# PY410 / 505
# Computational Physics 1

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# Code

- Code is in CompPhys/ReviewCpp/BasicExamples

# C++: Pointers

- The dread cry rang through the night…
  NO! POINTERS! NOOOOO!!!!!!

# Pointers and References

# C++: Pointers

| Memory Address | Value |
|---|---|
| 0x1000 | 0x04a45 |
| 0x1001 | 0x9ab38 |
| 0x1010 | 0x0000 |
| 0x1011 | 0x1003 |

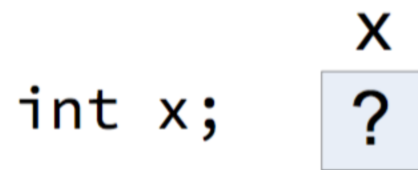
- Actually I've already taught you the concept, just not the syntax
- Pointer is just a variable that holds the **memory address**
- Syntax: "&" operator gives the address:

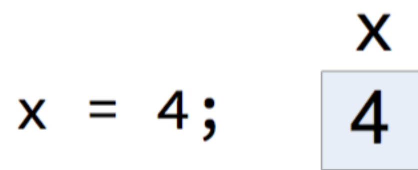
```
  int x = 123;
  int y = 456;
  int z = 789;
  std::cout << "Address of x= " << &x << ", value of x = " << x << std::endl;
  std::cout << "Address of y= " << &y << ", value of y = " << y << std::endl;
  std::cout << "Address of z= " << &z << ", value of z = " << z << std::endl;
  return 0;
```

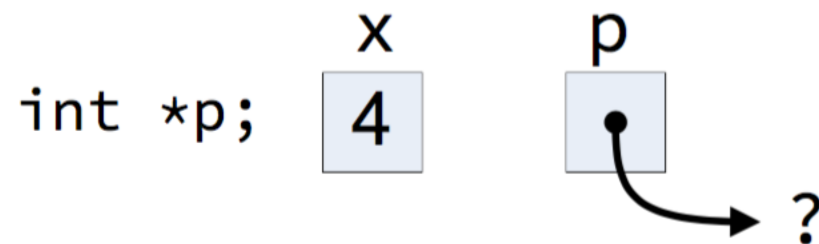
```
Address of x= 0x7fff59364aa8, value of x = 123
Address of y= 0x7fff59364aa4, value of y = 456
Address of z= 0x7fff59364aa0, value of z = 789
```

# C++: Pointers

- A pointer variable uses "*", assign to an address of a variable with "&":

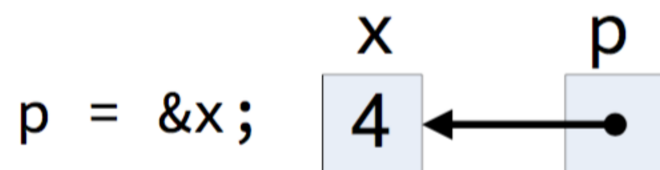


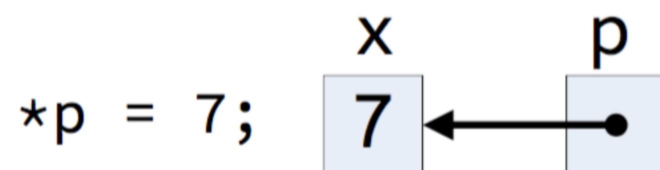




Read from right to left:
"p is a pointer to an int"

Accessing p here gives you GARBAGE. It MUST be initialized!!!




Assign the pointer to point to a variable by the ADDRESS operator (&)




Access the value of the register POINTED TO by p by DEREFERENCING (*).

# C++: References

- A safer alternative is to have REFERENCES:
  - Pointers that cannot be zero

- A reference variable uses “&”, can treat it like a standard variable
  - But it is not! Be careful! Underlying variable can change!

