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# Final
# CSE 131
# Winter 2014

| | | |
|---|---|---|
| **Page 1** | _____ | **(21 points)** |
| **Page 2** | _____ | **(30 points)** |
| **Page 3** | _____ | **(24 points)** |
| **Page 4** | _____ | **(35 points)** |
| **Page 5** | _____ | **(21 points)** |
| **Page 6** | _____ | **(13 points)** |
| **Page 7** | _____ | **(24 points)** |
| **Page 8** | _____ | **(23 points)** |
| **Page 9** | _____ | **(23 points)** |
| **Page 10** | _____ | **(16 points)** |
| **Page 11** | _____ | **(20 points)** |
| **Page 12** | _____ | **(18 points)** |
| **Total** | _____ | **(268 points)** |

**255 points = 100%**
**13 points Extra Credit [~5%]**

This exam is to be taken by yourself with closed books, closed notes, no electronic devices.
You are allowed both sides of an 8.5"x11" sheet of paper handwritten by you.

**1.** Given the following CUP grammar snippet (assuming all other Lexing and terminals are correct):

```
Stmt ::=   Des AssignOp Des T_SEMI {: System.out.println("1"); :}
     ;

Des  ::=   T_STAR {: System.out.println("2"); :} Des {: System.out.println("3"); :}
     |     T_AMPERSAND {: System.out.println("4"); :} Des {: System.out.println("5"); :}
     |     T_PLUSPLUS {: System.out.println("6"); :} Des {: System.out.println("7"); :}
     |     Des2 {: System.out.println("8"); :}
     ;

Des2 ::=   Des2 {: System.out.println("9"); :} T_PLUSPLUS {: System.out.println("10"); :}
     |     Des3 {: System.out.println("11"); :}
     ;

Des3 ::=   T_ID {: System.out.println("12"); :}
     ;

AssignOp ::=  T_ASSIGN {: System.out.println("13"); :}
     ;
```

What is the output when parsing the follow statement (you should have 18 lines/numbers in your output):

```
*++x = &*y++;
```

Output

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

In the above grammar, which T_PLUSPLUS has lower precedence, the one in the `Des` production or the one in the `Des2` production? _____

In the above grammar, does the pre-increment operator have left-to-right associativity or right-to-left associativity? _____

If variable `y` is defined to be type `int *`, what type must variable `x` be defined for this expression to be semantically correct?

_____ `x;`

**2.** Given the following Reduced-C code fragment:

```
function : int foo( int & x, int * y, int z ) { /* Body of code not important for this question */ }

function : int main()
{
  int a;
  int b = 42042;
  int c = b;

  a = foo( c, &a, b );

  return c;
}
```

Complete the SPARC Assembly language statements that might be emitted by a compliant Reduced-C compiler from this quarter for function main(). Allocate, store, and access all local variables on the Stack. See comments.

```
        .section __________

        .global __________
        .align 4

_______:
        set     ___________________, %g1

        save    ___________________, %g1, ___________________

        /* Initialize the local variables that have explicit initialization in this stack frame */

        set     _____________, %o0

        st      %o0, _____________                  ! int b = 42042;

        ld      _____________, %o0

        st      %o0, _____________                  ! int c = b;

        /* Set up the 3 actual arguments to foo() */

        _______  ___________________________, %o0  ! large blank can be one or two operands

        _______  ___________________________, %o1

        _______  ___________________________, %o2

        call    foo                                 ! Call function foo()

        __________

        st       _____________, [%fp - 16]          ! Save return value into local temp1

        /* Copy saved return value stored in temp1 into local var a */

        _______  [%fp - 16], ___________________

        _______  _____________, _____________       ! a = foo( ... );

        /* return c; */

        ld       _____________, _____________       ! return c;

        ___________

        ___________

        MAIN_SAVE = -(92 + _______) ________ ________  ! Save space for 3 local vars + 1 temp
```

