

# Garbage Collection: Problem Sheet

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Dec 2018

1. **(easy)**

- (a)  Why is stack allocation/deallocation more efficient than heap allocation/deallocation for dynamic data?
- (b)  What is the key restriction on stack allocated data, in terms of its lifetime?
- (c)  Explain how the concept of object ownership in the Rust programming language is helpful for automatic deallocation.

2. **(difficult)**

- (a)  Explain how free-list allocation works, for dynamic memory management.
- (b)  How might you determine the size of the cells in a free list?
- (c)  What is internal fragmentation, and how does it occur in a free-list allocation scheme?

3. **(moderate)** In a manual memory management system, with explicit `malloc` and `free` calls, explain the potential problems that might be caused by:

- (a)  never calling `free`
- (b)  accessing data through a pointer  $p$  after calling `free(p)`.
- (c)  calling `free(p)` more than once, for the same pointer value  $p$ .
- (d)  Outline how a dynamic memory checking tool like Valgrind might detect such errors.

4. **(easy)**

- (a)  Sketch how a simple reference counting garbage collector works.
- (b)  Give advantages and disadvantages of a reference counting system.
- (c)  Can you explain why interpreted scripting languages like Python and Perl use reference counting?

5. **(difficult)**

- (a) 2 points What is the *weak generational hypothesis*, in the context of garbage collection?
- (b) 3 points Explain why bump pointer allocation and copying collection are appropriate for nursery (young generation) collection.
- (c) 3 points Imagine a system has an allocation rate of  $a$  MB/s, a GC copying rate of  $c$  MB/s, and a nursery survival proportion of  $s$ , with  $0 < s < 1$ . If the nursery has size  $N$  MB, how long will it take to fill up with allocated data? How long will it take to copy surviving live data from the nursery to the mature space (the old generation).
- (d) 2 points Considering the GC system outlined in this question, how much is the GC overhead (i.e. the proportion of time spent in GC) for the nursery collection?