COMPUTER SCIENCE TRIPOS Part IA – 2024 – Paper 2

4 Operating Systems (rmm1002)

(*a*) Address binding refers to the process of resolving memory references in a program to physical addresses when that program is brought into memory. Describe what is required for it to happen:

(*i*) At compile time

(*ii*) At load time

(*iii*) During execution

[3 marks]

(*b*) In a system containing three frames, consider the following string of page references:

1 2 3 2 4 3 5 1 3 2 3 4

Compute the sequence in which pages are allocated frames under the following algorithms:

(*i*) Optimal, OPT

(*ii*) Least Recently Used, LRU

(*iii*) First-In First-Out, FIFO

[9 marks]

(*c*) FIFO can exhibit *Bélády's anomaly*. State Bélády's anomaly, and explain why neither OPT nor LRU can exhibit it, but FIFO can. [4 marks]

(*d*) LRU is relatively expensive to implement, so some systems approximate it cheaply, determining which page to replace by using a *reference* bit and a *dirty* bit, respectively indicating whether a page was recently referenced or written to. A focused engineer wishes to implement such an LRU approximation on a machine that does not have hardware support for either reference or dirty bits. How might they emulate reference and dirty bits using paging hardware?

[4 marks]