University of Waterloo
Department of Electrical and Computer Engineering

Final Examination E&CE 355 Solutions
Software Engineering Fall 2003

2:00 Sat. Dec. 13, 2003 **180 minutes**
Instructors: N. Young, M. Hembruch
NO ADDITIONAL MATERIAL ALLOWED **The marking scheme is an initial guide only.**
NO CALCULATORS ALLOWED **Other solutions and marks apply individually.**

NOTES:

Answer all questions.

Guesses on two-valued questions have an expected value of zero.

Question weights are indicated in brackets [...].

Proctors and TA's are NOT allowed to answer questions. Instructors will only correct obvious typos or other problems with the exam. They will not answer questions.

If information appears to be missing from a question, make a reasonable assumption, state your assumption, and proceed. Do not simplify the question.

Attempt to answer questions in the space provided. If necessary, you may use the back of another page. If you do this, please indicate it clearly.

If you separate the pages, make sure your initials are on the top of every page.

The last page includes copies of figures for questions 2, 4, 8 and 9. Tear the last page off, for quick reference. Do not write answers on this last reference page.

Hand in all pages except possibly the last page.

NAME _____

Signature: _____

SN: _____

1. Software lifecycles		15
2. SDL and MSC		25
3. Real time		15
4. Design patterns		20
5. Brook's Complexity		15
6. Build tools		10
7. V&V		15
8. Cyclomatic complexity		20
9. Coverage		30
10. Integration testing		15
Total		**180**

1. Software lifecycles [15]

We discussed two software development lifecycles in class, *waterfall* and *incremental*.

Our guest speaker, Mauricio De Simone of Nitido, made the following statements:

> Build the bones, then put on the meat.
> Have a small team that puts together the bones.
> Bring development muscle once the bones are in place.

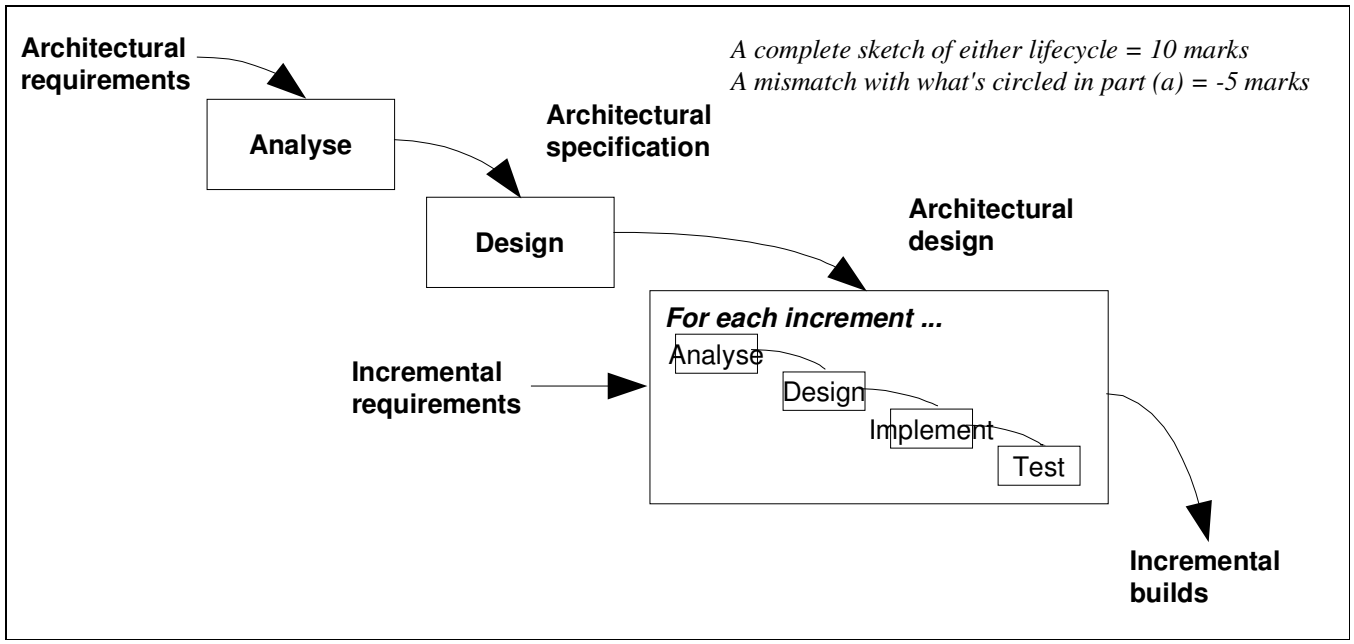
a) [5] Circle "waterfall" or "incremental" indicating whether Mauricio is describing the waterfall or incremental lifecycles. In two or three sentences, briefly explain your answer.

