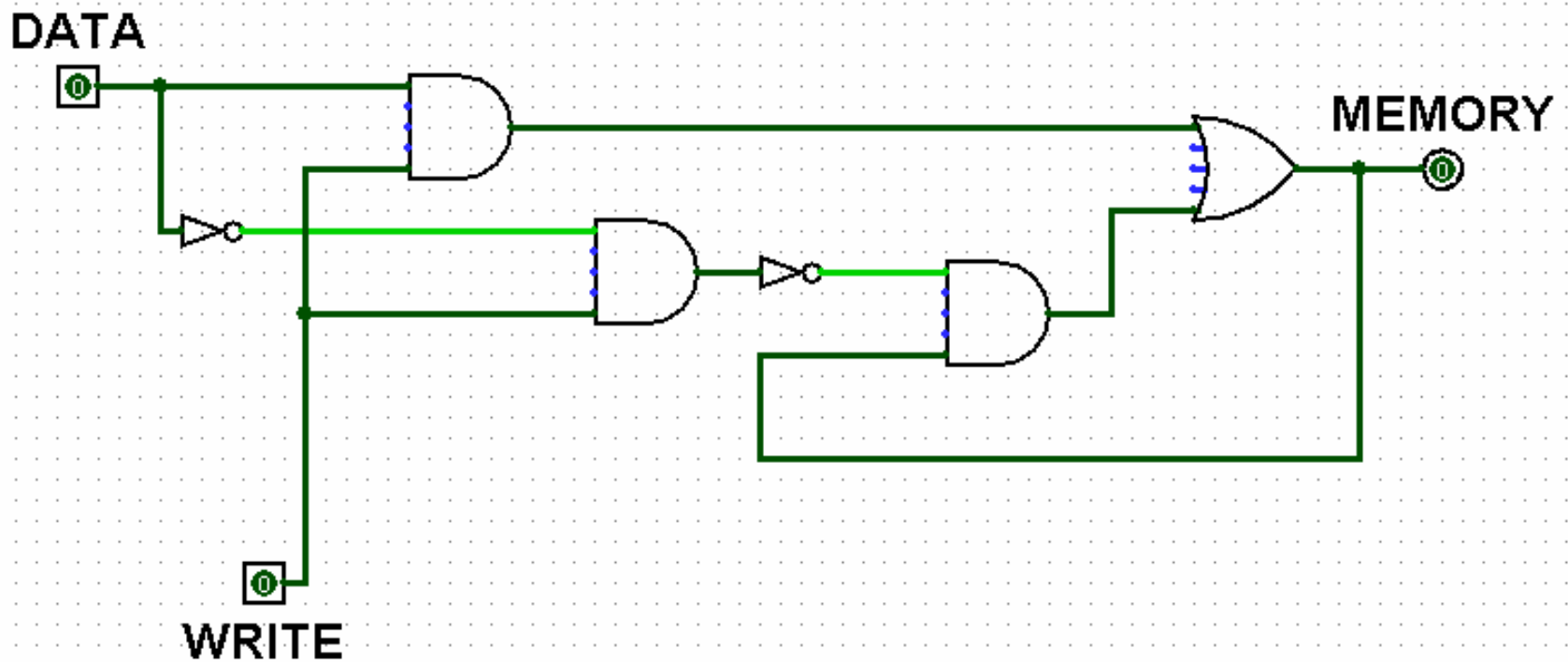




Today

- Brief review of last time.
- How computers manage memory.
- How computers multitask.

