1. How was Felten’s lecture
2. Announcements
   a. How is problem set 1?
   b. Problem Set 2 is available; more of the same and some differences; a few things that we will cover today
   c. How about Lab 1? Not due until Friday
   d. Lab 2 available now; you’ll build a web page
      i. Html is different everywhere; so you may see differences in different browsers
3. Where we were
   a. Making everything digital
      i. We said that sounds are sampled and converted into numbers
      ii. Images are a collection of pixels; each pixel has 3 numbers for intensities of RGB colors
      iii. Video = Sound + Images
   b. So, if it all comes down to numbers, how do we represent numbers?
      i. Could use decimal notation; why not ideal?
      ii. So, we land in binary
         1. And eventually hexadecimal
            a. Why hexadecimal?
4. How to represent data
   a. Decimal numbers are inconvenient because signals are on/off, so go binary
   b. Sidebar on base 2 vs. base 10
      i. Powers of 10, powers of 2
         1. abcd in base 10 is a*10^3 + b*10^2 + c*10^1 + d*10^0
         2. abcd in base 2 is a*2^3 + b*2^2 + c*2^1 + d*2^0
         3. Different number representations
         4. So, what is
            a. 10101 binary (base 2), expressed in decimal (base 10)?
            b. 111111 binary (base 2), expressed in decimal (base 10)?
   5. To represent 100 objects (base 10), how many digits does it take?
      a. Can represent up to 10^n objects with n decimal digits
   6. To represent 64 objects (base 2), how many bits does it take?
      a. Can represent up to 2^n objects with n binary digits (bits)
   c. Looking at number representations
      i. In decimal, positions correspond to units, tens, hundreds, thousands, ...
         1. So, abcd is a thousands, b hundreds, c tens, d units
      ii. In binary, positions correspond to units, twos, fours, eights, ....
         1. So, abcd is a eights, b fours, c twos and d units
      iii. How do we transform a binary number into a decimal number?
   d. How many digits (decimal) or bits (binary) to
      i. Assign a unique number to each Princeton student
      ii. Assign a unique number to each person in the united states
      iii. Assign a unique number to every apple in the residential colleges each week
   e. Questions above for bytes
f. Computers tend to use words that are composed of bytes and may be
   i. 2, 4, or 8 bytes long
   ii. Questions above for words

g. 4 bytes (32 bits) can store about 4 billion values
   i. Code.org had a table indexed by a 4 byte word to record student coding activity
      1. On January 20, 2017, things broke and work by the 16 million K-12 users
         was not recorded for an hour because the table ran out of space
   ii. Chess.com ran into a similar program – had space to record $2^{31}-1$ games users
       had played
      1. In June, 2017, this became a problem and the app stopped working for
         anyone playing on an iPhone or iPad made before mid-2013 because
         these devices cannot interpret such a large number
   iii. Similar thing happened on YouTube with views of Psy’s hit “Gangman style” in
        2014 when it broke the Youtube counter.

h. How to convert from decimal to binary
   i. Divide by 2 and record quotient and remainder
      1. Remainder is next bit in sequence
      2. Repeat for quotient until quotient is 0
   ii. Example
      1. Start with 37
         a. Divide 37 by 2 → 18 with remainder of 1
         b. Divide 18 by 2 → 9 with remainder of 0
         c. Divide 9 by 2 → 4 with remainder of 1
         d. Divide 4 by 2 → 2 with remainder of 0
         e. Divide 2 by 2 → 1 with remainder of 0
         f. Divide 1 by 2 → 0 with remainder of 1
         g. So 100101 is binary representation of 37 decimal
      2. Let’s do another example

5. Creepy or not creepy – hotel reservation system

6. Quantitative – what they said about apples
   a. From Linda Racine (assistant director, purchasing, Campus Dining)
      i. 58 cases, 2320 pounds, 6416 apples
         1. 88-113 apples per case; depends on variety; red delicious sizes can vary
            between the extremes; honey crisp are 100 per. She sorted by type to
            give us an accurate count.
         2. 95% or more are consumed; the rest are used for cooking
         3. She offered to send us a case for the class as a visual

7. Adding another twist – hexadecimal
   a. It’s base 16
   b. 4 bits fit together into one hexadecimal number
      i. 0000 is 0; 0001 is 1; 0010 is 2; ...
      ii. Gets complicated at 1010 because 10 is a single number, so use A
           1011 is B; 1100 is C; 1101 is D; 1110 is E; 1111 is F
      iii. abcd in base 16 (hexadecimal) is $a*16^3 + b*16^2 + c*16^1 + d*16^0$
d. Converting from hexadecimal to decimal is straightforward

e. Converting from decimal to hexadecimal, same as to binary but divide by 16
   i. Start with 37
      1. Divide 37 by 16 → 2 with remainder of 5
      2. Divide 2 by 16 → 0 with remainder of 2
      3. So 25 in hexadecimal representation of 37 decimal
      4. Note that 2 is 0010 in binary and 5 is 0101 in binary; combining, we get that (00)100101 in binary is 37 in decimal

8. Hexadecimal is a convenient way to talk about bytes
   a. A byte is two hexadecimal digits