Waterfall Incremental

The waterfall lifecycle implies that all design effort is completed in a single pass through the process. The incremental lifecycle first builds a central architecture ("bones") and returns to add incrementally more features ("meat") through successive iterations.

"Waterfall" = -1 mark; "Incremental" = 2 marks
Drawing a parallel between architecture and "bones" = 1 or 2 marks
Drawing a parallel between features and "meat" = 1 or 2 marks
Citing waterfall's strict sequence and/or incremental's multiple iterations = 1 or 2 marks
A thorough attempt based on waterfall is worth a maximum of 2 marks total, for part (a)

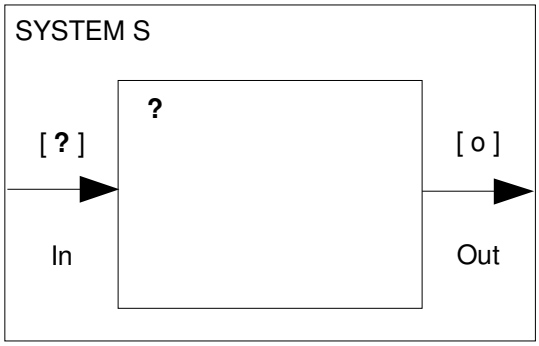
b) [10] Sketch the software development lifecycle that you circled in part (a) Label all blocks and arcs.

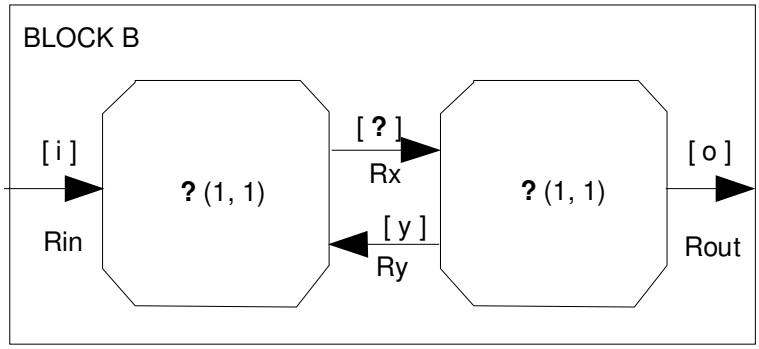


A complete sketch of either lifecycle = 10 marks
A mismatch with what's circled in part (a) = -5 marks

2. SDL and MSC [25]

a) [5] The Specification and Description (SDL) figures shown below describe a small system, S. The five question marks (?) show where labels are missing. Complete the figures by replacing the question marks with the correct labels.