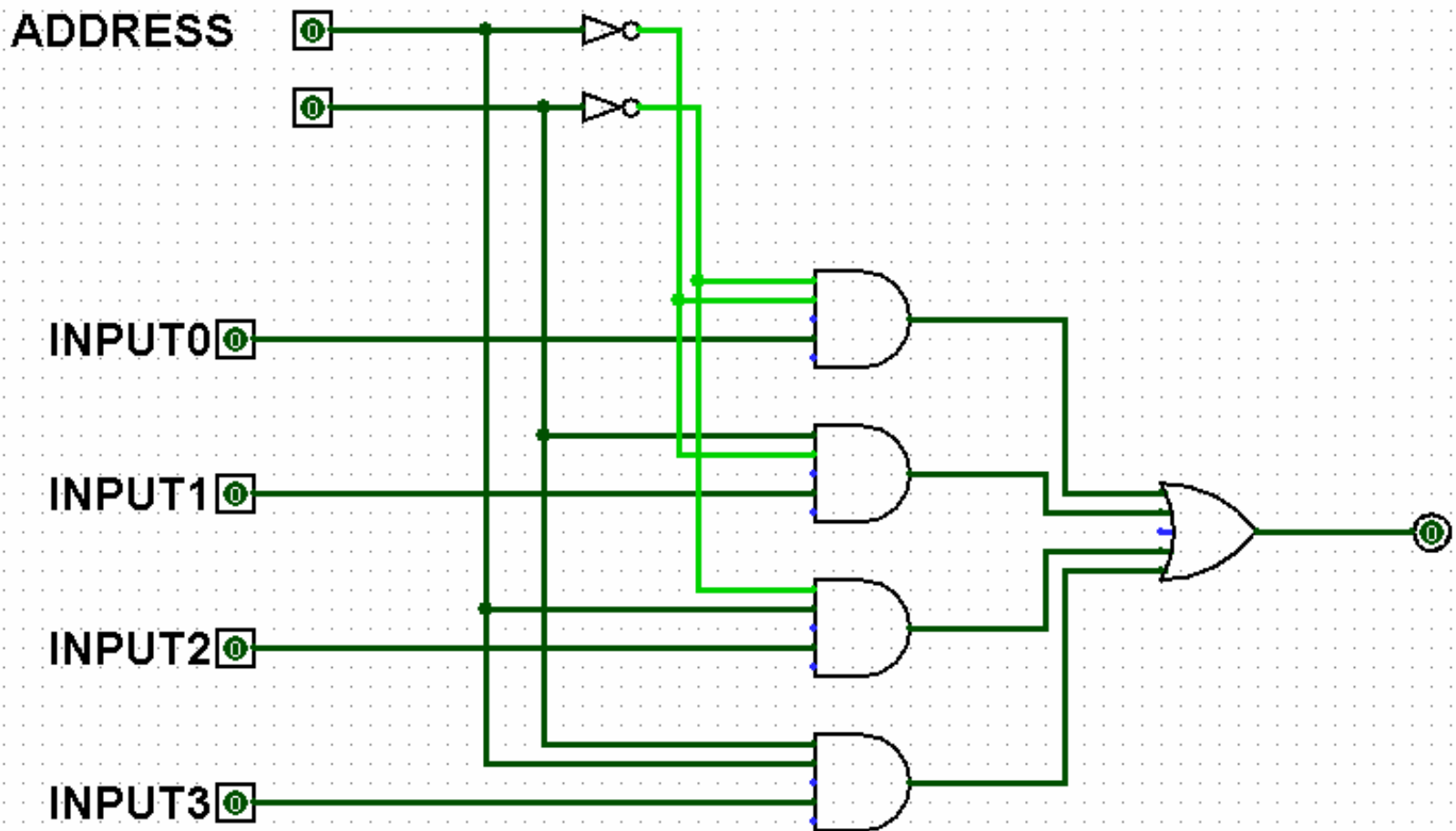
D Flip Flop



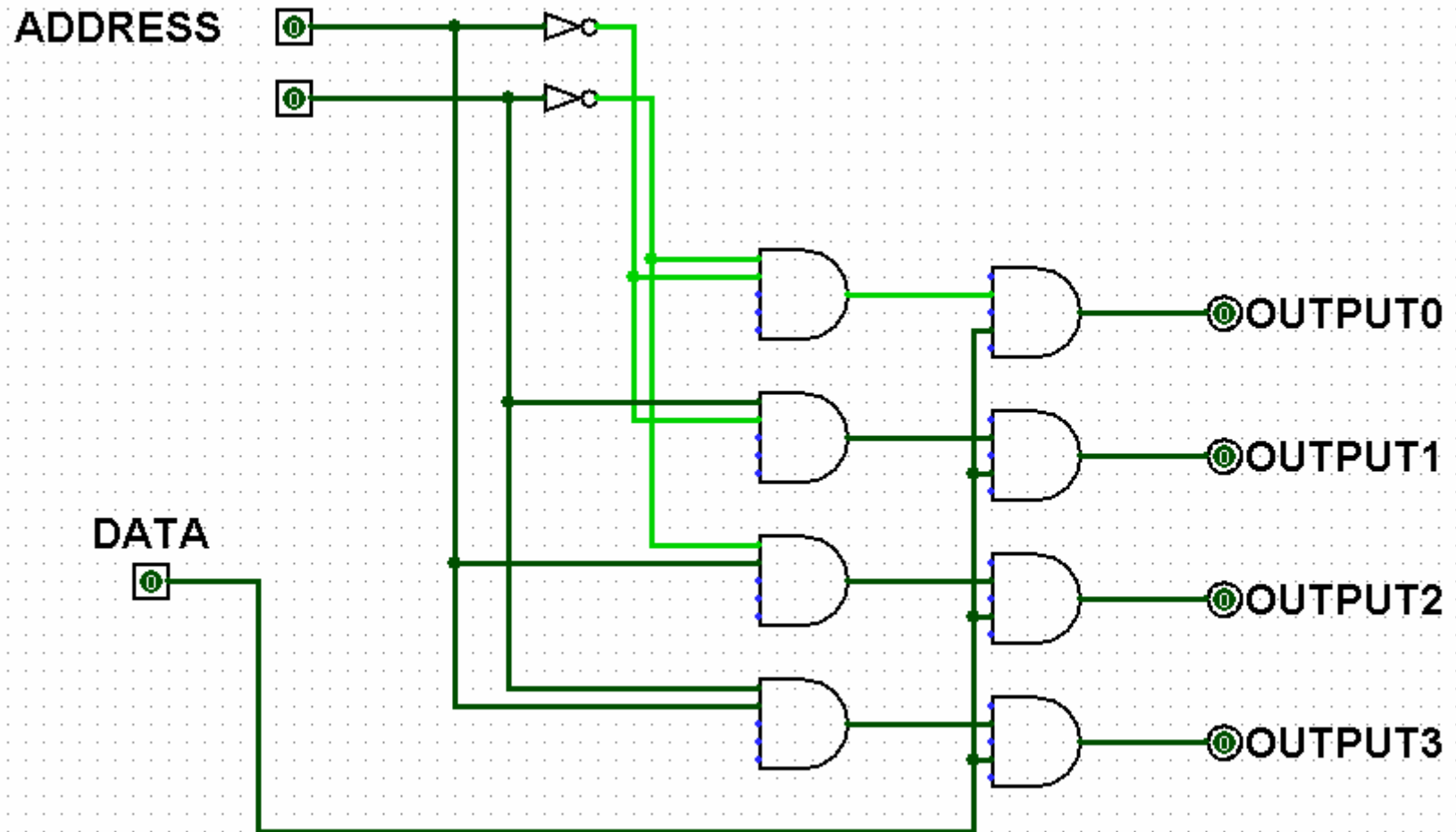
Try completing this for D F-F

DATA	WRITE	MEMORY (previous)	MEMORY
