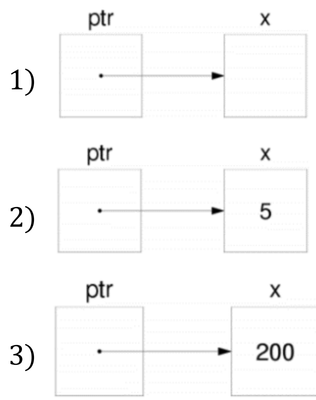
CSE 351 Section 2 – Pointers, Bit Operators, Integers

Pointers

A pointer is a variable that holds an address. C uses pointers explicitly. If we have a variable `x`, then `&x` gives the address of `x` rather than the value of `x`. If we have a pointer `p`, then `*p` gives us the value that `p` points to, rather than the value of `p`.

Consider the following declarations and assignments:

```
int x;
int *ptr;
ptr = &x;
```



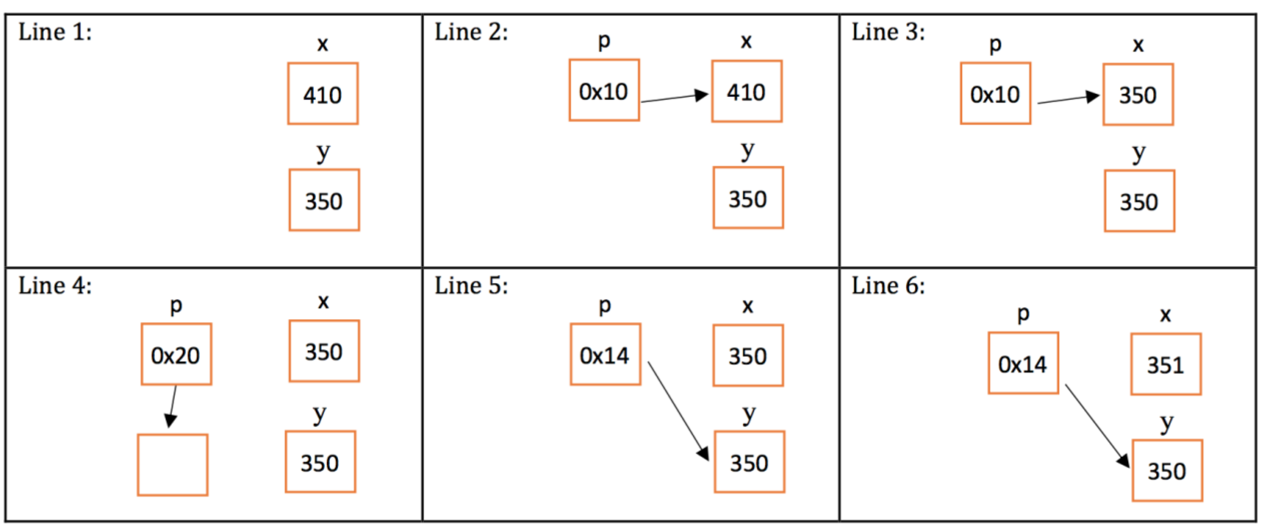
1) We can represent the result of these three lines of code visually as shown. The variable `ptr` stores the address of x, and we say "`ptr` points to x." `x` currently doesn't contain a value since we did not assign `x` a value!
2) After executing `x = 5;`, the memory diagram changes as shown.
3) After executing `*ptr = 200;`, the memory diagram changes as shown. We modified the value of `x` by dereferencing `ptr`.

Pointer Arithmetic

In C, arithmetic on pointers (++, +, --, -) is scaled by the size of the data type the pointer points to. That is, if `p` is declared with pointer **`type*`** `p`, then `p + i` will change the value of `p` (an address) by `i*sizeof(`**`type`**`)` (in bytes). If there is a line `*p = *p + 1`, regular arithmetic will apply unless `*p` is also a pointer datatype.

<u>Exercise</u>:
Draw out the memory diagram after sequential execution of each of the lines below:

```
int main(int argc, char **argv) {
  int x = 410, y = 350;    // assume &x = 0x10, &y = 0x14
  int *p = &x;             // p is a pointer to an integer
  *p = y;
  p = p + 4;
  p = &y;
  x = *p + 1;
}
```



C Bitwise Operators

&	0	1
0	**0**	**0**
1	**0**	**1**

← **AND** (`&`) outputs a 1 only when both input bits are 1.

