EECS 481 — Software Engineering — Exam #1

- **Write your name and UM uniqname on the exam.**
- There are ten (10) pages in this exam (including this one) and seven (7) questions, each with multiple parts. Some questions span multiple pages. If you get stuck on a question, move on and come back to it later.
- You have 1 hour and 20 minutes to work on the exam.
- The exam is closed book, but you may refer to your two page-sides of notes.
- Even vaguely looking at a cellphone or similar device (e.g., tablet computer) during this exam **is cheating**.
- Please write your answers in the space provided on the exam. Clearly mark your solutions. You may use the backs of the exam pages as scratch paper. Do not use any additional scratch paper.
- Solutions will be graded on correctness and clarity. Each problem has a relatively simple and straightforward solution. We may deduct points if your solution is far more complicated than necessary.
  - *Good Writing Example:* Testing is an expensive activity associated with software maintenance.
  - *Bad Writing Example:* Im in ur class, @cing ur t3stz!1!
- If you leave a non-extra-credit portion of the exam blank, **you will receive one-third of the points for that small portion (rounded down) for not wasting time.**

UM uniqname: ANSWER KEY

NAME (print): ANSWER KEY

UM uniqname: (yes, again!) ANSWER KEY

Problem	Max points	Points
1 — Software Process Narrative	13	
2 — Test Inputs and Coverage	18	
3 — Short Answer	15	
4 — Mutation Testing	15	
5 — Dataflow Analysis	20	
6 — Quality Assurance Analyses	19	
Extra Credit	0	
TOTAL	100	

How do you think you did? _____

1 Software Process Narrative (13 points)

(1 pt. each) Read the following narrative. If a text segment corresponds to, or demonstrates, a concept below, fill in its ____ blank with the letter of the *most appropriate or specific* concept. **Or,** if a text segment is false or very unlikely in the real world (cf. the readings), fill in its blank with an X. Otherwise, leave it untouched. An option may be used more than once.

A. a/b testing	B. beta testing	C. effort estimation	D. integration testing
E. priority	F. regression testing	G. resolution	H. severity
I. streetlight effect	J. threat to validity	K. worksforme	**X. *false***

Unrealistic Software is maintaining a hot new click-fest mobile game, *Clash of the Philosophers*.

__J__ For part of a tie-in campaign with another company, Unrealistic Software wants to determine how much their players like various philosophers, so they measure how often their players purchase them.

__A__ By slightly varying the icon border color, they find that in-app purchases of the Simone de Beauvoir character increase by 10%; they decide to implement that color change.

__X__ Developers and program managers are most interested in learning how to generate 100% test coverage for this new color-change code.

____ While development is focused on code coverage, new defects are reported by end users.

__X__ The majority of the defect reports include stack traces.

____ The stack traces seem to implicate the in-app purchase code.

__C__ Management asks the developers how long it will take to fix this defect.

__E__ It is decided that this defect must be fixed right now.

____ However, developers need help pinning down the defect.

__I__ Since they already have GPS location information about their players, they decide to look for a geographic correlation, but do not find one.

__X__ They then hypothesize that the problem could be a database issue, so they decide to use Microsoft's CHESS tool to gain more information.

__D__ Eventually, they test the new color-changing code in conjunction with the old in-app purchase code.

__G__ Developers check in a change that they believe fixes the bug, but later the bug resurfaces and the defect report is reopened.

2 Test Inputs and Coverage (18 points)

(4 pts. each) Consider the following program with blanks. We are concerned with statement coverage, but only for the statements labeled S_1 through S_5.

```
1  void liskov(int a, int b, int c) {
2    S_1;
3    if (a == __1__)
4      S_2;
5    if (b < __a__)  // if (b < _2_)
6      S_3;
7    else if (b == a)
8      S_4;
9    if (a == b __+__ c)
10     S_5;
11 }
```

Now consider the following three test inputs, T_1 through T_3:

T_1 = liskov(1,2,3)	T_2 = liskov(8,8,1)	T_3 = liskov(3,1,2)

Using all three test inputs results in 100% coverage of the labeled statements. Using either T_1 or T_2 alone results in 40%. Using T_1 with T_3 results in 80%. Using T_2 with T_3 also results in 80%. Fill in each blank in the program with a **single** letter, integer or symbol so that it matches this coverage.