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

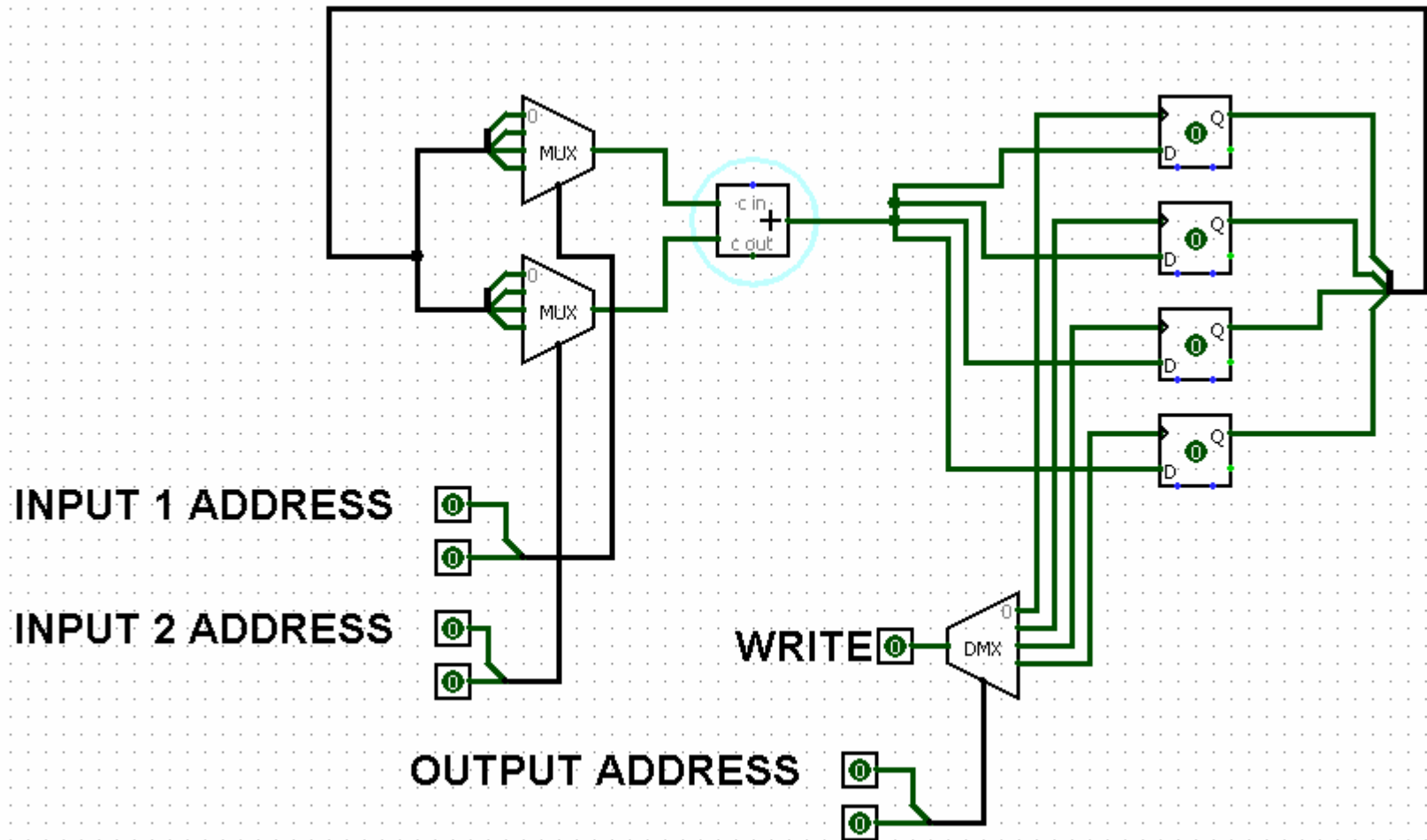
Multiplexer



Demultiplexer



Mini-CPU



What is a program?