- Go to “BasicExamples”

# C++: Pointers and References

- "ptrs.cc"

```
#include <iostream>

int main(void){

  int x = 10;
  int * px = &x;
  int & rx = x;
  std::cout << "Value of px= " << px << ", dereferenced = " << *px << std::endl;
  std::cout << "Value of rx= " << rx << std::endl;
  *px = 7;
  std::cout << "x = " << x << std::endl;
  rx = 9;
  std::cout << "x = " << x << std::endl;
  return 0;
}
```

- output:

```
Value of px= 0x7fff525a3a98, dereferenced = 10
Value of rx= 10
x = 7
x = 9
```

# C++: const with pointers

- You have “const” now with two objects, the variable and the pointer
- There are therefore four possibilities:

- Pointer to int
  - (value can change, pointer can change)
  - int * p
- Pointer to const int
  - (value cannot change, pointer can change)
  - int const * p
- Const pointer to int
  - (value can change, pointer cannot change)
  - int * const p
- Const pointer to const int:
  - (value cannot change, pointer cannot change)
  - const int * const

# C++: ptrs/refs in functions

- Can use pointers and refs as arguments to functions!
- “ptrs_and_funcs.cc”

```
#include <iostream>

void increment1( int p){ ++p; std::cout << "p = " << p << std::endl;}
void increment2( int &p){ ++p; std::cout << "p = " << p << std::endl;}
void increment3( int *p){ ++(*p); std::cout << "*p = " << *p << std::endl;}


int main(void){

  int x = 3;
  int & rx = x;
  int * px = &x;
  std::cout << "0: x = " << x << std::endl;
  increment1(x);
  std::cout << "1: x = " << x << std::endl;
  increment2(rx);
  std::cout << "2: x = " << x << std::endl;
  increment3(px);
  std::cout << "3: x = " << x << std::endl;

  return 0;
}
```

```
0: x = 3
p = 4
1: x = 3
p = 4
2: x = 4
*p = 5
3: x = 5
```

# C++: ptrs/refs in functions

- Pass by value:
  - COPIES value into a temporary variable called “x”

```
void func( int x);
```

- Use when you don’t want to modify value, and cheap to copy

- Pass by reference:
  - Pass REFERENCE to variable, temporarily called “x”

```
void func( int &x);
```

- Use when you want to modify value, and expensive to copy, ptr=0 disallowed

- Pass by pointer
  - Pass POINTER to variable, pointer is called “x”

```
void func( int *x);
```

- Use when you want to modify value, and expensive to copy, ptr=0 allowed

**Also usable with CONST**

# C++: Why are pointers hard?

- Dereferencing uninitialized pointers gives you a segmentation fault
  - That's the best case scenario
  - Worst case scenario: It works accidentally, and you accidentally give your credit card information to that Nigerian Prince who keeps emailing you
- Memory management!

# Memory management

# C++: Memory Management

- You have access to several pieces of memory:
  - Code: where your code lives
  - Data: static and global variables
  - Stack: static memory
    - local variables and function parameters known at compile time
  - Heap: dynamic memory
    - anything not known at compile time
  - The heap HAS to be accessed via pointer
    - Improperly handling this is a pain
  - The others can be accessed via value or reference

# C++: Memory Management

- Allocate on the heap with “new”
- Remove from the heap with “delete”:

```
int i = 123;
int * p = new int( 456 );

std::cout << "i = " << i << std::endl;
std::cout << "*p= " << *p << std::endl;

(*p) += 10;
std::cout << "*p= " << *p << std::endl;

delete p;
```

Allocate an integer off the heap, assign its address to “p”

Do stuff with that heap variable

Remove from the heap

# C++: Memory Management

- Every “new” has to come with a “delete”
  - Otherwise you get a **memory leak**
  - Adds memory that does not get cleaned up, eventually your program crashes the computer

- Can be non-obvious
  - What if a function creates a “new” variable and returns it?
  - Still in scope.
  - Stays on the heap.
  - This is called a “factory”

# C++: Memory Management

- In modern C++, use "std::auto_ptr" or "std::shared_ptr"
- These will automatically delete the object when the last reference to it goes out of scope
  - I.E. you don't have to worry about the delete operation
  - Also access like a standard pointer:

```
std::auto_ptr<int> pa ( new int(789) );
std::cout << "*pa=" << *pa << std::endl;
```

Can use the template argument to use ANY type
(more on templates later!)

# Arrays and vectors

# C++: Arrays and Vectors

- What if you want a group of objects together?
  - Arrays (off the stack)
    - Intrinsic to C++
    - Static at compile time
    - Syntax:

```
int array[5] = {0,1,2,3,4};
```

5 elements — Initialized to values here

NOTE: C++ arrays need EITHER a size, OR an initialization, but do not need both if you don't want.

