The exam is closed book and notes.
Please keep all electronic devices turned off and out of reach.
Note that a question may require multiple checked boxes for a correct answer. Checking some but not all of the required boxes will result in a partial answer worth only 2 of the 4 points. Checking any box that shouldn’t be checked results in an incorrect answer, worth zero.

1. ○ Return my exam to my Kingsbury mailbox. [0 pts]
   ○ Hold my exam in your office. I will pick it up prior to February 15.
   ✓ Shred my exam. I never want to see it again.

2. Interpret 0xODEFACED (shown in hexadecimal) as an IEEE single-precision floating-point value. Which of the following statements about this value are true? [4 pts]
   ○ It is negative.
   ✓ Its actual exponent is negative.
   ○ It is a denormalized value.
   ○ It is a NaN.

3. Concerning the reentrant readers-writers lock from the synchronizers assignment, which of the following statements are true: [4 pts]
   ○ Each readers-writers lock required two mutexes.
   ✓ Each readers-writers lock required two condition variables.
   ○ A reader always blocks when calling lockRLock function.
   ○ A writer never blocks when calling lockWLock function.

4. Encode the following Unicode character (shown in hex) as UTF-8: 0xF303. The sequence of bytes (shown in hex) would be: [4 pts]
   ○ F3 03.
   ○ 03 F3.
   ✓ EF 8C 83.
   ○ F0 8F 8C 83.
   ○ none of the above.

5. Which of the following statements about the Intel 64 are true? [4 pts]
   ○ All registers are 32 bits.
   ✓ The rip register points to the next instruction to execute.
   ○ The runtime stack grows from lower address up towards higher address.
   ○ The ret instruction pops the top of the runtime stack into the rax register.
6. Consider the following C function:

```c
int f(void)
{
    int x = -1;
    return *(signed char *) &x;
}
```

On a 2’s complement machine with a byte-addressable memory and where an `int` is 32 bits, the function will:

- return 0 if the machine is little-endian and -1 otherwise.
- return -1 if the machine is little-endian and 0 otherwise.
- always return 255.
- **always return -1.**
- none of the above.

7. Consider the following assembly code fragment from the Java Virtual Machine program:

```assembly
   top :
     ifle bottom
     iload_2
     iload_1
     iadd
     istore_2
     iinc 1, -1
     goto top
   bottom :
```

What is the encoding of the two-byte address (offset) stored in the `ifle` instruction? (The `iload_2`, `iload_1`, `iadd`, and `istore_2` instructions are one-byte instructions. The `ifle` instruction, `iinc`, and `goto` instructions are three-byte instruction.)

- 0x000C.
- 0x000D. **√**
- 0x000E.
- 0xFFF3.
- none of the above.

8. Consider how -39 (base 10) would be represented in the memory of a Little Endian machine as a 16-bit 2’s complement integer. The two bytes, shown left to right in increasing memory address order, would be:

- 0xFD9 0xFD. **√**
- 0x80 0x27.
- 0x27 0x80.
- none of the above.

9. The UTF-16 sequence (shown in hexadecimal) `0xDA22 0xDE22` is represented in UTF-32 (in hexadecimal) as:

- two Unicode characters, `0x0000DA22` and `0x0000DE22`.
- two Unicode characters, `0x00000220` and `0x00000222`.
- a single Unicode character, `0x00008A22`.
- **√** a single Unicode character, `0x00098A22`.
- none of the above.
10. Which of the following statements about using a POSIX condition variable are true? [4 pts]
   - If the caller of `pthread_cond_wait` holds the lock of the mutex passed as the second argument, then an error code is returned.
   - The `pthread_cond_signal` never causes its caller to block.
   - If `pthread_cond_wait` is called when there are threads waiting on the condition variable, then an error code is returned.
   - Multiple threads can be waiting on a condition variable at the same time.

11. Which of the following statements about a POSIX mutex are true? [4 pts]
   - Two threads can hold the lock of a mutex at the same time.
   - A thread will block if the thread tries to unlock a mutex that is locked by another thread.
   - A critical section is protected by first locking a mutex, then executing the critical section, then unlocking the mutex.
   - A thread cannot own the lock on two different mutexes at the same time.

12. Which of the following are examples of a program exhibiting temporal locality: [4 pts]
   - iterating through all members of an array in order.
   - repeatedly incrementing a loop counter variable inside a loop.
   - a sequence of instructions being executed in order without any branch or call instructions.
   - repeatedly testing the same variable in the condition of a loop.

13. Add together the following two 8-bit 2’s complement integers (shown in hexadecimal): 0x7F and 0x7F. Which of the following are true statements about the result? [4 pts]
   - The result (in hexadecimal) is 0xFE.
   - The result is negative.
   - The result overflows.
   - The result in decimal is −2.