- A program is a sequence of binary numbers -- *instructions*.
- Each bit of each instruction corresponds to a control line in a programmable circuit (e.g. Pentium processor).

Different CPUs have different machine languages

- Intel Pentium
- Power PC
- Palmpilot, etc.

“Backwards Compatibility” – Pentium 4’s machine language extends Pentium 2’s machine language

Machine languages now allow complicated calculations (eg for multimedia, graphics) in a single instruction



How to streamline your life (lessons from computer architecture).

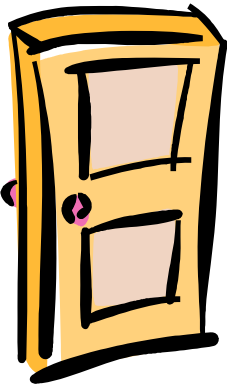
COS 116

4/3/2006

Instructor: Umar Syed

The Tired Librarian

Reserves



100 ft roundtrip



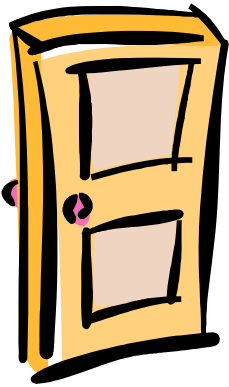
- 1000 checkouts/returns per day
- Distance covered = $1000 \times 100\text{ft} = 100,000 \text{ ft} \sim 20 \text{ miles}$
- Please help!!!

80-20 “Rule”

- Pareto [1906]: 20% of the people own 80% of the wealth
- Juran [1930's]: 20% of the organization does 80% of the work

Better Arrangement

Reserves



“Most popular” shelf:
20% most popular
books



10 ft
roundtrip

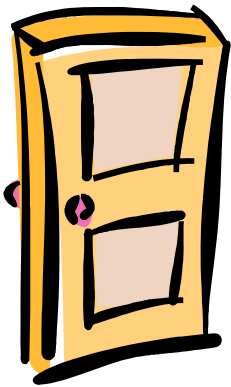


100 ft roundtrip

- Distance covered per day?
- $(80\% \times 1000 \times 10 \text{ ft}) + (20\% \times 1000 \times 100 \text{ ft}) = 28,000 \text{ ft}$

Even better arrangement

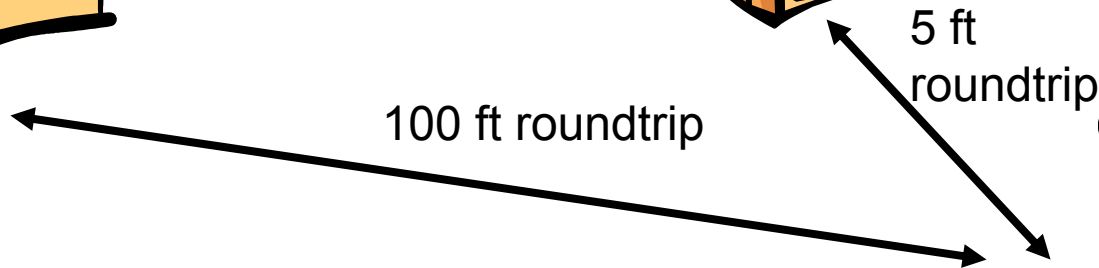
Reserves



Books in the 5th to 20th percentile of popularity



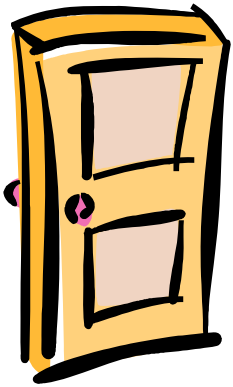
Top 4%
(i.e. 20%
of 20%)