(6 pts.) Consider the following program:

```
1  void lovelace(int a, int b, int c) {
2    int local = 0;
3    if (a < b)                    local += 1;       else local += 0;
4    if (c == 5)                   local += 2;       else local += 0;
5    if (local == 3 && c < 4)      local = 6;        else local = 7;
6  }
```

Give a smallest set of test inputs (in terms of the number of test inputs) resulting in maximal branch coverage for this program:

(1,2,5) visits true, true, false

(2,2,2) visits false, false, false

It is not possible to make the last branch true. You need at least two inputs to result in maximal branch coverage.

3 Short Answer (15 points)

(a) *(3 pts.)* Write a method accepting one input parameter for which test input generation via constraint solving will work better than test input generation at random.

```
1 def foo(x):
2         if (x == 123456789):
3                 print("a")
4         else:
5                 print("b")
```

(b) *(2 pts.)* In at most three sentences, support or refute the claim that Microsoft's Driver Verifier is an instance of Mocking.

"Support". Mocking, from Lecture 4, is "a way to dynamically (at runtime) substitute objects, functions with fake versions." The Driver Verifier, from Lecture 8, "replaces the default operating system subroutines with ones that are specifically developed to catch device driver bugs."

(c) *(3 pts.)* In at most three sentences, support or refute the claim that the Cyclomatic Complexity metric helps to identify difficult-to-understand code.

Typically "Refute". Cyclomatic Complexity, from Lecture 3, measures "linearly independent paths through a program" but does not consider comments, variable names, etc. It was "repeatedly refuted", and we are to "avoid claims about human factors (e.g., readability) and quality, unless validated".

Possibly "Support". You could argue, carefully, that CC is just code size, but larger methods are inherently more difficult to understand. This is difficult to make full credit but easier to make partial credit.

(d) *(3 pts.)* You believe slow code is more likely to be buggy, so you design a dynamic analysis similar to Tarantula (coverage-based fault localization) that multiplies the default suspiciousness rating of each statement by the time spent in its enclosing method. In at most three sentences, describe the instrumentation for your analysis.

The instrumentation would be a combination of statement coverage and profiling (Lecture 11). Instrumenting for statement coverage involves recording when each statement is visited (possibly to some sort of internal set to avoid slowdowns from printing inside loops). Instrumenting for profiling here involves a "float profile" that "computes the average call times for functions but does not break times down based on context". This could be done via statistical profiling: having the OS send a signal every X time units and recording the current method.

(e) *(2 pts.)* In at most three sentences, support or refute the claim that watchpoints help to debug race conditions.

Possibly "Support". A watchpoint "stops execution after any instruction changes the value at location `L`" (Lecture 11). If you have *already identified* the variable on which you have a race condition, you could use watchpoints to determine when the rogue edit occurs. The potential probably is that many other benign edits may change that location. This answer is harder to make full credit.

Likely "Refute". A watchpoint (as above) requires that you already know the location (variable) of interest. If you do not, and see quite a bit of memory corruption, watchpoints will not help you. By contrast, something like Delta Debugging (minimizes failure-inducing thread schedules) or Eraser (finds the variable accesses accessed without proper locking) would likely be more useful. Finally, it is not clear whether a debugger stops one thread or all threads at a breakpoint.

(f) *(2 pts.)* Describe a defect for which Delta Debugging would struggle to find a minimal failure-inducing input.