14. Which of the following statements about virtual memory are true? [4 pts]
   - The translation lookaside buffer (TLB) is a cache that stores recent virtual-to-physical page translations.
   - It is a stack-based architecture, in which most instruction operands are implicit, meaning they are values on top of the runtime stack.
   - The RAX register is used to return values from functions.
   - It uses PC-relative addresses for its branch instructions.

15. Which of the following statements about the Java Virtual Machine are true? [4 pts]
   - The instructions are of variable length.
   - It is a stack-based architecture, in which most instruction operands are implicit, meaning they are values on top of the runtime stack.
   - The RAX register is used to return values from functions.
   - It uses PC-relative addresses for its branch instructions.

16. Which of the following statements about assemblers are true? [4 pts]
   - They have two passes because the use of a label may come before its definition.
   - They translate machine code into human-readable form.
   - On the second pass, if the assembler sees a reference to a label that is not defined, it is a fatal error and the assembler immediately aborts.
   - They use a symbol table to store the address associated with each defined label.
17. Which of the following statements about the Intel 64 CMPXCHG instruction are true? [4 pts]

- √ It is used with the LOCK prefix to ensure that its memory actions are atomic.
- It is a convenient way to swap the values of two memory locations in a single instruction.
- √ It is used when implementing mutexes in order to protect the contents of the struct implementing the state of the mutex from concurrent updates by two threads.
- ○ It can only be called once per program execution.

18. Which of the following statements about goroutine control blocks (GCBs) are true? [4 pts]

- ○ The GCBs for all blocked goroutines are linked together to form the ready list.
- √ A GCB is used to store the current state of a goroutine when the goroutine yields to another goroutine.
- √ The GCB contains a pointer to the base of the goroutine’s stack so that the memory for the stack can be freed after the goroutine finishes executing its work function.
- √ The GCBs for all goroutines waiting to read from a channel are linked together to form a wait queue for the channel.

19. Add the following two IEEE single-precision floating-point values shown in hexadecimal: 0x80A00001 and 0x40A00001. The result in hexadecimal is: [4 pts]

- ○ 0x40000000.
- ○ 0xC1400002.
- ○ 0x40B00001.
- √ 0x40A00001.
- ○ none of the above.

20. In an implementation of an exception mechanism for C programs on the Intel 64, the catchException function: [4 pts]

- √ pushes the current rbp, the saved rbp and the saved rip onto the “snapshot” stack.
- ○ puts the exception number into the rax register.
- ○ prints an “uncaught exception” message if the “snapshot” stack is empty.
- ○ none of the above.

21. Which of the following statements about a mark-and-sweep garbage collector are true? [4 pts]

- ○ The mark phase is responsible for marking all allocated blocks that are no longer accessible.
- √ The sweep phase considers all unmarked blocks to be garbage that can be reclaimed as free (no longer allocated).
- √ The mark phase traverses the run-time stack in order to mark blocks pointed to by local variables, parameters and saved registers.
- ○ The sweep phase will combine adjacent marked blocks.

22. A memory cache with only one line per set is known as a: [4 pts]

- √ direct-mapped cache.
- ○ set-associative cache.
- ○ fully-associative cache.
- ○ translation lookaside buffer.
- ○ none of the above.
23. Consider how the following two C loops would be accessed by the virtual memory system (with handle \texttt{h}) of Program 6 with 16 virtual pages, 4 physical pages, 2 TLB entries, and a page size of 4 words. Assume that the virtual memory system is initialized as in Program 6.

```c
for (i = 0; i < 32; i++)
{
    writeInt(h, i, i);
}
for (i = 0; i < 32; i++)
{
    int tmp = readInt(h, i);
}
```

How many page faults and TLB misses will there be?

- $\sqrt{12}$ page faults and 14 TLB misses.
- 12 page faults and 12 TLB misses.
- $\sqrt{14}$ page faults and 12 TLB misses.
- $\sqrt{14}$ page faults and 14 TLB misses.
- none of the above.

24. Which of the following statements about the IAS computer are true? [4 pts]

- $\sqrt{It}$ was a stored-program computer.
- $\sqrt{Its}$ memory consisted of 40-bit words.
- $\sqrt{It}$ had 16 registers, numbered \(r0\) to \(r15\).
- 14 page faults and 12 TLB misses.
- none of the above.

25. Which of the following statements about the Control Data Corporation (CDC) 6600 are true? [4 pts]

- $\sqrt{It}$ had a hardware run-time stack.
- $\sqrt{It}$ had 1’s complement integer values.
- $\sqrt{Its}$ memory consisted of 60-bit words.
- $\sqrt{It}$ was a stored-program computer.
- none of the above.

26. Which of the following statements about the C programming language are true? [4 pts]

- $\sqrt{A}$ union is like a struct except all members are allocated storage starting at the beginning of the union, meaning all members are overlaid in memory.
- $\sqrt{The}$ \texttt{static} keyword is used on global variables and functions to make those symbols not visible outside the file.
- $\sqrt{The}$ language supports pointers to functions.
- There is no difference between the \texttt{\&} operator and the \texttt{\&\&} operator.