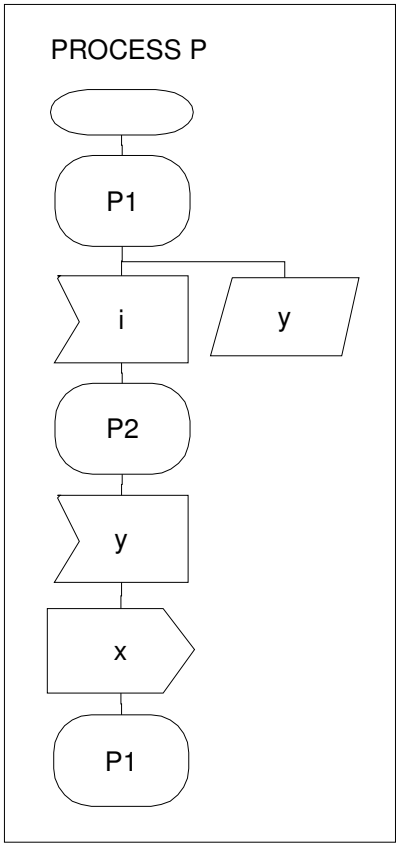


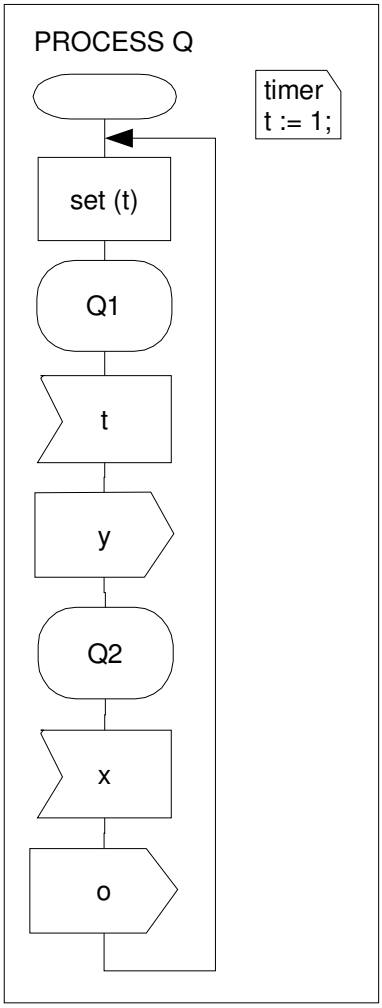


b) [5] Complete the following table.

Number of blocks	*1 or 2*
Number of signals	*4 or 5*
Number of states in process P	*2*
Number of inputs in process P	*2*
Number of outputs in process Q	*2*