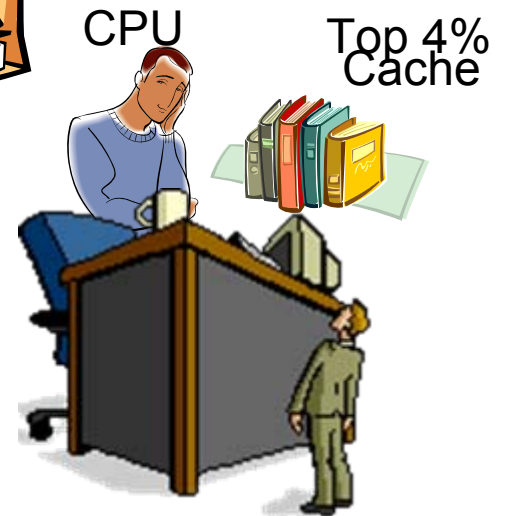
- Distance covered per day?
- $(80\% \times 80\% \times 1000 \times 0 \text{ ft}) + (20\% \times 80\% \times 1000 \times 10 \text{ ft}) + (20\% \times 1000 \times 100 \text{ ft}) = 21,600 \text{ ft}$

Computer ~~Librarian~~ arrangement

Disks
Reels



Books in the 5th to
20th percentile of
popularity
Memory



Often, today's computers have even more levels of caching

New and improved



XPS 600
Raw Power Unleashed

+ SPECIAL OFFERS

- Processor

Intel® Pentium® 4 Processor
640 with HT (3.20GHz, 800
FSB, 2MB L2 cache) up to
Pentium® Extreme Edition Dual
Core

- Operating System

Genuine Windows® XP Media
Center Edition 2005



XPS 200
Small, But Mighty

SPECIAL OFFERS

Processor

Intel® Pentium® 4 Processor
with Hyper-Threading
Technology - 600 Sequence -
up to 650 (3.48GHz, 800MHz
FSB, 2MB Cache).

Operating System

Genuine Windows® XP Media
Center Edition 2005

X
TI



Class Discussion

- Is problem solved?

How to predict the most popular memory locations?

It's not easy, because:

- Popularity is dynamic.
- Difficult to predict what a program will do in the future.
 - Remember the halting problem!
- Not a lot of time to make predictions.

Computer programs typically exhibit...

■ Temporal locality

- “If a memory location is accessed now, it will be accessed again in the near future.”

■ Spatial locality

- “If a memory location is accessed now, nearby locations will be accessed in the near future.”

Temporal and spatial locality?

```
sum ← 0
for i = 1 to n
{
    sum ← sum + A[i]
}
avg ← sum / n
```

Simple rules for managing the cache

- When accessing a memory location:
 - Bring that location into the cache.
 - Bring nearby locations into the cache.
- When the cache gets full:
 - Remove the memory location that was *Least Recently Used*.

Delay vs. cost of various memories

	Cost: \$ / GB	Delay: CPU cycles/byte
Hard drive	< 1	> 100,000
RAM	200	50-100
Cache	80,000	1

Moral

■ Performance:

- Speed is close to that of fastest memory (cache)
- Overall capacity is that of largest memory (disk)

Virtual Memory



Recall: Compilation

<p style="text-align: center;">$x \leftarrow y + z$</p> <p style="text-align: center;">↕</p> <p>ADD 10 11 12</p> <p style="text-align: center;">↕</p> <p>100 1010 1011 1100</p>	<ol style="list-style-type: none">1. Human writes this.2. “Add contents of Location 11 and 12, and store result in Location 10”<ul style="list-style-type: none">■ X in Location 10■ Y in Location 11■ Z in Location 123. Convert to binary
---	---

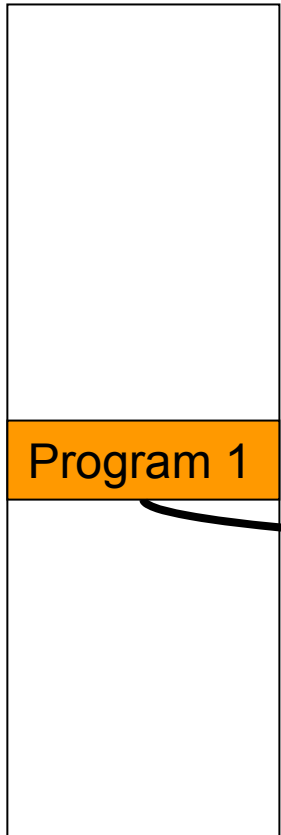
Question:

- What if two programs choose the same memory locations???

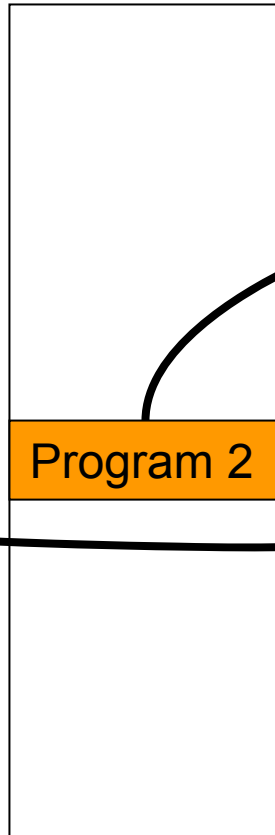
Program 1				Program 2			
	$x \leftarrow y + z$				$A \leftarrow B + C$		
		\updownarrow			\updownarrow		
ADD	10		11 12	ADD	10		11 12
		\updownarrow			\updownarrow		
100	1010	1011	1100	100	1010	1011	1100