  - Vectors (off the heap)
    - Part of the Standard Template Library
    - Not known at compile time
    - Syntax:

```
std::vector<int> vec;
```

    - Then use "push_back" to add variables
    - (can also "push_front", etc…)
    - more on this later
    - In C++0X and C++11: can initialize like an array (see above)
      - When compiling with g++: add "-std=c++0x"

# C++: Arrays and Vectors

- Can access individual elements with “[ ]”:

```
array[1] = 1;
```

- Arrays are just a sequential list of variables
  - Knows nothing about itself.
  - Can only LEGALLY access elements LESS THAN the size of the array!
  - Totally fine with illegal behavior, and will give you garbage
- Vectors are a CLASS, so does know something about itself
  - More on classes later
  - Can therefore:
    - check the size:

```
n = vec.size();
```

    - access elements only if they exist with the “at” method (more later)

```
int list[3];
list[0] = 5;
list[1] = -3;
list[2] = 12;
```

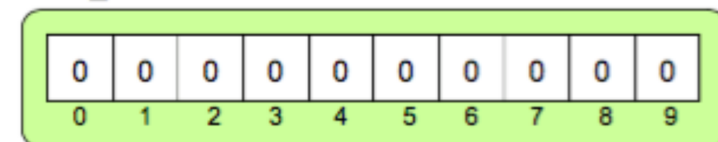
list

| 5 | -3 | 12 |
|---|---|---|
| 0 | 1 | 2 |

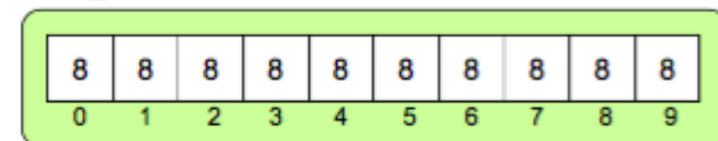
```
vector<int> vec_a;
vector<int> vec_b(10);
vector<int> vec_c(10, 8);
vector<int> vec_d{ 10, 20, 30, 40 };
```

vec_a

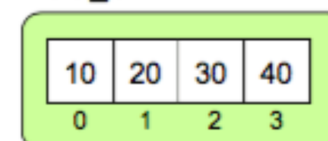
vec_b




vec_c




vec_d



# C++: Arrays and Vectors

- N objects in a CONTIGUOUS row of memory:
- For arrays, these are static and from the stack (*)
- For vectors, these are dynamic and from the heap

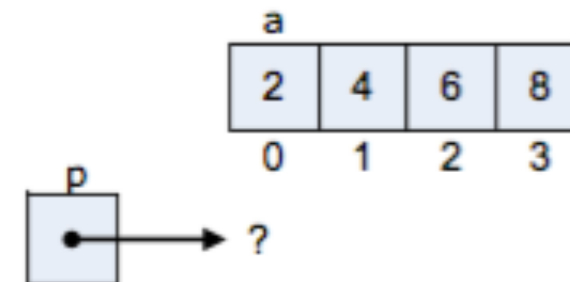
```
array[0] = 0, address = 0x7fff51618990
array[1] = 1, address = 0x7fff51618994
array[2] = 2, address = 0x7fff51618998
array[3] = 3, address = 0x7fff5161899c
array[4] = 4, address = 0x7fff516189a0
```

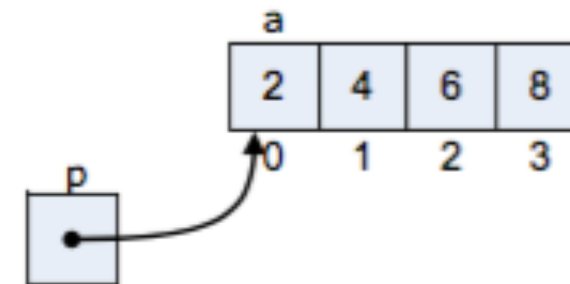
  - (*)
    Technically you can still get arrays off the heap also and do your own dynamic memory allocation. Don't do that. Just use std::vector.

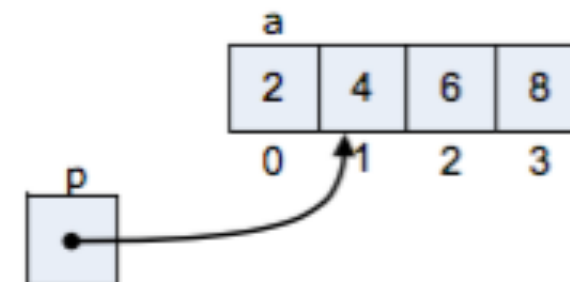
# C++: Arrays and Vectors

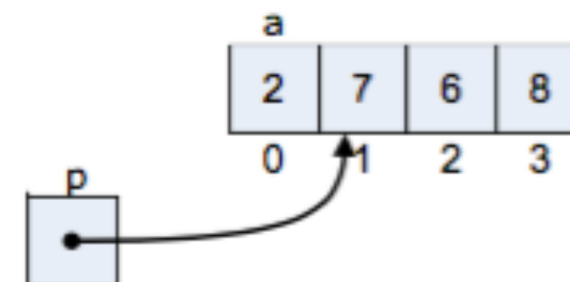
- Since arrays are just a list of variables, what is the relation between POINTERS and ARRAYS?