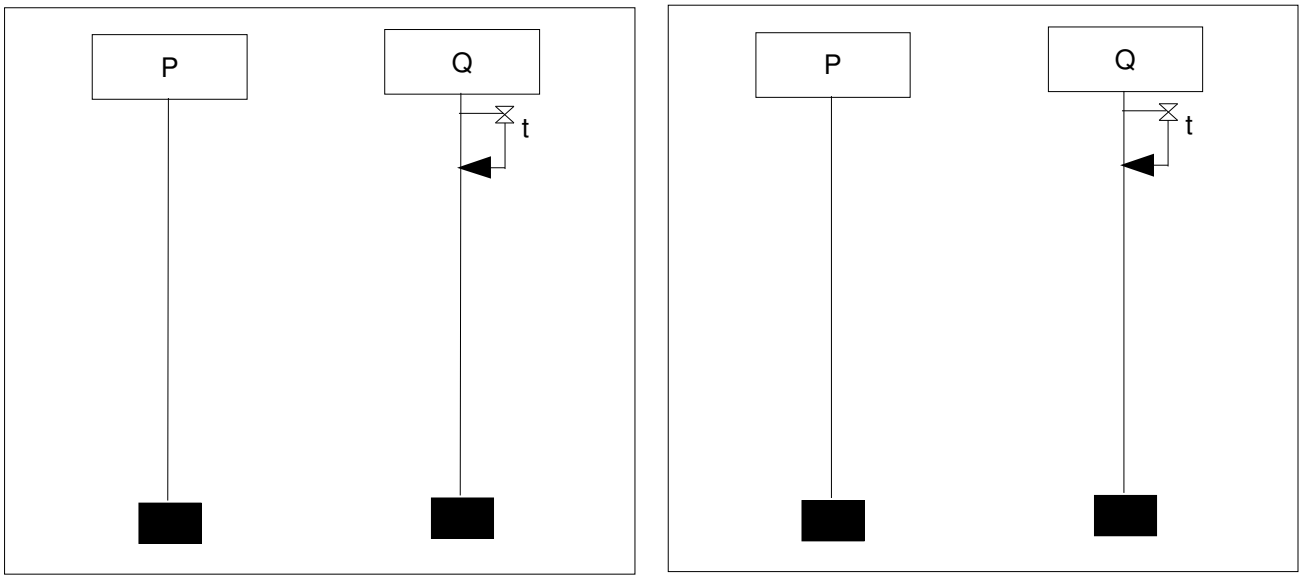
Part (a) solution: i, BLOCK B, x, P, Q





c) There are at least two message sequences for the system S that produce exactly one output message ("o") to the environment. Complete the two Message Sequence Charts (MSC's) shown below. showing

different message sequences that produce exactly one output of the signal “o”.



{y(P>Q), i(E>P), x(P>Q), o(Q>E)}; {i(E>P), y(P>Q), x(P>Q), o(Q>E)}
Any first solution = 10 marks; Any second solution = 5 marks

3. Real time [15]

a) [3] In one or two sentences, define the term real-time requirement as we discussed it in class.

Any requirement that includes a reference to physical time in its statement of correctness.

Reference to physical time, or a contrast w.r.t. computer time, etc. = 2 marks
Reference to “specification”, “correctness”, etc. = 1 mark

b) [12] The following table lists four software applications. Classify each application by circling “Not”, “Soft” or “Hard”, to indicate whether the application includes real-time requirements. Explain each answer with a sentence or two.

Application / Real time	***Explanation***
1. Stop light, i.e., 3-coloured traffic light (red, yellow, green) Not Soft Hard	*Soft: Physical time is part of the requirements (e.g., 2-minute delay) but correctness is perceived only by humans, i.e., only humans in the control loop*
2. Word processor Not Soft Hard	*Not: No timing constraints, as long as performance is reasonable; or* *Soft: With some explanation relating performance to time*

Application / Real time	*Explanation*
3. Missile flight surface control Not Soft Hard	*Hard: Correct performance of the missile depends on controlling the flight surfaces accurately w.r.t. physical time, i.e., only the laws of physics in the control loop*
4. Phantom Dialer PBX program Not Soft Hard	*Not: The specifications included no refernce to physical time; or Soft: Definition of switchhook events referred to time, but with only humans in the control loop*

4. Design patterns [20]

The following C++ code fragments show an example of a design pattern discussed in lecture.

```
class ioPattern
{
   public:
      virtual file *newfile(String filename);
      virtual shmem *newShmem(int key);
      virtual msgq *newMsgq(int key);
}

class unixIoPattern: public
{
   public:
      unixIoPattern() {
      file *newFile(String filename)
         {
            if (fileType == 1)
               return new unixFile(filename);
            else
               return new unixPipe(filename);
         }
      shmem *newShmem(int key)
         { return new unixShmem(key); }
      ...
}
...
```

```
main()
{
   ioPattern *iof;
   #ifdef UNIX
      iof = new unixIoPattern();
   #ifdef WINDOWS
      iof = new winIoPattern();
   #elseif QNX
      iof = new qnxIoPattern();
   #endif
   file xyz = iof-
>newFile("abc");
}
```

a) [3] Name the design pattern that this example illustrates.

"AbstractFactory" = 3 marks;
"Factory" = 2 marks

b) [3] How many instances of the design pattern are created during the execution of `main()`?

"1" = 3 marks
0", "2", or "3" explained = 3 marks;
"3" or "iof" = 1 mark

c) [5] Files (`file`), shared memory (`shmem`) and message queues (`msgq`) are examples of resources. List the names of the classes that you need to change and add to extend this example for a socket resource?

Classes changed	Classes added
ioPattern	
unixIoPattern	*unixSocket*
winIoPattern	*winSocket*
qnxIoPattern	*qnxSocket*

"ioPattern" (1) + "[unix, win, qnx]IoPattern" (all=2, some=1) + "[unix, win, qnx]Socket" (all=2, some=1) = 5 marks

d) [6] List the names of the classes that you would need to change and/or add to extend the original example (i.e., without the socket resource) for the Apple Macintosh ("mac") operating system?