Break one of Delta Debugging's assumptions. Possibilities:

i. The bug (and thus the Interesting function) is non-deterministic. DD may miss the defect entirely and return the entire, unminimized set.

ii. The bug is non-monotonic: input {1,2} is interesting but input {1,2,3,4} is not. DD will return a non-minimal set.

iii. The bug is inconsistent: some changes may yield programs that do not run. DD takes quadratic time (Slide 42).

Picking ambiguity is not a good choice because DD will find one subset and you can rerun it again to find another.

4 Mutation Testing (15 points)

Consider this method to convert a number of days (since January 1, 1980) into a year. Note that 1980 *is* a leap year. The original program is shown on the left; three first-order mutants are each indicated by a comment on the right.

```
1  def zune(days):
2    year = 1980
3    while (days > 365):
4      if isLeapYear(year):
5        if (days >= 366):    # Mutant 1 has if (days > 366):
6          days -= 366
7          year += 1          # Mutant 2 has year += 0
8      else:
9        days -= 365          # Mutant 3 has days = 0
10       year += 1
11   return year
```

(10 pts.) Complete the table below by indicating whether or not each test kills Mutant 2 and/or Mutant 3. (Mutant 1 is only killed by Test 2.)

	Input (`days`)	Oracle	Mutant 1	Mutant 2	Mutant 3
Test 1	365	1980	—	—	—
Test 2	366	1981	killed	killed	—
Test 3	366 + 1	1981	—	killed	—
Test 4	366 + 365 + 1	1982	—	killed	—
Test 5	366 + 365 + 365 + 1	1983	—	killed	killed

(1 pt.) What is the mutation score for Tests 1–5 using Mutants 1–3? 3/3 = 100%
(1 pt.) What is the mutation score for Tests 1–5 using Mutants 1–**2**? 2/2 = 100%
(1 pt.) What is the mutation score for Tests 1–**3** using Mutants 1–**3**? 2/3 = 66%
(2 pts.) In at most three sentences, support or refute the claim that mutation analysis agrees with your intuitive notion of test suite adequacy in this example.

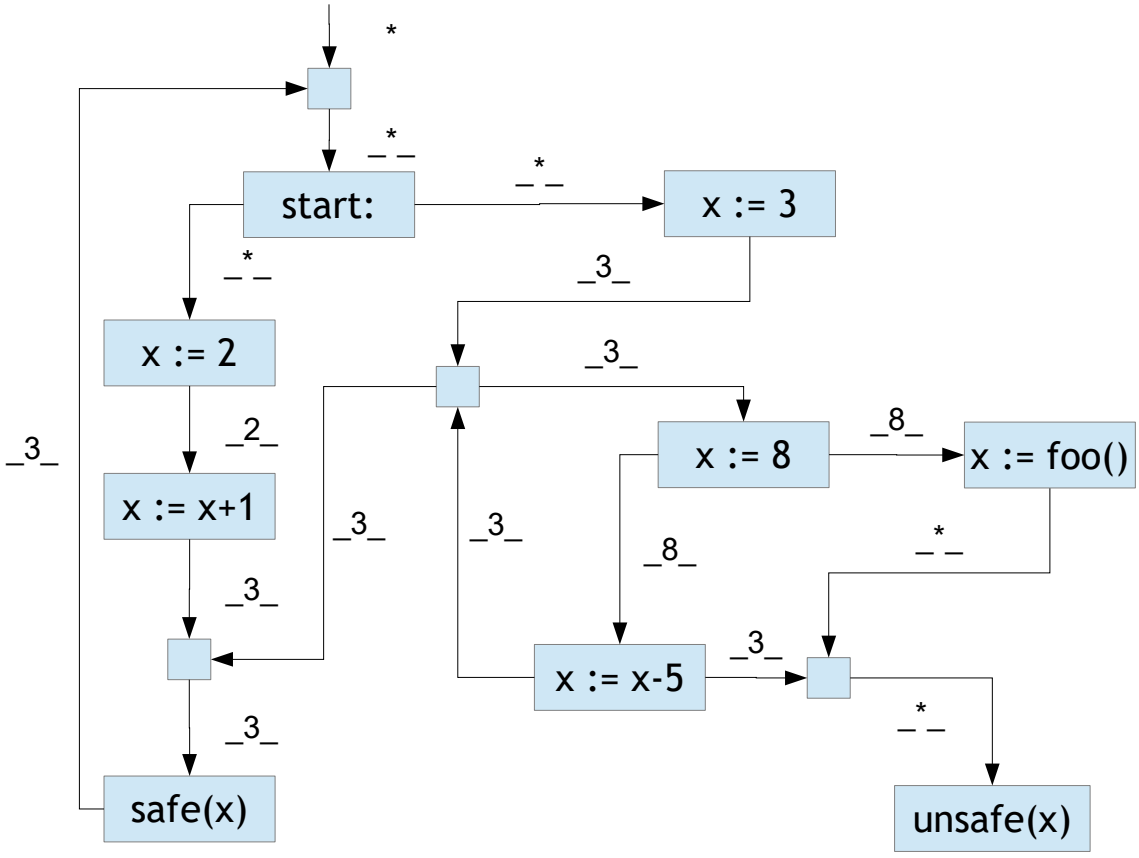
Either way. "Refute" would involve noting that as you increase the quality of the test suite *in this example*, such as by going from {1} to {1,3} to {1,3,4} (which have three different outputs), the mutation score does not smoothly increase (0, 50, 50).