**3.** In object-oriented languages like Java, determining which method code/instructions to bind to (to execute) is done at run time rather than at compile time (this is known as dynamic dispatch or dynamic binding). However, the name-mangled symbol denoting a particular method name is determined at compile time. Given the following Java class definitions, specify the output of each print() method invocation - **Use the letters A-F below to denote which string is printed**.

```
class C
{
    public void print(C p)
    {
        System.out.println("C 1");
    }
}
```

```
class CPP extends C
{
    public void print(CPP p)
    {
        System.out.println("CPP 1");
    }

    public void print(C p)
    {
        System.out.println("CPP 2");
    }
}
```

```
class JAVA extends CPP
{
    public void print(JAVA p)
    {
        System.out.println("JAVA 1");
    }

    public void print(CPP p)
    {
        System.out.println("JAVA 2");
    }

    public void print(C p)
    {
        System.out.println("JAVA 3");
    }
}
```

A) C 1
B) CPP 1
C) CPP 2
D) JAVA 1
E) JAVA 2
F) JAVA 3

Now <u>remove</u> the entire `print(C p) {}` method in `class CPP` and <u>remove</u> the entire `print(CPP p) {}` method in `class JAVA`. Specify the output of each print() method <u>with these changes</u> below.

```
public class Overloading_Final_Exam {
    public static void main (String [] args) {

        C lang1 = new C();
        C lang2 = new CPP();
        C lang3 = new JAVA();
        CPP lang4 = new CPP();
        CPP lang5 = new JAVA();
        JAVA lang6 = new JAVA();


        lang1.print( lang1 );                    _____________________    _____________________

        lang2.print( lang2 );                    _____________________    _____________________

        lang3.print( lang3 );                    _____________________    _____________________

        lang4.print( lang4 );                    _____________________    _____________________

        lang5.print( lang5 );                    _____________________    _____________________

        lang6.print( lang6 );                    _____________________    _____________________


        lang4.print( (C) lang6 );                _____________________    _____________________

        lang5.print( (CPP) lang6 );              _____________________    _____________________

        lang6.print( (JAVA) lang6 );             _____________________    _____________________


        lang4.print( lang6 );                    _____________________    _____________________

        ( (CPP) lang5).print( (CPP) lang6 );     _____________________    _____________________

        ( (JAVA) lang3).print( (C) lang6 );      _____________________    _____________________

    }
}
```

**4.** Fill in the blanks of the following Reduced-C program with correct types to test if your global scope resolution operator works correctly. If it does, this program should compile without error. If it does not, this program should generate an assignment error at the line y = ::x;

```
_________  x;

function : int main() {

  _________  x;

  int y;

  y = ::x;       // If :: working, this line will not cause an error!
                 // If :: not working, this line will cause an error!
  return 0;
}
```

In Reduced-C (which again follows closely the real C standard) all typedefs use _____ name equivalence. Struct operations (like =, ==, !=) use _____ name equivalence.

In RC (and C/C++), we do not support the assignment of an entire array to another array (of the same type) using the assignment operator. However, we do support assignment of an entire struct instance to another struct instance of the same type. Using this fact, fill in the template of the code below, allowing arrays to piggy-back on a struct type to simulate entire-array assignment/copy that is semantically and logically correct.

```
structdef INTARR5 { int [5] a; };
int [5] x;
int [5] y;
function : void foo()
{
     //  x = y would be a semantic error, but the following will work without an error

     ______ _____________________ ______ x[0] = ______ _____________________ ______ y[0];
}
```

Given the definitions below, indicate whether each expression is either a

1) R-val  2) Modifiable L-val  3) Non-Modifiable L-val

```
function : int & foo1() { /* Function body not important. */ }
function : int * foo2() { /* Function body not important. */ }
const int x = 5;
int y;
int[5] a;
int *p = &y;
```

