The Roux Institute
Northeastern University

CS5600 Computer Systems
Spring 2026

Homework Assignment 03
Memory Paging

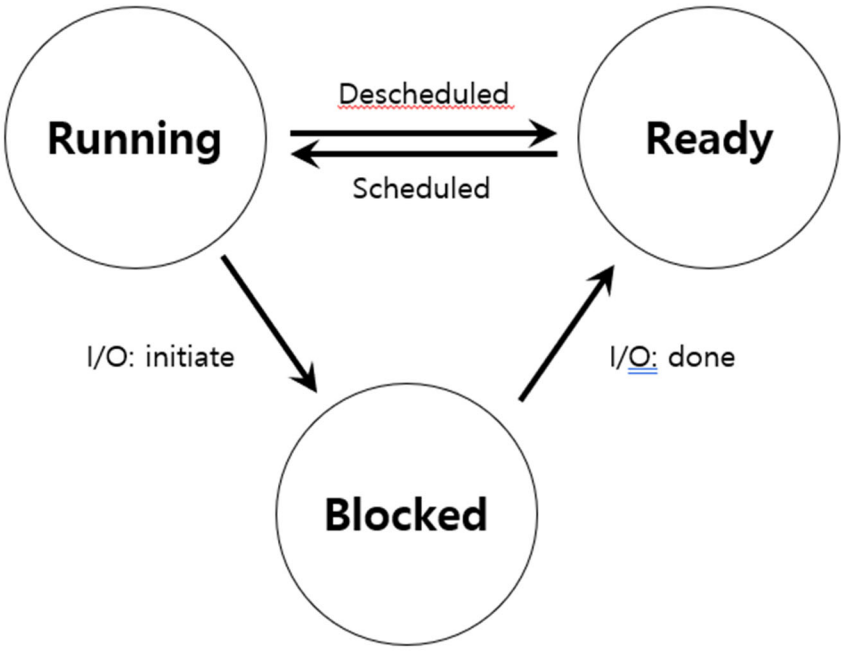
Assigned: Tue 03 FEB 2026
Due: Sun 15 FEB 2026

Instructions:

- The assignment is to be uploaded to Canvas by the due date, which is scheduled for 11:59pm ET that day since solutions will be distributed soon after.
- We expect that you will study with friends and often work out problem solutions together, but *you must write up your own solutions, in your own words*. **Cheating will not be tolerated.** Professors and TAs will be available to answer questions but will not do your homework for you. One of our course goals is to teach you how to think on your own and solve your own problems using your resources. Cut and paste from Google or ChatGPT will be considered plagiarism.
- We require that all homework submissions be neat and organized. You may either type your solutions in a word processor and print to an Adobe PDF or write them by hand and submit a legible scanned copy in Adobe PDF. Do write and submit your answers as if they were a professional report. **There will be point deductions if the submission is not neat** (is disordered, difficult to read, scanned upside down, etc.).
- To achieve full credit, **show INTERMEDIATE steps, if applicable,** leading to your answers throughout.

Problem 1 [30 points]: States of Memory

A simplified view of thread states is Ready, Running, and Blocked, when a thread is either ready and waiting to be scheduled, is running on the processor, or is blocked (for example, waiting for I/O). This is illustrated below.



Assuming a thread is in the Running state, answer the following questions, and explain your answer:

a. Will the thread change state if it incurs a page fault? If so, to what state will it change?

b. Will the thread change state if it generates a TLB miss that is resolved in the page table? If so, to what state will it change?

c. Will the thread change state if an address reference is resolved in the page table? If so, to what state will it change?

Problem 2 [30 points]: Page Faults

Consider the following page reference string:

7, 2, 3, 1, 2, 5, 3, 4, 6, 7, 7, 1, 0, 5, 4, 6, 2, 3, 0, 1

Assuming demand paging with three frames, how many page faults would occur for the following replacement algorithms?

a. LRU replacement

b. FIFO replacement

c. Optimal replacement

Problem 3 [40 points]: Page Replacement Algorithms

A page-replacement algorithm should minimize the number of page faults. We can achieve this minimization by distributing heavily used pages evenly over all of memory, rather than having them compete for a small number of page frames. We can associate with each page frame a counter of the number of pages associated with that frame. Then, to replace a page, we can search for the page frame with the smallest counter.

a. Define a page-replacement algorithm using this basic idea. Specifically address these problems:
    i. What is the initial value of the counters?
    ii. When are the counters increased?
    iii. When are the counters decreased?
    iv. How is the page to be replaced selected?

b. How many page faults occur for your algorithm for the following reference string with four page frames?

1, 2, 3, 4, 5, 3, 4, 1, 6, 7, 8, 7, 8, 9, 7, 8, 9, 5, 4, 5, 4, 2

c. What is the minimum number of page faults for an optimal page-replacement strategy for the reference string in part b above with four page frames?