- The syntax “a[3]” means:
  – Go to the position 3 variables after the first one
  – But you could just use also use pointers for that!



# C++: Arrays and Vectors

- Copying arrays:
  - C++: I have no idea what you're talking about. Do it yourself.

```
int array[5] = {0,1,2,3,4};
int array2[5];
for ( unsigned int i = 0; i < 5; ++i ) {
  array2[i] = array[i];
}
```

- Copying vectors:
  - C++: Oh! Yeah, sure, no problem!

```
std::vector<int> vec3( vec);
```

# C++: Arrays and Vectors

- Multi-dimensional arrays and vectors look like:

```
  int M[3][4];
```

3 x 4

- Literally: M is an array of "arrays of size 4"

- Alternatively can use a vector of vectors:

```
std::vector< std::vector<int> > N( 3, std::vector<int>(4) );
```

# C++: Arrays and Vectors

- std::vector also introduces ITERATORS
- Act like pointers, but are classes (hence smarter)

```
for( std::vector<int>::const_iterator i = vec.begin(); i != vec.end(); ++i ) {
  std::cout << "i = " << *i << std::endl;
}
```

- In C++0x and later, can also loop over each item like:

```
for ( int i : vec ) {
  std::cout << "i = " << i << std::endl;
}
```

- Why the complication?
  - Faster and safer.

# C++: Arrays and Vectors

- Special case of arrays: arrays of “char”

- Similar case as arrays and vectors, char a[10] is a fixed-width array (length 10) that can be printed to form characters.
- Then “std::string” is similar in spirit to “std::vector”

- Moral: use std::string when possible.

# I/O

# C++: Command Line Arguments

- Another nice use of arrays: COMMAND LINE ARGUMENTS

- You're already familiar with them (like, "cp old.txt new.txt")

- How to use?

```
int main(int argc, char * argv[] ){
```

- Literally:
  - argc = number of command line arguments
    - I.E. size of array "argv"
  - argv = array of char arrays, each with a string.

# C++: Command Line Arguments

- Example: Syntax “commandline.cc”:

```
int main(int argc, char * argv[] ){
  for ( unsigned int i = 0; i < argc; ++i ) {
    std::cout << "Argument " << i << " is " << argv[i] << std::endl;
  }
}
```

- If our executable is “a.out”, we type on the command line and get:

```
> ./a.out this is how we do it
Argument 0 is ./a.out
Argument 1 is this
Argument 2 is is
Argument 3 is how
Argument 4 is we
Argument 5 is do
Argument 6 is it
```

- notice: the first argument is the NAME of the executable!

# C++: File I/O

- Files in C++ can be opened and closed, in read or write mode.
- The interface to read and write is the same as “std::cout” and “std::cin”.
  - “std::ofstream” : output formatted stream
  - “std::ifstream” : input formatted stream

- Their “parents” (more later) are :
  - “std::ostream” : output stream
  - “std::istream” : input stream

See Chapter 13 of “progcpp.pdf” Textbook for details

# C++: File I/O

- Example : copy double from one file to another: “fileio.cc”

```
#include <fstream>
#include <iostream>

int main(void){

  std::ifstream  in("inputfile.txt");
  std::ofstream  out("myfile.txt");
  double d;
  in >> d;
  out << d;
  out.close();

  return 0;
}
```

# C++: File I/O

- Within a function, you can use “ostream” and “istream” (“fileio_infuncs.cc”):

```
void input ( std::istream & in ) {
  std::string line;
  std::getline( in, line, ',');
  std::string firstname = line;
  std::getline( in, line, ',');
  std::string lastname = line;
  std::getline( in, line );
  int score = std::atof( line.c_str() );

  std::cout << "First name is " << firstname << std::endl;
  std::cout << "Last name is " << lastname << std::endl;
  std::cout << "Score is " << score << std::endl;
}
```

Will need this snippet for your Homework!