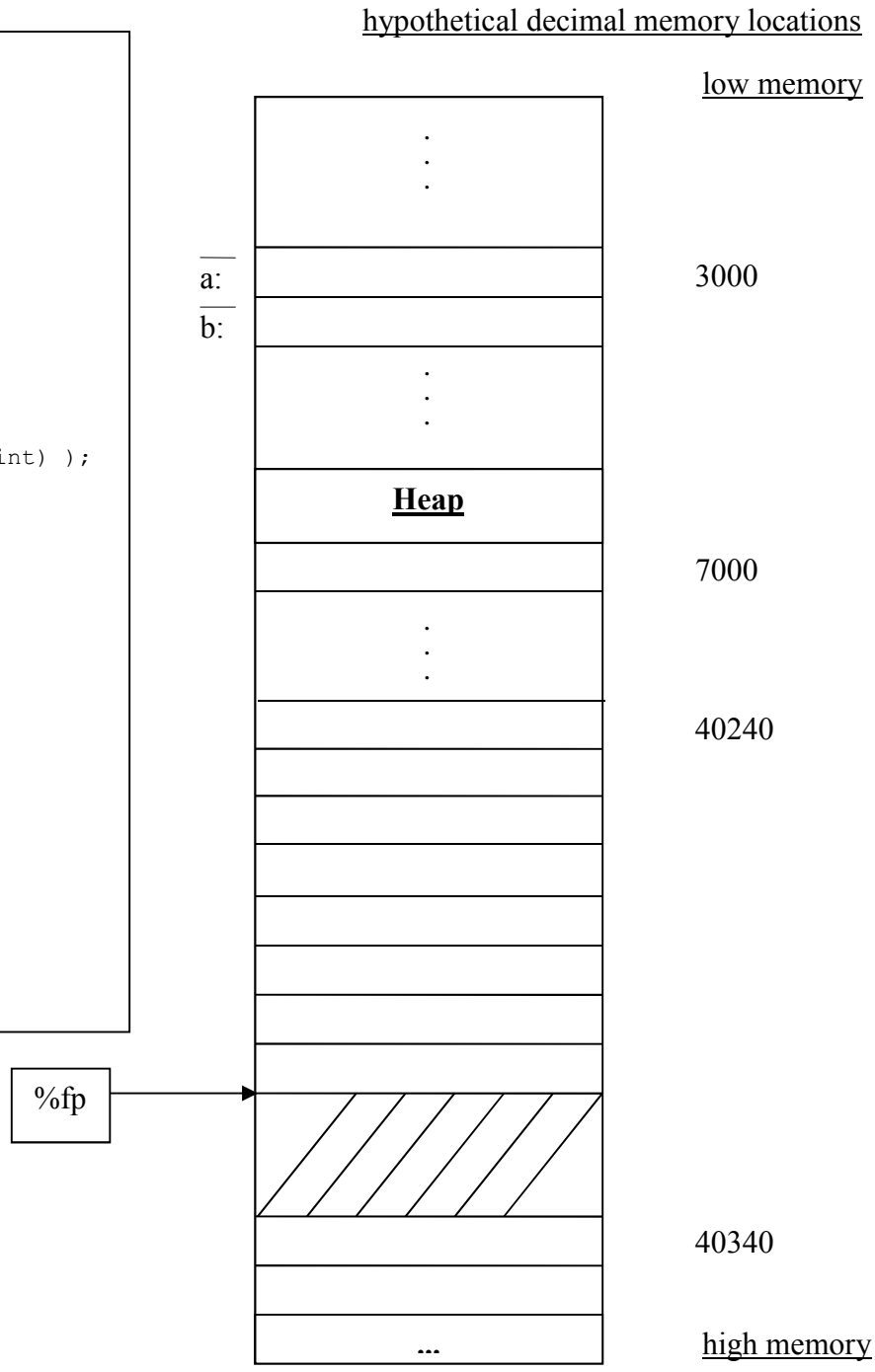
| | | | | |
|---|---|---|---|---|
| ____ a[2] | ____ &y | ____ a | ____ x | ____ x + y |
| ____ p | ____ *p | ____ *&*p | ____ &*p | ____ y |
| ____ 42 | ____ (float *)p | ____ *(float *)p | ____ (float *)&y | ____ *(float *)&y |
| ____ ::y | ____ foo1() | ____ foo2() | ____ foo1()++ | ____ y = *foo2() |
| ____ *p++ | ____ ++*p | ____ *++p | ____ --*++p | ____ ++*p-- |