Virtual Memory

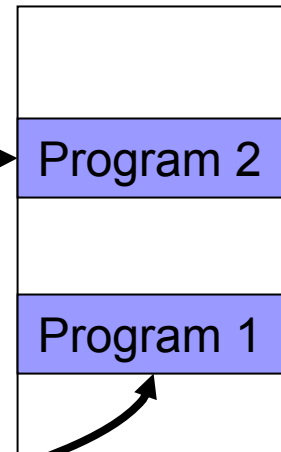
Program 1's
view of memory



Program 2's
view of memory:



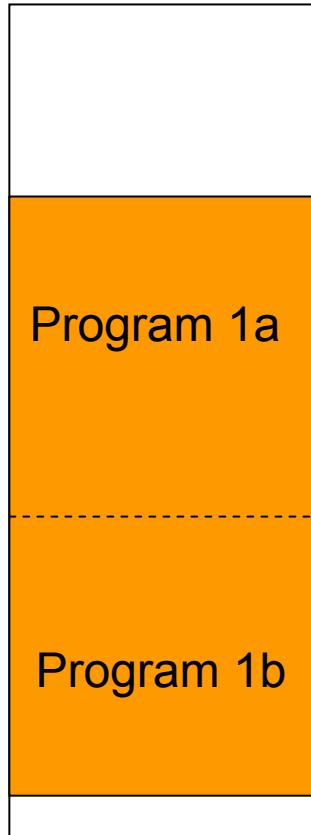
RAM:



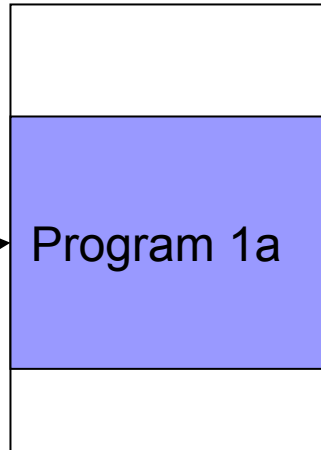
Virtual memory manager
handles the translation.

Virtual Memory

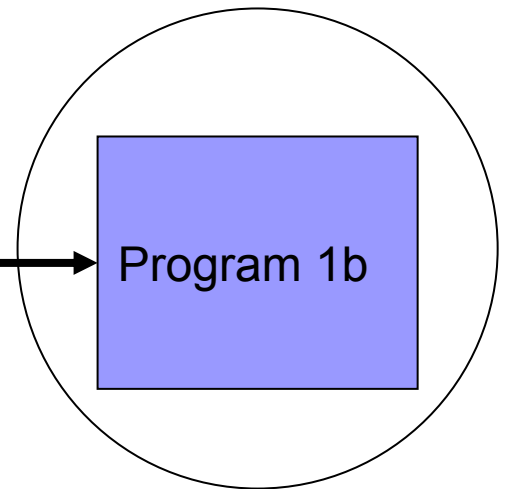
Program 1's
view of memory



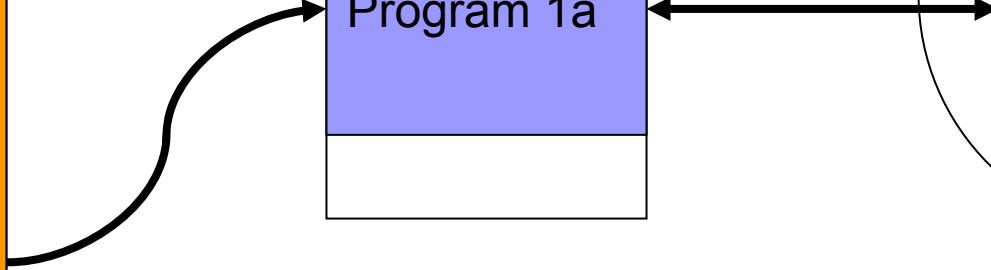
RAM



Hard Drive



Swap as
needed



Virtual memory manager
also handles RAM-to-HD
caching!