Classes changed	Classes added	
	macIoPattern	
	macFile	
	macPipe	
	macShmem	*@ 1 mark ea.*
	macMsgq	*+ 1 mark all = 6 marks*

e) [3] The use of the `#ifdef` directive shown in this example illustrates a common technique for implementing a product family, i.e., for using the same source code to generate a similar but distinct products for multiple different operating systems. We also discussed this technique in the lectures on configuration management. What name did we call the different members of a product family?

"variant" = 3 marks; "configuration" = 2 marks; "version" = 1 mark

5. Brooks' complexity [15]

Our guest speaker, Mauricio De Simone of Nitido, referred to Brooks' two categories of complexity. Mauricio defined the categories as follows:

Category A: Complexity arising from our choice of tools to use in solving a problem

Category B: Complexity inherent in the problem itself

Mattias Hembruch also used the same two catgories to explain the purpose of the Requisite Skills Package (RSP) portion of the project, where you implemented the Phantom Dialer (PhD).

a) [3] Brooks, De Simone and Hembruch used specific names for the categories. Name the categories.

Category A	Category B
incidental or accidental	*essential*

"incidental" or "accidental" = 1 mark; "essential" = 1 mark; swapped = 1 mark; Both = 3

b) [6] In one or two short paragraphs, explain the purpose for the Requisite Skills Package (RSP) using Brooks' two categories. (If you don't know the specific terms, just use "Category A" and "Category B".)

The purpose of the Requisite Skills Package (RSP) was to move the effort and risk arising from the incidental complexity of the project to the early part of the academic term. The incidental complexity in the project came from having to use specialized languages, software development tools and

environment, many of which were new to the students (e.g., SDL, MSC, Unix, multi-process programming, IPC, PBX hardware emulator, RCS or CVS, ACAT). Dealing with the incidental complexity on a simple problem early in the term gave the students more time to learn about how to use the tools before using them on the larger Call Processing problem.

The essential complexity of the Call Processing software arose from the need to design multi-user control software with real-time performance constraints, based on a communicating finite-state machine specification of the software. The inherent challenge of this design work was better met after having learned about the appropriate specification and design techniques during lecture (e.g., models of computation, transformational design, cohesion and coupling, DARTS, information hiding).

Relating tools and/or environment to category A = 2 marks
Relating specification and/or design challenge to category B = 2 marks
Refering to a reduction in any of effort, risk, and calendar time = 2 marks
Mismatching category terms with what was written as part (a) answer = -2 marks

c) [4] Circle "agree" or "disagree", depending on whether you agree that the RSP fulfilled its purpose for your project team. In about two or three sentences, explain why you agree or disagree. Refer to your project team's actual experience.

Agree Disagree

Circling an answer = 1 mark; Contradicting the circled answer = -1 mark
Citing some important criteria for the project's measure of success or failure (e.g., effort, risk, calendar time, software correctness, software performance, etc.) = 2 marks
Relating the benefit or detraction to the complexity catgories = 1 mark

6. Build tools [10]

Assume the file, `t.c`, shown at right. Also, assume the function `test()` in file `test.c` as shown on the last page (and as mentioned again in the cyclomatic complexity question).

```
/* t.c */

#include <stdlib.h>
extern void test(int a, int b);
int main(int argc, char *argv[])
{
   if( argc == 3 )
      test( atoi(argv[1]), atoi(argv[2]));
}
```

a) [6] Complete the Makefile shown at right such that it will compile the program "`t`" from `t.c` and `test.c`. Use the command `gcc` to compile and/or link the files. Do not assume the use of built-in makefile rules.

```
### Makefile to compile t

all: t

t: t.o test.o
           gcc t.o test.o -o t

t.o: t.c
           gcc -c t.c

test.o: test.c
           gcc -c test.c
```

b) [4] Assume `t.c` and `test.c` have been checked into a version control system which creates a repository file in the current directory with a "`.vc`" extension (that is, `test.c.vc` and `t.c.vc`). Assume the command "`cmd update <filename>`" will retrieve the latest version of the file. Write the additional Makefile rules to automatically check that the working copies of `t.c` and `test.c` are the latest version.

```
### Makefile to retrieve latest versions

test.c: test.c.vc
          cmd update test.c

t.c: t.c.vc
          cmd update t.c
```

7. V&V [15]

a) [3] In one or two sentences, define verification.