**5.** What gets printed in the following C++ program (just like Reduced-C without "function : " in front of each function definition)? If a value is unknown/undefined or otherwise cannot be determined by the code given, put a question mark ('?') for that output. Hint: Draw stack frames!

```
int a = 1;
int b = 3;
int c = 5;
int zach;

int & fubar( int * x, int & y, int z )
{
   static int m = *x;
   *x = *x + 3;
   y = y + 3;
   z = z + 3;
   zach = m++;

   return m;
}

void foo1( int d, int * e, int & f )
{
   d = d + 2;
   *e = *e + 2;
   f = f + 2;

   cout << a << endl;    ________

   cout << b << endl;    ________

   cout << c << endl;    ________

   cout << d << endl;    ________

   cout << *e << endl;   ________

   cout << f << endl;    ________

   cout << zach << endl; ________

   cout << fubar( &d, d, d ) << endl;   ________

   cout << fubar( e, *e, *e ) << endl;  ________

   cout << fubar( &f, f, f ) << endl;   ________

   cout << a << endl;    ________

   cout << b << endl;    ________

   cout << c << endl;    ________

   cout << d << endl;    ________

   cout << *e << endl;   ________

   cout << f << endl;    ________

   cout << zach << endl; ________
}

int main()
{
   foo1( a, &b, c );

   cout << a << endl;    ________

   cout << b << endl;    ________

   cout << c << endl;    ________

   cout << zach << endl; ________

   return 0;
}
```

**6.** Given the following C++ program (whose semantics in this case is similar to our Reduced-C) and a real compiler's code gen as discussed in class, fill in the **values** of the global and local variables and parameters in the run time environment for the SPARC architecture when the program reaches the comment `/* HERE */`. Do not add any unnecessary padding.

```
struct fubar {
  int   a;
  int * b;
  float c;
};

int   a = 5;
float b;

void foo( float & f, int i ) {
  int * var1;
  int   var2;
  struct fubar var3[2];

  var2 = -8;
  var1 = (int *) calloc( 1, sizeof(int) );
  f = 1.23;
  var3[0].c = b;
  var3[1].a = i + 6;
  var3[1].b = &var3[1].a;
  i = 73;
  var3[0].a = a;
  var3[0].b = &i;
  var3[1].c = f;
  *var1 = var2 - 1;

  /* HERE */

  free( var1 );
}

int main() {
  foo( b, a );

  return 0;
}
```



**7.** Given the C array declaration

```
          C
int b[2][4];
```

Mark with an **B** the memory location(s) where we would find

```
      b[1][0]
b:
```

```
low memory                                                    high memory
```

Each box represents a byte in memory.

Using the Right-Left rule write the C definition of a variable named foo that is a pointer to an array of 9 elements where each element is a pointer to a function that takes a pointer to a struct RT as the single parameter and returns a pointer to a 3x17 2-D array where each element is a pointer to a pointer to a struct Fubar.

Identify whether each of the following will cause an underlying bit pattern change.

A) Yes – Underlying bit pattern change
B) No – No underlying bit pattern change

```
int a = 5;
float b = -4.20;
int * ptr1;
float * ptr2;
void foo( float x, float & y ) { /* … */ }
```

| | | | |
|---|---|---|---|
| `a = (int) b;` | _____ | `foo( a, b );` | _____ |
| `b = a;` | _____ | `a = * (int *) & b;` | _____ |
| `ptr1 = (int *) & b;` | _____ | `ptr2 = (float *) ptr1;` | _____ |

Use the numbers 1 through 4 to indicate when you would expect to see each error listed below (assuming a *compiled*, not an interpreted, language).