Virtual Memory

■ Program's view:

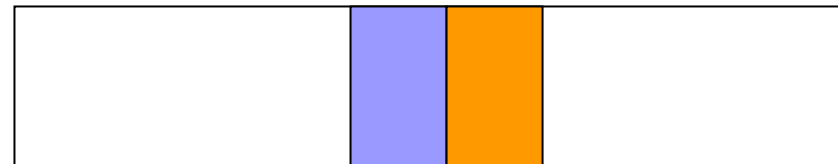
Powerpoint



Memory:

Lec15.ppt

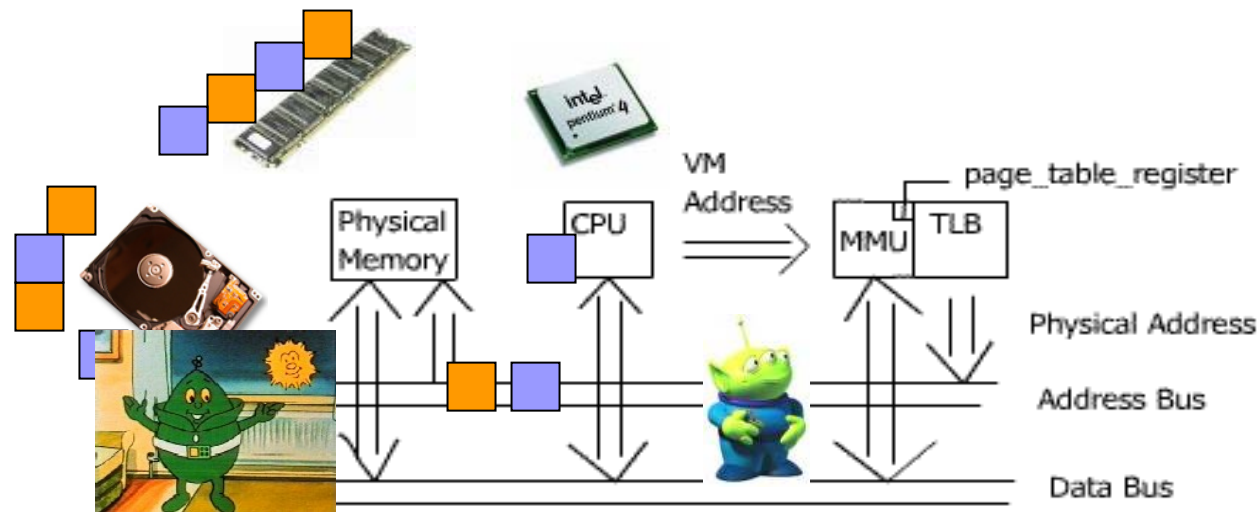
P ≠ NP.ppt



Address 0

Address $2^{64} - 1$

■ Underlying truth:



Multitasking

- “The Multitasking Generation”



