in the series (assuming both teams are evenly matched and play to the best of their ability)?

A. $\frac{2}{20}$  
B. $\frac{6}{20}$  
C. $\frac{8}{20}$  
D. $\frac{10}{20}$  
E. $\frac{12}{20}$