(1) compile-time (2) link-time (3) load-time (4) run-time

_____ Error message: Left-hand side is not a modifiable l-value.

_____ Running "gcc a.o b.o" gives the message "Multiple definition of 'main' ".

_____ An "array-index-out-of-bounds" error using a non-constant index expression.

_____ Undeclared identifier "foo".

_____ An "array-index-out-of-bounds" error using a constant-valued index expression.

_____ Segmentation fault.

_____ Running "gcc someModule.o" gives the message "Undefined reference to 'main' ".

_____ Non-addressable argument of type %T to address-of operator.

_____ Bus error.

**8.** Given the following program, specify the order of the output lines when run and sorted by the address printed with the %p format specifier on a Sun SPARC Unix and Linux system. For example, which line will print the lowest memory address, then the next higher memory address, etc. up to the highest memory address?

```
#include <stdio.h>
#include <stdlib.h>

void foo1( int *, int ); /* Function Prototype */
void foo2( int, int * ); /* Function Prototype */

int a;

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

   int b;
   double c;

   foo2( a, &b );

/*  1 */ (void) printf( "1: argc --> %p\n", &argc );
/*  2 */ (void) printf( "2: c --> %p\n", &c );
/*  3 */ (void) printf( "3: argv --> %p\n", &argv );
/*  4 */ (void) printf( "4: malloc --> %p\n", malloc(50) );
/*  5 */ (void) printf( "5: b --> %p\n", &b );
}

void foo1( int *d, int e ) {

   static struct foo {int a; int b;} f = { 1, 2 };
   int g;

/*  6 */ (void) printf( "6: f.b --> %p\n", &f.b );
/*  7 */ (void) printf( "7: d --> %p\n", &d );
/*  8 */ (void) printf( "8: e --> %p\n", &e );
/*  9 */ (void) printf( "9: f.a --> %p\n", &f.a );
/* 10 */ (void) printf( "10: foo2 --> %p\n", foo2 );
/* 11 */ (void) printf( "11: g --> %p\n", &g );
}

void foo2( int h, int *i ) {

   int j = 411;
   int k[3];

   foo1( i, j );

/* 12 */ (void) printf( "12: k[1] --> %p\n", &k[1] );
/* 13 */ (void) printf( "13: h --> %p\n", &h );
/* 14 */ (void) printf( "14: a --> %p\n", &a );
/* 15 */ (void) printf( "15: i --> %p\n", &i );
/* 16 */ (void) printf( "16: k[0] --> %p\n", &k[0] );
/* 17 */ (void) printf( "17: j --> %p\n", &j );
}
```

_____ smallest value (lowest memory address)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ largest value (highest memory addresses)

You are compiling foo1.c and foo2.c together with gcc. If foo1.c has the following statement

```
extern int a;
```

indicate whether each of the following would cause a linkage editor error or not if put separately (one at a time) in foo2.c?

A) Yes - Linkage Editor Error
B) No - No Linkage Editor Error

____ `extern int a;`

____ `static double a;`

____ `int a = 42;`

____ `int a( float b ) { return (int)b; }`

____ `static int a( float b) { return (int)b; }`

____ `extern void a( char * );`

**9.** Pick one of the following numbers to answer the questions below related to the cdecl calling convention covered in class.

1) Pre-Call (Caller) 2) call/jsr 3) Prologue (Callee) 4) Epilogue (Callee) 5) Post-Call (Caller)

_____ Allocates space for return value
_____ Copies actual arguments into argument space
_____ Allocates space for actual arguments
_____ Stores return value into return value location
_____ Allocates space for local variables & temps
_____ Saves registers in caller-save scheme
_____ Retrieves return value from return value location
_____ Copies args passed in regs to param stack space

_____ Restores caller-save registers
_____ Saves registers in callee-save scheme
_____ Saves %pc into the return address location
_____ Retrieves saved return address for return
_____ Performs initialization of local variables
_____ Restores callee-save registers
_____ Deallocates argument space in cdecl mode
_____ Deallocates local variable & temps space

Many older programmers prefer to use pre-increment/pre-decrement to perform a stand-alone inc/dec of a variable. For example, `++i;` or `for ( i = 0; i < SIZE; ++i )`

Why might a pre-increment/pre-decrement be thought of as preferred for these seasoned programmers? Think in terms of code gen from your compiler.