Verification evaluates a system or component to determine whether the products of a development activity satisfy the conditions imposed at the start of the activity. Verification is only done by the development organization.

Reference to individual steps, actvities, work products or components = 1 mark
Reference to correctness, evaluation, or specification = 1 mark
Coherent presentation of the same = 1 mark
"Building the product right", also = 3 marks

b) [3] In one or two sentences, define validation.

Validation evaluates whether a system or component at or near the end of the development cycle to determine whether the software does what the user really requires. Validation is likely done by the customer, or may be done by the development organization on behalf of the customer.

Reference to the end of, whole, or completed development process or product = 1 mark
Reference to customer, user or real requirements = 1 mark
Coherent presentation of the same = 1 mark
"Building the right product", also = 3 marks

The Cleanroom software development method emphasizes fault prevention over failure detection. All failures of the product are traced to faults in the development process: the failed product is discarded; the process fault is isolated and corrected. The Cleanroom method was created by Harlan Mills at IBM Federal Systems and has been used at organizations such as NASA, Ericsson and Texas Instruments.

c) [9] The following table outlines three important aspects of the Cleanroom method. For each aspect, provide two pieces of information. First, circle "static" or "dynamic" indicating whether the aspect applies static or dynamic verification or validation. Second, write about two or three sentences explaining the benefit that the aspect brings to the development process and/or product quality.

Cleanroom	***Benefits explanation***
1. Individual developers are not allowed to compile or run their own modules. Each developer is responsible for their own modules' entire syntactic and semantic correctness, which the developer achieves purely by inspection. Static Dynamic	*Static = 1 mark; Any reasonable benefit = 2 marks* *Reduced faults; Lower cost; Faster delivery* *Preventing individual developers from compiling or running their own modules forces them to understand their modules thoroughly, thereby reducing the likelihood of them overlooking faults. This prevents faults from being passed on to later, more expensive process steps, where more developers are involved and the cost of correcting faults is higher.*
2. Modules are specified as the functional composition of other modules, through the elementary constructs of sequence, alternation and iteration. Each module's correctness is verified by mathematically proving that the module implements its specified function. Static Dynamic	*Static = 1 mark; Any reasonable benefit = 2* *Reduced faults; Lower cost; Faster delivery* *Specifying each module mathematically eliminates ambiguity, thereby reducing the likelihood of developers and inspectors making mistakes. Use of the elementary program constucts further ensures that the inspection process remains orderly and objective.*
3. Completed systems are validated through tests that are selected according to statistical models of how the system will be used. Features that are used more often are tested more than features that are used less often. Static Dynamic	*Dynamic = 1 mark; Any reasonable benefit = 2* *Reduced faults; Lower cost; Faster delivery* *Testing cannot show the absence of faults, only the presence. Of the practically-infinite set of possible tests, applying the tests that reflect the actual system usage will improve the chances of revealing failures that are relevant to the actual system usage.*

8. Cyclomatic complexity [20]

a) [12] In the space below, draw the control flow graph for the C function, `test()`. Label the edges to show which condition each edge represents. (Assume short-circuit evaluation, i.e., the same as in class.)