"Support" would involve arguing that very weak test suites (such as {1} alone, or {3,4}) have low mutation scores while more complete test suites (such as all of them, or all but one of them) have higher scores (66% or 100%).

5 Dataflow Analysis (20 points)

Consider the *constant propagation* dataflow analysis used in class to determine if a pointer variable is definitely null when used. We associate with each variable a dataflow analysis fact: either * ("the variable holds a value, but our analysis cannot be certain which value"), # ("this point in the program has not yet been reached by our analysis") or a number c ("at this point in the program, we are certain the value of this variable is exactly c").

For this problem, we also **extend** our notion of dataflow analysis to include simple arithmetic (called *constant folding*). For example, if we know that `x = 7` before the statement `x = x+2`, we immediately conclude that `x = 9` after it.



(10 pts.) Use each of the statements from the box below exactly once to fill in each of the five large bolded nodes so that the dataflow analysis correctly indicates that `x` is not null when used at `safe` but conservatively indicates that `x` may be null when used at `unsafe`.

x := x + 1	x := 2	x := 3	x := x - 5	x := foo()

(10 pts.) Fill in each blank (___) with the final dataflow analysis fact associated with that edge.

6 Quality Assurance Analyses (19 points)

Consider the Eraser dynamic lockset analysis, which tracks and intersects the set of locks held by threads as they access variables.

```
1 def thread1(a):                    def thread2(b):
2   global lock1                       global lock1
3   global shared                      global shared
4   if (a == 5):                       if (b == 7):
5     acquire(lock1)                     acquire(lock1)
6   shared = shared + 1                shared = shared + 1
7   if (a == 5):                       if (b == 7):
8     release(lock1)                     release(lock1)
```

(3 pts.) Either give an input (a, b) that would cause Eraser to mistakenly conclude that there is no race condition or indicate that it is impossible to do so.

a=5, b=7. Shared is always accessed with lock1 held.

(3 pts.) Either give an input (a, b) that would cause Eraser to correctly conclude that there is a race condition or indicate that it is impossible to do so.

Anything with a!=5 or b!=7, such as (0,7) or (5,0) or (0,0). The lockset for shared is the empty set.

(5 pts.) Briefly summarize the sub-activities that make up modern ("passaround") code review. Describe multiple outcomes.