Given the following C type definitions

```
struct foo {
  short  a;
  char   b;
  double c;
  int    d;
};

struct fubar {
  int        e;
  char       f[6];
  struct foo g;
  int        h;
};

struct fubar fubaz;
```

What is the `sizeof( struct fubar )`? _____ What is the `offsetof( struct fubar, g.d )`? _____

If `struct fubar` had been defined as `union fubar` instead, what would be the `sizeof(union fubar)`? _____

What is the resulting type of the following expression?

```
* (int *) & ( ( (struct fubar *) & fubaz.g.c ) -> g ) _________________
```

Write the equivalent expression that directly accesses this value/memory location without all the fancy casting and `&` operators.

```
fubaz._________________
```

**10.** Identify <u>where</u> each of the following program parts live in the Java runtime environment as discussed in class.

```
public class Foo {
  private static Foo a;                          a          _____________

  private int b;                                 b          _____________

  public Foo() {                           code for Foo()   _____________

    a = this;                                    this       _____________
    ++b;
  }
                                           code for main()  _____________

  public static void main( String[] args ) {     args       _____________

    double c = 4.20;                             c          _____________

    Foo d;                                       d          _____________

    d = new Foo();            where d is pointing           _____________
    d.method( c );
  }
                                           code for method() _____________

  private void method( double e ) {              e          _____________

    double f = e;                                f          _____________

  }
}
```

Given this short simple Reduced-C program, show how you tested call-by-reference parameters in your compiler to ensure the implementation is truly call-by-reference vs. any other implementation.

```
int global = 5;
    /* A */
function : void foo( int & param )
{
    /* B */
    param = 10;
    /* C */
}
    /* D */
function : void main()
{
    foo( global );
    /* E */
}
    /* F */
```

Which two places should you put the following statement to output the value of global to accurately test call-by-reference implementation in the (your) compiler (specify the LETTER associated with the location)? And what value should be printed with each output statement if the (your) compiler correctly implemented call-by-reference?

```
cout << global << endl;
```

_____ Location one  Expected output _____

_____ Location two  Expected output _____

**11.** Match the compilation process with the various tasks done in the compilation sequence.

1) C++ Preprocessor 2) C++ Compiler 3) Assembler 4) Linkage Editor 5) Loader

_____ combines all object modules into a single executable file.

_____ performs name mangling of function names.

_____ performs semantic analysis on its input high-level language (HLL).

_____ takes an executable file on disk and makes it ready to execute in memory.

_____ translates assembly code into machine code.

_____ expands # directives from its input high-level language (HLL).

_____ performs syntax analysis on its input high-level language (HLL).

_____ resolves undefined external symbols with defined global symbols in other modules.

_____ translates high-level language (HLL) code into assembly code.

_____ zero fills the BSS segment in memory.

_____ puts globally defined symbols in the export list of the resulting object file.

Use virtual register notation for each of the following.

Perform step-wise peephole optimization on the following window of pseudo three-address instructions (max of three operands are allowed in an instruction – up to two source and one destination):

```
... other instructions ...

r3 = r2 * 16          _______________        (instruction eliminated)

r0 = r3               r0 = r3                _______________        (same instr as step 2)

r3 = 13 + 7           r3 = 13 + 7            r3 = 13 + 7            _______________

... other instructions ...

                           step 1                 step 2                 step 3
```

Change the following instructions into two instructions which are most likely a time improvement over the set of instructions when it comes to actual execution time.

```
r1 = r2 * r5
r3 = r1
r6 = r2 * r5
r4 = r6

r1 = …
r6 = …
…  = … r3
…  = … r4
```

```
_____________________

_____________________
r1 = …      ! r1 overwritten
r6 = …      ! r6 overwritten
… = … r3    ! r3 used as src op
… = … r4    ! r4 used as src op
```

What terms describe these particular kinds of peephole optimizations? List <u>two</u> that apply.