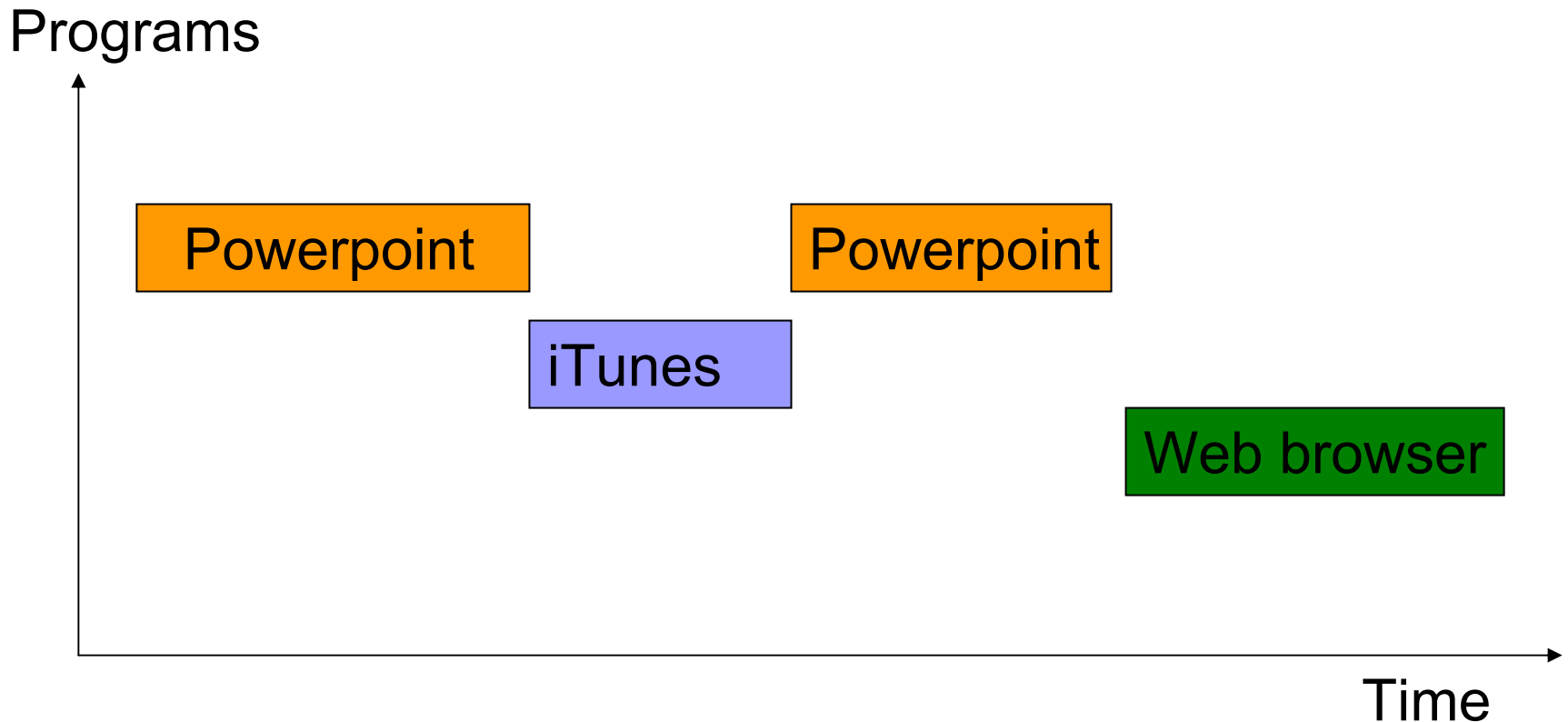
An Evening's Tasks for a Gen-M'er


- Homework
- Listen to music
- Instant Messaging
- Call Mom (goes to bed by 11 PM!)
- Answer phone
- Read a bit more of Joyce's *Ulysses*
- Watch the Daily Show
- How do you do it all?



How does a CPU multitask?

- Answer: It doesn't!





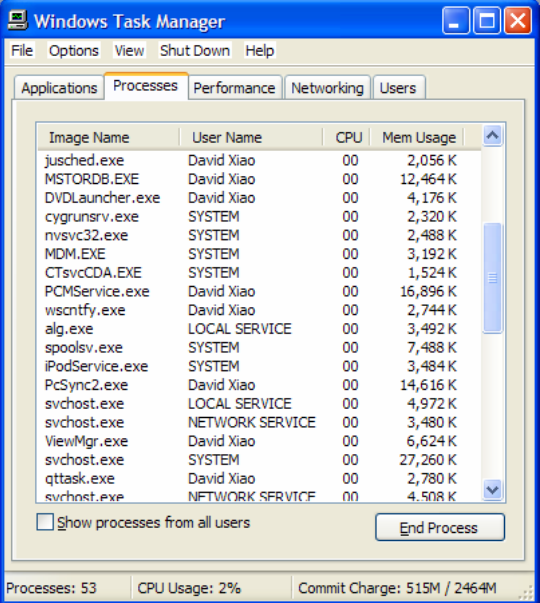
Scheduler's objectives

- Fairness
- Timeliness
- Critical tasks processed promptly
- Low overhead

Class Discussion: How can one achieve these (often conflicting) goals?

Tasks done by my PC last night


- Word processing
- Play CD
- Download news updates
- Download email
- Run clock
- Hidden tasks: handle network traffic, manage disk and RAM traffic, scheduler, etc.



The screenshot shows the Windows Task Manager window with the 'Processes' tab selected. The window title is 'Windows Task Manager' and it has a menu bar with 'File', 'Options', 'View', 'Shut Down', and 'Help'. Below the menu bar are tabs for 'Applications', 'Processes', 'Performance', 'Networking', and 'Users'. The 'Processes' tab is active, displaying a list of running processes with columns for 'Image Name', 'User Name', 'CPU', and 'Mem Usage'. The status bar at the bottom indicates 'Processes: 53', 'CPU Usage: 2%', and 'Commit Charge: 515M / 2464M'. There is an 'End Process' button at the bottom right of the list.

Image Name	User Name	CPU	Mem Usage
jusched.exe	David Xiao	00	2,056 K
MSTORDB.EXE	David Xiao	00	12,464 K
DVDLauncher.exe	David Xiao	00	4,176 K
cygrunsrv.exe	SYSTEM	00	2,320 K
nsvsc32.exe	SYSTEM	00	2,488 K
MDM.EXE	SYSTEM	00	3,192 K
CTsvcCDA.EXE	SYSTEM	00	1,524 K
PCMSvc.exe	David Xiao	00	16,896 K
wscntfy.exe	David Xiao	00	2,744 K
alg.exe	LOCAL SERVICE	00	3,492 K
spoolsv.exe	SYSTEM	00	7,488 K
iPodService.exe	SYSTEM	00	3,484 K
PcSync2.exe	David Xiao	00	14,616 K
svchost.exe	LOCAL SERVICE	00	4,972 K
svchost.exe	NETWORK SERVICE	00	3,480 K
ViewMgr.exe	David Xiao	00	6,624 K
svchost.exe	SYSTEM	00	27,260 K
qttask.exe	David Xiao	00	2,780 K
svchost.exe	NETWORK SERVICE	00	4,508 K

Managed by “Operating System”
(WinXP, Linux, MacOS, etc.)

- 
- Bonus reading (in the “Extras” section):
Proof of the halting problem, written in Dr. Seuss rhyme.
 - Please pick up your graded lab reports.