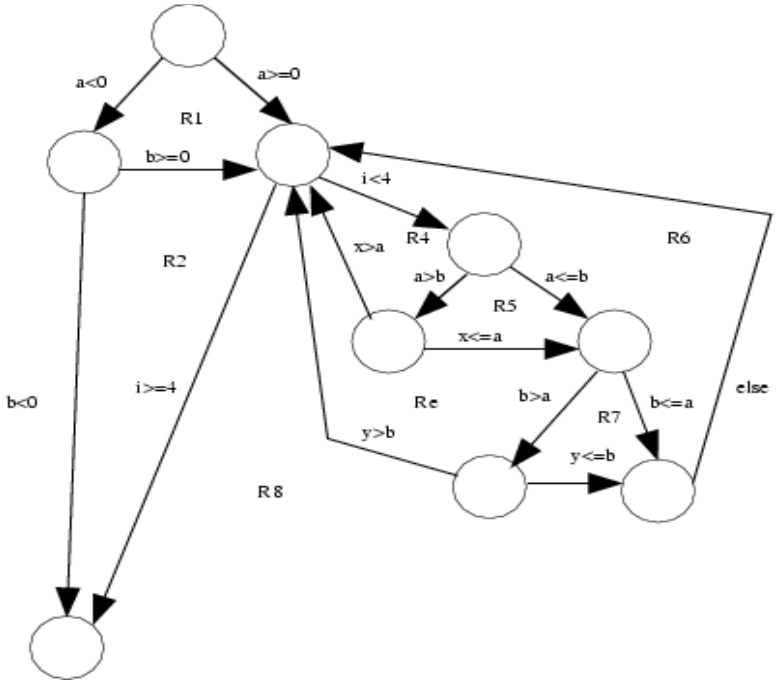
```
    /* test() function */
    void test(int a, int b)
    {
       int i, x, y;

01     x=a*b+2;
02     y=(b+a)*5;

03     if( (a<0) && (b<0) ) return;

04     for(i=0;i<4;i++)
       {
05        if( (a>b) && (x>a) )
06           printf("Case 1!\n");
07        else if( (b>a) && (y>b) )
08           printf("Case 2!\n");
09        else printf("Case 3!\n");
10       y++;
11       x--;
       }
    }
```

b) [4] The cyclomatic complexity, V(G), can be calculated by counting the regions of the graph. Label the regions of the graph, R1, R2, etc., and state the cyclomatic complexity.

V(G) = *8*

c) [4] In addition to counting the regions of the graph, we discussed two other methods of calculating the cyclomatic complexity. Choose either method and calculate the cyclomatic complexity again. Clearly show all steps in detail, including the original equation and variable substitutions.

V(G) = *E -N + 2* = *p + 1*
= *15 - 9 + 2* = *7 + 1*
= *8* = *8*



9. Coverage [30]

Consider the C function, `test()`, in the previous question, and the three test cases listed in the table.

a) [20] Complete the table by listing the statements and edges covered by each of the test cases. The first test case is done for you, as an example.

b) [5] Circle "yes" or "no", indicating whether the set of three cases give statement coverage of the program. If you circle "no", write at least one statement not covered.

c) [5] Circle "yes" or "no", indicating whether the set of three cases give edge coverage of the program. If you circle "no", write at least one edge not covered.

Case	***Statements***	***Edges***
(a = 0, b = 0)	01, 02, 03, 04, 05, 07, 09, 10, 11	a >= 0, a <= b, b <= a, i < 4, i >= 4
(a = 2, b = 2)	*01, 02, 03, 04,* *05, 07, 09,* *10, 11* *5 marks*	*a >= 0,* *a <= b,* *b <= a,* *i < 4, i >= 4* *5 marks*
(a = 9, b = 1)	*01, 02, 03, 04,* *05, 06, 07, 09,* *10, 11* *5 marks*	*a >= 0,* *a > b,* *x > a, x <= a,* *b <= a,* *i < 4, i >= 4* *5 marks*
Coverage	Yes No	Yes No
Not covered	*No: 08* *"No" = 2, "Yes" = -1, "08" = 3*	*No: y<=b, y>b, a<0, b<0, b>a, b>=0* *"No" = 2, "Yes" = -1, Either = 3*

10. Integration testing [15]

Our guest speaker, Mauricio De Simone of Nitido, made the following statements.

> Integration is the hardest part.
> Independently test layers. Divide and conquer the layers of your system.

a) [2] Define the term "integration".