1)

2)

What C/C++ compiler option should you use to produce a `.o` file from a .c file? _____

What C/C++ compiler option should you use to produce a `.s` file from a .c file? _____

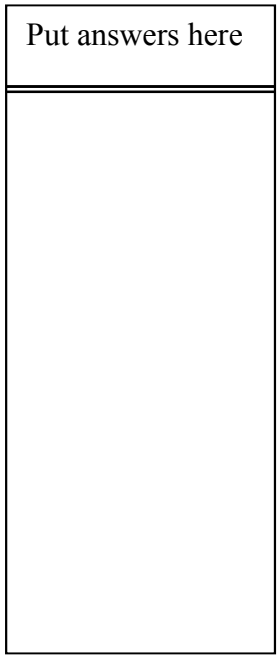
**12.** What gets printed when this C program is executed?

```
#include <stdio.h>

int
main()
{
  char a[] = "Build!";
  char *p = a + 3;

  printf( "%c\n", *p-- );              ______

  printf( "%c\n", ++*--p );            ______

  printf( "%c\n", 2[a]++ );            ______

  printf( "%c\n", p[-1] = *(a+5) );    ______

  printf( "%c\n", ++*p++ );            ______

  printf( "%c\n", ++*++p );            ______

  printf( "%d\n", p - a );             ______

  printf( "%s\n", a );                 ____________________

  return 0;
}
```

What is Rick's favorite guilty pleasure? _____

What gets printed if the following function is invoked as `recurse( 2, 10 )` ? Hint: Draw stack frames.

```
int
recurse( int a, int b ) {
  int local = b - a;
  int result;

  printf( "%d\n", local );

  if ( b > 7 )
    result = local + recurse( a, b - 1 );
  else
    result = local;

  printf( "%d\n", result );

  return result;
}
```




Crossword Puzzle (next page) (1 point)

Hexadecimal - Character

| 00 NUL | 01 SOH | 02 STX | 03 ETX | 04 EOT | 05 ENQ | 06 ACK | 07 BEL |
|---|---|---|---|---|---|---|---|
| 08 BS | 09 HT | 0A NL | 0B VT | 0C NP | 0D CR | 0E SO | 0F SI |
| 10 DLE | 11 DC1 | 12 DC2 | 13 DC3 | 14 DC4 | 15 NAK | 16 SYN | 17 ETB |
| 18 CAN | 19 EM | 1A SUB | 1B ESC | 1C FS | 1D GS | 1E RS | 1F US |
| 20 SP | 21 ! | 22 " | 23 # | 24 $ | 25 % | 26 & | 27 ’ |
| 28 ( | 29 ) | 2A * | 2B + | 2C , | 2D - | 2E . | 2F / |
| 30 0 | 31 1 | 32 2 | 33 3 | 34 4 | 35 5 | 36 6 | 37 7 |
| 38 8 | 39 9 | 3A : | 3B ; | 3C < | 3D = | 3E > | 3F ? |
| 40 @ | 41 A | 42 B | 43 C | 44 D | 45 E | 46 F | 47 G |
| 48 H | 49 I | 4A J | 4B K | 4C L | 4D M | 4E N | 4F O |
| 50 P | 51 Q | 52 R | 53 S | 54 T | 55 U | 56 V | 57 W |
| 58 X | 59 Y | 5A Z | 5B [ | 5C \ | 5D ] | 5E ^ | 5F _ |
| 60 ‘ | 61 a | 62 b | 63 c | 64 d | 65 e | 66 f | 67 g |
| 68 h | 69 i | 6A j | 6B k | 6C l | 6D m | 6E n | 6F o |
| 70 p | 71 q | 72 r | 73 s | 74 t | 75 u | 76 v | 77 w |
| 78 x | 79 y | 7A z | 7B { | 7C \| | 7D } | 7E ~ | 7F DEL |

A portion of the Operator Precedence Table

| Operator | Associativity |
|---|---|
| ++ postfix increment | L to R |
| -- postfix decrement | |
| [] array element | |
| () function call | |
| -> struct/union pointer | |
| . struct/union member | |
| * indirection | R to L |
| ++ prefix increment | |
| -- prefix decrement | |
| & address-of | |
| sizeof size of type/object | |
| (type) type cast | |
| * multiplication | L to R |
| / division | |
| % modulus | |
| + addition | L to R |
| - subtraction | |
| . | |
| . | |
| . | |
| = assignment | R to L |

**Scratch Paper**

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