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# Written exam

# TDDC90 Software Security

# 2023-08-23

**Permissible aids**

Dictionary (printed, NOT electronic)

**Teacher on duty**

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**Instructions and grading**

There are 7 questions on the exam. Your grade will depend on the total points you score. The maximum number of points is 38. The following grading scale is preliminary and might be adjusted during grading. You may answer in Swedish or English.

| Grade | 3 | 4 | 5 |
|---|---|---|---|
| Points required | 19 | 27 | 32 |

**Question 1: Secure software development (4 points)**

Many software vendors today use a mechanism where parts of the functionality of an application (e.g., a document viewer) is disabled for untrusted files, and the user needs to click a button to activate all functionality.

a) What is the purpose of this mechanism?

b) Which important security principle is this an example of? Explain the general principle using a sentence or two.

c) In which phase of the SDL is application of this principle mandated?

**Question 2: Exploits and mitigations (5 points)**

Using pseudocode, provide an example of a program with a *heap-based buffer overflow* bug that could be exploited for *arbitrary code execution*. Clearly explain why the code is vulnerable, and how an arbitrary code execution attack would be carried out. (You don't need to provide a detailed exploit.)

The example program should be *complete*, i.e., the pseudocode should roughly mirror a C/C++ source file that implements all functionality of the program. (You don't need to provide pseudocode for common library functions, just the core functionality of the program.)

**Question 3: Design patterns (4 points)**

a) Explain the intent and motivation of the *Resource Acquisition Is Initialization* (RAII) pattern. Name a type of vulnerability that is avoided by using this pattern.

b) The two similar design patterns *Privilege Separation* and *Defer to Kernel* are both special cases of the more general pattern *Distrustful Decomposition*. Briefly discuss in which cases it is more appropriate to use one or the other.

**Question 4: Web security (6 points)**

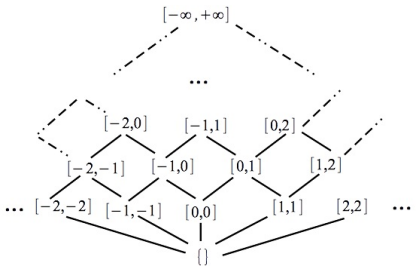
a) Give *two* examples of web attack types discussed in the course that can lead to arbitrary code execution on a *web server*, and briefly explain how they work.

b) Explain how the *HTTP Strict Transport Security* (HSTS) mitigation works. What kind of vulnerability does it mitigate?

# Question 5: Static analysis (7 points)

Assume `int` denotes integers with an absolute value that can be arbitrarily large (i.e., no integer overflows). Recall `%` is the modulo operator (`x % 2` returns 0 if `x` is even and 1 otherwise). Consider the following procedure.

```
1  int foo(int in){
2    int out = 0;
3    if(in < 0){
4      out = -3;
5    }else{
6      out = 3;
7    }
8    if((in % 2) != 0){
9      out = 2 * out;
10   }
11   assert(-10 <= out && out <= 10);
12   assert(!(in < 0 && out > 0));
13   return out;
14 }
```




We aim to check the assertions at line 11 and 12 in procedure `foo`. Questions:

1. Symbolic execution: Give, without discussing its satisfiability, the SSA formula for each path condition through the procedure `foo` that satisfies the assertion at line 11 but violates the one at line 12. (4 pt)

2. Abstract interpretation: Annotate, after convergence of a most precise analysis, the start of each line in `foo` with an abstract element associated to each one of the defined variables. Use, for each variable, the interval domain, i.e., the abstract elements depicted in the lattice to the right of `foo`. (2 pt)

3. Give, without justification, two conditions: a precondition $P$ and a postcondition $Q$ such that the Hoare triple $\{P\}$`foo`$\{Q\}$ holds. (1 pt).

**Question 6: Security testing (6 points)**

a) Consider cross-site scripting (XSS) vulnerabilities. Which of the two vulnerability types *Stored XSS* and *Reflected XSS* is generally easier to detect using a black-box web application fuzzer? Clearly motivate your answer. (Make sure to include an explanation of the difference between Stored and Reflected XSS in your motivation.)

b) What is *Penetration testing*? State one benefit and one disadvantage of Penetration testing.

c) What are the two main black-box fuzzing techniques called? What is the principal difference between them? Also, state the main disadvantage of each technique

**Question 7: Vulnerabilities in C/C++ programs (6 points)**

The code on the next page shows part of a program that reads data from a simple data stream format. Each message in the stream consists of two 32-bit integers, followed by a variable-size data part. The first number specifies the type of data in the message, and the second number specifies the length of the data. The data part then follows directly.

The part of the program we are concerned with (`print_text_record`) parses a message, and prints its data if it is of text type (plain text or XML). We also give function declarations for a simple API for reading data from streams. It can be assumed that the API functions are correctly implemented, and function in accordance with the comments given above each function declaration. The program may be used to read streams from untrusted sources.

`print_text_record` contains at least one serious bug that can lead to a potentially exploitable condition.

a) Identify and explain the vulnerability in the code.

b) Explain the consequences of a successful exploit. (I.e., what could an attacker achieve by triggering the bug?)

c) Clearly explain how to modify the code to fix the bug.

```c
/* Constants defining message data types. */
enum DStream_Types {
   DS_PLAIN_TEXT  = 1,
   DS_XML_TEXT    = 2,
   DS_RGB_RASTER  = 3
};


/* Reads 4 bytes off the stream 'ds' and returns them as an int. */
int DStream_read_int32(struct DStream* ds);


/* Reads 'sz' bytes from stream 'ds' into buffer 'dest' */
void DStream_read_data(struct DStream* ds, char* dest, size_t sz);


/* Check if a previous operation on 'ds' has caused an error.
   Returns zero (false) in case of no error, and non-zero otherwise. */
int DStream_has_error(struct DStream* ds);


int print_text_record(struct DStream* ds)
{
   char buffer[1024];

   int type = DStream_read_int32(ds);
   int size = DStream_read_int32(ds);

   // Check if we failed to read header from stream
   if(DStream_has_error(ds))
      return -1;

   size_t text_size = size;

   if(text_size <= 0)
      return -1; // Invalid size

   if(type == DS_PLAIN_TEXT)
      printf("Type: TEXT\n");
   else if(type == DS_XML_TEXT)
      printf("Type: XML\n");
   else
      return 1; // Not a text-type record

   // Check that input fits in buffer
   if(size >= 1024)
      return -1; // Oversized record

   // Read into buffer
   DStream_read_data(ds, buffer, size);

   if(DStream_has_error(ds))
      return -1; // Error reading string off stream

   buffer[size] = 0; // Make sure string is terminated

   // Print string
   printf("%s\n", buffer);

   return 0; // Signal success
}
```