Following Lecture 7, "In a code review, another developer examines your proposed change and explanation, offers feedback, and decides whether to accept it. Modern code reviews have significant tool support." You could also mention GitHub pull requests, Google's language requirement, Mondrian, Phabricator, the inclusion of unit test results, etc.

The two main outcomes are that the patch is validated and becomes part of the main branch or that the patch is rejected (usually because of the human review, but possibly because of testing failures or tool reports). See Slide 24.

(8 pts.) Pick **two** of manual code inspection, automatic static analysis, testing, and automatic dynamic analysis. For each chosen approach, describe a defect or quality concern and explain, in one sentence, why that defect would be better handled with that approach than with the other three approaches.

Manual inspection. If the quality concern is "code improvement", code review commonly achieves it ("Expectations, Outcomes" reading, Figure 4). The other approaches do not directly suggest code changes.

Testing. If the quality concern is "regression" (on previously-identified failure-inducing inputs), testing is well-suited. Manual inspection may not be as good (especially if you want regression testing as part of code review: no reviewing recursively), dynamic analyses may be too expensive, and static analyses may have false positives.

Static analysis. If the defect involves complicated control flow paths (e.g., "is there a way for sensitive data to sneak through this sanitization code?"), static analysis is typically much better at considering all of them than humans (who cannot reason about many at once) and dynamic analysis (which requires an input to reach that tricky path).

Dynamic analysis. If the defect involves available data or input, dynamic analysis can often be best. For example, if the quality concern is "reproducibility", a Delta Debugging dynamic analysis to minimize the failure-inducing input is likely to be much better than a manual one (takes too long); testing and static analyses do not really minimize inputs.

These are just examples. Many arguments could be made.

7 Extra Credit (1 point each)

What is one thing you would change about this class for next year?
What is one thing you would retain about this class for next year?

The "Producing Wrong Data Without Doing Anything Obviously Wrong!" paper argues that *which kind* of bias is significant and commonplace?

"This phenomenon is called **measurement bias** in the natural and social sciences."

Name *one benefit* and *one cost* of a test suite augmented with MC/DC coverage (compared to standard functional testing) described in "An Empirical Evaluation of the MC/DC Coverage Criterion on the HETE-2 Satellite Software".

"We found in our study that the test cases generated to satisfy the MC/DC coverage requirement detected important errors not detectable by func- tional testing. We also found that although MC/DC coverage testing took a considerable amount of resources (about 40% of the total testing time), it was not significantly more dif fi- cult than satisfying condition/decision coverage and it found errors that could not have been found with that lower level of structural coverage."

List *one approach* to oracle automation from "The Oracle Problem in Software Testing: A Survey".

"The literature on test oracles has introduced techniques for oracle automation, including modelling, specifications, contract-driven development and metamorphic testing. When none of these is completely adequate, the final source of test oracle information remains the human, . . . "

What was the "surprising" *result* in "Gender differences and bias in open source: pull request acceptance of women versus men"?

"Surprisingly, our results show that women's contributions tend to be accepted more often than men's. However, for contributors who are outsiders to a project and their gender is identifiable, men's acceptance rates are higher. Our results suggest that although women on GitHub may be more competent overall, bias against them exists nonetheless."

List *one issue* discussed in "A Few Billion Lines of Code Later: Using Static Analysis to Find Bugs in the Real World".

"Law: You can't check code you can't parse." "What's 'make'? We use ClearCase." "Compounding it (and others) the person responsible for running the tool is often not the one punished if the checked code breaks." "The award for most widely used extension should, perhaps, go to Microsoft support for precompiled headers." "If developers don't feel pain, they often don't care. Indifference can arise from lack of accountability; if QA cannot reproduce a bug, then there is no blame." "Users really want the same result from run to run. " "False positives do matter."

What *personality difference* was found between managers and testers in "Beliefs, Practices, and Personalities of Software Engineers: A Survey in a Large Software Company"?

"We observed no personality differences between developers and testers; managers were conscientious and more extraverted."