Reference to the action "combination", "composition", etc. = 1 mark
Reference to pieces "unit", "component", "layer", etc. = 1 mark

b) [6] In a short paragraph, explain why Mauricio would say "Integration is the hardest part." Give at least two reasons. Use the the concepts and terms we discussed in class.

Integration is difficult because of at least four factors. First, integration combines the components of the software system for the first time. If the actual interfaces for the components do not match the originally-specified interfaces, then the interfaces and/or components must be corrected before integration can proceed. This is an example of an internal problem area. Second, the integration often combines the components with an operating system or other outside software for the first time. If the supplied software does not perform as required, then the integration can be delayed for having to obtain corrected software, or for having to adjust the components to work around the problems. This is an example of an external problem area. Third, fault isolation is more difficult among multiple combined components than among separately-tested components. Fourth, integration often involves components and people from multiple separate groups, which can complicate communication and scheduling, by having more people involved who are not accustomed to working together.

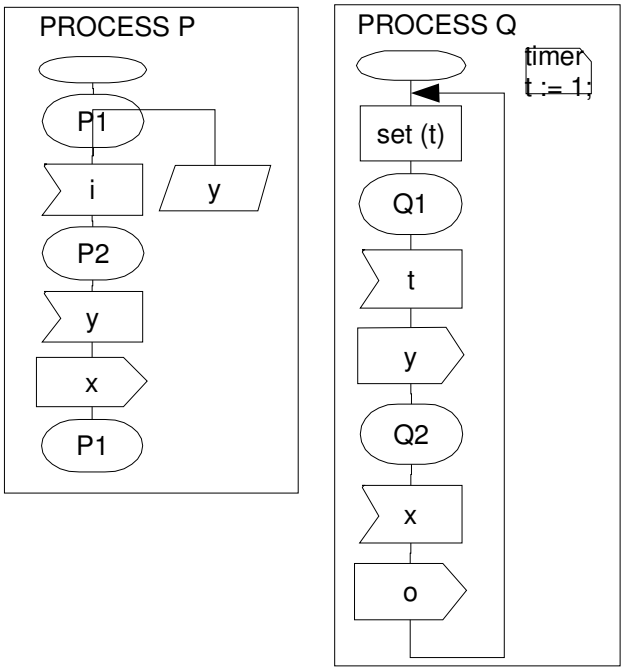
Reference to any two of the sample factors or other good reasons = 2 factors x 3 marks ea. = 6

c) [2] Circle "yes" or "no" indicating whether Mauricio recommends performing integration testing separately from system testing. In one or two sentences, briefly explain your answer.

Yes No

"Independently test the layers"
Circling "yes" = 1 mark; Inconsistent explanation = -1 mark
Consistent explanation = 1 mark

2. SDL and MSC



8. Cyclomatic Complexity & 9. Coverage

```
    /* test() function */
    void test(int a, int b)
    {
       int i, x, y;

01     x=a*b+2;
02     y=(b+a)*5;

03     if( (a<0) && (b<0) ) return;

04     for(i=0;i<4;i++)
       {
05        if( (a>b) && (x>a) )
06           printf("Case 1!\n");
07        else if( (b>a) && (y>b) )
08           printf("Case 2!\n");
09        else printf("Case 3!\n");
10       y++;
11       x--;
       }
    }
```

4. Design patterns

```
class ioPattern
{
   public:
      virtual file *newfile(String filename);
      virtual shmem *newShmem(int key);
      virtual msgq *newMsgq(int key);
}

class unixIoPattern: public
{
   public:
      unixIoPattern() {
      file *newFile(String filename)
         {
            if (fileType == 1)
               return new unixFile(filename);
            else
               return new unixPipe(filename);
         }
      shmem *newShmem(int key)
         { return new unixShmem(key); }
      ...
}
...
```

```
main()
{
   ioPattern *iof;
   #ifdef UNIX
      iof = new unixIoPattern();
   #ifdef WINDOWS
      iof = new winIoPattern();
   #elseif QNX
      iof = new qnxIoPattern();
   #endif
   file xyz = iof-
>newFile("abc");
}
```