

3 Operating Systems (rmm1002)

Consider an operating system that uses hardware support for paging to provide virtual memory to applications.

- (a) (i) Explain how the hardware and operating system support for paging combine to prevent one process from accessing another's memory. [3 marks]
- (ii) Explain how space and time overheads arise from use of paging, and how the Translation Lookaside Buffer (TLB) mitigates the time overheads. [3 marks]
- (b) Consider a system with a five level page table where each level in the page table is indexed by 9 bits and pages are 4 kB in size. A TLB is provided that is indexed by the first 57 bits of the address provided by the process, and achieves a 90% hit rate. A main memory access takes 40 ns while an access to the TLB takes 10 ns. The maximum memory read bandwidth is 100 GB/s.
- (i) What is the effective memory access latency? [4 marks]
- (ii) A colleague suggests replacing the system above with one that provides 80 GB/s memory read bandwidth and main memory access latency of 30 ns. Explain whether you should accept the replacement or not, and why. [4 marks]
- (c) A creative engineer suggests structuring the TLB so that not all the bits of the presented address need match to result in a hit. Suggest how this might be achieved, and what might be the costs and benefits of doing so. [6 marks]