CSE 351 Section 2 – Pointers and Bit Operators

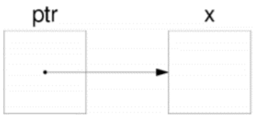
Pointers

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`.

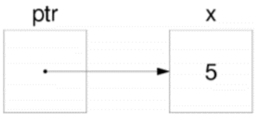
Consider the following declarations and assignments:

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

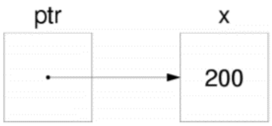
1)



2)



3)



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`.

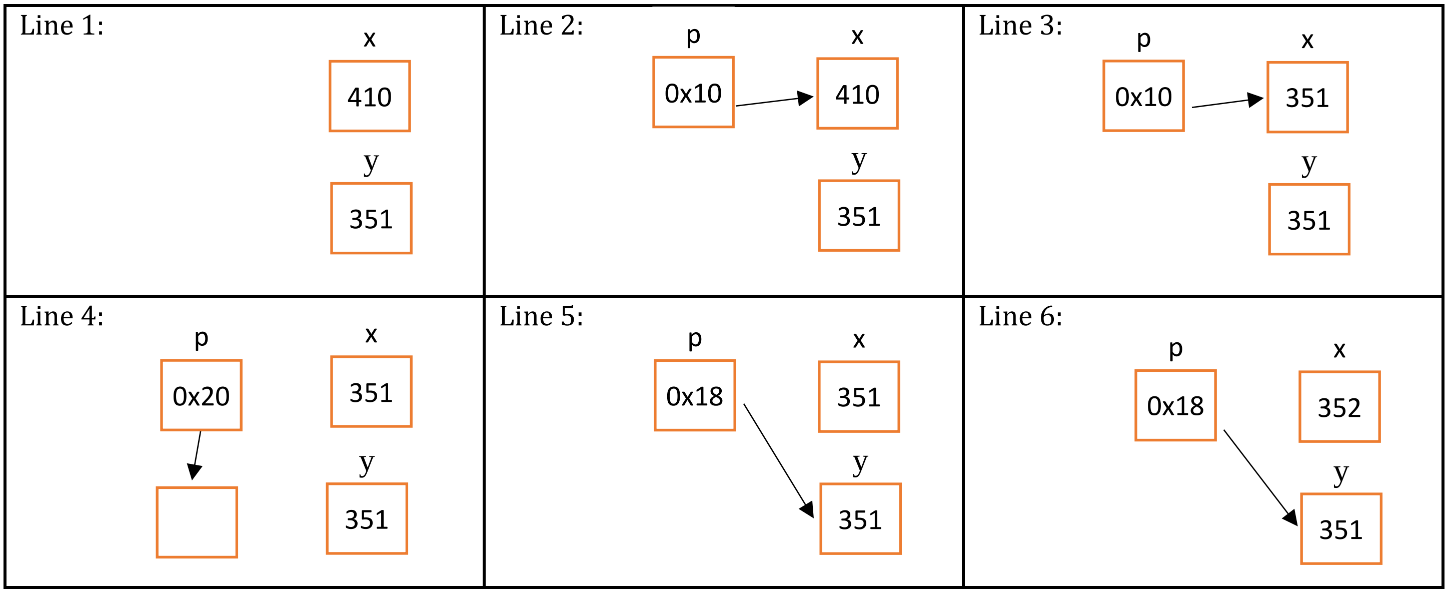
Pointer Arithmetic

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). However, `*p` returns the data *pointed at* by `p`, so pointer arithmetic only applies if `p` was a pointer to a pointer.

Exercise:

Draw out the memory diagram after sequential execution of each of the lines below:

```
int main(int argc, char **argv) {
  int x = 410, y = 351;   // assume &x = 0x10, &y = 0x18
  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) What happens when we fix/set one of the inputs to the binary bitwise operators? Let x be the other input. Fill in the following blanks with either 0, 1, x, or x̄ (NOT x):

x & 0 = _0_____   x | 0 = __x___   x ^ 0 = __x___

x & 1 = _x_____   x | 1 = __1___   x ^ 1 = __x̄___

2) **Lab 1 Helper Exercises:** Lab 1 is intended to familiarize you with bitwise operations in C through a series of puzzles. These exercises are either sub-problems directly from the lab or expose concepts needed to complete the lab. Start early!

Bit Extraction: Returns the value (0 or 1) of the 19th bit (counting from LSB). Allowed operators: >>, &, |, ~.

```
int extract19(int x) {
    return (x >> 18) & 0x1;
}
```

Subtraction: Returns the value of x-y. Allowed operators: >>, &, |, ~, +.

```
int subtract(int x, int y) {
    return x + ((~y) + 1);
}
```

Equality: Returns the value of x==y. Allowed operators: >>, &, |, ~, +, ^, !.

```
int equals(int x, int y) {
    return !(x ^ y);
}
```

Divisible by Eight? Returns the value of (x%8)==0. Allowed operators: >>, <<, &, |, ~, +, ^, !.

```
int divisible_by_8(int x) {
    return !((x << 29);
}
```

Greater than Zero? Returns the value of x>0. Allowed operators: >>, &, |, ~, +, ^, !.

```
int greater_than_0(int x) {
     /* invert and check sign; we need the third operand for the T_min case */
    return ((~x + 1) >> 31) & 0x1 & ~(x >> 31)_OR_!!x & ~(x >> 31);
}
```