OR (`|`) outputs a 1 when either input bit is 1. →

|	0	1
0	**0**	**1**
1	**1**	**1**

^	0	1
0	**0**	**1**
1	**1**	**0**

← **XOR** (`^`) outputs a 1 when either input is *exclusively* 1.

NOT (`~`) outputs the opposite of its input. →

~	
0	**1**
1	**0**

Masking is very commonly used with bitwise operations. A mask is a binary constant used to manipulate another bit string in a specific manner, such as setting specific bits to 1 or 0.

Exercises:

1) [Autumn 2019 Midterm Q1B] If `signed char a = 0x88`, complete the bitwise C statement so that `b = 0xF1`. The first blank should be an operator and the second blank should be a numeral.

`b = a __^__ 0x79`

2) Implement the following C function using control structures and bitwise operators.

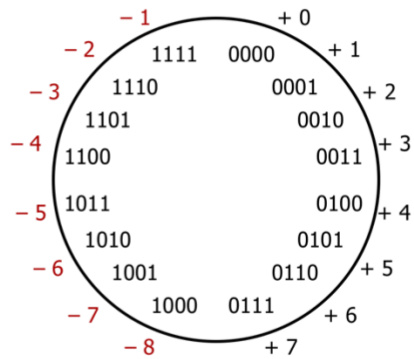
```
// returns the number of pairs of bits that are the
// opposite of each other (i.e. 0 and 1 or 1 and 0)
//
// bits are "paired" by taking adjacent bits
// starting at the lsb (0) and pairs do not overlap.
// For example, there are 16 distinct pairs in a 32-bit integer
int num_pairs_opposite(int x) {
  int count = 0;

  for (int i = 0; i < 16; i++) {  // 32 bits in an integer
    int bit0 = x & 1;
    int bit1 = (x >> 1) & 1;
    count += bit0 ^ bit1;
    x >>= 2;
  }
  return count;
}
```

Signed Integers with Two's Complement

Two's complement is the standard for representing signed integers:

- The most significant bit (MSB) has a negative value; all others have positive values (same as unsigned)
- Binary addition is performed the same way for signed and unsigned
- The bit representation for the negative value (additive inverse) of a Two's Complement number can be found by:

  flipping all the bits and adding 1 (i.e. $-x = \sim x + 1$).



The "number wheel" showing the relationship between 4-bit numerals and their Two's Complement interpretations is shown on the right:

- The largest number is 7 whereas the smallest number is -8
- There is a nice symmetry between numbers and their negative counterparts except for -8

Exercises:

1) If we have 8 bits to represent integers, answer the following questions:

   a. What is the **largest integer**? The **largest integer + 1**? The most **negative integer**? If it doesn't apply, write n/a.

Unsigned:	Two's Complement:
Largest: 1111 1111	**Largest:** 0111 1111
Largest + 1: 0000 0000	**Largest + 1:** 1000 0000
Most Negative: n/a	**Most Negative:** 1000 0000

   b. How do you represent (if possible) the following numbers: **39**, **-39**, **127**?

Unsigned:	Two's Complement:
`39: 0010 0111`	`39: 0010 0111`
`-39: Impossible`	`-39: 1101 1001`
`127: 0111 1111`	`127: 0111 1111`

2) [Autumn 2017 Final M1A] Take the 32-bit numeral 0xC0800000. Circle the number representation below that has the most negative value for this numeral.

   Sign & Magnitude   Two's Complement   Unsigned

   Unsigned: Can only represent positive numbers.
   Sign & Mag: Negative number with magnitude 100 0000 $10\ldots0_2$.
   Two's: Negative number with magnitude 011 1111 $10\ldots0_2$ (flip bits + 1).

3) [Winter 2018 Midterm 1C] Given the 4-bit bit vector 0b1101, what is its value in decimal (base 10)? Circle your answer.

   13   -3   -5   Undefined

   Need to specify if we want unsigned, sign & magnitude, two's complement, etc.